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Midway Landfill Remedial Investigation Landfill Gas Technical Report

Seattle Engineering Department
Solid Waste Utility

March 1988

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MIDWAY LANDFILL REMEDIAL INVESTIGATION
LANDFILL GAS TECHNICAL REPORT

Prepared for:

SEATTLE ENGINEERING DEPARTMENT
SOLID WASTE UTILITY

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

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1.0 INTRODUCTION

Midway Landfill was created in January 1966 by the City of Seattle, Washington, to receive nonputrescible waste. In solid waste operations terminology, "nonputrescible" waste is differentiated from "putrescible" waste mainly by its rate of decomposition. The category of putrescible waste includes rapidly decomposing food scraps such as household and restaurant garbage. The category of nonputrescible wastes includes organic material that decomposes slowly, such as the demolition debris and wood wastes that were deposited in the Midway Landfill. The landfill received demolition debris from commercial haulers and wood wastes and yard trimmings from the City's transfer stations. Records indicate that beginning in 1978 limited amounts of industrial wastes also were deposited at Midway Landfill with the approval of the Seattle-King County Health Department. Information in the EPA's Emergency and Remedial Response Information System (ERRIS) files suggests that the landfill may have received industrial liquid and sludge wastes prior to 1980. Much of this information is drawn from local newspaper articles and is otherwise unsubstantiated. The landfill was closed in October 1983. Clean soil materials from excavation projects are still accepted at the site to assist in final grading and cover.

Because of its proximity to their properties, local residents perceived the landfill as potentially damaging to their environment. In its later years of operation, the City of Seattle received numerous complaints regarding odor, surface water runoff, traffic, possible health effects, and the risk of fire or explosion. In response to these indications of possible environmental problems related to the operation of the landfill, the City of Seattle instituted a program to determine the area and extent of any problems, control gas migration, eliminate gas from offsite areas, and control air emissions on the site. Both investigative and remedial action was initiated; as more data became available, additional remedial measures were undertaken.

The City closed the landfill in the fall of 1983 and began extensive testing of gas and water in the landfill and its vicinity. A series of gas probes was installed around the perimeter of the site to monitor gas concentrations in the landfill. Samples of leachate and groundwater from monitoring wells in and around the landfill and gas samples from the gas probes indicated that the landfill contained high levels of organic and inorganic contaminants with a high potential for offsite migration. Additional tests for gas were conducted in the landfill soil and in utility corridors beyond the perimeter probes. At the same time, the Washington State Department of Ecology also began installing numerous shallow probes offsite. The City also established a program to monitor homes for gas.

Gas was detected both in the utility corridors and in nearby residential structures. Because methane, carbon dioxide, and small amounts of hydrogen sulfide are normally generated by the decomposition of landfill waste materials, Midway Landfill was suspected as the source of gases detected on the adjacent properties. Measures were taken by City crews to seal cracks in building foundations to prevent gas from seeping into the buildings. Data from offsite probes and the monitoring program indicated that gas had

migrated up to 2600 feet from the landfill and was seeping into homes located at that distance from the site. Additional probes were installed by the City further from the site, and it expanded its sealing programs within homes and businesses. Some families were evacuated.

In September 1985, and again in September 1986, the City of Seattle installed a series of gas migration control wells around the perimeter of the site on an emergency basis as part of the final landfill closure process. The wells were connected by manifold piping to temporary motor blowers and flares.

Evaluation of the environmental effects of the landfill by the Department of Ecology and the EPA led to placing the site on the National Priority List for site cleanup. In August 1986, a remedial investigation (RI/FS) was initiated.

This report describes investigations and remedial actions taken as part of the RI contracted between the City of Seattle and Ecology. Before the RI began, the migration of gas from the landfill appeared to be controlled by the installation and operation of the migration control wells, manifold, blowers, and flares. However, some areas of concern still existed. Most of the combustible gases detected offsite were removed by the 17 offsite control wells. Under Superfund regulations, further data and control measures are necessary for complete cleanup of the offsite reservoirs of landfill gas that has accumulated.

2.0 EXISTING CONDITIONS

Midway Landfill is located in Kent, Washington, approximately 15 miles south of Seattle. It occupies 60 acres located north of 252nd Street between Interstate 5 and Highway 99. The landfill is surrounded mainly by residential neighborhoods; some homes lie within 120 feet of the southern boundary.

In 1986 when the Remedial Investigation began, the City's active gas migration control system was in operation; portions of this system will be replaced by permanent facilities as part of final landfill closure construction.

The following sections describe the possible sources of the combustible gas found offsite, the investigations conducted to determine its sources, and the actions taken to stop migration of gas offsite and remove the residual offsite gas.

2.1 Possible Sources of Gas Affecting Offsite Receptors

2.1.1 Midway Landfill

The landfill material consists primarily of demolition debris from commercial haulers and wood wastes and yard trimmings (but not household wastes) from the City's transfer stations. The landfill may have also received industrial liquid and sludge wastes prior to 1980. In climates such as the Puget Sound area, anaerobic decomposition and methane generation start about a year after burial of wet or damp solid waste. Anaerobic bacteria produce methane as a by-product of digestion of waste. The gas is expelled from the bacteria under a slight positive pressure. Although an individual bacterium produces a small amount of gas, many millions of bacteria over a period of time can create significant volumes and pressures sufficient to cause the gas to move away from the area where it is generated.

Geological information about the soils underlying the landfill was not available prior to the remedial investigation. However, it is known that soil conditions facilitate or retard landfill gas migration. Sandy-gravel soils, where present, act as a low-resistance pathway for gas migration. Fluctuations in atmospheric pressure expand and contract the gas reservoir, increasing its tendency to migrate. Annual changes in the groundwater table also help extend the migration by compressing the reservoir from beneath, encouraging lateral expansion.

2.1.2 Wetlands or Peat Deposits

Several peat deposits exist in the area around the Midway Landfill. Peat can decompose anaerobically, if air is kept out by water, earth cover, or overlying layers of peat. Anaerobic decomposition of the organic matter in peat produces methane gas just as in solid waste. To the west of the landfill is a large swamp containing approximately 90,000 cubic yards of peat, to the southeast one of about 60,000 cubic yards. A smaller deposit

north of the landfill around probe 2 is reported to have existed at one time, but it has apparently been covered. Investigations to confirm this are continuing. In 1981 a smaller peat bog southwest of the landfill near probe AC was observed by a geologist with Terra and Associates (D. Wintermute, personal communication, 1988).

2.1.3 Other Landfills

The Kent Highlands Landfill, located approximately 1 mile northeast of the Midway Landfill, was in operation between 1968 and 1986. The landfilling operations at the site included disposal of both putrescible and nonputrescible wastes (90% residential, 10% commercial) from the City of Seattle's transfer stations and contract haulers, and from the City of Kent. It is estimated that the entire landfill volume exceeds 5 million cubic yards. As with the solid waste deposited at the Midway Landfill, the waste deposited at the Kent Highlands Landfill is currently undergoing anaerobic decomposition.

Reports have been received that small, unauthorized dumping operations have taken place in other areas around the Midway site in the past. These locations have since been covered as the areas were developed. This action allows the deposited solid waste to undergo anaerobic decomposition. These reports are being investigated.

2.1.4 Organic Material in Soils

In general, soils surrounding the site are of glacial origin. The mixing action of the glacial advances and retreats left organic material buried deep below the present ground surface. For example, during the installation of an offsite probe a tree trunk was drilled through at a depth of 350 feet below ground surface. As such organic material decomposes anaerobically, small amounts of methane are produced. Typically, drillers will encounter methane as they drill boreholes in the Puget Sound lowland area even where there are no known sources of methane such as landfills, coal seams, or natural gas pipelines. For example, Georgia Ramlo, operator of Ramlo Well Drilling and manager of drilling for Tacoma Pump, reports that while drilling in Firgrove, Washington, near Thun Field, she encountered methane that she was unable to attribute to any known source. She also encountered large amounts of methane of unknown origin while drilling near Yelm (G. Ramlo, personal communication, 1988).

Drilling records in western Washington from 1900 to 1982 examined by C. R. McFarland and reported in Department of Natural Resources Information Circular 75 (1983) yield many examples of high gas readings during drilling, sometimes combined with very high pressure. In these records there are 34 instances of gas at approximately 450 feet or less and 28 instances at 200 feet or less.

2.1.5 Natural Gas Pipelines

Leaking natural gas pipelines have been discovered during this and other studies of the site near Ecology probe 45 and City control well C-6 (see map, Appendix A). Generally, pipeline-quality natural gas is distinguishable from

landfill gas because the ratio of pentane and ethane to methane in natural gas is higher than that of landfill gas. Also, natural gas from pipelines contains an odorant added for identification.

2.1.6 Gases in Offsite Groundwater

Groundwater may contain variable quantities of gases because of the natural tendency for gases to be absorbed by liquids when the two are in contact, particularly when they are under pressure, as may occur underground.

2.1.6.1 Naturally Occurring Gases

Methane occasionally is found in groundwater. In the Pacific Northwest, drillers installing water wells sometimes observe a "milky" artesian flow of water from boreholes. Some of the gas creating this milky effect is methane. In one instance, the methane concentration was great enough to blow off the top of a water tower when the gas was ignited accidentally by a fan motor.

2.1.6.2 Gases Absorbed Onsite and Released Offsite

A portion of the gas generated in a landfill can be absorbed into the water present in the landfill, particularly when the water is under pressure. Encountering various impermeable layers of clay or waste materials, this water would tend to move horizontally, joining perched groundwater flowing offsite. As the water head diminishes, the pressure would be released and in turn the gas would be released.

Gas absorption into water in the Midway Landfill can be quantified using the following calculations:

(1) The average flow of groundwater from the landfill (F_a) is approximately equal to the average cross-sectional area (A) times percent voids (V_p) times the velocity of the water (V) or $F_a = A \times V_p \times V$

- o the average cross-sectional area of the landfill aquifer is approximately 30,000 sq. ft. (see Appendix G)
- o the average percent voids in the landfill aquifer is assumed to be 20%
- o the average velocity of water leaving the landfill through this aquifer is approximately 0.00195 cm./sec. or 5.5276 ft./day (see Appendix G)

THEREFORE the average flow of groundwater from the landfill

= 30,000 sq. ft. x 20% x 5.5276 ft./day
= 33,165.6 cu. ft./day

(2) The solubility of CH_4 at atmospheric pressure (S_a) equals the solubility coefficient of CH_4 (C_{ch4}) times the pressure CH_4 exerts on water at atmospheric pressure (P_a) (from Henry's Gas Law) or $S_a = C_{ch4} \times P_a$

- the solubility coefficient of methane (CH_4) in water (from Henry's Gas Coefficient) equals 1 g/L / 3950 atm. or 1 g/L / 300200 mm Hg.

- the pressure CH_4 exerts on water at atmospheric pressure equals atmospheric pressure (760 mm Hg) minus the vapor pressure of water (31.824 mm Hg) or 728.176 mm Hg.

THEREFORE the solubility of CH4 at atmospheric pressure

= 1 g/L / 300200 mm Hg x 728.176 mm Hg
= 0.002426 g/L

(3) Based on an approximate water depth of 39 ft (H) in the three wells in refuse with the deepest water (wells 23, 38, and 46), and an average depth of water in the entire landfill of 33% of that maximum, and an average head in that water of 50% of the average depth (H_a), the average head is calculated as:

H_a = H X 33% X 50%
= 39.0 X 0.33 X 0.50
= 6.435 ft WC
= 1452.88 mm Hg

THEREFORE the pressure CH_4 exerts on water (P_t) at the average head (H_a) equals atmospheric pressure (P_p) (760 mm Hg) plus the average head (H_a) (1452.88 mm Hg) minus the vapor pressure of water (P_w) (31.824 mm Hg) or:

$P_t = P_p + H_a - P_w$
= 760 mm Hg + 1452.88 mm Hg - 31.824 mm Hg
= 2181.056 mm Hg

(4) The solubility of CH_4 at its average head (S_h) equals the solubility coefficient of CH_4 (C_{cH4}) times the pressure CH_4 exerts on water at its average head (P_t) (from Henry's Gas Law) or $S_h = C_{ch4} \times P_t$

THEREFORE the solubility of CH4 at its average head

= 1 g/L / 300200 mm Hg x 2181.056 mm Hg
= 0.007265 g/L

(5) The amount of CH_4 that will escape from the water into the soil after the groundwater leaves the site and the average head pressure is released (D) equals the difference between the solubility of CH_4 in water at its average head (S_h) and the solubility of CH_4 in water at atmospheric pressure (S_a) or $D = S_h - S_a$

= 0.007265 g/L - 0.002426 g/L
= 0.004839 g/L

(6) The actual amount of CH_4 that will escape from the groundwater that leaves the site over time (V_t) equals the flow of water from the landfill (F_a) times the actual amount of CH_4 that will escape the water per unit volume (D); or, since 28.31 L = 1 cu ft and the density of CH_4 at atmospheric pressure = 20.32 g per cu ft, $V_t = F_a \times D$

THEREFORE the actual amount of CH4 that will escape from the groundwater that leaves the site over time

= 33,165.354 cu ft/day X 28.31 L/cu ft X 0.004839 g/L
X (1 cu ft (CH_4) / 20.32 g)
= 223.59 cu ft(CH_4)/day

On an annual basis, this would be 224 cu ft (CH_4)/day X 365 days/yr = 81,760 cu ft/year. However, since water is present in the landfill only during the rainy season, one half of this total is more accurate, or 40,880 cu ft/year.

Assuming this methane generation is spread over the plume area, which is roughly 1500 ft X 1500 ft, or 2,250,000 ft^2, this is 40,880 cu ft/yr divided by 2,250,000 ft^2 = 0.02 cu ft of methane/ft^2 groundwater/year.

This is a relatively small amount considering it would be generated over a large area; however, it may be a factor contributing in a small way to offsite gas. The release rate would be highest in the area closest to the landfill. This area is under the influence of the migration control system vacuum, and the small amounts of released gas will be drawn back to the landfill. It should also be noted that when the final cover is placed on the landfill and the surface water is diverted away from the landfill, this pathway for gas migration will be eliminated entirely.

2.1.6.3 Gases Generated Offsite

A plume of groundwater slightly contaminated by the landfill appears to be migrating offsite to the southeast. The biochemical oxygen demand of this plume was measured. Its methane generation potential can be quantified using the following calculations:

(1) The average flow of groundwater from the landfill (F_a) is approximately equal to the average cross-sectional area (A) times percent voids (V_p) times the velocity of the water (V) or $F_a = A \times V_p \times V$

- o the average cross-sectional area of the landfill aquifer is approximately 30,000 sq. ft. (see Appendix G)
- o the average percent voids in the landfill aquifer is assumed to be 20%
- o the average velocity of water leaving the landfill through this aquifer is approximately 0.00195 cm./sec. or 5.5276

ft./day (see Appendix G)

THEREFORE the average flow of groundwater from the landfill

= 30,000 sq ft x 20% x 5.5276 ft/day
= 33,165.354 cu ft/day

(2) The carbonaceous fraction of those pollutants measured by biochemical oxygen demand (BOD) have the ability under anaerobic conditions to generate methane gas. The relationship is that 7.8 cubic feet of methane gas can be generated for each pound of carbonaceous biochemical oxygen demand (BOD_c).

Although the highest BOD found, 230 ppm, is in MW-7, this well is immediately adjacent to the landfill. More appropriate values to use appear to be from MW-13 (< 2 ppm), MW-14 (7 ppm), and MW-15 (4 ppm). The average of these is (2 + 7 + 4) divided by 3 = 4.3 ppm. The ratio of BOD_c to BOD is 0.8.

The methane generation rate is computed by:

groundwater flow rate X avg BOD_c X density of water X 7.8 ft^3/lb, or:

33,165 ft^3/day X 4.3 X 10^{-6} X 0.8 X 62.4 lb/ft^3 X 7.8 ft^3/lb
= 56 ft^3/day

On an annual basis, this would be 56 ft^3/day X 365 days/yr
= 20,500 ft^3/yr

Assuming this methane generation is spread over the plume area, which is roughly 1500 ft X 1500 ft, or 2,250,000 ft^2, this is 20,500 ft^3/yr (CH_4) divided by 2,250,000 ft^2
= 0.009 ft^3 of methane/ft^2 ground surface/year.

To put this in perspective, the landfill directly generates about 1000 ft^3 per minute,
X 1440 min/day = 1,440,000 ft^3 per day
X 365 days/year = 526,600,000 ft^3 per year

This is a relatively small amount considering it would be generated over a large area; however, it may be a factor contributing in a small way to offsite gas. The release rate would be highest in the area closest to the landfill. This area is under the influence of the migration control system vacuum, and the small amounts of released gas will be drawn back to the landfill. It should also be noted that when the final cover is placed on the landfill and the surface water is diverted away from the landfill, this pathway for gas migration will be eliminated entirely.

2.2 Installation of Probes

The City of Seattle and Ecology had installed many offsite monitoring probes around the landfill prior to this study. The probes installed by the City are labeled "A" through "X"; the probes installed by Ecology are numbered 1 through 92. The locations of these probes are shown on the Midway Landfill Vicinity Map (Appendix A). Such monitoring probes provide information on gas concentrations and also yield data concerning subsurface conditions.

In addition to the onsite gas migration control system installed by the City and the offsite monitoring probes installed by the City and Ecology, several offsite gas extraction wells have been installed by the City and Ecology in neighborhoods around the landfill. These were installed as an emergency measure to prevent methane from reaching explosive levels in structures. Data from the probes and the offsite extraction wells are used in evaluating onsite and offsite gas control.

2.3 Onsite Gas Migration Control Wells

Thirty-four Phase I migration control wells (see Figure 2-1) were installed in waste on 100- to 200-foot centers around the perimeter of the landfill. This spacing was designed to create overlapping spheres of influence between wells. However, many areas of the landfill lack sufficient clay cover to prevent air being drawn into the soil surrounding the wells. This air intrusion results in a low operational vacuum in the wells. Accordingly, these Phase I wells could not influence a large enough area to provide confidence that the vacuum barrier was being produced, especially along the eastern boundary. Therefore, three additional migration control wells, numbers 35, 36, and 37, were installed between existing migration control wells 18, 19, 20, and 21. These three new wells are double-completed, that is, they have two pipes of different depths so that gas flow can be adjusted to minimize air intrusion at the shallow level but maximize vacuum at the deeper level.

Because of the operational limitations of the Phase I migration control wells in preventing offsite migration of landfill gas, forty additional Phase II migration control wells were planned. Forty-one Phase II wells, also shown on Figure 2-1, were installed between November, 1986 and December, 1987. Twelve of the Phase II migration control wells were installed in native soil on approximately 175-foot centers along the eastern border of the landfill. These wells are labeled PD-1 through PD-12.

Nineteen of the Phase II migration control wells were installed in native soil on approximately 300-foot centers along the north, west and south boundaries of the landfill. These wells are numbered PA-1 through PA-10 and PC-1 through PC-9.

Ten of the Phase II migration control wells were installed in waste in the interior of the landfill. Six wells were placed in the north half of the landfill and four in the south. These wells are numbered 38 through 47.

2.4 Offsite Control Wells

Nineteen offsite control wells have been installed. Due to reductions in gas concentrations over time, fourteen of these control wells have been shut down. Their locations are shown on Figure 2-2. A table, indicating blower horsepower, depths, screened intervals, and operating status is shown on Table 2-1.

In early 1986, the first five of these wells were installed adjacent to structures with severe gas infiltration problems. It had become apparent after a few months of operating the onsite migration control wells that the reservoir of offsite gas was not going to be pulled back to the landfill quickly. The body of gas in the soil under residential neighborhoods was still causing concern because of its potential for migrating through basements and structure slabs into the houses. The first five wells created a negative pressure in the soil underneath the structures, reversing the flow of gas away from the structures.

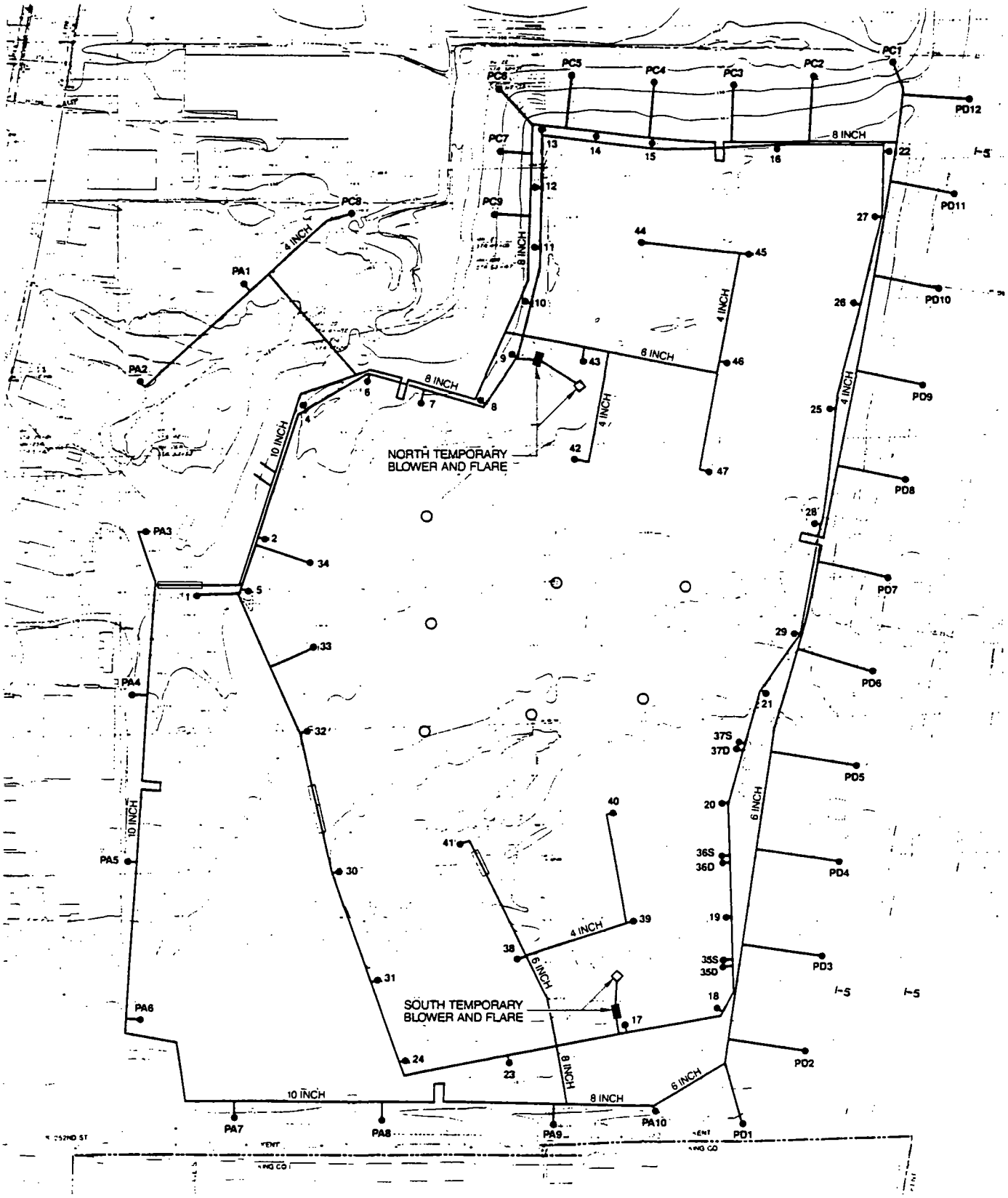
At that time, the Department of Ecology began installing two similarly designed but larger offsite control wells in the same vicinity. These wells were 100 feet deep with 5 HP motor blowers; they created vacuums near 40 inches water column (W.C.). The earlier wells were 60 feet deep with 1.5 HP motor blowers and created vacuums of 8.5 inches W.C.

Meanwhile, based on the good performance of the initial five control wells, the City had contracted with Parametrix to install up to ten more control wells, nine in the neighborhood east of the landfill and one directly west of the landfill. After observing the ability of the larger Ecology control wells to remove large quantities of gas from an extensive area, the City and Parametrix decided to make the last three wells of the larger design. These wells are labeled C-13, C-14, and C-15.

Because of continuing high gas concentrations south and northeast of the landfill in the summer of 1987, the City contracted with Parametrix, Inc. to drill two additional offsite control wells. C-16 was drilled northeast of the site (see Figure 2-2) in November, 1987. Negotiations with the homeowner on whose property the control well is located have delayed the connection of a motor blower to this well. C-17 was drilled south of the site (see Figure 2-2) in November, 1987. A temporary 1.5 HP motor blower was installed on the well to test gas concentrations and the effect, if any, that the control well will have on the reservoir of migrated gas in the area. From this test, a determination will be made as to the need for a permanent 5 HP motor blower.

2.5 Potential Gas Migration Pathways

Subsurface gases can travel through porous materials or voids created naturally by varying soil composition or artificially by human construction such as utility conduits. Both types of pathways in the landfill vicinity were investigated for the RI.



SCALE IN FEET

0 100 200

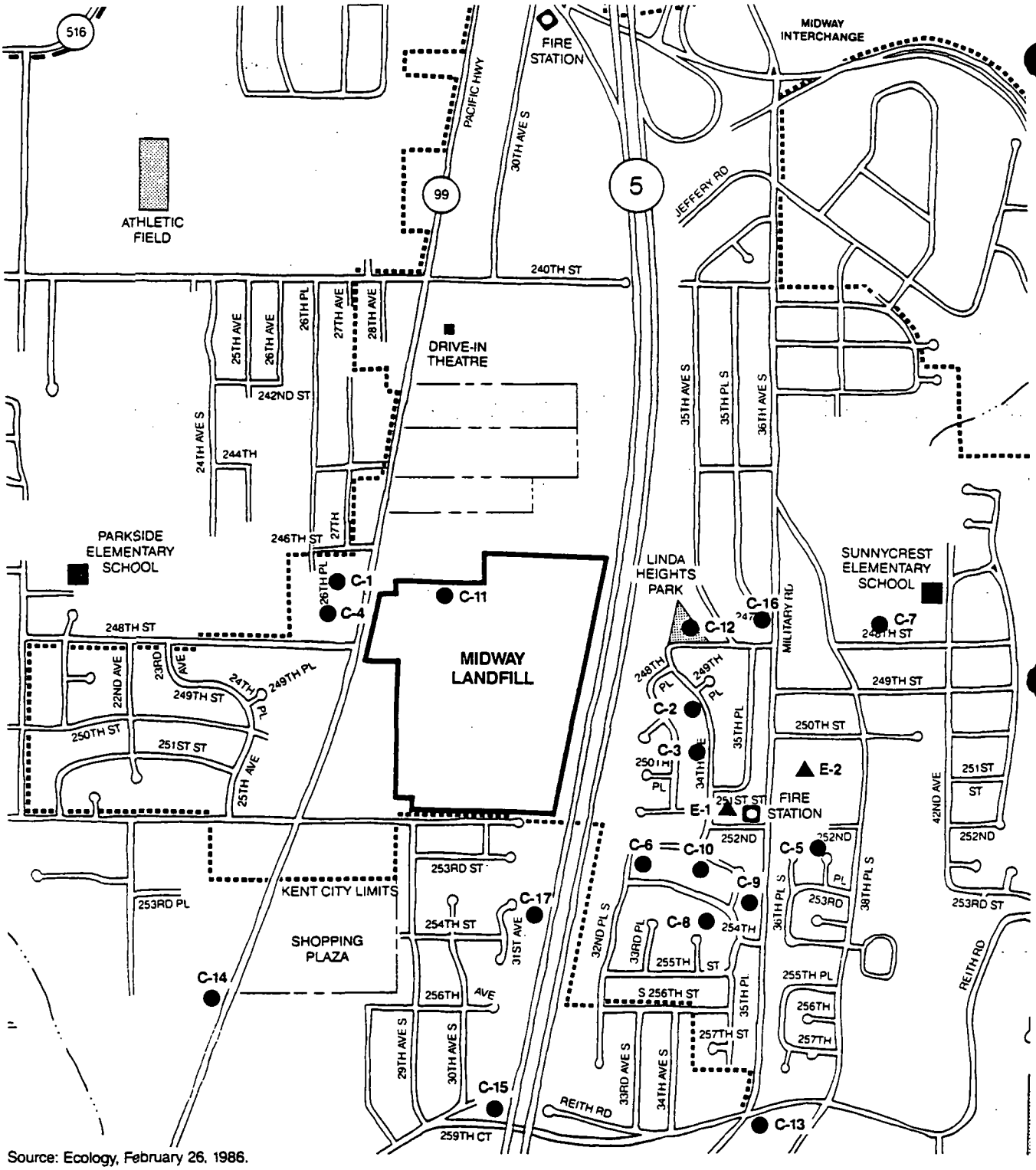
N

● Existing Wells

○ Proposed Wells

—— Existing Pipeline

Figure 2-1
Location of Onsite Migration Control Wells



Source: Ecology, February 26, 1986.

SCALE IN FEET

0 500 1,000

E-1▲ Ecology Extraction Well

C-1● City of Seattle Extraction Well

Figure 2-2
Location of Offsite Control Wells

TABLE 2-1
CONTROL WELL INFORMATION

WELL	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DIST TO SCRN TOP	DIST TO SCRN BOT	LGT OF SCRN	BLWR SIZE	CASG SIZE	STATUS
C-1	12/23/85	PMX/TERRA	CITY	7	55	48	1.5	3"	OFF
C-2	12/31/85	PMX/TERRA	CITY	10	58	48	1.5	3"	OFF
C-3	12/30/85	PMX/TERRA	CITY	10	58	48	1.5	3"	OFF
C-4	01/21/86	PMX/TERRA	CITY	9	58	49	1.5	3"	OFF
C-5	02/03/86	PMX/TERRA	CITY	8	76	68	1.5	3"	OFF
C-6	05/14/86	PMX/TERRA	CITY	8	95	87	1.5	3"	*T*
C-7	05/16/86	PMX/TERRA	CITY	11	79	68	1.5	3"	*T*
C-8	05/19/86	PMX/TERRA	CITY	10	66	56	1.5	3"	OFF
C-9	05/20/86	PMX/TERRA	CITY	11	59	48	1.5	3"	OFF
C-10	05/22/86	PMX/TERRA	CITY	9	77	68	1.5	3"	OFF
C-11	06/02/86	PMX/TERRA	CITY	5	73	68	1.5	3"	OFF
C-12	06/04/86	PMX/TERRA	CITY	10	67	57	1.5	3"	ON
C-13	08/26/86	PMX/TERRA	CITY	21	101	80	5.0	4"	OFF
C-14	09/09/86	PMX/TERRA	CITY	40	95	55	5.0	4"	OFF
C-15	09/16/86	PMX/TERRA	CITY	29	93	64	5.0	4"	OFF
C-16	11/25/87	PMX	CITY	20	120	100	*A*	4"	*A*
C-17	11/19/87	PMX	CITY	20	120	100	1.5	4"	*T*
E-1	N/A	HART/CRO	DOE	N/A	N/A	N/A	5.0	4"	OFF
E-2	01/23/86	HART/CRO	DOE	20	83	63	5.0	4"	OFF

A = Well is drilled, but is not attached to a blower yet.
T = Well is throttled to a low vacuum.

2.5.1 Utility Conduits

Locations of the major underground utilities in the vicinity of the Midway Landfill are described in Section 5.5 and Appendix F. No significant changes have taken place since the beginning of this study.

2.5.2 Geologic Pathways

Drilling logs for all wells and probes have provided stratified soil samples of the landfill and vicinity. These data were used for the study undertaken as part of the RI to identify naturally occurring geologic pathways for landfill gas migration. Appendix G is a report of the geologic investigation.

3.0 OBJECTIVES

The objectives of the Remedial Investigation with respect to combustible gases are (1) to monitor the gases both onsite and offsite; (2) to characterize the gases detected offsite and determine their source; (3) to evaluate the control well systems now in operation and (4) to identify potential underground utility and geologic pathways for gas migration.

3.1 Monitor Onsite and Offsite Gas

The purpose of monitoring onsite and offsite gases is to make it possible to evaluate the effectiveness of the control well system. Monitoring information comes from the daily operation of the wells and from the offsite monitoring probes. (A probe is a borehole drilled in the same way a well is drilled, but generally smaller in diameter.) Offsite probes monitor the gas contained in the soil and provide data on the effectiveness of the offsite control wells. These probes also help to evaluate the onsite migration control system. The core samples taken while drilling give geologic information needed to identify potential geologic pathways for gas migration.

Approximately 150 probes have been installed offsite in the vicinity of the landfill by Ecology and the City to monitor the offsite gas. In addition, ten multi-completion offsite monitoring probes were installed specifically for the remedial investigation to supplement the existing data base. Up to four screened intervals were installed in each probe to enable sampling from the lithologic layers that are potential gas transmitters.

Specific questions that were to be answered included whether offsite subsurface gases originate within the landfill or from other sources and whether there is a subsurface conduit for landfill gas migration between the Midway Landfill and the Kent Highlands Landfill.

3.1.1 Levels of Methane, Oxygen, Carbon Dioxide, and Static Pressure in Offsite Probes

The extent of offsite landfill gas migration can be determined by monitoring certain parameters in the offsite monitoring wells. Also, data from these wells can supplement knowledge of subsurface conduits for landfill gas migration. Monitoring the static pressure in the various completion zones in the offsite monitoring probes near the landfill over time determines if the vacuum induced in the landfill by the active onsite migration control system is having an influence on the soil surrounding the offsite probes.

Static pressure will vary with changing barometric conditions. To evaluate the influence of the onsite gas migration control system on an offsite probe, it is necessary to evaluate the change in static pressure in the probe over time during similar barometric conditions.

3.1.2 Gas Levels and Temperatures in Onsite Migration Control Wells

Methane gas and carbon dioxide are produced in the **anaerobic** decomposition of organic materials. Carbon dioxide, water, and heat are produced in the **aerobic** decomposition of organic materials. The major constituents of the gas in an onsite migration control well are monitored carefully to determine the amount of anaerobic and aerobic decomposition taking place in the surrounding waste. These data allow the operator to decide how to adjust the well to maintain its safe operation.

The temperature of the gas stream is an important characteristic to monitor in the migration control wells installed in waste. The heat produced in aerobic decomposition can cause the decomposing waste to combust spontaneously if it is not carefully monitored. However, temperature is not as useful an indicator in migration control wells drilled in native soil, because the soil acts to cool the gas stream before it can be sampled.

3.2 Characterize Onsite and Offsite Gas

In order to control the gases detected offsite in the vicinity of the landfill it is necessary to identify their source or sources. This is done by analyzing the chemical components of the offsite gases and possible local sources. Both matching characteristics and relative distances of the matching samples are used to infer the most likely source.

The objectives for characterizing onsite and offsite Midway Landfill gases as part of the Remedial Investigation were to:

- o Identify chemical components present in onsite subsurface landfill gas samples collected from:
  - Onsite gas extraction wells
  - Pre-combustion flare gas (flare inlet gas)
- o Identify a list of onsite gas contaminants comprising a potential "fingerprint" of Midway Landfill gas
- o Identify chemical components present in offsite subsurface gases
- o Evaluate the relationship between onsite gas composition and offsite gas composition

Appendix E of this report contains the technical memorandum describing the gas characterization study.

3.3 Evaluate Onsite and Offsite Gas Extraction Well Performance

The onsite gas migration control system and offsite gas extraction wells are closely interrelated. The effectiveness of offsite control wells in reducing gas concentrations in structures and surrounding shallow soil can be eval-

uated by studying the gas measurements recorded in structures and probes near the offsite control wells before and after well startup. These readings make it possible to assess the need, if any, for additional offsite control wells, and to ascertain the point at which the offsite control wells have effectively removed the gas within their radius of influence and can therefore be shut down.

It is possible for offsite control wells to draw landfill gas away from the landfill. To help prevent this, an onsite migration control system must be in operation before offsite control wells are started up. It is important to study the field data from the monitoring probes near the offsite control well to assure that this phenomenon does not occur.

As the data from the offsite probes are accumulated, isopleths (computer generated maps) of methane concentrations can be developed for various time periods to show trends in landfill gas migration. From these data, areas around the landfill in which the onsite gas migration control system is or is not having sufficient influence can be identified and appropriate adjustments can be made. Also, areas that need additional probes or extraction wells can be identified. Sample isopleths are included in this report as Figures 5-1 through 5-6.

3.4 Identify Potential Gas Migration Pathways

Gas produced from decomposition of waste in the Midway Landfill has been detected in offsite gas probes, and also has been found in structures such as basements and underground utility vaults. It was not clear at the beginning of this investigation whether gas was leaving the landfill via gas-transmitting geologic strata or by following a path or conduit created by underground utility lines or pipes, or a combination of both.

3.4.1 Utility Conduits

To ascertain whether landfill gas may have migrated through utility conduits, the locations of major underground utility lines were identified and mapped, then compared to the locations of known offsite gas. This investigation is described in Appendix F of this report.

3.4.2 Geologic Pathways

To identify potential geologic pathways for gas migration, drilling log data were correlated to construct a picture of the geologic strata underlying the area. Gas concentration data from the monitoring probes were compared to the map of potential pathways. The geologic pathways study is described in Appendix G of this report.

4.0 METHODOLOGY

This section describes the methods used to accomplish the study objectives.

The City of Seattle has been monitoring the Midway Landfill gas both onsite and offsite since 1985. This monitoring is expected to continue for many years. Monitoring data come from two types of sources: (1) the daily operation of the onsite and offsite gas extraction wells, and (2) the gas probes installed specifically to monitor gas offsite and also used to monitor the control wells. Thus, data for the RI are drawn from the data base created by routine ongoing monitoring. The gas extraction wells and gas probes installed before initiation of the RI are described in greater detail in Section 2, Existing Conditions. Methods of monitoring the control wells and the additional probes designed and installed specifically for the RI are discussed in this section.

In order to characterize chemical composition of the gas detected offsite and to determine its source, special analyses were made of gas samples taken both onsite and offsite. The effectiveness of the onsite migration control wells was evaluated by means of data from the offsite probes. The offsite control wells were evaluated using both monitoring data and probes located near the wells.

4.1 Monitoring Onsite and Offsite Gas

Both the gas produced at the landfill and the gas that has migrated offsite are monitored routinely through measurement and analysis of the content of the extraction wells and gas probes. Data obtained from the onsite and offsite wells are evaluated to form conclusions as to the extent of migration and effectiveness of the control system.

4.1.1 Onsite Gas

At the site, gas may be found in various strata of waste and in the underlying soil. This gas is measured to determine the status of the migration control wells. The operational goal at present is to draw out the maximum amount possible while staying within safe parameters. Aerobic decomposition should be minimized, but at the same time the BTU content of the gas should be high enough to keep the flare lit. The operational goal will change after offsite gas is removed and final cover is placed on the waste. The goal then will be to match extraction rates with the rate of gas generation in the waste.

4.1.1.1 In-Waste Gas Migration Control Wells

In-waste gas migration control wells installed at the Midway Landfill are monitored at least weekly to assure their optimum performance with respect to control of offsite migration of landfill gas, and to assure that the operation of the well system is not "over stressing" the landfill (extracting landfill gas too aggressively and thereby creating the potential for landfill

fires).

Anaerobic decomposition, or decomposition of organic materials in an oxygen depleted environment, is accomplished by anaerobic bacteria. The by-products of anaerobic decomposition are methane and carbon dioxide. The anaerobic bacteria require organic materials (in this case, solid waste) and water to produce appreciable amounts of methane and carbon dioxide. Aerobic decomposition, or decomposition of organic materials in an oxygen-rich environment, is accomplished by aerobic bacteria. The by-products of aerobic decomposition are carbon dioxide, water, and heat. The aerobic bacteria require organic materials (in this case, solid waste) and oxygen to produce appreciable amounts of carbon dioxide, water, and heat.

The heat produced by aerobic decomposition can start an underground fire in the deposited solid waste. Therefore, the amount of aerobic decomposition taking place in the landfill is closely monitored to assure safe operation of the system. The safe operation of the system is accomplished by minimizing the amount of air allowed to enter the solid waste.

The following three steps are taken to assure that a minimum of aerobic decomposition is taking place in the landfill:

- Improve the landfill cover with low permeability material.
- Reduce the vacuum in the landfill so that less air is drawn through the cover to the solid waste.
- Closely monitor the amount of aerobic decomposition taking place in various areas of the landfill and adjust well vacuums accordingly.

To accomplish the system goals of gas control without refuse fires, the following information is gathered about the gas stream from each completion zone of each well in the field:

- Combustible gas percentage
- Oxygen percentage
- Carbon dioxide percentage
- Static pressure
- Temperature
- Velocity of gas stream in well

The sum of concentrations of combustible gas, oxygen, and carbon dioxide in the sampled gas stream will always equal less than 100% of the total gas stream make-up. Experience has shown that the balance of the gas stream consists of water vapor and nitrogen, except for trace quantities of various organic compounds. The percentage of water vapor in the gas stream can be calculated from the following formula:

$$\%H^2O = 10^{\left(7.89 - \frac{3207}{395.43 + T}\right)} \Big/ (P_a + P_w)$$

Where

T = Temperature in degrees Fahrenheit of the gas stream
P_a = Atmospheric pressure in inches water column
P_w = Pressure (or vacuum) in inches water column in the well

The balance of the gas stream is nitrogen. In other words, 100% - % methane - % oxygen - % carbon dioxide - % water vapor = % nitrogen. Free (or breathing) air consists of approximately 21% oxygen and 79% nitrogen, a ratio of 1:3.76. By multiplying the percent of oxygen recorded in the field by 3.76, the amount of nitrogen associated with free air can be known.

As stated previously, aerobic decomposition consumes oxygen. It gets its oxygen from air. The nitrogen associated with this consumed oxygen is not used in the chemical process of aerobic decomposition and is still present in the gas stream. This "carried over" nitrogen is considered "residual nitrogen." This residual nitrogen is the balance of nitrogen present in the gas stream after the nitrogen associated with free air is subtracted.

Example:

Readings taken in the field:

WELL#	CH_4%	O_2%	CO_2%	TEMP	PRESS.	FLOW
X	21	7	18	48degF	-5.0"WC	22 CFM

Calculated quantities:

H_2O% (from above formula) = 1%
Total N_2% (100% - CH_4% - O_2% - CO_2% - H_2O%) = 53%
N_2 from free air (from ratio described above) = 26%
Residual N_2% (difference between total N_2 and N_2 from free air) = 27%

Operational experience at Midway and other landfill sites has shown that a safe limit of aerobic decomposition in the waste surrounding an extraction well is indicated by a maximum of 30% residual nitrogen in the well gas stream. In consideration of this fact and the present goal to maximize flow and vacuum, wells in refuse are adjusted to allow no more than 30% residual nitrogen. Because heat is produced in aerobic decomposition, temperature is a very quick indicator of dangerous amounts of aerobic decomposition. Experience has shown that 108 degrees F in the well gas stream is a safe maximum temperature at which to operate an in-waste extraction well at the Midway site. Temperature is measured at least three times a week.

The above calculations and parameters are used only to give the operator an idea of what biochemical processes are taking place in the area of influence

of a particular well. Other variables such as ambient temperature vs. temperature in the well, barometric pressure, and influence of areas outside the landfill are also taken into consideration in the adjustment of migration control wells.

4.1.1.2 In-Soil Migration Control Wells

The primary purpose of migration control wells installed in native soil around the landfill is to create a vacuum barrier that will prevent offsite migration. These wells also are used in conjunction with offsite control wells to remove reservoirs of gas that have accumulated over time.

In-soil wells are monitored and adjusted similarly to the wells installed in waste. Pressure in the onsite wells is measured and compared with pressure in the offsite probes to verify the effectiveness of the extraction wells. The chemical make-up of the gas is monitored to determine the amounts of aerobic and anaerobic decomposition taking place in the area of the landfill influenced by a particular in-soil extraction well. However, temperature in in-soil wells is not as quick an indicator of aerobic decomposition in the waste influenced by the well, because the landfill gas extracted by an in-soil well has cooled somewhat by migrating through native soil. Therefore, the operator must rely more heavily on the calculations of residual nitrogen described in 4.1.1.1 to determine adjustments to be made to the in-soil wells.

As with migration control wells installed in waste, in-soil wells are monitored at least weekly.

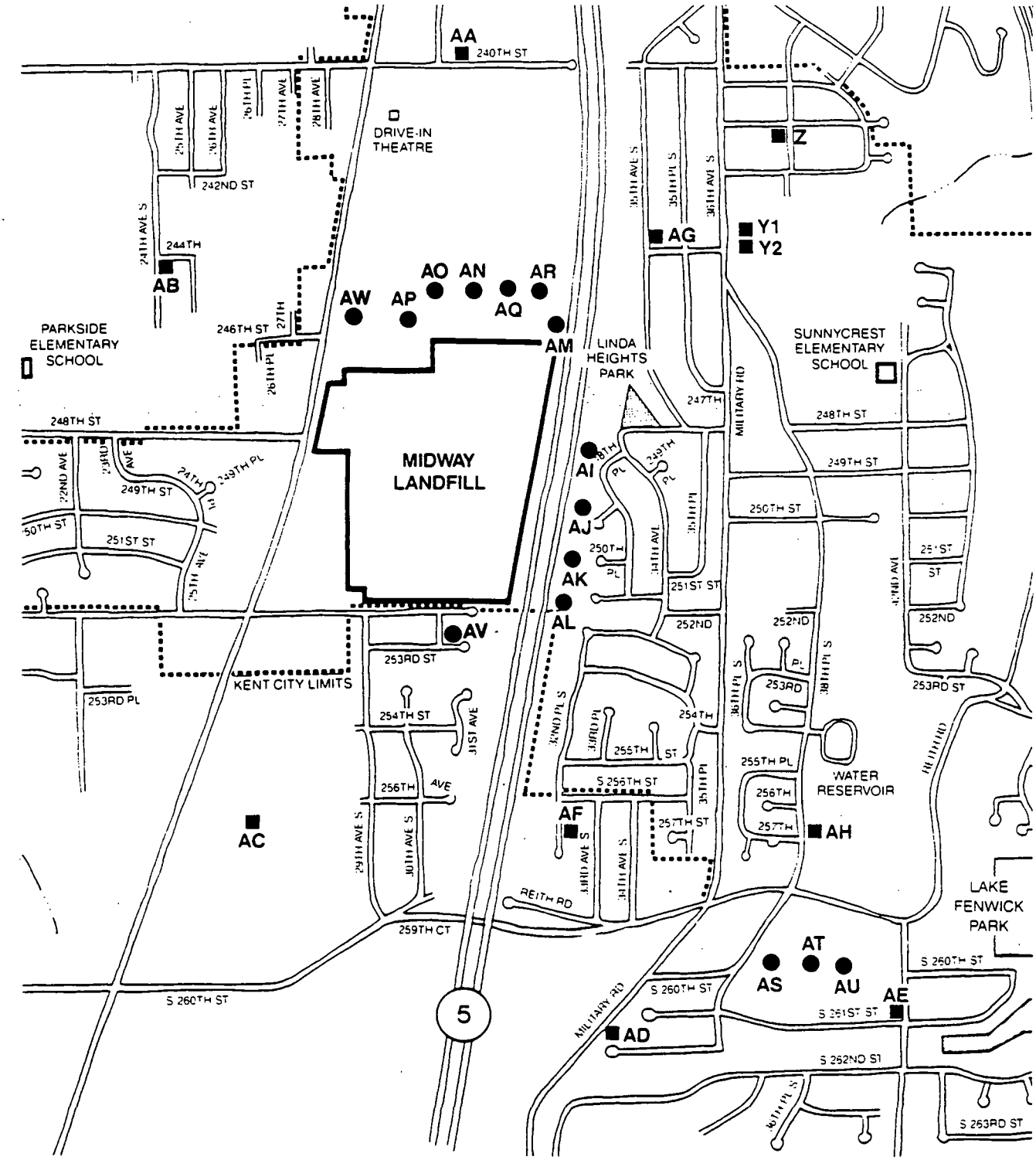
4.1.2 Offsite Monitoring Probes

Between 1983 and 1986, 24 gas probes were installed by Parametrix for the City of Seattle and 92 by Black and Veatch for Ecology to monitor offsite gas in the vicinity of the landfill. Appendix A shows the locations of the probes. When the RI process began, 11 additional offsite gas monitoring probes were installed. Parametrix, the City of Seattle, and Ecology selected the locations for these probes, shown in Figure 4-1 and labelled "Y1" through "Z" and "AA" through "AH."

Nine of the RI probes are on street rights-of-way. Probe "AC" is located on private property. Drilling the boreholes and installing the in-ground probes was subcontracted to Richardson Well Drilling Company of Tacoma, Washington. All of this work was closely supervised by an experienced engineering geologist from Terra Associates, Inc. of Redmond, Washington.

Drilling began on November 3, 1986. A top-drive rotary drill rig was used to drill and sample the first three boreholes, Y1, Y2, and Z. Soil samples were taken at 5-foot intervals using a tube sampler driven with the casing hammer.

Work progress with the rotary drill rig proved to be much slower than expected, primarily because of the time required to take the soil samples.



N

SCALE IN FEET

0 500 1000

■ Approximate Location of Monitoring Probes Installed for R.I.

● Approximate Location of Monitoring Probes Installed Subsequent to R.I.

Figure 4-1
Locations of Offsite Monitoring Probes Installed for and Subsequent to the Remedial Investigation

Consequently, the rotary rig was assigned to other Midway Landfill work and a cable-tool drill rig was mobilized to complete the remaining eight gas monitor probes.

The borehole was advanced 5 feet at a time. Once the borehole was bailed free of cuttings, the sampling tube was inserted in the borehole and driven with a down-the-hole hammer operated by the cable. It was usually driven 1 to 2 feet once in every 5 feet of borehole.

An engineering geologist from Terra Associates, Inc. maintained a log of each borehole, collected the soil samples and supervised the installation of the gas collecting completion zones. The soil samples and cuttings were visually classified in accordance with the Unified Soil Classification System.

A typical schematic drawing of the as-built probe installations is shown in Figure 4-2. Schematic drawings of probes installed previously are shown on Figures 4-3, 4-4, and 4-5 for reference.

The gas monitor wells consist of either two, three or four gas probes packed in pea gravel collection zones. Each probe uses Schedule 80 PVC slotted pipe within the collection zones and solid-wall PVC riser pipe to bring the gases collected to the ground surface. The slot width is either .02 or .04 inches. All joints are threaded flush. No glues or solvents are used. The probes are closed on the bottom end with either slip caps or threaded caps. The top of each probe is threaded and closed off with a Schedule 80 1/4-inch PVC ball valve and threaded cap.

In each well, the deepest probe is 3/4-inch-diameter pipe and the shallower probes are 1/2-inch-diameter pipe. Because it was anticipated that the deep probes might encounter the regional groundwater table, the larger pipe was installed to make it easier to insert the sensor used to measure the water level in the wells.

In each probe, pea gravel for the collection zone was installed to a point at least a few feet above the uppermost slots. The seals separating adjacent collection zones vary in thickness from about 2 to 5 feet. The seals were made from bentonite pellets, except for the deepest seal in probe AF, where concrete grout was used. At least 100 pounds of pellets were used for the bentonite seals. Once in place, water was added to swell the pellets and activate the seals. To exclude surface water from the probes, a seal was placed at the ground surface. These seals were either concrete grout over a layer of bentonite pellets or concrete grout mixed with a few percent of bentonite powder.

Each well was secured at the ground surface with a cast iron locking cover 12 inches in diameter. The last hole was completed on March 26, 1987.

Subsequent to the installation of the 11 probes for the RI, the City contracted with Parametrix, Inc. to install 11 additional multi-completion gas probes north, east and south of the landfill to gather additional information concerning offsite migration of gas. The additional probes are shown in Figure 4-1, labeled "AI" through "AV". These 11 subsequent probes were

installed using methodology similar to that described for the RI probes.

To gather additional information near the peat bog located southeast of the landfill, the City contracted with Parametrix, Inc. to install three shallow single-completion probes in the peat deposits. These probes are 6 to 9 feet deep, hand-augured holes. In each probe, pea gravel was installed to within one foot of the surface, and a bentonite surface seal was installed in the upper one foot. The probe is perforated in the pea gravel zone. These probes are shown on Figure 4-1, labeled "AS", "AT", and "AU".

City of Seattle field technicians monitor the offsite probes (see schedule below). Instruments used for monitoring are listed in Appendix B, Section 4.2. Barometric pressure for the Midway area is recorded 4 to 6 times a day in order to determine the effect of barometric conditions on the readings.

Probes are monitored daily until confidence in the readings and a general knowledge of trends in the probes is established. If unacceptable levels of combustible gas are indicated at a probe, it will be monitored more frequently than those indicating lower levels. Probes nearer the landfill will generally be monitored more frequently than those farther away. This makes it possible to determine quickly if gas is escaping from the landfill so that appropriate measures can be taken using the onsite migration control system.

The monitoring schedule is reviewed and revised, as necessary, on a bi-weekly basis in meetings between the City of Seattle, Parametrix, Inc., and the Department of Ecology.

Currently (December 1987), the monitoring schedule for probes around the Midway landfill is as follows:

DAILY

AE

TWO TIMES WEEKLY (evenly spaced)

A, C, I, J, K, L, M, AB, AF, AH, AM, AN, AO, AP, AQ, AR, AS, AT, AU, AV, AW
37, 39, 44, 45, 48, 49, 50, 56, 59, 60, 61, 78, 79, 81, 82, 85, 87, MW-21, MW-23, MW-15, MW-24, MW-27

ONE TIME WEEKLY

B, D, E, H, N, O, R, V, Y, AA, AC, AD, AG, AI, AJ, AK, AL, 2, 10, 13, 17, 18, 64, 66, 69, 76, 84, 88, 90, MW-8, MW-10, MW-14, MW-20, MW-29

MONTHLY

P, Q, S, T, U, W, X, Z, 5, 6, 7, 8, 9, 12, 20, 21, 22, 26, 27, 29, 31, 32, 33, 34, 35, 40, 41, 43, 46, 47, 51, 52, 53, 54, 57, 58, 67, 70, 72, 73, 74, 75, 77, 80, 83, 86, 89, 91, 92, BARHOLES*

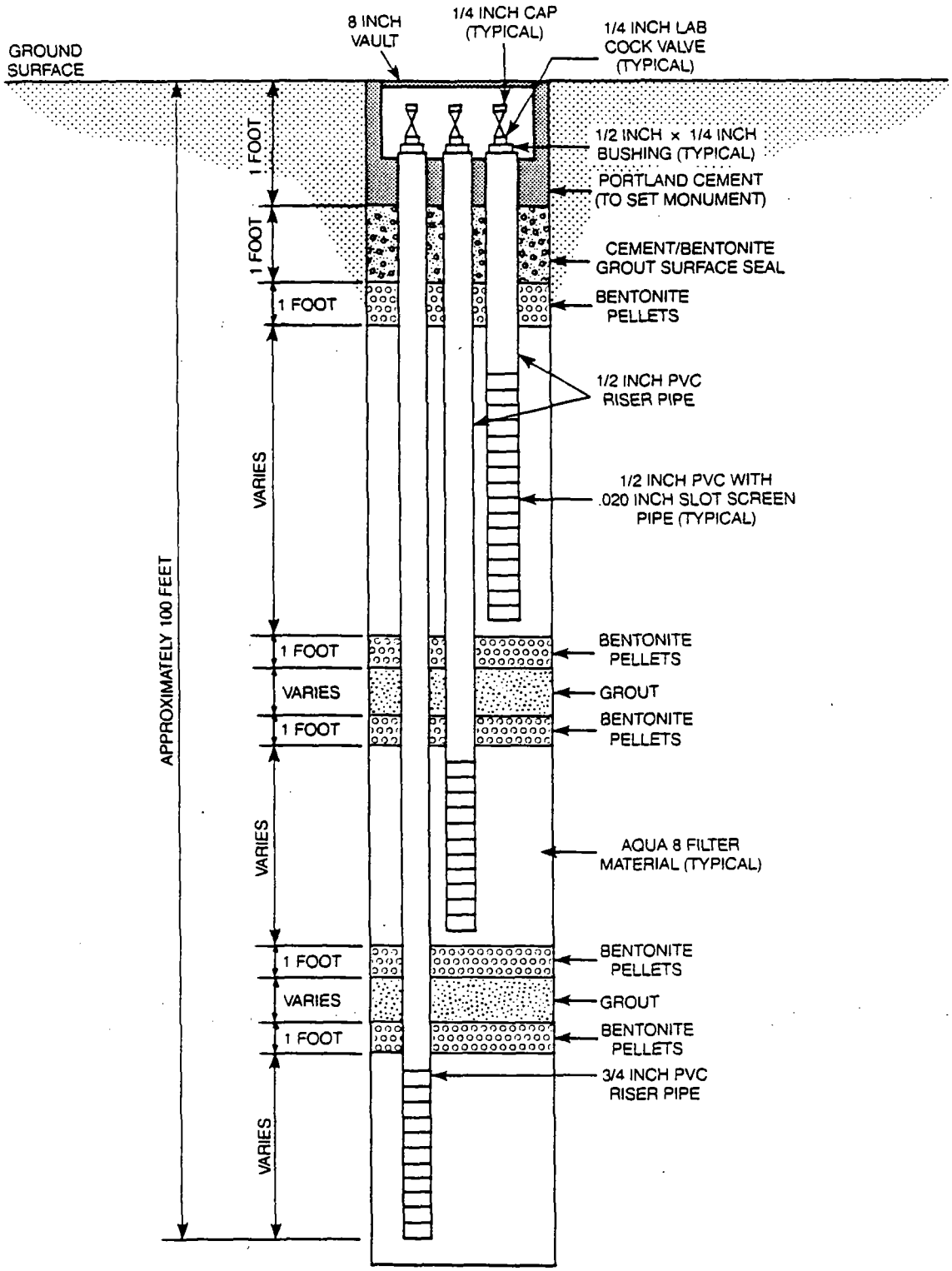


Figure 4-2
Cross Section of a Typical Multi-Level Monitoring Probe Installed by City of Seattle for the Remedial Investigation

NOT TO SCALE

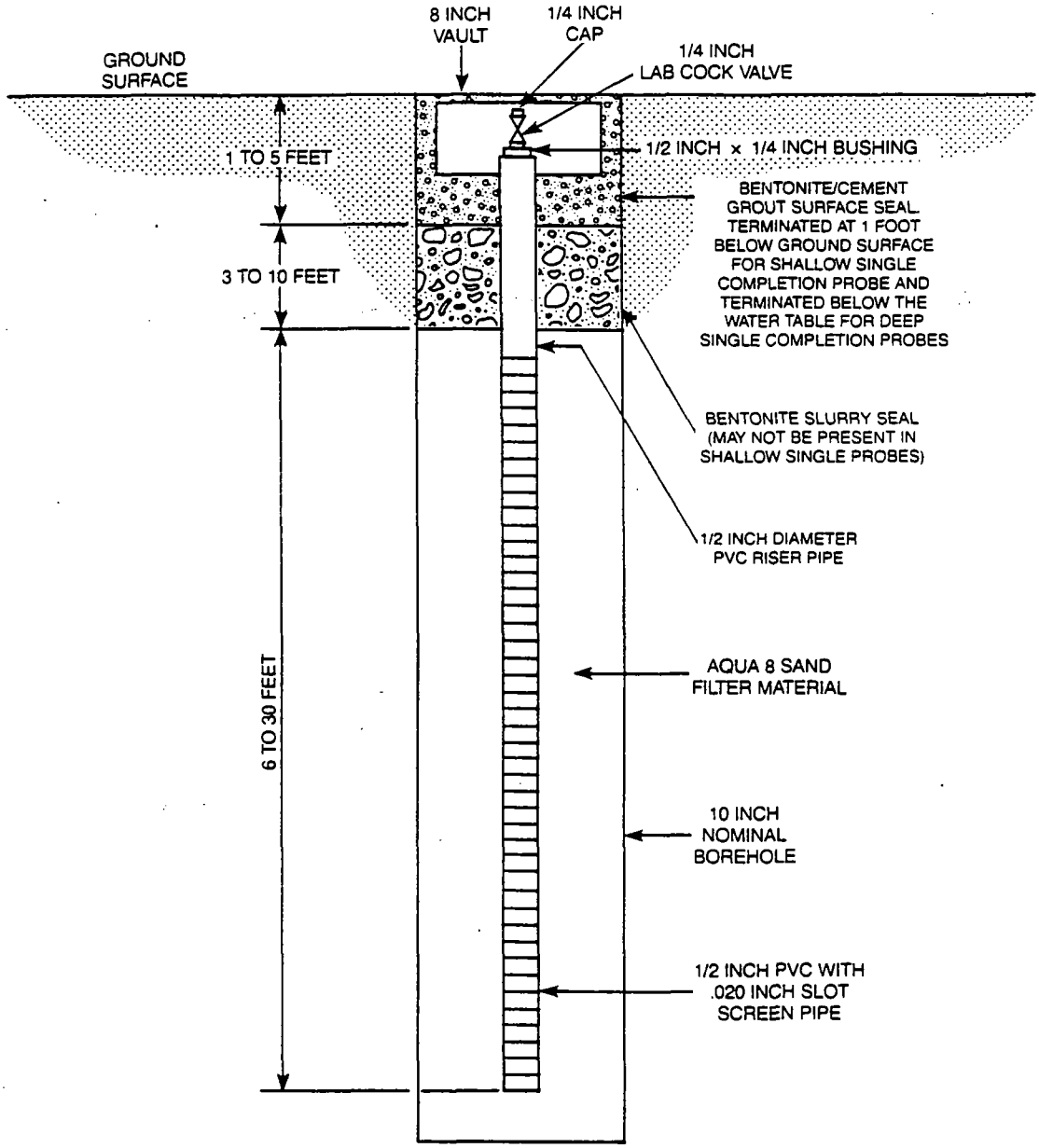


Figure 4-3
Cross Section of a Typical Single Completion Monitoring Probe Installed by Ecology

NOT TO SCALE

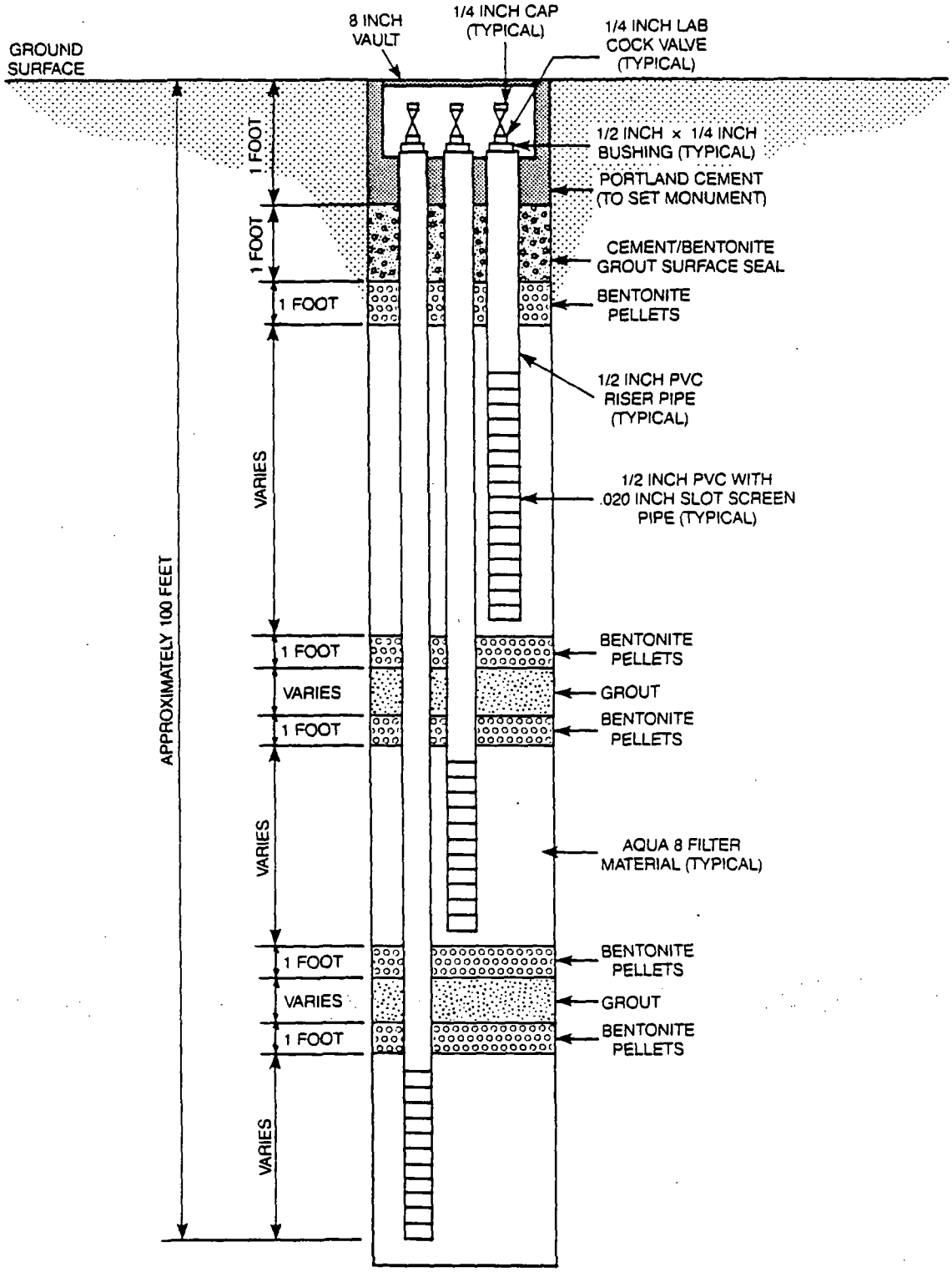


Figure 4-4
Cross Section of a Typical Multi-Level Monitoring Probe Installed by Ecology

NOT TO SCALE

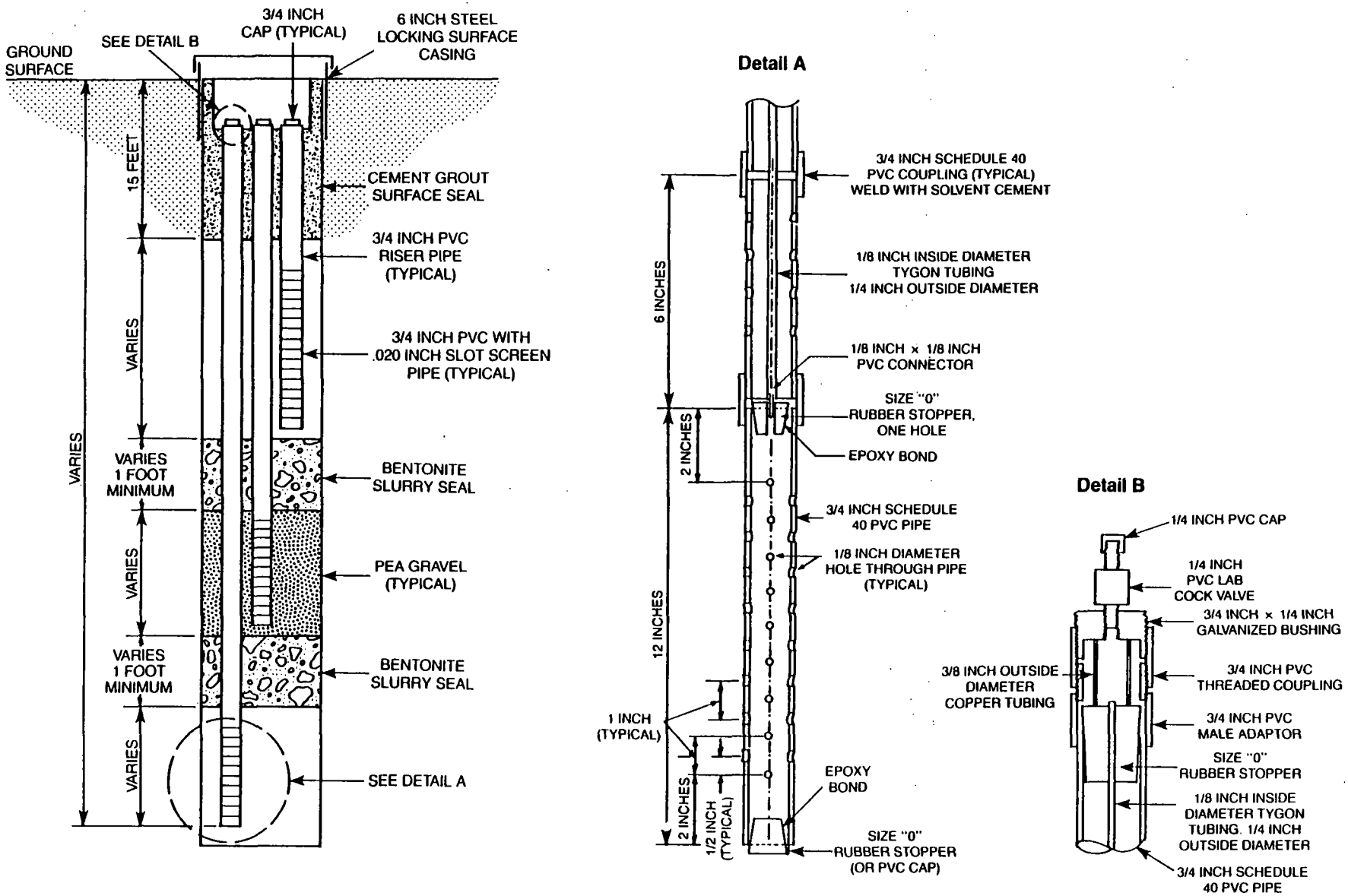


Figure 4-5
Cross Section of a Multi-Level Monitoring Probe Installed by the City of Seattle Prior to the Remedial Investigation

NOT TO SCALE

SPECIAL MONITORING

TWO TIMES WEEKLEY (evenly spaced)

C-4

*Barholes are shallow, temporary holes made to measure gas in shallow soil on days of low barometric pressure.

4.1.3 Offsite Control Wells

Offsite control wells are monitored for three purposes: first, to determine when levels of offsite gas have decreased to the point that the control wells should be shut down; second, to correlate the gas concentrations in each well with those read in nearby offsite probes in order to determine the sphere of influence of the well, and third, to ensure that no discharges to the atmosphere would create health hazards.

The offsite control wells operate continuously. The control well equipment has proven to be quite reliable, with a minimum of downtime from mechanical failure.

When the control wells were first put on line, they were monitored at least daily. In control wells where the gas concentrations were quickly reduced to near zero and remained at that level for several weeks, the frequency of monitoring was reduced to approximately once per week. As confidence in the data recorded increased, the frequency of monitoring was reduced accordingly.

Measurements normally taken at offsite control wells include:

- Combustible gas (percent, parts per million, or percent LEL)
- Oxygen (percent)
- Carbon dioxide (percent)
- Hydrogen sulfide (parts per million)
- Static pressure (vacuum in the well)
- Velocity

Velocity is converted mathematically to a flow measurement. The static pressure and flow measurements are used to evaluate the well's relative sphere of influence.

Samples of the discharge are analyzed periodically for volatile organics and priority pollutants.

4.2 Characterizing the Chemical Composition of Onsite and Offsite Gas

In order to characterize the gas detected offsite and to determine its source, special analyses were made of subsurface gas samples from onsite gas extraction wells, inlets to temporary gas flares, and offsite gas monitoring

probes.

Field measurements were taken using the following instruments:

- HNu PI-101 photoionization detector (total non-methane volatile organic compounds)
- MSA 361 portable detector (combustible gas, hydrogen sulfide, and oxygen)
- Fyrite carbon dioxide analyzer

Gas samples were collected in Tedlar bags and shipped to Analytical Technologies, Inc. Gas samples were analyzed for Hazardous Substances List volatile organic compounds by gas chromatography/mass spectrometry (GC/MS) in accordance with USEPA Method 624 guidelines.

Gas from individual onsite gas extraction wells was first characterized to describe substances known to be present at specific locations deep within the landfill. Pre-combustion flare gas, representing the combined gases extracted from the numerous individual onsite gas extraction wells, was then characterized to provide a description of the "average" composition of gases extracted from the landfill. Finally, gas collected from offsite gas monitoring probes and offsite gas control wells was compared with onsite gas to evaluate the nature and extent of potential offsite migration of the substances found in the landfill gas.

A report of the results of the gas characterization study is included as Appendix E of this report.

4.3 Evaluating the Effectiveness of the Gas Control System

4.3.1 Onsite Migration Control Wells

The effectiveness of the onsite migration control system is measured in the offsite probes. It depends on the strength and continuity of the "vacuum curtain" established around the site by operation of the migration control wells. This vacuum curtain is created by overlapping zones of influence of the individual wells. The zone of influence around a well is a product of well vacuum and flow, soil or refuse porosity, cover permeability, screened interval, and water table. The variable factors of vacuum, flow, and water table are monitored. If the onsite migration control system is successfully creating a vacuum curtain around the site, probes closer to the landfill will show vacuums in the medium and deep soil zones. Methane concentrations in offsite probes will fall or reach zero.

Methane concentrations may rise temporarily after system startup as offsite pools of gas are pulled back to the landfill. To study this phenomenon, several tools are used. First, pressure gradients emanating from the onsite extraction system are studied to determine if the vacuums created onsite are pulling offsite gas back toward the landfill, or if gas is being allowed to

migrate offsite. Gas will tend to flow perpendicular to pressure gradients through the path of least resistance. In other words, if gas is present within the zone of influence of an induced vacuum point (i.e. an extraction well), the gas will tend to flow toward the vacuum point. Experience at the Midway Landfill has shown that methane and carbon dioxide are produced during anaerobic decomposition in a ratio of 1.45:1. It is also known that carbon dioxide is readily soluble in water. Therefore, if the ratio of methane to carbon dioxide in an offsite gas probe is considerably less than the ratio in probes on the landfill, it can be assumed that the missing carbon dioxide was absorbed into soil moisture as the gas migrated. Further, if the pressure gradients between the offsite probe and the onsite extraction system indicate that gas is flowing toward the landfill, it is concluded that the gas being sampled is not newly migrated landfill gas, but gas that migrated offsite long ago and is now being pulled back to the landfill.

4.3.2 Offsite Control Wells

The offsite control wells, unlike the onsite migration control wells, were installed as temporary remedial measures because of high levels of gas detected in neighborhoods surrounding the landfill. Tests (described below) were performed to determine the optimum size for these wells. When the wells have succeeded in removing or reducing offsite gas, the vacuum they create may begin drawing new gas from the landfill. For this reason, they must be monitored carefully and shut down at the appropriate time.

On February 6, 1986, Hart Crowser & Associates performed a pumping test on extraction well EW-2 to determine the strength of induced soil vacuums at varying distances from the well. The test involved measuring the pressure drawdowns in the extraction well and in observation probe 82 as a function of time while the extraction well was pumped at a constant rate. Well EW-2 and observation probe 82 are shown on the site vicinity map in Appendix A of this report.

After this test, selected other offsite control wells and probes near these wells were monitored upon startup to determine the area of influence of these control wells and provide engineering data for the design of additional control wells. This intensive monitoring program was conducted by Parametrix, Inc. The original plan was to monitor several times a day for a week or more. This was performed in the first test period from June 24, 1986 to June 30, 1986. Evaluation of monitoring results showed very rapid probe pressure swings due to barometric changes. Monitoring of the probes several times per day was not often enough to give defined curves for pressure-time relationships. A second test period was planned during which probes were monitored every ninety minutes for twenty four hours. The second series of tests was performed from July 22, 1986 to July 23, 1986.

In June, 1987, in light of continuous low gas reading in gas probes near control wells C-1, C-2, C-3, C-5, E-1, and E-2, it was determined that these wells had accomplished their task of removing gas from their spheres of influence. They were, therefore, shut off. Probes near these wells were monitored with increased frequency immediately before and for weeks after the shutdown. Probes near control well E-2 were monitored intensively by

Parametrix for approximately 48 hours following its shutdown (see Table 5-4). This increased monitoring schedule was implemented to determine whether or not gas was likely to return to the area surrounding these control wells following their shutdown, or if gas had been effectively removed from the area. Static pressures, combustible gas concentrations, and oxygen were read in the monitoring probes during this study.

The results of the tests described above are discussed in Section 5.1.2.2 of this report.

4.4 Identifying Potential Gas Migration Pathways

4.4.1 Utility Corridors

Information on the locations of major underground utilities was compiled from existing maps and records. Cities of Kent and Des Moines Sewer Districts, Water District #75, City of Kent water supply utility, and Washington Natural Gas provided copies of their utility location maps. The information from these maps was then transferred to a common base map. Base maps were provided to Pacific Northwest Bell Telephone Company and Puget Sound Power and Light Company, and these utilities transferred their information to the base maps. Individual contacts were made by telephone call, letter, or both.

4.4.2 Geologic Pathways

A hydrogeologic study of the Midway Landfill area was conducted by Applied Geotechnology, Inc., a subcontractor of Parametrix, Inc., as part of the Remedial Investigation. The report of this study is Appendix A of the Groundwater Technical Report. Subsurface strata described in the hydrogeologic study were examined for evidence of undersaturated zones in the aquifers underlying the study area. Undersaturated zones are located where the potentiometric surface of the groundwater (i.e., the level to which the water would rise if it were unconfined) is below the roof of the aquifer, leaving a portion of the aquifer through which air and other gases can travel.

The undersaturated zones of the aquifers identified in the hydrogeology report were plotted on cross sections and then mapped. The next phase of the analysis involved comparing potential gas migration pathways with known concentrations of gas offsite, using computer-generated gas concentration isopleths that illustrate the distribution of subsurface gases by plotting data points from gas extraction wells and monitoring probes. Finally, the variables that can affect the migration of gases within the geologic pathways, such as barometric pressure, hydraulic conductivity and permeability, fluctuations in water tables, and gas concentrations and mass flux, were evaluated.

A report of the results of this study is included as Appendix G of this report.

5.0 RESULTS

Gas was eliminated from structures in the vicinity of the landfill within the influence area of the offsite extraction wells within one day of startup. Some residences adjacent to control well installations typically recorded levels of methane above 10,000 ppm, despite repeated efforts to seal the foundations of the structures. Since startup of the control wells, no gas has been detected in these residences.

Landfill gas detected offsite at shallow depths has been reduced greatly, from as high as 55% by volume in some areas to less than 5% by volume in all areas, except to the north, where installation of in-soil migration control wells has been delayed. This reduction is the result of the operation of both the onsite migration control wells and the offsite gas extraction wells, which were installed concurrently.

Deep gas concentrations offsite also have been reduced from as high as 70% by volume in some areas down to less than 5% by volume west of the landfill and less than 40% by volume in areas north, northeast and southeast of the landfill. Evidence indicates that the remaining areas of high concentrations of gas in deep soil zones are caused by gas reservoirs that have accumulated over time. These areas are still causing concern. Monitoring continues, and steps to remove this gas, such as the installation of additional offsite control wells and in-soil migration control wells, are being studied.

The ongoing operation of the migration control wells has been stabilized, based on a large database accumulated in their year and a half of operation. Analysis of offsite and onsite gas composition and concentrations suggests that the Midway Landfill is indeed the source of at least some of the offsite gas. A comparison of maps of shallow gas concentrations and underground utility lines gives no indication that utility conduits are transmitting methane from the landfill. However, the investigation of potential geologic pathways of gas migration found extensive undersaturated zones with high potential for gas movement to the south, east, and southwest of the landfill. These zones are more limited to the west and northwest of the landfill, and very limited to the north. These findings correlate well with known gas concentrations attributed to the landfill on the basis of other data.

5.1 Gas Monitoring Program

The ongoing program to monitor the landfill gas includes frequent checks of the concentration, composition, temperature, flow, and velocity of gases pumped by onsite and offsite control wells and indicated by offsite probes.

The migration control system is intended to prevent offsite migration of landfill gas and also to stabilize and control gas production in the landfill. Monitoring this system, therefore, requires information from both the onsite and offsite wells and probes. The onsite and offsite data are described separately in this section and interrelated in Section 5.3, Evaluation.

5.1.1 Onsite Gas

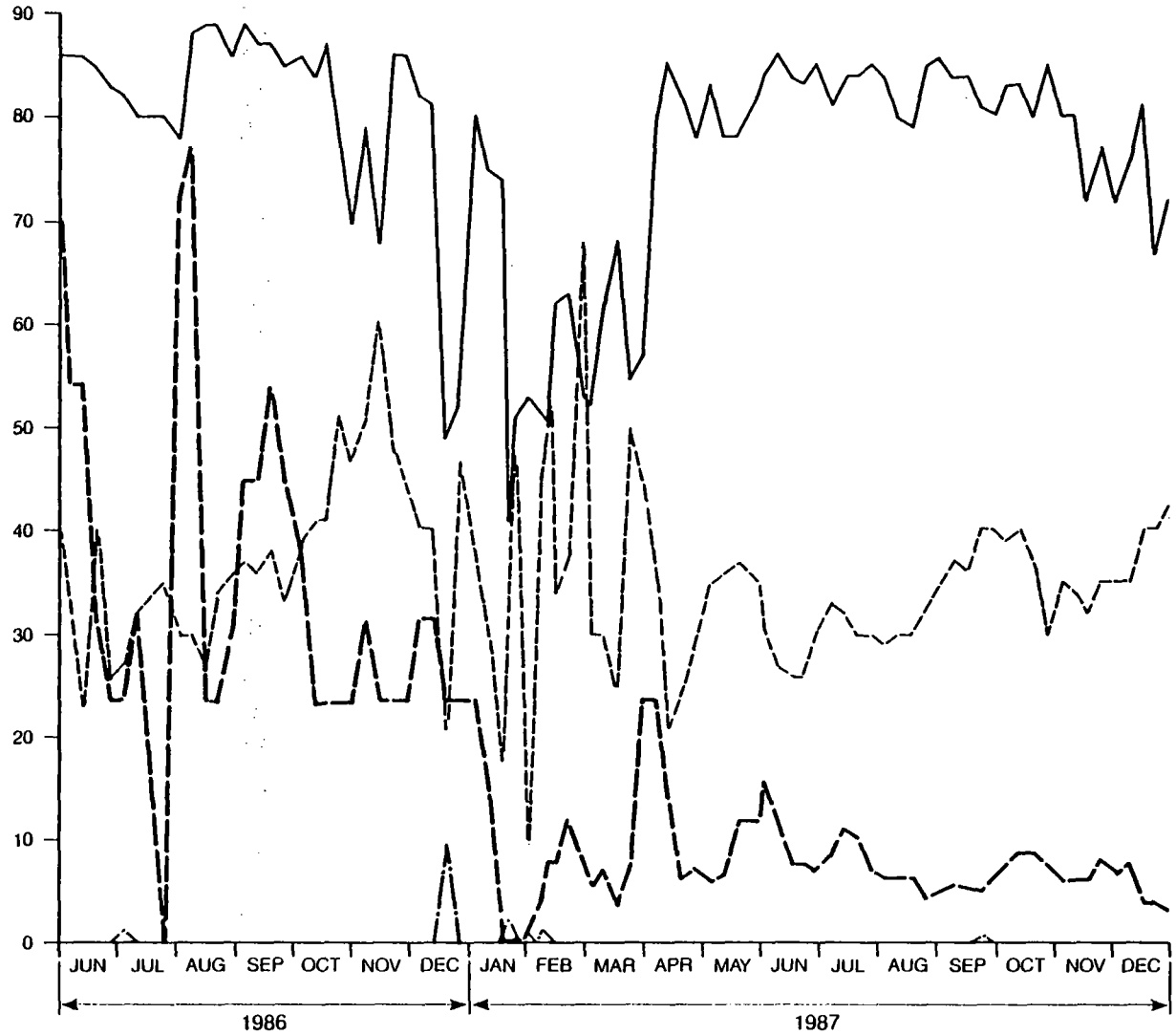
Prior to the installation of the Phase II wells, the average extracted gas flow throughout the landfill was approximately 900 to 1000 cfm of 35% to 50% methane. After the installation of the Phase II wells in February, 1987, an initial high flow of nearly 2000 cfm of 30% methane was measured as gas from the area was being drawn through the soil surrounding the in-soil extraction wells. Over the course of about one month, this flow was reduced to 1200 to 1400 cfm of 30% gas. This is approximately the flow at which the system has been operating since April, 1987. Figures 5-1 through 5-8 show this history of well performance in four typical wells in four different areas of the landfill. Please note that the static pressure for each well is graphed separately for clarity.

The average combined methane concentration throughout the migration control system is currently approximately 30% by volume. Many in-waste wells produce methane at levels over 40%. In contrast, most of the in-soil wells produce very low concentrations of methane mixed with free air. This is to be expected, because most of the landfill gas is extracted by the in-waste wells.

Many areas of the landfill lack the 3 feet of clay cover considered adequate to prevent intrusion of air into the waste when wells are installed and operated. For this reason gas flow in several of the migration control wells must be restricted to prevent unsafe levels of aerobic decomposition near the wells. Normally operating in-waste extraction wells are currently producing gas at temperatures between 90 and 100 degrees F. This temperature reflects the level of aerobic decomposition allowed to occur in the landfill as a compromise between optimum operation of the extraction wells and safe limits of heat.

When the influenced waste near a migration control well exhibits the characteristics of aerobic decomposition above safe limits, the flow from that well is reduced by use of the control valve installed on each completion of every well. Inversely, when readings taken indicate that a well can be drawn on harder and still be within safe limits, the flow is increased. Generally, changes in gas concentrations can be witnessed within 24 hours, although sometimes this process can take weeks. Except for the effect of barometric changes, the flow in wells remains fairly constant between adjustments. Wells eventually will be adjusted to a stable level of maximum safe flow. After this has been accomplished, the frequency at which a well is monitored can be reduced. The only future adjustments necessary should be those in response to seasonal changes in average barometric pressure and the gradual decline of methane production in the landfill. Slightly lower well flow rates may be necessary in winter to offset the flow increase caused by low barometric pressure.

In a test performed in the winter of 1986, it was found that 12 of the migration control wells contained significantly high water levels (see Table 5-1). The effectiveness of these wells was reduced depending on the ratio of well screen above and below the water table. Because these wells were



CH4%
02%
Temperature deg F.
Flow cfm

Figure 5-1
Well Performance Graph
Well #16

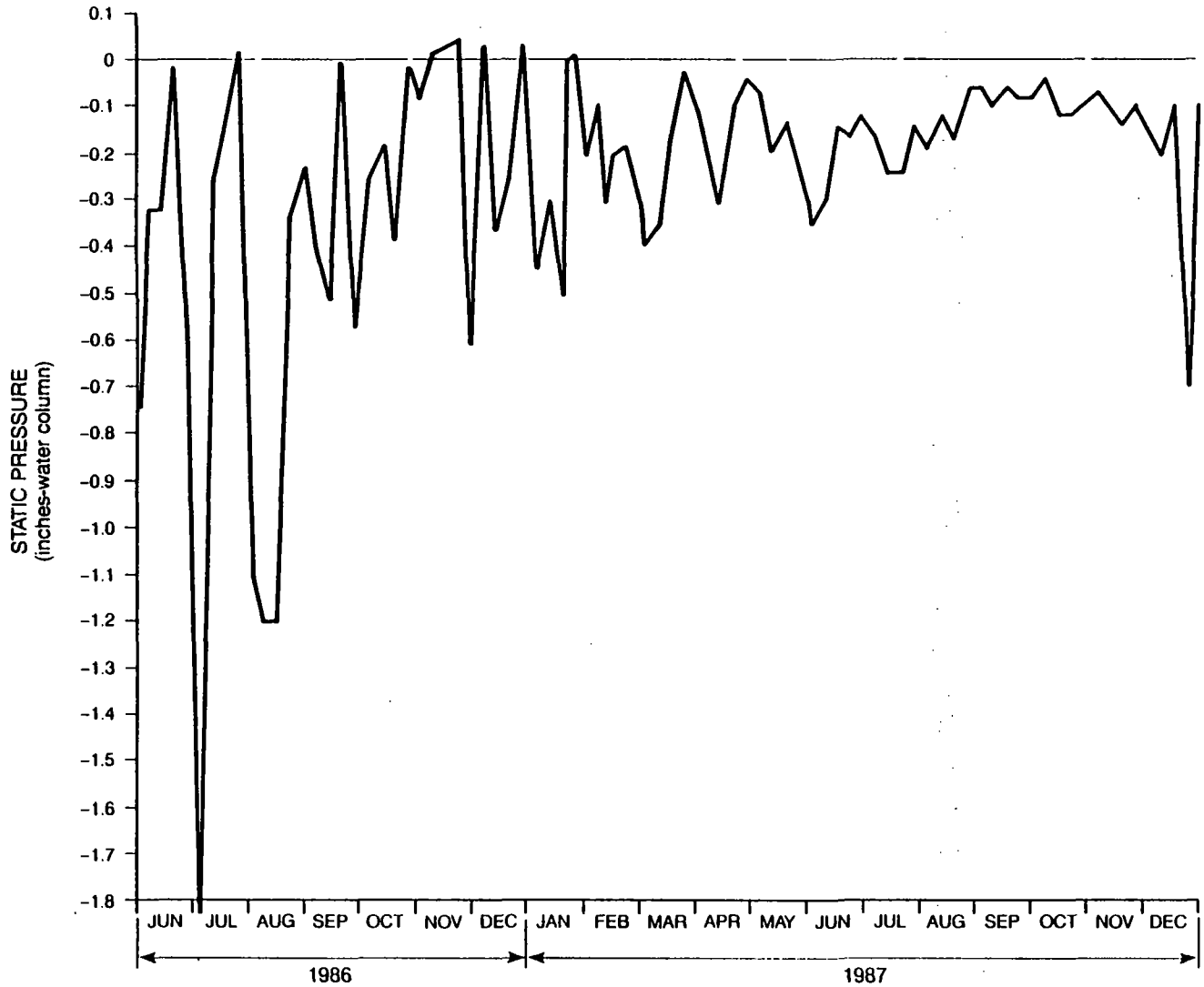
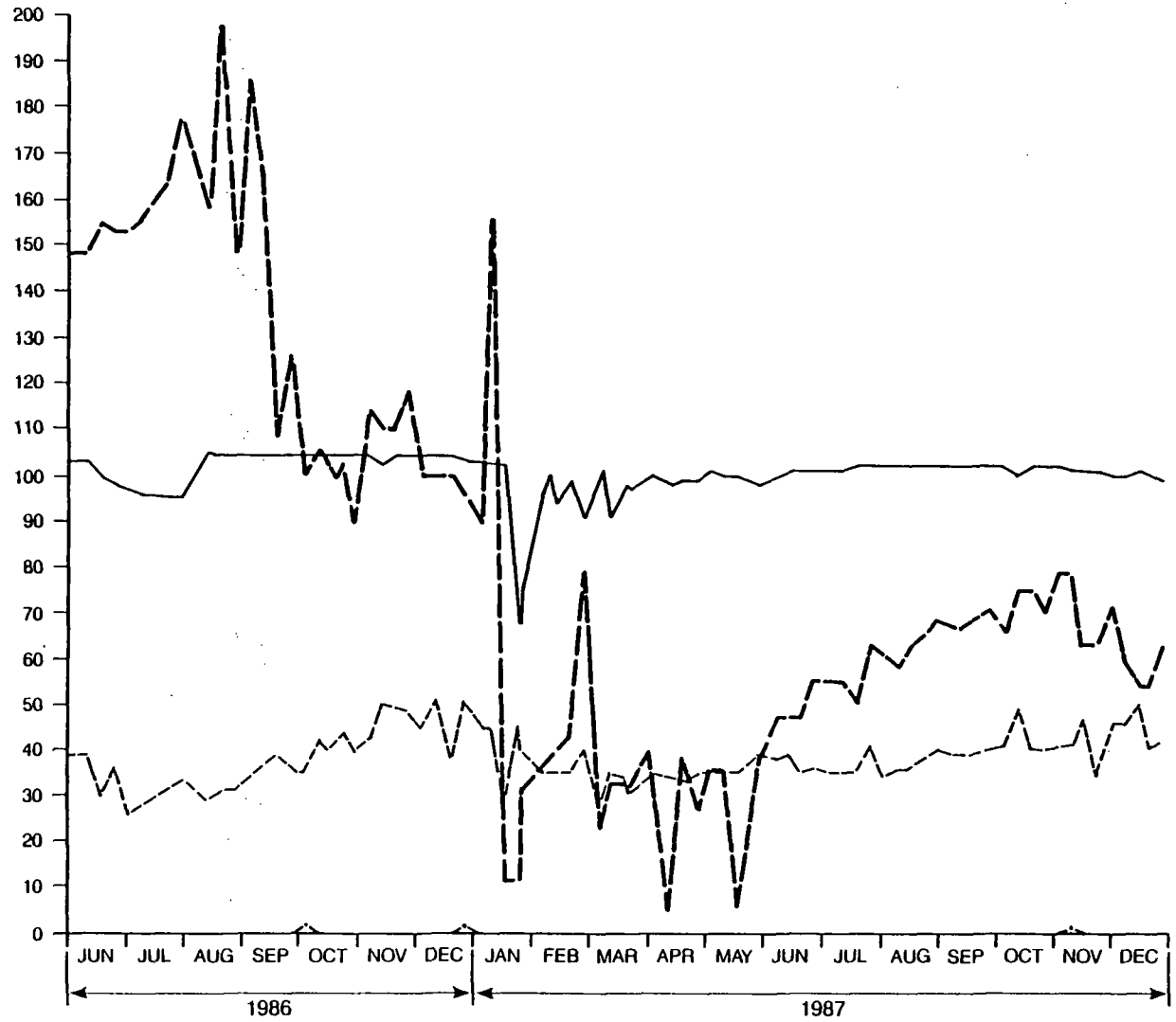


Figure 5-2
Static Pressure Graph
Well #16



CH4%
02%
Temperature deg F.
Flow cfm

Figure 5-3
Well Performance Graph
Well #17

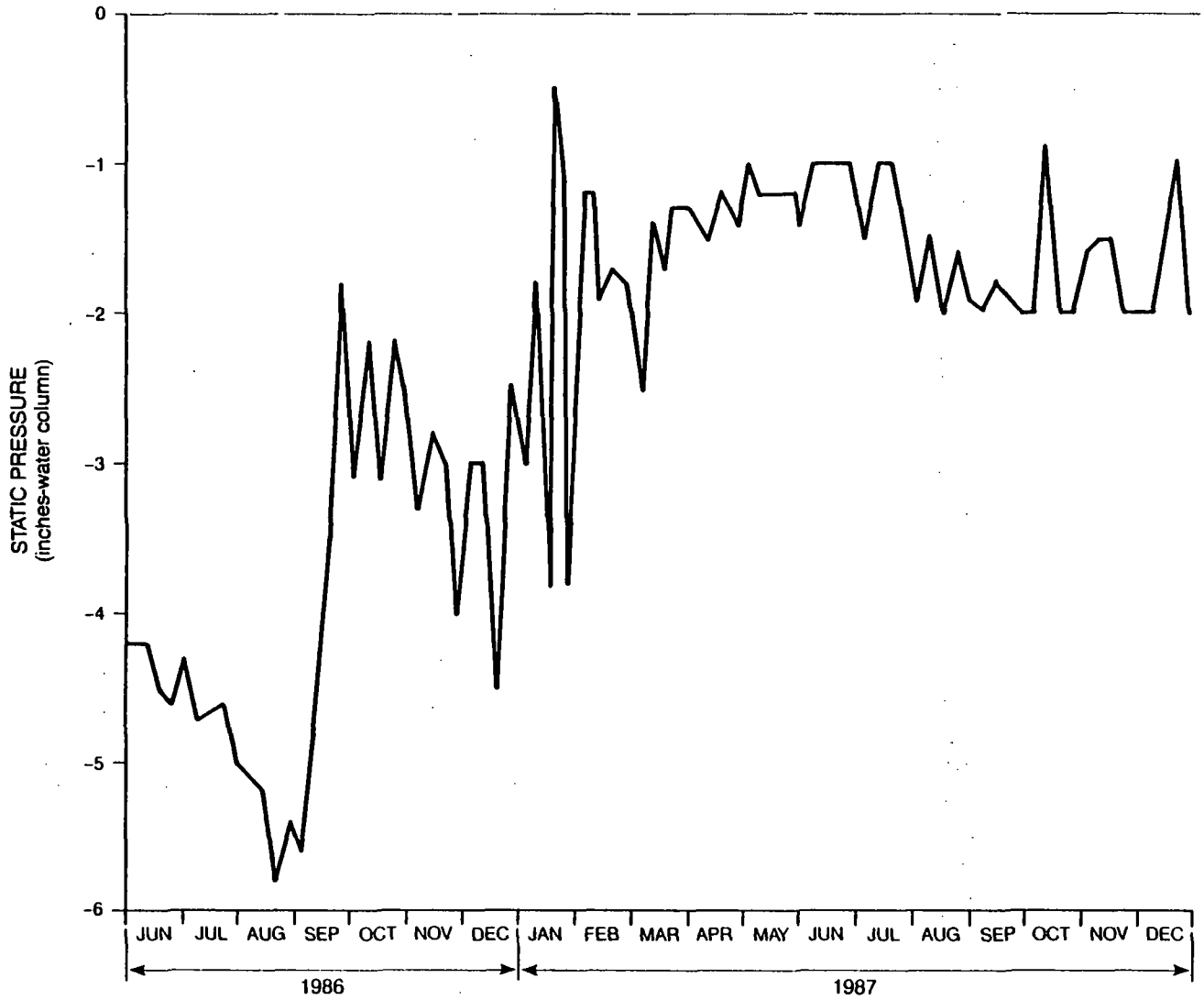
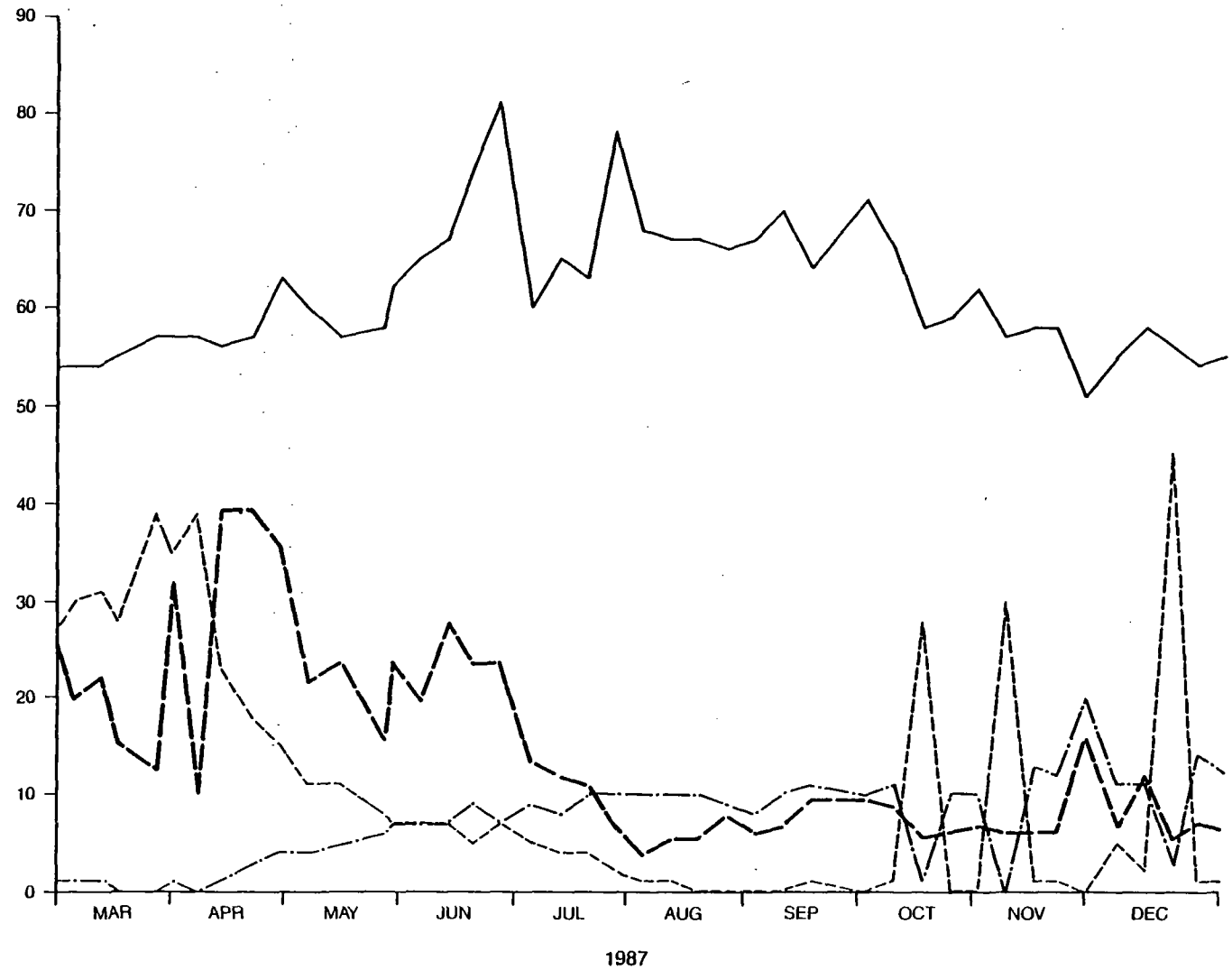


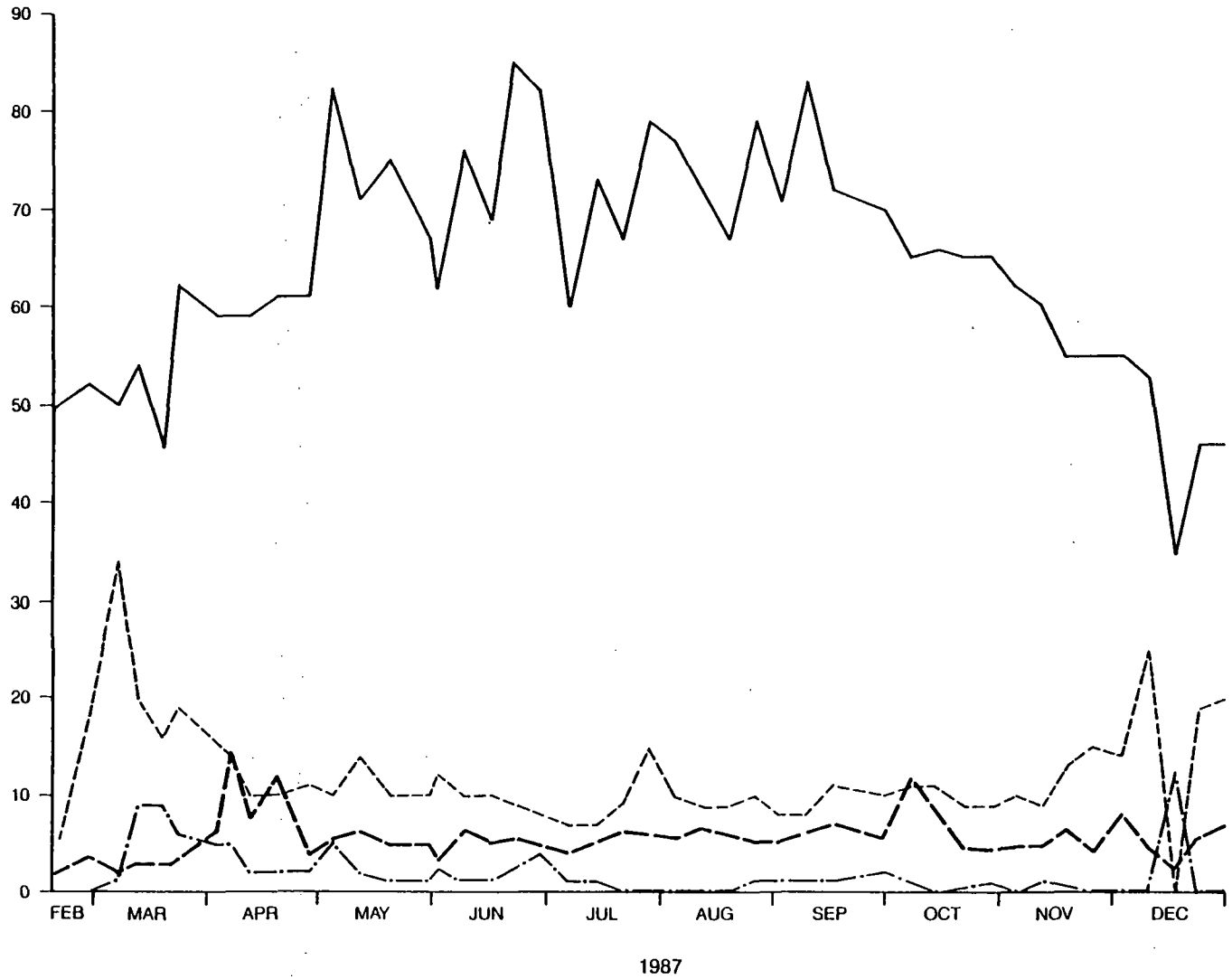
Figure 5-4
Static Pressure Graph
Well #17



CH4%
02%
Temperature deg F.
Flow cfm

Figure 5-5
Well Performance Graph
Well #PA4D

Figure 5-6
Static Pressure Graph
Well # PA4D



CH4%
02%
Temperature deg F.
Flow cfm

Figure 5-7
Well Performance Graph
Well #PD6D

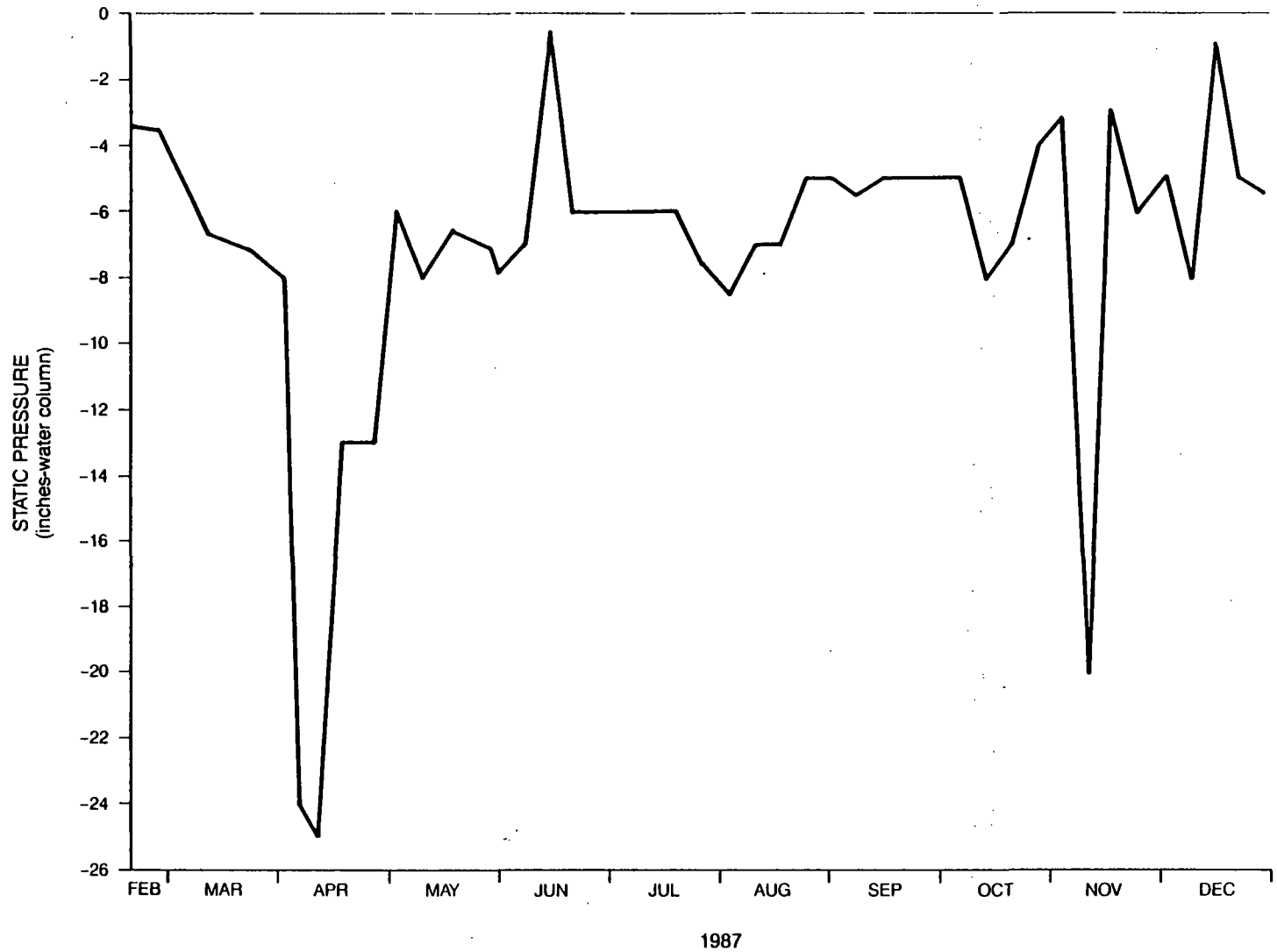


Figure 5-8
Static Pressure Graph
Well #PD6D

TABLE 5-1
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (WINTER, 1986)

WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
1	49.5	47	2.5
2	60.5	37.5	14.8
3	51.5	37	14.5
4	61	31.5	29.5
5	66	36	30
6	60.5	42.5	18
7	70.5	56.5	13.5
8	67.5	65	2.5
9	71	56.5	14.5
10	65.5	55	10.5
11	61.5	59	2.5
12	61.5	57	4.5
13	62	40.5	21.5
14	65.5	55	10.5
15	61	57.5	4.5
16	61	55	6
17	87	N/A	N/A
18	101	N/A	N/A
19	93.5	N/A	N/A
20	92.5	N/A	N/A
21	101	96.5	4.5
22	76.5	69	7.5
23	79	47.5	31.5
24	60.7	51	9.7
25	89	60.5	28.5
26	87.5	50	33.5
27	86	72.5	13.5
28	89.5	86	3.5
29	87	81.5	5.5
30	50	47	3
31	76.4	52.5	24.1
32	81	76	5
33	68	41	27
34	68	57	11

clustered principally in three nonadjacent groups, and no water table was known to correlate with the water levels in the wells, it was concluded that these were local perched water tables within the refuse. By the summer of 1986, when it was decided to pump the wells down, they were dry again.

A second test performed in the winter of 1987 again found no evidence of a single continuous water table throughout the landfill. Table 5-2 shows the results of the second study, including a list of the drill depths and completion levels of each migration control well.

5.1.2 Offsite Gas

According to City monitoring records, when offsite control wells were installed near structures where high levels of gas had been detected, the gas was effectively removed from the structure within one day of startup. Furthermore, gas concentrations have been eliminated in all monitored structures in the vicinity of the landfill since the implementation of the offsite control wells. Combustible gas above 100 parts per million has not been recorded in a structure in the vicinity since November, 1986.

5.1.2.1 Reduction of Gas Concentrations

Data recorded from the monitoring probes were compiled and input to a computer to generate gas concentration isopleths. This program uses the Inverse Distance method, which assumes a logarithmic progression between data points. These maps show gradient lines of gas concentrations around the Midway Landfill.

The isopleths for February 1986, shown in Figures 5-9 and 5-10, represent the status of landfill gas migration just after the Phase I onsite gas migration control system was put into continuous operation. Methane was detected northwest of the landfill in concentrations over 75%, north in concentrations over 25%, and east and southwest in concentrations over 40%.

The effect of the offsite control wells placed in various locations in the neighborhoods east of the landfill can be seen on Figure 5-9. This figure shows a shallow soil zone east of Interstate 5 in which high concentrations of gas were detected. The areas near the offsite control wells show concentrations of gas 5% or less by volume. Figure 5-10 shows that methane was detected in the deep soil zone in all directions away from the landfill and in concentrations over 90% in some areas.

The detection of extremely high concentrations of methane (75-95%) was surprising. However, experience has shown that gas remaining in the soil over a long period of time may show rising methane concentrations. One explanation for this phenomenon is that the carbon dioxide initially included in the gas as a product of decomposition is removed through absorption by soil moisture. Other possibilities such as equipment failure, operator error, or natural gas leaks, were investigated. Some natural gas leaks were found (see Appendix F), but they were not sufficient to cause such widespread high concentrations. Equipment failure and operator error were not involved.

TABLE 5-2
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (FEBRUARY 20, 1987)

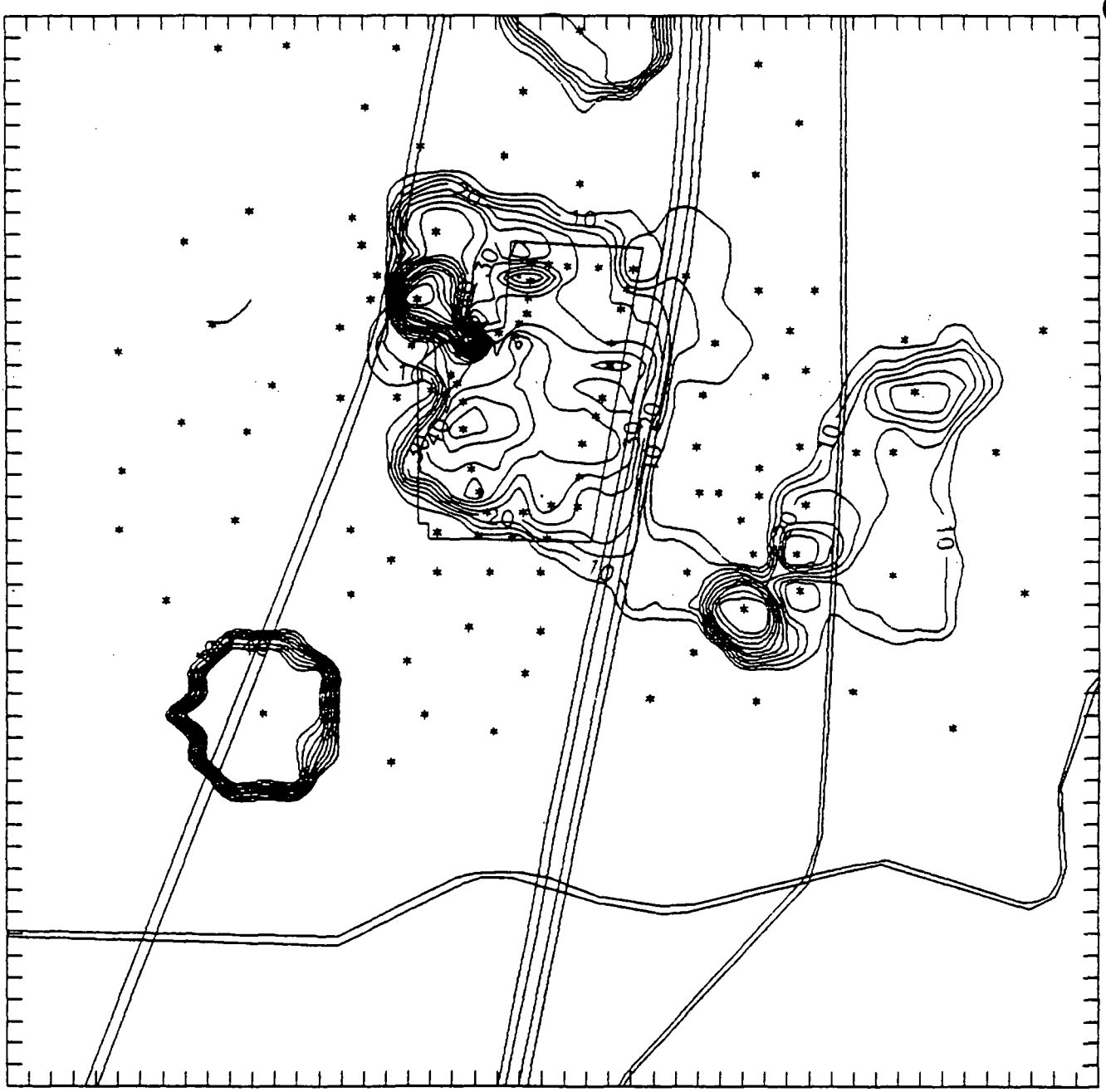
WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
1	49.5	N/A	N/A
2	60.5	60.5	0
3	51.5	30.58	20.92
4	61	61	0
5	66	34.41	31.67
6	60.5	37.64	22.86
7	70.5	50.22	20.28
8	67.5	63.17	4.33
9	71	51.67	19.33
10	65.5	51.62	13.88
11	61.5	58.31	3.19
12	61.5	50.37	11.13
13	62	37.26	24.74
14	65.5	65.5	0
15	61	54.11	6.89
16	61	53.69	7.31
17	87	91	6
18	101	99	2
19	93.5	86	7.5
20	92.5	85	7.5
21	101	94	7
22	76.5	67.75	8.75
23	79	40	39
24	60.7	47	13.7
25	89	60	29
26	87.5	61	26.5
27	86	68.8	17.2
28	89.5	87	2.5
29	87	82	5
30	50	46.53	3.47
31	76.4	74	2.4
32	81	69	12
33	68	44.53	23.47
34	68	54.87	13.13
35S	42	41	1
35D	98	91	7
36S	46	42	4
36D	94	91	3
37S	48	48	0
37D	98	97	1
38S	56	56	0
38D	110	75	35
39S	64	64	0
39D	126	110	16
40S	64	64	0

TABLE 5-2 (CONT.)
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (FEBRUARY 20, 1987)

WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
40D	126	110	16
41S	60	60	0
41D	118	91	27
42S	32	21.72	10.28
42D	62	62	0
43S	39	38.51	0.49
43D	78	48.5	29.5
44S	39	38.51	0.49
44D	79	51.15	27.85
45S	42	42	0
45D	82	57.01	24.99
46S	47.5	43.22	4.28
46D	93	53.05	39.95
47S	43.5	40.28	3.22
47D	85	52.24	32.76
PA1S	29	12	17
PA1D	67	56.66	10.34
PA2S	35	N/A	N/A
PA2D	67	N/A	N/A
PA3S	56	56	0
PA3D	93	93	0
PA4S	44	44	0
PA4D	98	98	0
PA5S	60	60	0
PA5D	118	118	0
PA6S	63	30	33
PA6D	120	55	65
PA7S	58	56	0
PA7D	117	74.9	42.1
PA8S	52	48.5	3.5
PA8D	112	109	3
PA9S	64	44.5	19.5
PA9D	138	138	0
PA10S	66	66	0
PA10D	133	133	0
PC8S	32	13	19
PC8D	76	59.27	16.73
PD1S	65	65	0
PD1D	130	128	2
PD2S	63	63	0
PD2D	130	130	0
PD3S	56	56	0
PD3D	113	113	0
PD4S	68	68	0
PD4D	130	130	0

TABLE 5-2 (CONT.)
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (FEBRUARY 20, 1987)

WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
PD5S	60	60	0
PD5D	118	118	0
PD6S	50	50	0
PD6D	110	94	16
PD7S	58	56	2
PD7D	117	89	28
PD8S	46	46	0
PD8D	101.5	86	15.5
PD9S	44	44	0
PD9D	99.5	80.5	19
PD10S	51	47	4
PD10D	101.5	81	20.5
PD11S	51	51	0
PD11D	101	76	25
PD12S	38	38	0
PD12D	91	78	13



Note: All sets of probes and wells may not be shown.

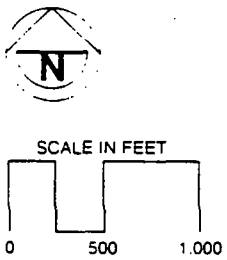
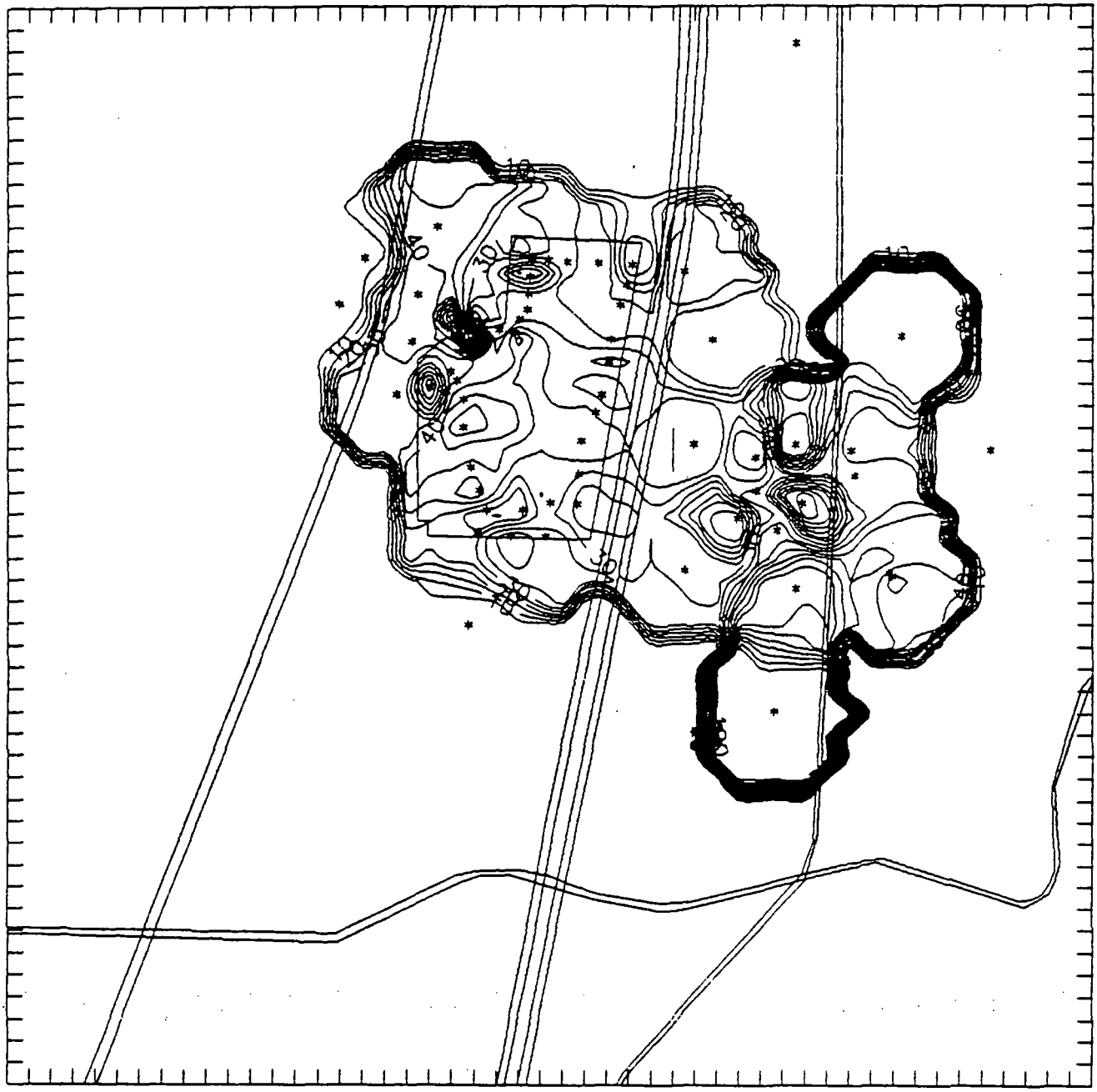


Figure 5-9
Shallow Gas Concentration Isopleth, February, 1986



Note: All sets of probes and wells may not be shown.

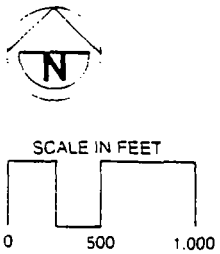


Figure 5-10
Deep Gas Concentration Isopleth, February, 1986

Figures 5-11 and 5-12 depict maximum shallow and deep gas concentrations during the first half of September, 1986. This represents the status of migrated landfill gas seven months after the Phase I onsite migration control system was put into continuous operation. As shown on Figure 5-11, shallow gas concentrations to the east, south, and west of the landfill have been greatly reduced. This is due not only to the influence of the onsite gas migration control system but also to the operation of the offsite control wells.

Shallow gas concentrations over 25% by volume were detected 1300 feet west of the landfill. A peat bog located in that area was believed to be the source of this gas rather than the landfill. Shallow gas concentrations over 30% by volume were detected north of the landfill in probe 2 during this time. Without sufficient probe data north of the landfill, it was difficult to determine the source of this gas, but it appeared to be generated offsite.

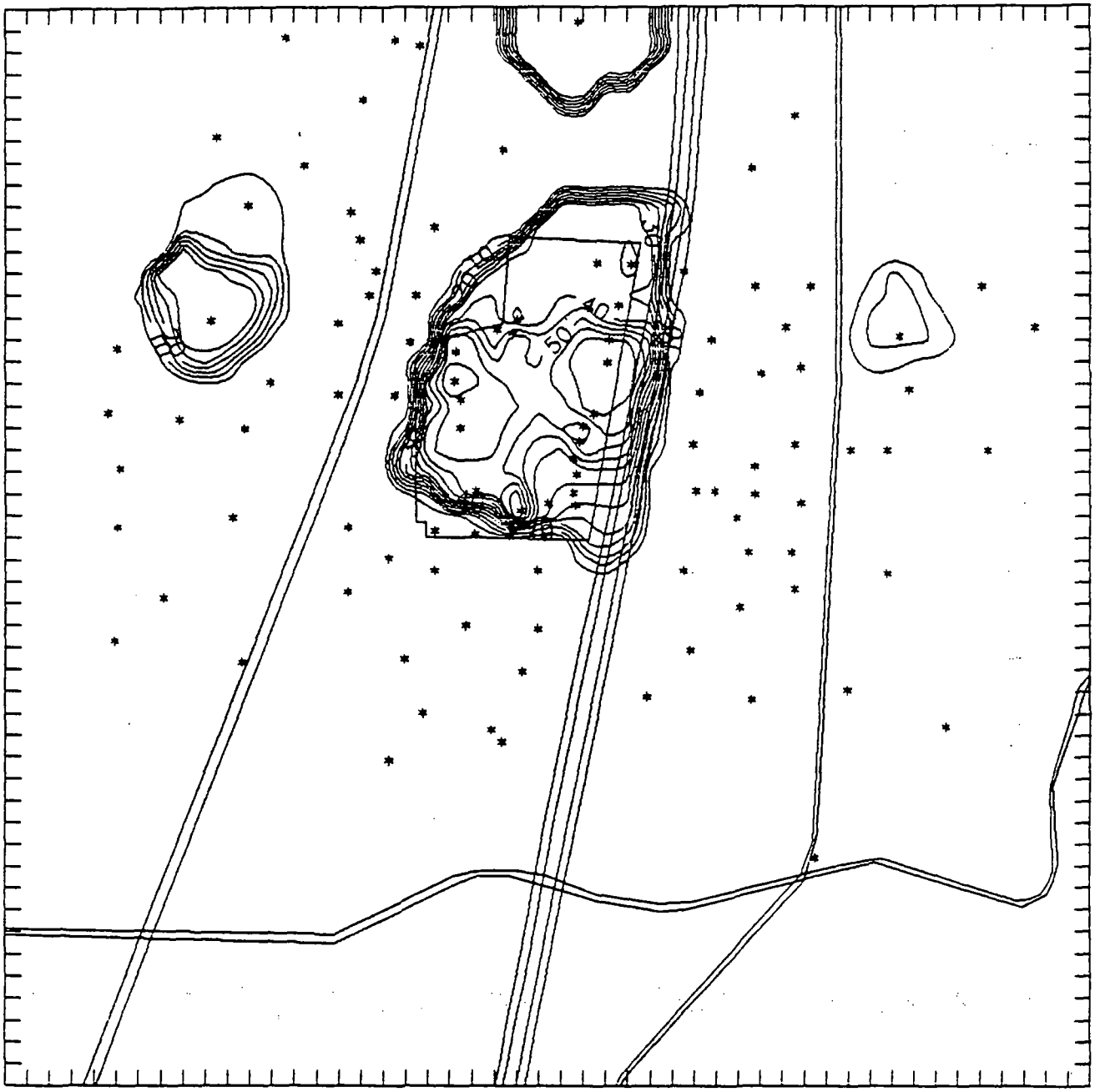
Figure 5-12, a deep gas concentration isopleth for September 1986, shows significant reductions in deep gas concentrations west of the landfill. The concentrations of gas to the north, east, and south also are shown to have been reduced greatly (from over 90% by volume in some areas to 35% by volume east of the landfill). However, it is not possible to ascertain the exact extent of offsite landfill migration in these areas because of the lack of offsite probe data.

Figures 5-13 and 5-14 show even further reductions in offsite gas concentrations by July 1987. Figure 5-15 shows no significant changes in offsite migration of shallow gas between July and December of 1987. Additional evidence suggests strongly that the gas previously detected in shallow soil zones to the west of the landfill is a product of the peat bog located in that area. Gas concentrations in shallow soil zones north of the landfill are still causing concern. Further actions are underway to determine the source and alleviate the problem, if the landfill is determined to be the source.

Also shown on Figure 5-14 is a high level of offsite gas to the northwest of the landfill, indicated by data from a gas probe installed in groundwater monitoring well MW-21. This high concentration has been reduced over time (see Figure 5-16 showing December 1987 isopleths) by the operation of control well C-11 and onsite migration wells PA-1 and PC-8.

5.1.2.2 Results of Probe Monitoring During Offsite Control Well Shut Down

Tests performed by Hart Crowser and Associates, Inc. in February 1986, and by Parametrix, Inc. in June and July of 1986 (see Section 4.3.2 of this report), indicate that offsite control wells have an increasingly stronger vacuum effect proportional to the depth of the soil. In shallow soils air exchange with the atmosphere is quicker and pressures equalize faster than in deep soil zones. For a typical 1.5 horsepower blower producing 30 cubic feet per minute, the relationship between distance from the well and pressure in the surrounding soil is approximately as shown in Table 5-3.



Note: All sets of probes and wells may not be shown.

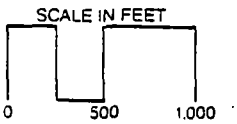


Figure 5-11
Shallow Gas Concentration Isopleth, September 1986

Note: All sets of probes and wells may not be shown.

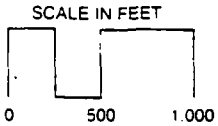
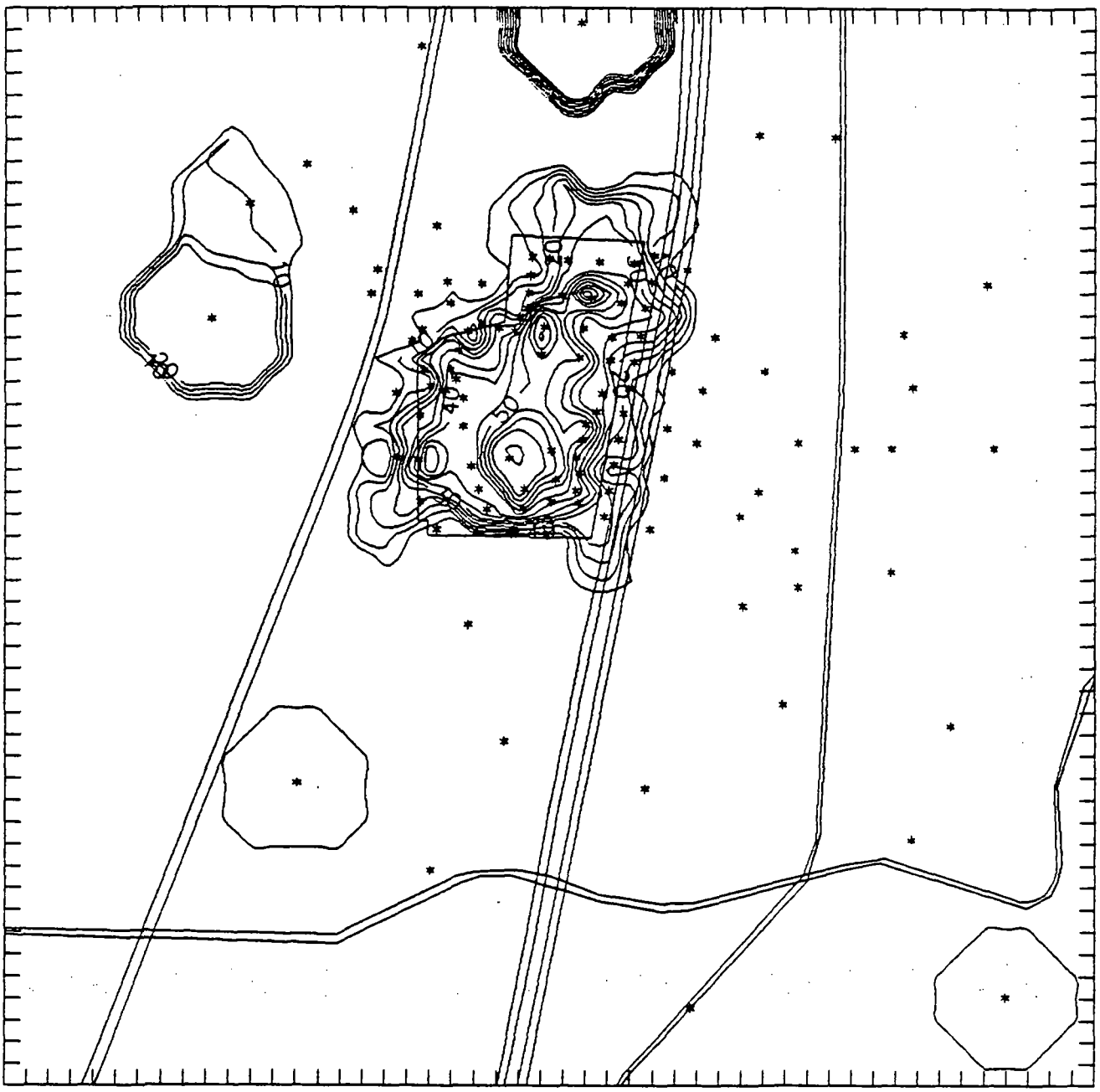


Figure 5-12
Deep Gas Concentration Isopleth, September 1986



Note: All sets of probes and wells may not be shown.

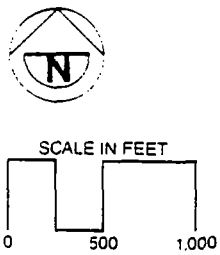


Figure 5-13
Shallow Gas Concentration Isopleth, July 1987

Note: All sets of probes and wells may not be shown.

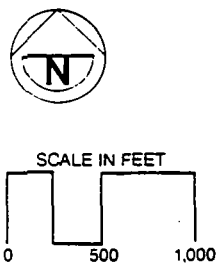


Figure 5-14
Deep Gas Concentration Isopleth, July 1987

Note: All sets of probes and wells may not be shown.

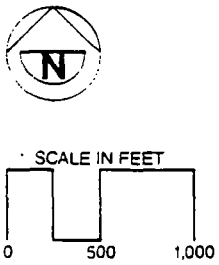


Figure 5-15
Shallow Gas Concentration Isopleth, December 1987

Note: All sets of probes and wells may not be shown.

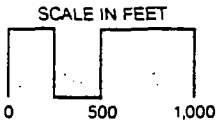


Figure 5-16
Deep Gas Concentration Isopleth, December 1987

The soil vacuum produced by the 1.5 horsepower blower well system protects structures from gas infiltration within a radius of influence of 200 to 300 feet. Once the gas is removed from the structure, the prime objective of the installation of the well is to remove pockets of gas. Although the 1.5 horsepower system can remove gas from the soil surrounding it, it does so rather slowly. It takes roughly two months to remove gas from the soil in a 200-foot radius and 12 months to remove gas from within 500 feet, because of the relatively low flow rates produced by the 1.5 HP blower. In contrast, a 5 horsepower blower producing 250 cfm will remove gas from the soil in a 500-foot radius in approximately 1.5 months, and will also protect structures within a 500-foot radius. Considering this increased performance, it was felt that any additional offsite control well installations should be the larger type, as long as they can be placed far enough away from the landfill to be sure that they are not drawing new gas out of the landfill. Where there is a zone of relatively slow air flow in the soil midway between two adjacent control wells, air infiltration from the soil surface will tend to cleanse gases from this "dead" zone.

TABLE 5-3
PRESSURE DRAWDOWN RELATED TO DISTANCE FROM OFFSITE CONTROL WELLS (1.5 H.P. MOTOR BLOWER)

DISTANCE	PRESSURE DRAWDOWN (inches W.C., measured at least 50 feet below ground surface)
50 ft.	1.0
100 ft.	0.7
200 ft.	0.4
500 ft.	0.1

Table 5-4 shows the results of the test performed by Parametrix, Inc. in June 1987 during the shutdown of selected offsite control wells (see Section 4.3.2). These results indicate that both shallow and deep-level gas has been effectively removed from the areas surrounding these control wells, and that the wells can remain shut down. Probes near these wells are still monitored at least weekly. If in the future gas levels are found to be rising, the control wells will be restarted.

TABLE 5-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987

PROBE 46 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.)	CH4
6/29/87	-60	0700	0745	-0.06	100
6/29/87	0	0800	0800	--	--
6/29/87	1	0801	0809	-0.08	--
6/29/87	3	0803	0803	--	--
6/29/87	6	0806	0806	--	--
6/29/87	10	0810	0810	--	--
6/29/87	15	0815	0815	--	--
6/29/87	20	0820	0823	-0.085	--
6/29/87	25	0825	0825	--	--
6/29/87	30	0830	0830	--	--
6/29/87	45	0845	0850	-0.06	100
6/29/87	60	0900	0906	-0.08	100
6/29/87	100	0940	0946	-0.075	100
6/29/87	160	1040	1051	-0.06	100
6/29/87	300	1300	1312	-0.05	100
6/29/87	500	1620	1626	-0.025	80
6/29/87	740	2020	2034	-0.04	100
6/30/87	980	0020	0026	-0.075	80
6/30/87	1180	0340	0344	-0.07	180
6/30/87	1420	0740	0808	-0.045	200
6/30/87	1660	1140	1150	-0.055	100
6/30/87	1900	1540	1540	-0.04	200
6/30/87	2140	1940	2040	-0.06	180
6/30/87	2300	2340	2330	-0.08	200
7/01/87	2620	0340	0345	-0.08	200
7/01/87	2880	0800	0845	-0.1	240

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4	O2
6/29/87	2034	0	16
6/30/87	0808	0	16
6/30/87	2040	0	16
7/01/87	0845	0	16

TABLE 5-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 50 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.) PROBE S	PRESSURE (IN. W.C.) PROBE M	PRESSURE (IN. W.C.) PROBE D	CH4 PROBE S	CH4 PROBE M	CH4 PROBE D
6/29/87	-60	0700	0710	-0.48	-1	-2.2	--	--	--
6/29/87	0	0800	0800	--	--	--	--	--	--
6/29/87	1	0801	0801	-0.52	-1.1	-2	--	--	--
6/29/87	3	0803	0803	-0.52	-1.1	-2	--	--	--
6/29/87	6	0806	0806	--	-1.1	-2	--	--	--
6/29/87	10	0810	0810	--	-1.1	-2	--	--	--
6/29/87	15	0815	0815	--	-1.1	-2	--	--	--
6/29/87	20	0820	0820	-0.54	-1.1	-2	--	--	--
6/29/87	25	0825	0825	-0.55	-1.1	-2	--	--	--
6/29/87	30	0830	0830	-0.55	-1.2	-1.9	--	--	--
6/29/87	45	0845	0845	-0.58	-1.2	-1.9	46	46	16
6/29/87	60	0900	0900	-0.54	-1.2	-1.8	64	64	20
6/29/87	100	0940	0940	-0.49	-1	-1.5	64	64	20
6/29/87	160	1040	1040	-0.32	-0.75	-1.3	75	75	30
6/29/87	300	1300	1300	-0.12	-0.27	-0.65	90	90	320
6/29/87	500	1620	1622	0.1	0.22	-0.215	82	82	1200
6/29/87	740	2020	2017	-0.05	-0.115	-0.7	90	90	6000
6/30/87	980	0020	0019	-0.225	-0.5	-1.2	58	58	9000
6/30/87	1180	0340	0340	-0.23	-0.6	-1.3	90	90	6000
6/30/87	1420	0740	0804	-0.26	-0.87	-1.7	100	100	4000
6/30/87	1660	1140	1140	-0.17	-0.45	-1.4	150	150	84
6/30/87	1900	1540	1530	-0.11	-0.29	-1.1	120	120	90
6/30/87	2140	1940	2020	-0.17	-0.42	-1.2	100	100	84
6/30/87	2300	2340	2319	-0.3	-0.8	-1.8	100	100	16
7/01/87	2620	0340	0340	-0.37	-0.9	-1.9	140	140	15
7/01/87	2880	0800	0840	-0.49	-1.2	-2.3	140	140	4000

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4 PROBE S	O2 PROBE S	CH4 PROBE M	O2 PROBE M	CH4 PROBE D	O2 PROBE D
6/29/87	2017	0	19	0	19	12	9
6/29/87	2115	--	--	--	--	14	9
6/30/87	0019	--	--	--	--	18	9
6/30/87	0340	--	--	--	--	12	9
6/30/87	0804	0	19	0	19	8	11
6/30/87	2020	0	19	0	19	0	21
7/01/87	0840	0	19	0	19	8	11

TABLE 5-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 66 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.)	CH4
6/29/87	-60	0700	0715	-0.18	220
6/29/87	0	0800	0800	--	--
6/29/87	1	0801	0807	-0.19	--
6/29/87	3	0803	0803	--	--
6/29/87	6	0806	0806	--	--
6/29/87	10	0810	0810	--	--
6/29/87	15	0815	0815	--	--
6/29/87	20	0820	0821	-0.17	--
6/29/87	25	0825	0825	--	--
6/29/87	30	0830	0830	--	--
6/29/87	45	0845	0845	-0.19	190
6/29/87	60	0900	0903	-0.14	110
6/29/87	100	0940	0940	-0.11	150
6/29/87	160	1040	1046	-0.07	140
6/29/87	300	1300	1325	-0.02	140
6/29/87	500	1620	1635	0.07	140
6/29/87	740	2020	2047	0.025	120
6/30/87	980	0020	0037	-0.06	100
6/30/87	1180	0340	0357	-0.05	200
6/30/87	1420	0740	0816	-0.045	200
6/30/87	1660	1140	1200	0	200
6/30/87	1900	1540	1550	0.055	200
6/30/87	2140	1940	2059	-0.03	100
6/30/87	2300	2340	2347	-0.09	200
7/01/87	2620	0340	0352	-0.05	200
7/01/87	2880	0800	0852	-0.09	200

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4	O2
6/29/87	2047	0	16
6/30/87	0816	0	17
6/30/87	2100	0	17
7/01/87	0852	0	17

TABLE 5-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 76 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.) PROBE S	PRESSURE (IN. W.C.) PROBE M	PRESSURE (IN. W.C.) PROBE D	CH4 PROBE S	CH4 PROBE M	CH4 PROBE D
6/29/87	-60	0700	0722	-0.045	-0.25	-0.075	--	--	--
6/29/87	0	0800	0800	--	--	--	--	--	--
6/29/87	1	0801	0802	-0.01	-0.22	-0.065	--	--	--
6/29/87	3	0803	0803	--	--	--	--	--	--
6/29/87	6	0806	0806	--	--	--	--	--	--
6/29/87	10	0810	0810	--	--	--	--	--	--
6/29/87	15	0815	0815	--	--	--	--	--	--
6/29/87	20	0820	0820	--	--	--	--	--	--
6/29/87	25	0825	0825	--	--	--	--	--	--
6/29/87	30	0830	0830	--	--	--	--	--	--
6/29/87	45	0845	0848	-0.01	-0.23	-0.07	--	--	--
6/29/87	60	0900	0900	-0.005	-0.21	-0.04	--	--	--
6/29/87	100	0940	0942	-0.04	-0.21	-0.06	--	--	--
6/29/87	160	1040	1041	0.01	-0.11	-0.03	--	--	--
6/29/87	300	1300	1328	0.055	0.07	0.13	--	--	--
6/29/87	500	1620	1640	0.095	0.15	0.165	--	--	--
6/29/87	740	2020	2102	0	-0.095	0.02	92	100	88
6/30/87	980	0020	0054	-0.065	-0.26	-0.12	--	--	--
6/30/87	1180	0340	0405	-0.06	-0.24	-0.1	--	--	--
6/30/87	1420	0740	0819	-0.05	-0.19	-0.085	140	200	100
6/30/87	1660	1140	1205	0.06	0.03	0.1	--	--	--
6/30/87	1900	1540	1555	0.07	0.06	0.12	--	--	--
6/30/87	2140	1940	2106	-0.05	-0.22	-0.26	130	200	100
6/30/87	2300	2340	2355	-0.09	-0.32	-0.165	--	--	--
7/01/87	2620	0340	0359	-0.065	-0.25	-0.13	--	--	--
7/01/87	2880	0800	0858	-0.105	-0.33	-0.185	180	240	100

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4 PROBE S	O2 PROBE S	CH4 PROBE M	O2 PROBE M	CH4 PROBE D	O2 PROBE D
6/29/87	2102	0	18	0	18	0	18
6/30/87	0819	0	18	0	16	0	19
6/30/87	2109	0	18	0	18	0	19
7/01/87	0858	0	18	0	16	0	18

TABLE 5-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 82 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.) PROBE S	PRESSURE (IN. W.C.) PROBE M	PRESSURE (IN. W.C.) PROBE D	CH4 PROBE S	CH4 PROBE M	CH4 PROBE D
6/29/87	-60	0700	0722	-0.9	-4.5	-3.2	66	14	15
6/29/87	0	0800	0800	--	--	--	--	--	--
6/29/87	1	0801	0801	-1.2	-4.4	-3.2	--	--	--
6/29/87	3	0803	0803	-1.2	-4.6	-3.4	--	--	--
6/29/87	6	0806	0806	-1.2	-4.6	-3.2	--	--	--
6/29/87	10	0810	0810	-1.2	-4.5	-3	--	--	--
6/29/87	15	0815	0815	-1.2	-4.2	-2.8	--	--	--
6/29/87	20	0820	0820	-1.2	-3.9	-2.5	--	--	--
6/29/87	25	0825	0825	-1.1	-3.6	-2.4	--	--	--
6/29/87	30	0830	0830	-1.1	-3.4	-2.2	--	--	--
6/29/87	45	0845	0845	-0.9	-2.6	-1.8	62	14	13
6/29/87	60	0900	0900	-0.72	-2.2	-1.5	72	14	19
6/29/87	100	0940	0940	-0.4	-1.3	-1	75	16	80
6/29/87	160	1040	1040	-0.2	-0.8	-0.72	72	33	90
6/29/87	300	1300	1300	0	-0.07	-0.015	76	54	90
6/29/87	500	1620	1632	0.15	0.34	0.26	68	68	90
6/29/87	740	2020	2040	0.05	0.04	-0.1	46	40	78
6/30/87	980	0020	0034	-0.13	-0.43	-0.6	66	40	100
6/30/87	1180	0340	0352	-0.13	-0.45	-0.62	100	70	140
6/30/87	1420	0740	0812	-0.12	-0.57	-0.64	100	72	140
6/30/87	1660	1140	1155	-0.02	-0.18	-0.3	100	80	160
6/30/87	1900	1540	1545	0.025	-0.045	-0.185	90	82	160
6/30/87	2140	1940	2047	-0.11	-0.3	-0.45	100	100	160
6/30/87	2300	2340	2337	-0.2	-0.7	-0.8	120	100	200
7/01/87	2620	0340	0348	-0.9	-0.6	-0.18	210	100	120
7/01/87	2880	0800	0850	-0.245	-0.92	-1.1	140	140	200

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4 PROBE S	O2 PROBE S	CH4 PROBE M	O2 PROBE M	CH4 PROBE D	O2 PROBE D
6/29/87	2040	0	18	0	19	0	19
6/30/87	0812	0	18	0	19	0	19
6/30/87	2047	0	18	0	20	0	18
7/01/87	0850	0	18	0	19	0	18

5.2 Gas Characterization Study

The results of the gas characterization studies described in Appendix E of this report showed that subsurface gas collected from the onsite gas extraction wells and flare manifolds contained a wide variety of substances, including 23 USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs). The compounds found most frequently and in the highest concentrations in the onsite subsurface gas included ethylbenzene, vinyl chloride, total xylenes, toluene, and benzene. The maximum concentrations of these compounds were in the low parts-per-million (ppm) range. The toxic inorganic gases hydrogen sulfide and carbon monoxide were also reported present onsite in the low parts-per-million range. Hydrogen cyanide was not detected in onsite gas.

The association of five HSL VOCs, ethyl-benzene, benzene, toluene, total xylenes, and styrene, referred to here as the "BTX group," was judged to comprise the "fingerprint" of the HSL VOCs that are found in landfill gas. These compounds were found most frequently and in the highest concentrations onsite; other HSL VOCs were found less frequently and in lower concentrations, generally in the parts-per-billion range.

For the 23 HSL VOCs detected in the onsite subsurface gas, the mean onsite concentration for a given contaminant was typically less than 10% of the corresponding maximum onsite concentration. The maximum observed onsite concentration for any HSL VOC detected during sampling of subsurface landfill gas was 31 ppm of vinyl chloride, detected at gas extraction well 44D-0. The mean concentration of vinyl chloride across all onsite gas extraction well samples was slightly less than 3 ppm.

Subsurface gas from onsite gas extraction well 44D-0 was generally observed to have higher concentrations of HSL VOCs than gas from other onsite sampling points. Of the 23 HSL VOCs detected in onsite subsurface gas, the maximum concentrations reported for 13 of the compounds were observed at well 44D-0. One possible explanation is that well 44D-0 had a relatively low gas flow rate, 6 ft^3/min ("equilibrium flow"), at the time of sampling, which may have resulted in increased opportunity for these gas contaminants to accumulate in the relatively smaller, slower-moving volume of gas.

Mapping of these and other selected gas components suggested that offsite migration of at least some onsite gas contaminants has occurred, potentially in all directions away from the Midway Landfill. However, offsite concentrations of the five BTX-group compounds appear to be attenuated with increasing distance from the landfill. (See Table 5-5). No BTX-group compounds were found more than 2300 feet from the landfill perimeter.

Comparison of maximum on-site and off-site concentrations of the five BTX compounds showed estimated attenuation of these compounds to be in the range of 73.6 to 99.7%. Comparison of mean on-site and off-site concentrations of the five BTX compounds showed estimated attenuation of these compounds to be in the range of 56.1 to 99.4%.

Table 5-5 Estimated on-site/off-site attenuation of primary HSL VOCs detected in subsurface gas samples.

CAS #	Target Compound	MAXIMUM CONCENTRATIONS On-Site (ppb)	Off-Site (ppb)	Attenuation (%)	MEAN CONCENTRATIONS On-Site (ppb)	Off-Site (ppb)	Attenuation (%)
100-41-4	Ethylbenzene	16,610	127	99.2	2,825	44	98.4
1330-20-7	Xylenes (Total)	29,195	106	99.6	3,419	19	99.4
108-88-3	Toluene	24,044	68	99.7	1,920	18	99.1
71-43-2	Benzene	1,384	185	86.6	318	28	91.2
100-42-5	Styrene	508	134	73.6	41	18	56.1
75-01-4	Vinyl chloride	31,215	275	99.1	2,807	35	98.8

$$\text{Attenuation (\%)} = \frac{\text{On-Site Concentration (ppb)} - \text{Off-Site Concentration (ppb)}}{\text{On-Site Concentration (ppb)}} \times 100$$

Source: Parametrix, 1987.

Vinyl chloride was frequently associated with the BTX-group compounds in onsite subsurface gas, but during sampling offsite it was found at only two of the gas monitor probe locations, both south of the landfill. In a separate study, conducted by Farr, Friedman & Bruya, Inc., under subcontract to Parametrix, vinyl chloride was also found at concentrations of up to 1-3 ppm at other locations to the east and south of Midway Landfill in the subsurface gas samples collected from offsite gas control wells. Factors affecting the distribution of vinyl chloride in subsurface gas in the vicinity of Midway Landfill may be different from those affecting the distribution of the BTX-group compounds; this is discussed in further detail in the Midway Landfill Remedial Investigation Summary Report (Parametrix, 1988).

Vinyl chloride was not found offsite at as many locations as the BTX compounds. Its offsite concentrations were substantially lower than its onsite concentrations (see Table 5-5). Comparison of maximum onsite and offsite concentrations of vinyl chloride showed an approximate attenuation of 99.1%. Comparison of mean onsite and offsite concentrations of vinyl chloride showed an approximate attenuation of 98.8%.

The gas characterization studies conducted for the Midway Landfill Remedial Investigation were not designed to identify the mechanisms responsible for observed attenuation of subsurface gas components; however, some possible mechanisms might be biodegradation, chemical interactions with water or soil components, adsorption onto soil organic matter, and the action of the onsite gas extraction system in drawing subsurface gas back toward the landfill.

Several HSL VOCs were detected in subsurface gas samples collected west of the landfill at offsite gas monitoring probe completions 88-S and 88-M, which are adjacent to a wetland area. It is difficult to determine solely from the gas characterization studies the degree to which compounds found at this location may be associated with materials present in the wetland, as opposed to being materials that have possibly migrated from Midway Landfill.

Although some HSL VOCs were detected in offsite subsurface gas monitoring probes to the east, remedial investigation data do not suggest extensive migration of subsurface gas contaminants in this direction; none of the compounds reported at gas monitoring probe M-M appear to have migrated as far east as probe 50-S.

Results of a study conducted outside the scope of the remedial investigation (Farr, Friedman, and Bruya, 1987) further indicated that evaluation of the ethane/methane and propane/methane ratios might be useful in distinguishing Midway Landfill gas from natural gas that is supplied by local utilities such as the Washington Natural Gas Company.

5.3 Evaluation of Onsite Migration Control and Offsite Control Wells

As seen in the isopleths in Section 5.2, gas levels have been reduced around the landfill since the implementation of the onsite gas migration control system and the offsite gas extraction wells. The early isopleths were based on data from a limited number of probes, and in many instances at the time represented did not include areas farther from the site that contained gas. Probes installed over time and represented in later isopleths have helped to further define the extent of offsite gas migration, information that assists in determining the proper measures to be implemented both onsite and offsite to eliminate the gas accumulated offsite. Table 5-6 lists all probes installed around the landfill for this and other studies.

Offsite control wells are installed to remove a reservoir of gas that has accumulated offsite. In this capacity, offsite control wells have proven quite successful. However, once the reservoir of gas surrounding the offsite control well has been eliminated, the control well should be shut down. If it is not, it may begin to draw gas out of the landfill. This potential effect can be minimized by the proper operation of the onsite migration control system, but it forces operation of the onsite system to create a greater vacuum curtain around the landfill than would otherwise be necessary.

An example of this phenomenon is shown on Figure 5-17, a pressure gradient isopleth of an area of the landfill in which gas is potentially migrating from the landfill to an offsite extraction well. The average vacuum induced along the perimeter of the landfill in this area is -2.0 inches WC. The vacuum induced at the control well shown to the southeast of the landfill is -5.5 inches WC. Note that the pressure gradient lines indicate an increase in vacuum away from the landfill. This indicates a flow path in the

TABLE 5-6
OFFSITE MONITORING PROBE COMPLETION DETAILS

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
A-S	03/15/85	GA	CITY	13.5	14.0	0.5
A-D	03/15/85	GA	CITY	58.4	59.0	0.6
A1-S	03/21/85	GA	CITY	13.5	14.0	0.5
A1-M	03/21/85	GA	CITY	37.4	38.0	0.6
A1-D	03/21/85	GA	CITY	58.5	59.0	0.5
B-S	03/14/85	GA	CITY	12.5	13.0	0.5
B-M	03/14/85	GA	CITY	32.5	33.0	0.5
B-D	03/14/85	GA	CITY	57.5	58.0	0.5
C-S	03/22/85	GA	CITY	24.0	24.5	0.5
C-M	03/22/85	GA	CITY	40.5	41.0	0.5
C-D	03/22/85	GA	CITY	56.0	56.5	0.5
D-S	03/18/85	GA	CITY	13.5	14.0	0.5
D-M	03/18/85	GA	CITY	43.5	44.0	0.5
D-D	03/18/85	GA	CITY	74.0	74.5	0.5
E-S	03/20/85	GA	CITY	13.5	14.0	0.5
E-M	03/20/85	GA	CITY	41.5	42.0	0.5
E-D	03/20/85	GA	CITY	67.4	68.0	0.6
H-S	03/01/85	GA	CITY	9.5	10.0	0.5
H-M	03/01/85	GA	CITY	33.5	34.0	0.5
H-D	03/01/85	GA	CITY	65.5	66.0	0.5
I-S	03/02/85	GA	CITY	11.4	12.0	0.6
I-M	03/02/85	GA	CITY	40.5	41.0	0.5
I-D	03/02/85	GA	CITY	69.5	70.0	0.5
J-S	03/04/85	GA	CITY	12.0	12.5	0.5
J-M	03/04/85	GA	CITY	43.8	44.5	0.7
J-D	03/04/85	GA	CITY	72.5	73.0	0.5
K-S	03/11/85	GA	CITY	12.2	13.0	0.8
K-M	03/11/85	GA	CITY	49.2	50.0	0.8
K-D	03/11/85	GA	CITY	79.8	80.5	0.7
L-S	06/27/85	GA	CITY	12.7	14.0	1.3
L-M	06/27/85	GA	CITY	53.7	55.0	1.3
L-D	06/27/85	GA	CITY	96.0	97.5	1.5
M-S	07/01/85	GA	CITY	12.7	14.5	1.8
M-M	07/01/85	GA	CITY	62.9	64.5	1.6
M-D	07/01/85	GA	CITY	102.1	103.5	1.4
N-S	03/21/85	GA	CITY	12.5	13.0	0.5
N-M	03/21/85	GA	CITY	50.5	51.0	0.5
N-D	03/21/85	GA	CITY	86.5	87.0	0.5
O-S	04/17/85	GA	CITY	12.2	13.0	0.8
O-M	04/17/85	GA	CITY	39.2	40.0	0.8
O-D	04/17/85	GA	CITY	73.3	74.0	0.7
P-S	03/26/85	GA	CITY	12.5	13.0	0.5
P-M	03/26/85	GA	CITY	28.5	29.0	0.5
P-D	03/26/85	GA	CITY	46.5	47.0	0.5
Q-S	09/02/86	TERRA	CITY	10.0	30.0	20.0
Q-M	09/02/86	TERRA	CITY	35.0	85.0	50.0

TABLE 5-6
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
Q-D	09/02/86	TERRA	CITY	100.0	197.0	97.0
R-S	09/05/86	TERRA	CITY	8.0	30.0	22.0
R-M	09/05/86	TERRA	CITY	40.0	100.0	60.0
S-S	08/28/86	TERRA	CITY	9.0	19.0	10.0
S-M	08/28/86	TERRA	CITY	30.0	51.0	21.0
S-D	08/28/86	TERRA	CITY	70.0	80.0	10.0
T-S	09/22/86	TERRA	CITY	10.0	22.0	12.0
T-M	09/22/86	TERRA	CITY	33.0	63.0	30.0
U-S	09/17/86	TERRA	CITY	6.0	17.0	11.0
U-M	09/17/86	TERRA	CITY	20.0	55.0	35.0
U-D	09/17/86	TERRA	CITY	60.0	99.0	39.0
V-S	09/19/86	TERRA	CITY	7.0	15.0	8.0
V-M	09/19/86	TERRA	CITY	18.0	36.0	18.0
V-D	09/19/86	TERRA	CITY	40.0	84.0	44.0
W-S	09/27/86	TERRA	CITY	10.0	20.0	10.0
W-M	09/27/86	TERRA	CITY	30.0	102.0	72.0
X-S	09/29/86	TERRA	CITY	8.0	27.0	19.0
X-M	09/29/86	TERRA	CITY	34.0	75.0	41.0
X-D	09/29/86	TERRA	CITY	88.0	121.0	33.0
Y1-S	11/11/86	TERRA	CITY	10.0	20.0	10.0
Y1-M	11/11/86	TERRA	CITY	44.0	54.0	10.0
Y1-I	11/11/86	TERRA	CITY	58.0	68.0	10.0
Y1-D	11/11/86	TERRA	CITY	98.0	147.0	49.0
Y2-S	11/19/86	TERRA	CITY	13.0	37.0	24.0
Y2-M	11/19/86	TERRA	CITY	49.0	75.0	26.0
Y2-I	11/19/86	TERRA	CITY	87.0	107.0	20.0
Y2-D	11/19/86	TERRA	CITY	118.0	147.0	29.0
Z-S	12/19/86	TERRA	CITY	7.0	17.0	10.0
Z-M	12/19/86	TERRA	CITY	25.0	35.0	10.0
Z-D	12/19/86	TERRA	CITY	45.0	137.0	92.0
01-M	09/25/85	HC	DOE	19.0	48.5	29.5
02-S	11/07/85	HC	DOE	5.8	10.8	5.0
02-M	06/05/86	HC	DOE	27.7	49.3	21.6
02-D	06/03/86	HC	DOE	67.9	100.7	32.8
03-M	09/27/85	HC	DOE	27.0	51.5	24.5
04-M	09/30/85	HC	DOE	25.0	59.0	34.0
05-S	12/12/85	HC	DOE	6.4	11.4	5.0
06-S	11/08/85	HC	DOE	6.1	11.1	5.0
07-S	11/08/85	HC	DOE	5.0	10.0	5.0
08-S	11/08/85	HC	DOE	6.0	11.0	5.0
09-S	11/12/85	HC	DOE	8.8	13.8	5.0
10-S	11/12/85	HC	DOE	5.5	10.5	5.0
11-S	11/11/85	HC	DOE	5.8	10.8	5.0
12-S	11/11/85	HC	DOE	5.7	10.7	5.0
13-S	11/11/85	HC	DOE	6.0	11.0	5.0
13-M	06/10/86	HC	DOE	44.3	58.8	14.5

TABLE 5-6
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
14-S	11/06/85	HC	DOE	6.4	11.4	5.0
15-S	11/07/85	HC	DOE	5.0	10.5	5.5
16-S	11/15/85	HC	DOE	6.0	11.0	5.0
17-S	11/14/85	HC	DOE	3.0	5.2	2.2
18-S	11/13/85	HC	DOE	5.8	10.8	5.0
19-S	11/13/85	HC	DOE	5.4	5.4	10.4
20-S	11/14/85	HC	DOE	6.2	11.2	5.0
21-S	11/14/85	HC	DOE	6.1	11.1	5.0
22-S	12/11/85	HC	DOE	6.1	11.1	5.0
23-M	11/05/85	HC	DOE	23.5	57.5	34.0
25-S	11/11/85	HC	DOE	6.0	11.0	5.0
26-S	11/15/85	HC	DOE	6.1	11.1	5.0
27-S	11/13/85	HC	DOE	5.9	10.9	5.0
28-S	11/13/85	HC	DOE	5.7	10.7	5.0
29-S	12/12/85	HC	DOE	3.6	6.4	2.8
30-S	11/18/85	HC	DOE	8.5	13.5	5.0
31-S	11/19/85	HC	DOE	5.5	10.5	5.0
32-S	11/18/85	HC	DOE	3.4	7.4	4.0
33-S	11/18/85	HC	DOE	3.3	7.3	4.0
34-S	11/15/85	HC	DOE	4.5	9.5	5.0
35-S	11/19/85	HC	DOE	6.0	11.0	5.0
36-S	11/20/85	HC	DOE	6.0	11.0	5.0
37-S	02/13/86	HC	DOE	4.3	7.8	3.5
37-M	02/13/86	HC	DOE	30.0	40.0	10.0
37-D	02/13/86	HC	DOE	58.0	88.0	30.0
38-S	11/20/85	HC	DOE	6.0	11.0	5.0
39-S	12/10/85	HC	DOE	6.2	11.2	5.0
40-S	12/05/85	HC	DOE	6.1	11.1	5.0
41-S	12/04/85	HC	DOE	9.9	14.9	5.0
42-S	12/04/85	HC	DOE	6.4	11.4	5.0
43-S	11/26/85	HC	DOE	6.3	11.3	5.0
44-S	11/25/85	HC	DOE	6.3	11.3	5.0
44-M	11/25/85	HC	DOE	20.0	40.0	20.0
44-D	11/25/85	HC	DOE	72.0	101.0	29.0
45-S	11/26/85	HC	DOE	6.1	11.1	5.0
45-M	11/26/85	HC	DOE	20.0	40.0	20.0
45-D	11/26/85	HC	DOE	27.5	92.5	65.0
46-S	11/26/85	HC	DOE	6.4	11.4	5.0
47-S	11/27/85	HC	DOE	6.1	11.1	5.0
48-S	12/02/85	HC	DOE	6.3	11.3	5.0
49-S	12/02/85	HC	DOE	6.2	11.2	5.0
50-S	01/11/86	HC	DOE	6.3	11.3	5.0
50-M	01/11/86	HC	DOE	20.0	40.0	20.0
50-D	01/11/86	HC	DOE	70.3	100.3	30.0
51-S	12/03/85	HC	DOE	6.1	11.1	5.0
52-S	12/03/85	HC	DOE	6.3	11.3	5.0

TABLE 5-6
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

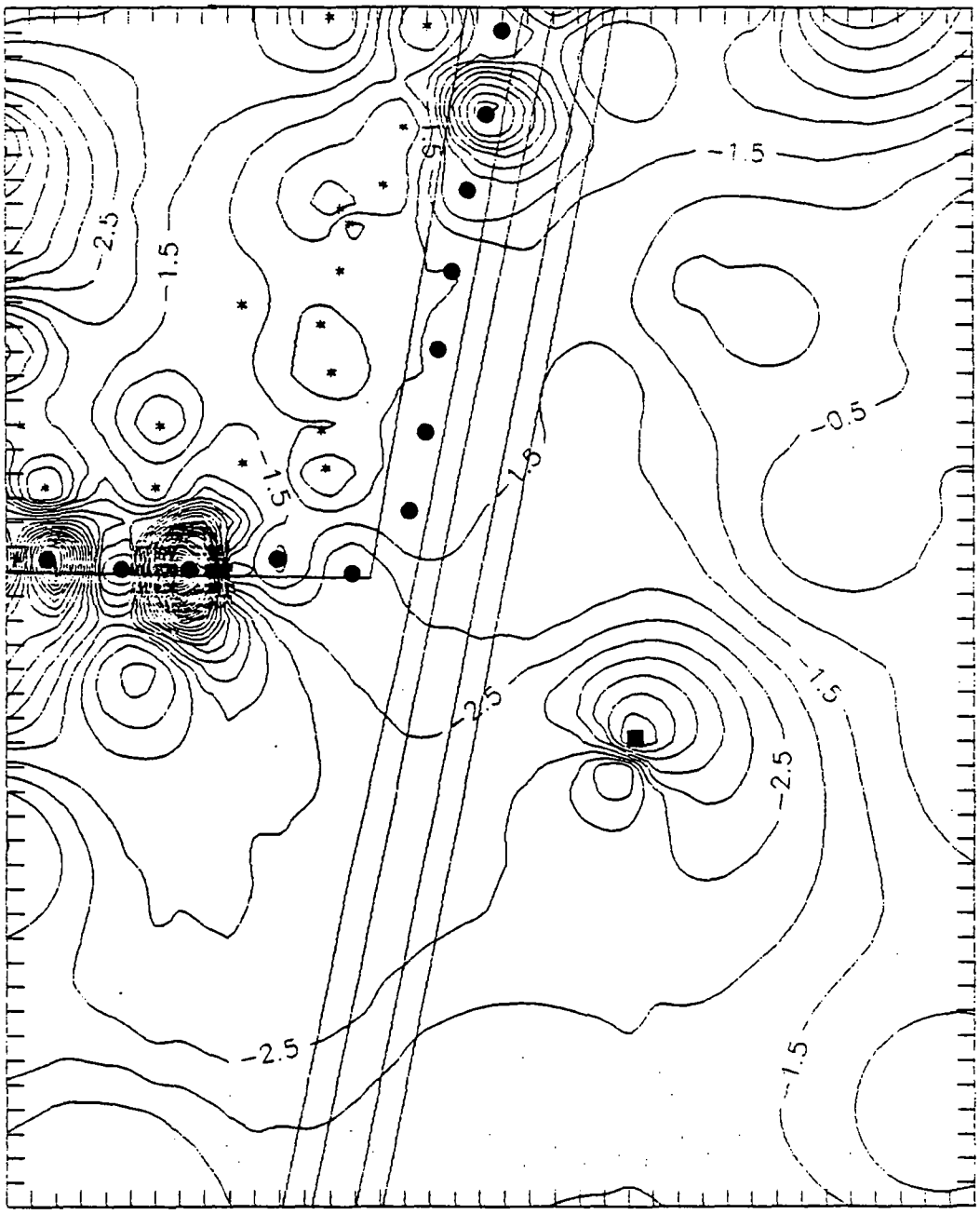
PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
53-S	12/03/85	HC	DOE	6.0	11.0	5.0
54-S	12/03/85	HC	DOE	6.0	11.0	5.0
55-S	12/09/85	HC	DOE	6.1	11.1	5.0
56-S	12/09/85	HC	DOE	6.2	11.2	5.0
57-S	12/04/85	HC	DOE	6.3	11.3	5.0
58-S	12/04/85	HC	DOE	6.2	11.2	5.0
59-S	12/04/85	HC	DOE	6.0	11.0	5.0
59-M	01/14/86	HC	DOE	20.0	40.0	20.0
59-D	01/14/86	HC	DOE	67.5	99.5	32.0
60-S	12/06/85	HC	DOE	6.2	11.2	5.0
61-S	12/11/85	HC	DOE	6.3	11.3	5.0
62-S	11/19/85	HC	DOE	5.6	10.6	5.0
63-S	12/12/85	HC	DOE	5.3	10.3	5.0
64-S	12/13/85	HC	DOE	6.3	11.3	5.0
65-S	11/07/85	HC	DOE	5.4	10.4	5.0
66-S	12/06/85	HC	DOE	6.3	11.3	5.0
67-S	11/08/85	HC	DOE	5.8	10.8	5.0
68-S	11/15/85	HC	DOE	5.9	10.9	5.0
69-S	12/13/85	HC	DOE	6.3	11.3	5.0
70-S	11/25/85	HC	DOE	6.0	11.0	5.0
71-S	11/25/85	HC	DOE	6.0	11.0	5.0
72-S	12/09/85	HC	DOE	6.4	11.4	5.0
73-S	11/27/85	HC	DOE	6.2	11.2	5.0
74-S	12/10/85	HC	DOE	6.1	11.1	5.0
75-S	12/17/85	HC	DOE	6.1	11.1	5.0
76-S	01/16/86	HC	DOE	6.3	11.3	5.0
76-M	01/16/86	HC	DOE	20.0	40.0	20.0
76-D	01/16/86	HC	DOE	70.5	100.5	30.0
77-S	12/16/85	HC	DOE	6.0	11.0	5.0
78-S	12/16/85	HC	DOE	6.4	11.4	5.0
79-S	01/30/86	HC	DOE	6.0	8.0	2.0
79-M	01/30/86	HC	DOE	36.0	51.0	15.0
79-D	01/30/86	HC	DOE	67.5	100.0	32.5
80-M	02/07/86	HC	DOE	10.0	22.5	12.5
80-D	02/07/86	HC	DOE	68.0	98.0	30.0
81-M	01/24/86	HC	DOE	30.0	48.5	18.5
81-D	01/24/86	HC	DOE	64.0	79.0	15.0
82-S	02/05/86	HC	DOE	8.5	13.5	5.0
82-M	02/05/86	HC	DOE	20.0	49.0	29.0
82-D	02/05/86	HC	DOE	78.0	93.0	15.0
83-M	02/24/86	HC	DOE	15.5	35.5	20.0
84-S	06/30/86	HC	DOE	9.0	17.0	8.0
84-M	06/30/86	HC	DOE	43.9	63.1	19.2
84-D	06/30/86	HC	DOE	80.7	100.0	19.3
85-M	07/02/86	HC	DOE	44.0	63.9	19.9
85-D	07/02/86	HC	DOE	78.4	98.6	21.2

TABLE 5-6
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
86-S	06/15/86	HC	DOE	7.7	15.4	7.7
86-M	06/15/86	HC	DOE	54.1	63.7	9.6
87-S	06/20/86	HC	DOE	8.1	13.2	5.1
87-M	06/20/86	HC	DOE	25.6	44.3	18.7
87-D	06/20/86	HC	DOE	68.9	93.4	24.5
88-S	06/13/86	HC	DOE	5.4	10.4	5.0
88-M	06/13/86	HC	DOE	19.9	34.8	14.9
88-D	06/13/86	HC	DOE	53.8	69.3	15.5
89-S	06/23/86	HC	DOE	10.4	15.7	5.7
89-M	06/23/86	HC	DOE	25.3	45.0	19.7
90-M	06/27/86	HC	DOE	52.5	57.8	5.3
91-S	07/09/86	HC	DOE	9.5	19.2	9.7
91-M	07/09/86	HC	DOE	30.6	50.0	19.4
92-S	07/11/86	HC	DOE	10.2	19.9	9.7
92-M	07/11/86	HC	DOE	29.5	49.2	19.7
AA-S	01/08/87	TERRA	CITY	8.0	38.0	30.0
AA-M	01/08/87	TERRA	CITY	49.0	69.0	20.0
AA-D	01/08/87	TERRA	CITY	77.0	99.0	22.0
AB-S	01/16/87	TERRA	CITY	7.0	28.0	21.0
AB-M	01/16/87	TERRA	CITY	30.0	34.0	4.0
AB-D	01/16/87	TERRA	CITY	50.0	60.0	10.0
AC-S	01/26/87	TERRA	CITY	9.0	28.0	19.0
AC-M	01/26/87	TERRA	CITY	35.0	50.0	15.0
AC-D	01/26/87	TERRA	CITY	60.0	75.0	15.0
AD-S	02/13/87	TERRA	CITY	9.0	28.0	19.0
AD-D	02/13/87	TERRA	CITY	35.0	100.0	65.0
AE-S	03/05/87	TERRA	CITY	7.0	26.0	19.0
AE-M	03/15/87	TERRA	CITY	31.0	49.0	18.0
AF-S	03/02/87	TERRA	CITY	8.0	27.0	19.0
AF-M	03/02/87	TERRA	CITY	35.0	75.0	40.0
AF-D	03/02/87	TERRA	CITY	95.0	150.0	55.0
AG-S	03/12/87	TERRA	CITY	6.0	26.0	20.0
AG-M	03/12/87	TERRA	CITY	33.0	50.0	17.0
AH-S	03/26/87	TERRA	CITY	10.0	23.0	13.0
AH-M	03/26/87	TERRA	CITY	28.0	67.0	39.0
AH-D	03/26/87	TERRA	CITY	75.0	105.0	30.0
AI-S	06/09/87	PMX	CITY	26.0	37.0	11.0
AI-M	06/09/87	PMX	CITY	47.5	82.5	35.0
AI-D	06/09/87	PMX	CITY	93.0	118.0	25.0
AJ-S	06/15/87	PMX	CITY	24.0	34.0	10.0
AJ-M	06/15/87	PMX	CITY	46.0	76.0	30.0
AJ-I	06/15/87	PMX	CITY	85.0	110.0	25.0
AJ-D	06/15/87	PMX	CITY	117.5	142.5	25.0
AJ-W	06/15/87	PMX	CITY	183.0	203.0	20.0
AK-S	06/25/87	PMX	CITY	23.0	43.0	20.0
AK-M	06/25/87	PMX	CITY	52.0	92.0	40.0

TABLE 5-6
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
AK-I	06/25/87	PMX	CITY	101.0	136.0	35.0
AK-D	06/25/87	PMX	CITY	152.0	192.0	40.0
AK-W	06/25/87	PMX	CITY	206.0	239.0	33.0
AL-S	07/01/87	PMX	CITY	23.0	43.0	20.0
AL-M	07/01/87	PMX	CITY	53.0	82.0	29.0
AL-I	07/01/87	PMX	CITY	96.0	136.0	40.0
AL-D	07/01/87	PMX	CITY	144.0	179.0	35.0
AL-W	07/01/87	PMX	CITY	188.0	233.0	45.0
AM-S	08/04/87	PMX	CITY	25.0	40.0	15.0
AM-M	08/04/87	PMX	CITY	52.5	72.5	20.0
AM-D	08/04/87	PMX	CITY	83.0	118.0	35.0
AN-S	09/14/87	PMX	CITY	6.0	21.0	15.0
AN-M	09/14/87	PMX	CITY	22.0	32.0	10.0
AN-I	09/14/87	PMX	CITY	37.0	42.0	5.0
AN-W	09/14/87	PMX	CITY	75.0	85.0	10.0
AO-S	09/23/87	PMX	CITY	5.0	20.0	15.0
AO-M	09/23/87	PMX	CITY	21.0	51.0	30.0
AO-W	09/23/87	PMX	CITY	73.0	98.0	25.0
AP-S	09/24/87	PMX	CITY	5.0	20.0	15.0
AP-M	09/24/87	PMX	CITY	30.0	50.0	20.0
AP-I	09/24/87	PMX	CITY	58.0	88.0	30.0
AP-W	09/24/87	PMX	CITY	97.0	112.0	15.0
AQ-S	09/14/87	PMX	CITY	6.0	19.0	13.0
AQ-M	09/14/87	PMX	CITY	23.0	48.0	25.0
AQ-I	09/14/87	PMX	CITY	57.0	67.0	10.0
AQ-D	09/14/87	PMX	CITY	74.0	89.0	15.0
AR-S	09/21/87	PMX	CITY	5.0	20.0	15.0
AR-M	09/21/87	PMX	CITY	20.0	45.0	25.0
AR-I	09/21/87	PMX	CITY	61.0	66.0	5.0
AR-D	09/21/87	PMX	CITY	73.0	93.0	20.0
AS-S	09/01/87	PMX	CITY	2.0	7.0	5.0
AT-S	09/03/87	PMX	CITY	2.0	6.0	4.0
AU-S	09/03/87	PMX	CITY	2.0	6.0	4.0
AV-S	09/29/87	PMX	CITY	21.0	45.0	24.0
AV-M	09/27/87	PMX	CITY	52.0	82.0	30.0
AV-D	09/27/87	PMX	CITY	95.0	125.0	30.0
AV-W	09/27/87	PMX	CITY	135.0	150. 0	15.0



● In Soil Migration Control Wells

■ Offsite Control Well

NOT TO SCALE

Figure 5-17
Pressure Gradient Isopleth Offsite Control Well at -5.5 " Water Column

direction of the control well, perpendicular to the pressure gradient lines. Figure 5-18 shows this same area of the landfill after the control well has been turned down, with approximately the same vacuum induced along the perimeter of the landfill, but only -1.0 inches WC at the control well. Note that the pressure gradient lines now indicate a flow path toward the landfill.

As seen in Figure 5-14, July 1987 gas concentrations in the deep soil zones east and south of the landfill were reduced from the levels recorded in September 1986. However, this reduction is proving to be a slow process.

5.4 Identification of Potential Gas Migration Pathways

5.4.1 Utility Corridors

Figure F-1 in Appendix F is a map showing the underground utility lines in the Midway Landfill vicinity, based on information obtained from the major utilities listed in Section 4.4.1. The map includes the complete information obtained from the utilities on underground lines and pipes, but does not show hookups to individual households.

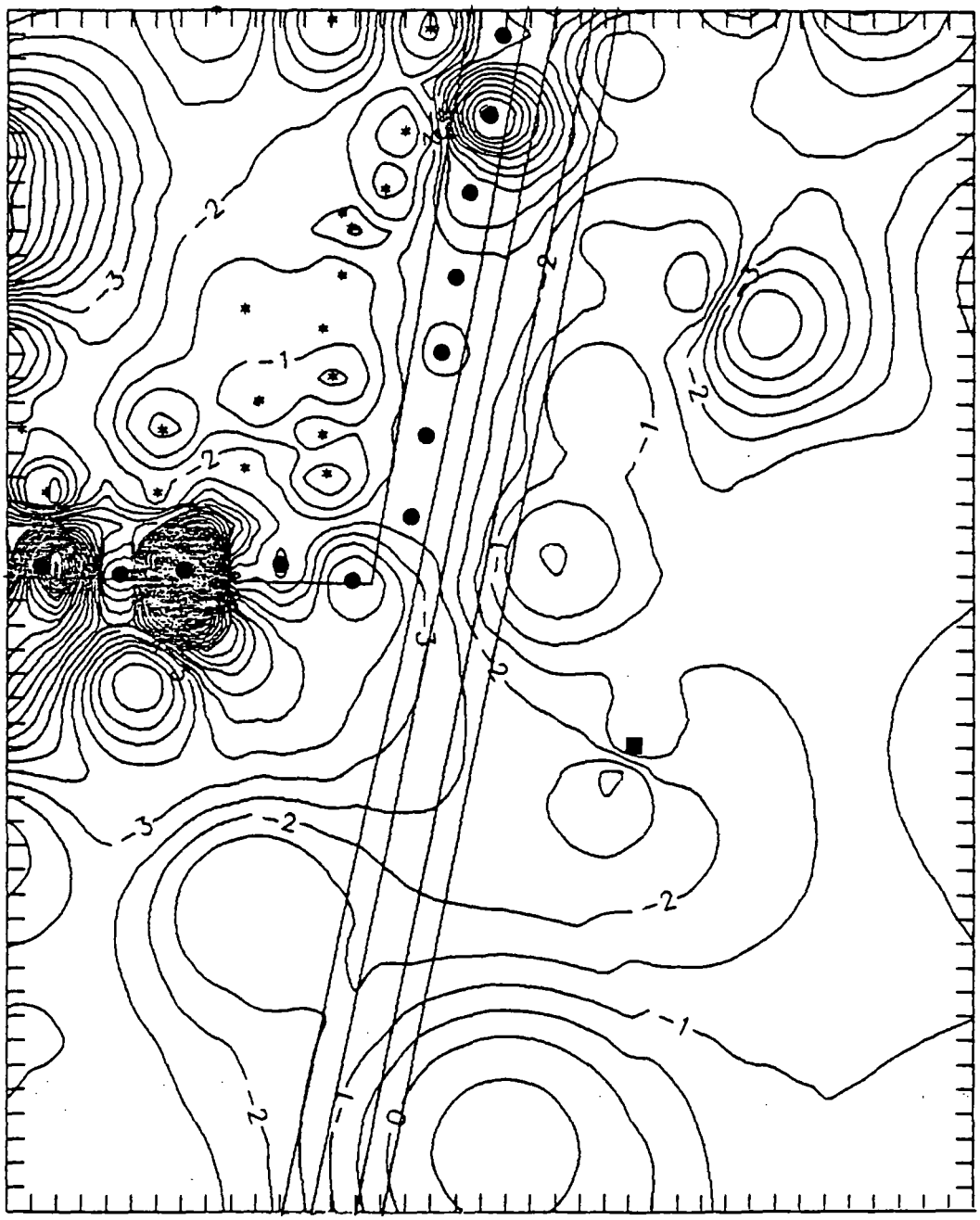
The most recent shallow gas isopleths (Figure 5-15) indicate that significant methane concentrations remain in only three offsite areas in the shallow soil zone. These areas appear to be isolated from the landfill. A comparison of the areas of high methane concentrations with the utility conduits shown in Figure F.1 of Appendix F does not suggest that utility conduits are transmitting methane from the landfill. It is felt that the shallow gas detected in probe "AE," southeast of the site, is from a nearby peat bog. The shallow gas detected in probe 2, north of the site, appears to be from peat or other deposits buried nearby. The shallow gas in probe "AC," southwest of the site, is from an unknown source. However, because this gas is only detected in the shallow zone, while no shallow gas has been detected between the landfill and this probe, this gas is not believed to be from the landfill. Additional monitoring, testing, and evaluation of these areas will continue. No significant gas has been reported in structures, vaults, or utilities for several months.

5.4.2 Geologic Pathways

The investigation of geologic pathways for gas migration considered physical factors affecting the movement of gas as well as subsurface stratigraphy and known concentrations of offsite gas.

5.4.2.1 Physical Factors Influencing Gas Movement

After refuse has been in place one to two years, it begins to generate methane gas. For a particular deposit of refuse, the gas generation rate peaks two to five years after burial, depending on moisture content and air exclusion. After peaking, the rate for a particular deposit slowly decreases with time. In ten years, more than half of the total gas will usually have been generated. Generation at continually decreasing rates can extend thirty years and more.



NOT TO SCALE

● In Soil Migration Control Wells

■ Offsite Control Well

Figure 5-18
Pressure Gradient Isopleth Offsite Control Well at -1.0″ Water Column

The Midway Landfill is a combination of a large number of particular deposits begun in 1965 and ended in 1983. Based on experience with other landfills, we can say that the landfill gas generation probably began in 1966 or 1967, increased as additional refuse was deposited, and peaked in about 1987.

As the landfill generates gas, a small positive pressure is created, pushing the gas away from the origin of generation. The gas will move fastest through paths of least resistance, which include porous portions of the solid waste, porous cover material, utility conduits, and layers of more permeable soil stratigraphy around the site.

Barometric pressure fluctuations, together with the gas generation pressure, produce complex gas migration dynamics. The low gas generation pressures in the landfill initially move the gas away from the points of origin through the paths of least resistance. The generation pressures are in the range of two inches of water column. Atmospheric pressure is measured with a barometer as inches of mercury. One inch of mercury equals 13.5 inches of water column. Changes in atmospheric pressure of -0.7 inches of mercury or -9.5 inches of water column are common during the winter months as high pressure ridges give way to low pressures during storms. This can create a relatively strong pressure differential between the air or gas within the soil or landfill, and the air at the ground surface. The air or gas within the soil or the landfill tends to flow toward the ground surface through the paths of least resistance in response to this pressure differential. This is referred to as the expansion phase during a falling barometer.

During rising atmospheric pressures, similar gas and/or air movements take place, but in reverse directions. Air from the ground surface tends to move down into the soil both vertically and horizontally through the undersaturated aquifers. However, this reverse movement is not sufficient to draw back all the gas that has diffused through the soil pores during the expansion phase.

The combined effect of the generation pressures and the repeated expansion phases during falling barometers results in a pumping action within the soils, which, over time, could have moved the gas up to 2600 feet horizontally from the landfill (its maximum observed extent).

Operation of the active gas migration control system has created a vacuum in and around the landfill, eliminating the gas generation pressure, and moving the gas slowly back toward the landfill. However, falling barometric conditions could still cause gas to vent to ground surface, if there are areas beyond the influence of the migration control system vacuum where gas in significant concentrations remains in the ground.

5.4.2.2 Undersaturated Zones in Aquifers

Four major aquifers underlie the Midway Landfill and its vicinity, named by AGI (Appendix A, Groundwater Technical Report) the upper gravel aquifer, the sand aquifer, and the northern and southern gravel aquifers. The upper gravel aquifer is made up of glacial outwash gravels; the sand aquifer consists of saturated sand and finer-grained sediments possibly deposited in

a lake environment; and the northern and southern gravel aquifers are nonglacial gravel beds.

The distribution of undersaturated zones (through which gas can potentially travel) in the study area is not uniform. In large portions of the upper gravel aquifer, the potentiometric head varies from the roof to the base of the aquifer. In some locations, the upper gravel aquifer is undersaturated for its entire thickness. In contrast, the potentiometric surface of the sand aquifer is usually above the roof of the aquifer; thus, the aquifer is said to be under pressure as well as saturated. The sand aquifer has only a few isolated undersaturated zones that may transport or contain gas.

In the upper gravel aquifer, undersaturated zones exist to the north, east and south of the landfill. The gravel pit into which the landfill was developed cuts through an undersaturated zone in the upper gravel aquifer. This creates a path of direct access to the upper gravel aquifer. There is a good potential for gas to migrate from the landfill into the upper gravel aquifer, and from the aquifer back to the landfill.

It would appear that the undersaturated portions of the upper gravel aquifer formed the major gas migration pathway to the east and southeast of the landfill, allowing gas to migrate up to 2600 feet from the landfill. This affected area extends from I-5 to the east of Military Road. The gas could have been drawn to the ground surface by the pumping action of barometric changes, contributing to the gas in shallow soils near Military Road. The undersaturated portion of the upper gravel aquifer does not extend southeast to Probe AE.

The undersaturated portion of the upper gravel aquifer also could have been the major gas migration pathway to the south of the landfill, allowing gas to migrate up to 2000 feet from the landfill. However, the upper gravel aquitard appears to have been impermeable enough to limit gas movement to the ground surface. The affected area extends from the landfill to S. 259th Pl. between 29th Avenue S. and I-5. The undersaturated portion of the upper gravel aquifer does not extend to Probe AC southwest of the landfill, east of Highway 99 at about S.257th St.

The undersaturated portion of the upper gravel aquifer also appears to be a gas migration pathway for a short distance west of the landfill, but here again the upper gravel aquitard appears to have been impermeable enough to limit gas movement to the ground surface. The area affected was from the landfill to Highway 99, between S. 249th St. and S. 252nd St. The undersaturated portion of the upper gravel aquifer does not appear to extend to Probes 10 and 17 west of the landfill.

And finally, the undersaturated portion of the upper gravel aquifer could have been a gas migration pathway for a limited distance northwest of the landfill. The upper gravel aquitard and an overlying perched water table appear to have limited gas movement to the ground surface. The area affected was from the landfill north to about S. 244th St., between Highway 99 and 30th Avenue S. extended. The undersaturated portion of the upper gravel

aquifer does not appear to extend to Probe 2, just south of the Midway Drive-in Theater.

The undersaturated portions of the upper gravel aquifer east of the landfill and the near-surface sand and gravel layer west of the landfill both probably contributed directly to gas migration away from the landfill and surface venting of gas into structures. Affected areas east of the landfill between 34th Ave S. and Military Road and west of the landfill between the landfill and Highway 99 appear on Figure G-14 of Appendix G. The near-surface sand and gravel layer does not extend to the Parkside wetland and Probes 10 and 17.

The technical memorandum describing the geologic pathway investigation is included as Appendix G of this report.

6.0 CONCLUSIONS

Based on the results of offsite probe monitoring data discussed in Appendix B of this report and the geologic pathways evaluated in Appendix G, confidence is high that the gas bearing strata that allowed the extensive offsite landfill gas migration at the Midway Landfill have been identified and intercepted. Offsite migration of gas appears to have been eliminated since the installation and continued operation of the onsite migration control system began in early 1986. Areas of concern at this time are to the east and southeast, where large reservoirs of migrated landfill gas have accumulated, and removal is continuing.

The gas characterization study, Appendix E of this report, found that offsite migration of at least some of the contaminants consistently identified in landfill gas has occurred, possibly in all directions away from the landfill. The basis for this conclusion is the presence of the "BTX" group compounds in gases found onsite and offsite. However, offsite concentrations of most BTX group compounds were attenuated by more than 98 percent. Furthermore, no BTX compounds were found beyond 2300 feet from the landfill perimeter. Because BTX-group compounds are also present in gas from other sources, their presence in a particular sample of offsite gas is not conclusive evidence that the gas originated from the landfill; it is only further evidence that the gas may have originated in the landfill.

Installation of a final cover may not completely solve the air intrusion and subsequent aerobic decomposition problem. Because of the vacuum induced by the migration control wells, the permeable gravel surrounding the site could possibly allow enough air to be drawn from offsite, even after the final cover is placed, to overstimulate aerobic decomposition and raise temperatures to the danger point. Careful monitoring and adjustment of all migration control wells will continue to be needed for the life of the system. Monitoring will be needed for at least 20 years, but will decrease in frequency with time. The data will be evaluated, and if any system weaknesses are indicated, wells can be added.

6.1 Effect of Operation of Onsite and Offsite Systems

6.1.1 Onsite Migration Control System

The current onsite migration control system is doing an effective job in eliminating offsite landfill gas migration. The addition of the final cover will allow for increased flows from both in-waste wells and in-soil wells, which should help to decrease the concentrations of methane gas that have accumulated offsite over time. In the future, if weaknesses in the system are found through data evaluation, it may be necessary to install additional wells to increase confidence in the system's ability to control migration.

The completion of the final cover onsite and the rerouting of surface water runoff that is now discharged into the landfill from Interstate 5 and areas east will eliminate most of the variable water within the landfill. This will improve the efficiency of certain extraction wells.

6.1.2 Offsite Control Wells

The offsite control wells installed in the vicinity of the Midway Landfill have proven successful in protecting nearby structures from the seepage of migrated landfill gas. The larger offsite control wells have also been successful in reducing the concentrations of methane gas that has migrated from the landfill to form large reservoirs offsite.

As a result, many offsite control wells have been shut down after extremely low methane concentrations were recorded in nearby monitoring probes over a period of several months. Because of the influence of the onsite migration control system, it is not expected that landfill gas will return to these areas. However, the probes will continue to be monitored and the control wells will be restarted if any significant rise in methane levels is detected.

6.2 Intermediate Remedial Measures

- Continue the operation of the onsite migration control system.
- Continue the offsite probe monitoring program. Review the monitoring procedures to prevent recording falsely high methane concentrations from the top of the gas column.
- Continue the operation of the offsite control wells until the gas concentrations fall within the levels set by the program. Adjust extraction rates to prevent pulling gas from the landfill.
- Construct the final cover on the site.
- Reroute the surface water runoff from Interstate 5 and areas east that now discharge into the landfill.
- Continue to evaluate the area of shallow soil gas concentration to the north of the site near Probe 2. Perform test borings to check for the presence of buried peat or refuse. Check old photographs for evidence of either.
- Continue to evaluate the area of shallow soil gas concentrations to the west of the site near probes 10 and 17. Monitor the shallow probes in the nearby peat deposit. Check for H_2S in all of these probes.
- Continue to evaluate the area of shallow soil gas concentration to the southeast of the site near Probe AE. Monitor the shallow probes in the nearby peat deposit. Check for H_2S in Probe AE, C-13 and AF.
- Continue to evaluate the area of shallow soil gas concentration to the southwest of the site near Probe AC. Review old aerial

photographs for evidence of peat deposits. Compare H_2S and CO_2 values in Probes AC, 37 and V.

- Continue the Special Gas Characterization Studies reported in draft form in Appendix H of this report to further differentiate between landfill gas and gas from other sources.

- Compare methane-to-carbon dioxide ratios in gas in Probes AJ, M and MW 23 to the east of the site for indications of the length of time the gas has been away from the site. The higher the ratio, the longer the time away from the site; thus, given the induced vacuum onsite, a high concentration of methane may indicate that this gas is being pulled back to the site.

  Make the same comparison for Probes J, 37, 87, AF, 85, 15, MW24, and 81; and control wells C-12 and C-7.

- Probes AB, AH, and 78 may be included as part of the investigation of the areas around the listed probes.

- Install a new deep probe approximately 300 feet south of the site on the west side of Interstate 5.

- Monitor the rate of reduction of methane concentrations in Probe AF, then consider the results from the methane-to-carbon dioxide ratio comparison above. If there is a slowing of the present trend of reductions, consider the installation of an offsite control well in that vicinity.

- Monitor the average pressures in all offsite deep probes within 700 feet of the landfill. The averages should be a pressure gradient with increasing vacuum strength closer to the landfill. Probes that do not exhibit vacuums or show a reverse pressure gradient may indicate weaknesses in the onsite migration control system. The onsite migration control wells near such probes should be evaluated; if vacuum and flow cannot be increased, consider installing additional wells. A reverse pressure gradient may indicate too strong a vacuum in an offsite control well. Consider decreasing the vacuum in that control well.

- Within the three areas offsite where probes consistently indicate that shallow gas concentrations are above the lower explosive limit, utility conduits and vaults should be monitored periodically. Limited monitoring of structures in those areas also should be considered, depending on concentrations.

- If outlying pockets of gas that are not being pulled back to the landfill are determined to be landfill gas, the installation of additional offsite control wells should be considered. This consideration should also be addressed if the origin of the gas is indeterminate.

If these pockets of gas are found to be generated offsite in peat-bogs or other buried refuse, action should be considered to either remove the decomposing material or install control wells to control the gas being produced. This IRM would not be the responsibility of the City. The Seattle-King County Health Department should be notified and assume responsibility for the appropriate action.

APPENDIX A

MIDWAY LANDFILL VICINITY MAP

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 SIXTH AVENUE
SEATTLE, WA 98101

TARGET SHEET

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APPENDIX B

OFFSITE GAS PROBE INSTALLATION AND MONITORING TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM

FOR

THE MIDWAY LANDFILL RI

OFFSITE GAS PROBE INSTALLATION AND MONITORING

Prepared for:

SEATTLE ENGINEERING DEPARTMENT
SOLID WASTE UTILITY

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

March 24, 1988
PMX #55-1550-11 (Task 2.5.2)

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1.0 INTRODUCTION

The Midway Landfill site is located in an old gravel quarry and was in operation as a landfill between 1966 and 1983. The waste covers approximately 40 acres and over is 100 feet deep in places. It is surrounded mainly by residential neighborhoods, with the closest homes being within 120 feet of the southern boundary.

Since the landfill was closed in the fall of 1983, the City of Seattle has been performing extensive testing of the gas and water in the landfill. Samples of leachate and groundwater from groundwater monitoring wells in and around the landfill, and gas samples from gas probes installed prior to this study indicate elevated levels of organic and inorganic contaminants and a high potential for offsite migration. Methane has been detected in the basements of homes in the area.

Methane, carbon dioxide, and small amounts of hydrogen sulfide, are gases which are normally generated by the decomposition of landfill waste materials. Midway Landfill is the originator of the majority of these gases detected in the surrounding areas, although numerous surface and buried peat bogs, other organic material, and natural gas pipelines in the area may also be sources of methane. There is no protective barrier between the landfill and the aquifer beneath, and no leachate collection system.

2.0 EXISTING CONDITIONS

2.1 Landfill Conditions

The Midway Landfill is located within the City of Kent approximately 15 miles south of the City of Seattle. The landfill occupies a 60-acre site located between Interstate 5 and Highway 99, north of 252nd Street. In January 1966, the City of Seattle leased the site and began using it as a landfill. The landfill received demolition debris from commercial haulers and wood wastes and yard trimmings from the City's transfer stations. Records beginning in 1978 indicate that some industrial wastes also were deposited with the approval of the Seattle-King County Health Department. Information included in EPA's Emergency and Remedial Response Information System (ERRIS) files indicates that the landfill may have received industrial liquid and sludge wastes before 1980. It was closed in 1983, although clean soil materials from excavation projects are still accepted at the site to assist in final grading and cover. During the course of operations at the landfill, an estimated 3 million cubic yards of solid wastes were deposited. The waste covers approximately 40 acres and is over 100 feet deep in places.

From September, 1985 through December, 1987, the City of Seattle installed a series of gas migration control wells around the perimeter of the site as interim remedial measures. These wells were connected by manifold piping to temporary motor blowers and flares. This system has been under continuous operation since shortly after installation. Portions of this manifold/blower system will be replaced by permanent units as a part of final closure construction.

The City of Seattle began negotiations with the site property owners in 1985 and in March, 1986, they executed the purchase agreement to acquire the leasehold portion of the site. Additionally, the City of Kent, who held title to approximately 14 acres of property in the south central portion of the site, have deeded this property to the City of Seattle in exchange for a release from any liability associated with the site closure and/or offsite environmental impacts.

2.2 Existing Probe Locations

The City of Seattle and the Department of Ecology had installed many offsite monitoring probes around the landfill prior to this study. The offsite monitoring probes installed by the City were numbered "A" through "X" and the probes installed by Black and Veatch for the Department of Ecology were numbered 1 through 92. The location of these probes can be seen on Appendix A, Midway Landfill Vicinity Map.

In addition to the onsite gas migration control system installed by the City and the offsite monitoring probes installed by the City and the Department of

Ecology, the City and the Department of Ecology have installed several off-site gas extraction wells in neighborhoods around the landfill. These were installed as an emergency measure to prevent methane from reaching explosive levels in structures. The offsite extraction wells remove methane from the offsite reservoir of gas that has accumulated away from the landfill, and prevent seepage into structures within approximately four hundred feet of each well. Testing of air in homes and businesses, and the data from probes in the vicinity of the extraction wells indicate that they are successful in reducing methane levels. Analysis of the discharge from these wells has shown that no health hazards have been created by venting them to the atmosphere (see Table B-1 and Eaton, 1986). The location of these offsite gas extraction wells can be seen in Appendix A, Midway Landfill Vicinity Map.

2.3 Gas Extent at Start

At the beginning of this study, gas was present at shallow depths north-west of the site at levels of 80 percent CH_4, west, south and east of the site at levels up to 40 percent CH_4. As a result of this and other studies, the gas found 1300 feet west of the site is believed to be generated by a peat bog in that location and not a result of offsite landfill gas migration. Peat bogs produce methane by the same mechanisms as that of decomposing wastes. This, coupled with the lack of a continuous geological gas bearing zone from the landfill west (see Appendix G) has led to this conclusion. The full extent of shallow gas migration east and south of the site could not be accurately determined due to lack of monitoring probes in these areas south-west, north-west, east and south.

Deep gas was present north, east, and south of the site in concentrations up to 90 percent CH_4. The offsite gas extraction wells installed by the City and Department of Ecology were doing an effective job of reducing the gas concentrations within approximately 400 feet of each well in both shallow and deep zones in the neighborhoods east of the landfill. Again, accurate determinations of the full extent of landfill gas migration could not be made due to lack of deep monitoring probes to the north, east and south of the landfill.

TABLE B-1
CONCENTRATIONS OF ORGANIC COMPOUNDS IN SAMPLES COLLECTED FROM THE DISCHARGE TO ATMOSPHERE OF CONTROL WELLS IN THE VICINITY OF THE MIDWAY LANDFILL
ALL RESULTS REPORTED AS uL/L (ppm)

	CONTROL WELL				
COMPOUND	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**
Vinyl Chloride	<1.0	<1.0	1.0	<1.0	<1.0
Chloroethane	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethylene	0.04	<0.005	<0.005	<0.005	<0.005
Methylene Chloride	<0.005	0.02	<1.0	<0.005	0.02
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	0.04	<0.01	<0.01	0.04	0.04
Carbon Tetrachloride	<0.01	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethane	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethylene	0.04	<0.01	0.02	<0.01	0.04
Acetone	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon Disulfide	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	<0.5	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene/Styrene	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene

Note: This is a complete list of all compounds analyzed.

TABLE B-1 (cont.)
CONCENTRATIONS OF ORGANIC COMPOUNDS IN SAMPLES COLLECTED FROM THE DISCHARGE TO ATMOSPHERE OF CONTROL WELLS IN THE VICINITY OF THE MIDWAY LANDFILL
ALL RESULTS REPORTED AS uL/L (ppm)

	CONTROL WELL				
COMPOUND	**C-6**	**C-7**	**C-8**	**C-9**	**C-10**
Vinyl Chloride	<1.0	<1.0	<1.0	1.0	<1.0
Chloroethane	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethylene	<0.005	<0.005	<0.005	<0.005	<0.005
Methylene Chloride	0.05	<1.0	<1.0	0.2	0.05
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	0.08	<0.01	<0.01	<0.01
Carbon Tetrachloride	<0.01	<0.01	<0.01	0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethane	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethylene	0.02	<0.01	0.02	<0.01	0.02
Acetone	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon Disulfide	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	20	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene/Styrene	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene

Note: This is a complete list of all compounds analyzed.

TABLE B-1 (cont.)
CONCENTRATIONS OF ORGANIC COMPOUNDS IN SAMPLES COLLECTED FROM THE DISCHARGE TO ATMOSPHERE OF CONTROL WELLS IN THE VICINITY OF THE MIDWAY LANDFILL
ALL RESULTS REPORTED AS uL/L (ppm)

	CONTROL WELL		
COMPOUND	**C-12**	**C-13**	**C-15**
Vinyl Chloride	<1.0	<1.0	3.0
Chloroethane	<0.5	<0.5	<0.5
Chloromethane	<1.0	<1.0	<1.0
1,1-Dichloroethylene	<0.005	0.1	<0.005
Methylene Chloride	<1.0	<1.0	<1.0
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	0.1	0.1
Carbon Tetrachloride	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	0.04	<0.01
1,1,2,2-Tetrachloro-ethane	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethylene	<0.01	<0.01	<0.01
Acetone	<0.5	<0.5	<0.5
Carbon Disulfide	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2
Toluene	<0.5	20	<0.5
p-Xylene	<0.5	<0.5	<0.5
o-Xylene/Styrene	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5

* - Based on response for toluene

Note: This is a complete list of all compounds analyzed.

3.0 OBJECTIVES

3.1 Install Off-Site Gas Probes

Eleven multi-completion offsite monitoring probes were installed to provide additional data to an existing data base on offsite landfill gas migration and concentrations of gas in the surrounding area. Specific questions that were to be answered include whether offsite subsurface gasses originate within the landfill or from other sources and whether there is a subsurface conduit for landfill gas migration between the Midway landfill and the Kent Highlands Landfill.

Up to four screened intervals were installed in each probe to enable sampling from shallow and deeper lithologic layers which were potential gas transmitters. It was anticipated that a correlation between stratigraphies could be made from this and the above questions could be answered.

3.2 Monitor Levels of CH_4, O_2, CO_2, and Static Pressure

The extent of offsite landfill gas migration can be determined by monitoring certain parameters in each offsite monitoring well. Also, knowledge of subsurface conduits for landfill gas migration can be supplemented. Monitoring the static pressure in the various completion zones in the offsite monitoring probes over time determines if the vacuum induced in the landfill by the active onsite migration control system is having an influence on the soil surrounding the offsite probe.

Static pressure will vary due to changing barometric conditions. To evaluate the influence of the onsite gas migration control system on an offsite probe, it is necessary to evaluate the change in static pressure in the probe over time during similar barometric conditions.

3.3 Plot Data as Isopleths

As the data from the offsite probes was accumulated, isopleths of methane concentrations and pressure gradients were developed for various time periods to show trends in landfill gas migration. These isopleths are computer generated maps showing the highest methane concentration curves around the landfill site for a given time period. From this data, areas around the landfill in which the onsite gas migration control system is or is not having sufficient influence can be identified and appropriate adjustments can be performed onsite. Also, areas which need additional probes or extraction wells can be identified. Sample isopleths are included in this memo in Section 5 as Figures B-6, B-7, B-8, B-9, B-10, B-11, B-12, B-13, and B-14.

3.4 Assess Changes in Methane Levels

As the methane levels in the offsite probes change, determinations can be made as to the effectiveness of the onsite gas migration control system. It is important to note trends in offsite gas migration as shown on the methane concentration isopleths generated. Increased methane concentrations in offsite monitoring probes do not necessarily indicate landfill gas is escaping from the landfill. Rises in methane concentrations can be caused by "old" landfill gas, or gases from other sources, being pulled back toward the site by the onsite gas migration control system. An indicator of this would be decreased carbon dioxide levels in the gas sample. Experience at the Midway Landfill has shown that methane and carbon dioxide are produced during anaerobic decomposition in a ratio of 1.45:1. It is also known that carbon dioxide is readily soluble in water. Therefore, if the ratio of methane to carbon dioxide in an offsite gas probe is considerably less than the ratio in probes on the landfill, it can be assumed that the missing carbon dioxide was adsorbed into the soil moisture as the gas migrated.

If landfill gas is found to be still migrating away from the landfill, appropriate measures such as adding more extraction wells onsite or increasing the flow rate in existing onsite extraction wells can be implemented to achieve more complete control.

4.0 METHODOLOGY

4.1 Gas Probe Design, Drilling, Sampling and Logging

Eleven gas monitoring probes were installed as part of this investigation. These probes were labeled "Y1" through "Z" and "AA" through "AH". The location of these probes can be seen on Figure B-1. The probe locations were selected by Parametrix and the City of Seattle. Ten wells are on street rights-of-way. Well "AC" is located on private property. Street addresses and other information to locate the gas monitor probes are provided in Appendix B-1. Drilling the boreholes and installing the in-ground probes was subcontracted to Richardson Well Drilling Company of Tacoma, Washington. All of their work was closely supervised by an experienced engineering geologist from Terra Associates, Inc. of Redmond, Washington.

Drilling began on November 3, 1986. A top-drive rotary drill rig was used to drill and sample the first three boreholes: Y1, Y2, and Z. Compressed air and water mist were used to remove the cuttings. To support the boreholes, eight-inch-diameter steel casing was driven using a pneumatic hammer. Soil samples were taken at five-foot intervals using a tube sampler driven with the casing hammer.

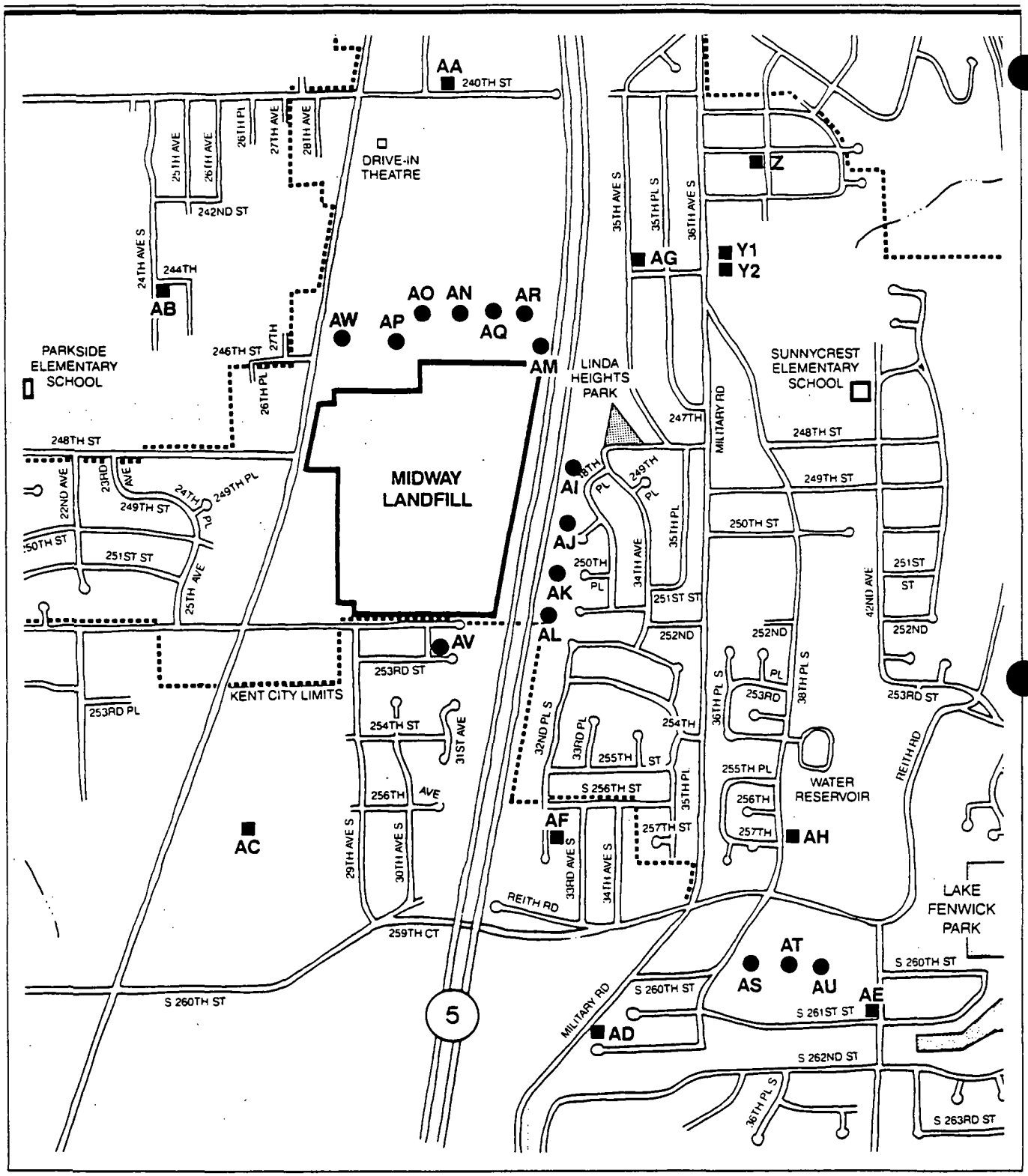
Due mostly to the time required to take the soil samples, work progress with the rotary drill rig proved to be much slower than expected. Consequently, the rotary rig was assigned to other Midway Landfill work and a cable-tool drill rig was mobilized to complete the remaining eight gas monitor probes.

The cable-tool rig advances casing by driving it with a dead-weight hammer. The drill tool is lowered into the casing on a steel cable. The borehole is advanced below the casing by dropping a heavy drill tool repeatedly onto the material at the bottom of the borehole. Water is added as needed to produce muddy, fluid cuttings. The cuttings are removed from the borehole with a trap-door bailer lowered into the casing after the drill tool is removed.

The borehole was advanced five feet at a time. Once the borehole was bailed free of cuttings, the sampling tube was inserted in the borehole and driven with a down-the-hole hammer operated by the cable. It was usually driven one to two feet once in every five feet of borehole.

The steel casings were removed from the boreholes as the boreholes were backfilled with well screen and gravel pack. To assure the boreholes would not collapse while the casings were being withdrawn, the pea gravel level was kept a few feet above the bottom of the casings, except when the seals were being placed.

At each well, an engineering geologist from Terra Associates, Inc. maintained a log of each borehole, collected the soil samples and supervised the installation of the gas collecting completion zones. All cuttings were



SCALE IN FEET

0 500 1,000

■ Approximate Location of Monitoring Probes Installed for R.I.

● Approximate Location of Monitoring Probes Installed Subsequent to R.I.

Figure B-1
Locations of Offsite Monitoring Probes Installed for and Subsequent to the Remedial Investigation

removed and disposed of onsite. The soil samples and the cuttings were visually classified in accordance with the Unified Soil Classification System. The well installation logs included in Appendix B-1 report the results of this visual classification.

While the gas monitor probes were being installed, methane was detected only at probe AF. The quantity of gasses venting through the borehole was small. Maintaining the safe working environment prescribed by the Health and Safety Plan was readily accomplished.

A typical schematic drawing of the as-built probe installations is shown in Figure B-2. Schematic drawings of probes installed previously are shown on Figures B-3, B-4, and B-5 for reference. The gas monitor wells consist of either two, three or four gas probes packed in pea gravel collection zones. Each probe uses Schedule 80 PVC slotted pipe within the collection zones and solid-wall PVC riser pipe to bring the gases collected to the ground surface. The slot width is either two hundredths or four hundredths of an inch. All joints are threaded flush. No glues or solvents were used. The probes are closed on the bottom end with either slip caps or threaded caps. The top of each probe is threaded and closed off with a Schedule 80 1/4-inch PVC ball valve and threaded cap.

In each probe, the deepest probe is 3/4-inch-diameter pipe and the shallower probes are 1/2-inch-diameter pipe. Because it was anticipated that the deep probes might encounter the regional groundwater table, the larger pipe was installed to make it easier to insert the sensor used to measure the water level in the wells.

In each probe, pea gravel for the collection zone was installed to a point at least a few feet above the uppermost slots. The seals separating adjacent collection zones vary in thickness from about two to five feet. The seals were made from bentonite pellets, except for the deepest seal in probe AF, where concrete grout was used. At least 100 pounds of pellets were used for the bentonite seals. Once in place, water was added to swell the pellets and activate the seals. To exclude surface water from the probes, a seal was placed at the ground surface. These seals were either concrete grout over a layer of bentonite pellets, or concrete grout mixed with a few percent of bentonite powder.

Each well was secured at the ground surface with a cast iron locking cover twelve inches in diameter. The last hole was completed on March 26, 1987.

After the installation of the eleven probes for the RI, the City contracted with Parametrix, Inc. to install 11 additional multi-completion gas probes north, east and south of the landfill to gather additional information with respect to off-site migration of gas in these areas. These probes are shown in Figure B-1 and labeled "AI" through "AV". These probes were installed using similar methodology as that described for the R.I. probes.

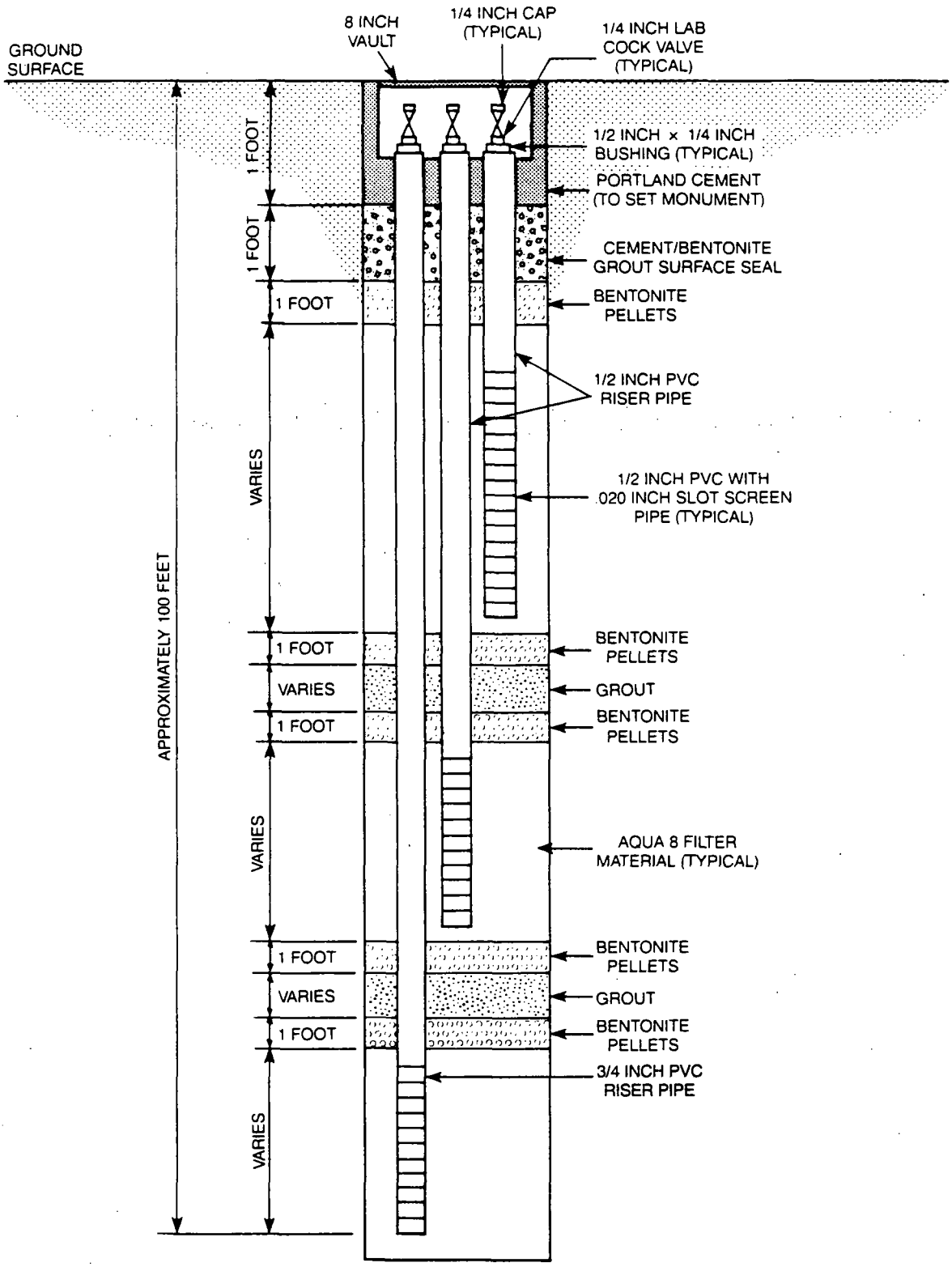


Figure B-2
Cross Section of a Typical Multi-Level Monitoring Probe Installed by City of Seattle for the Remedial Investigation

NOT TO SCALE

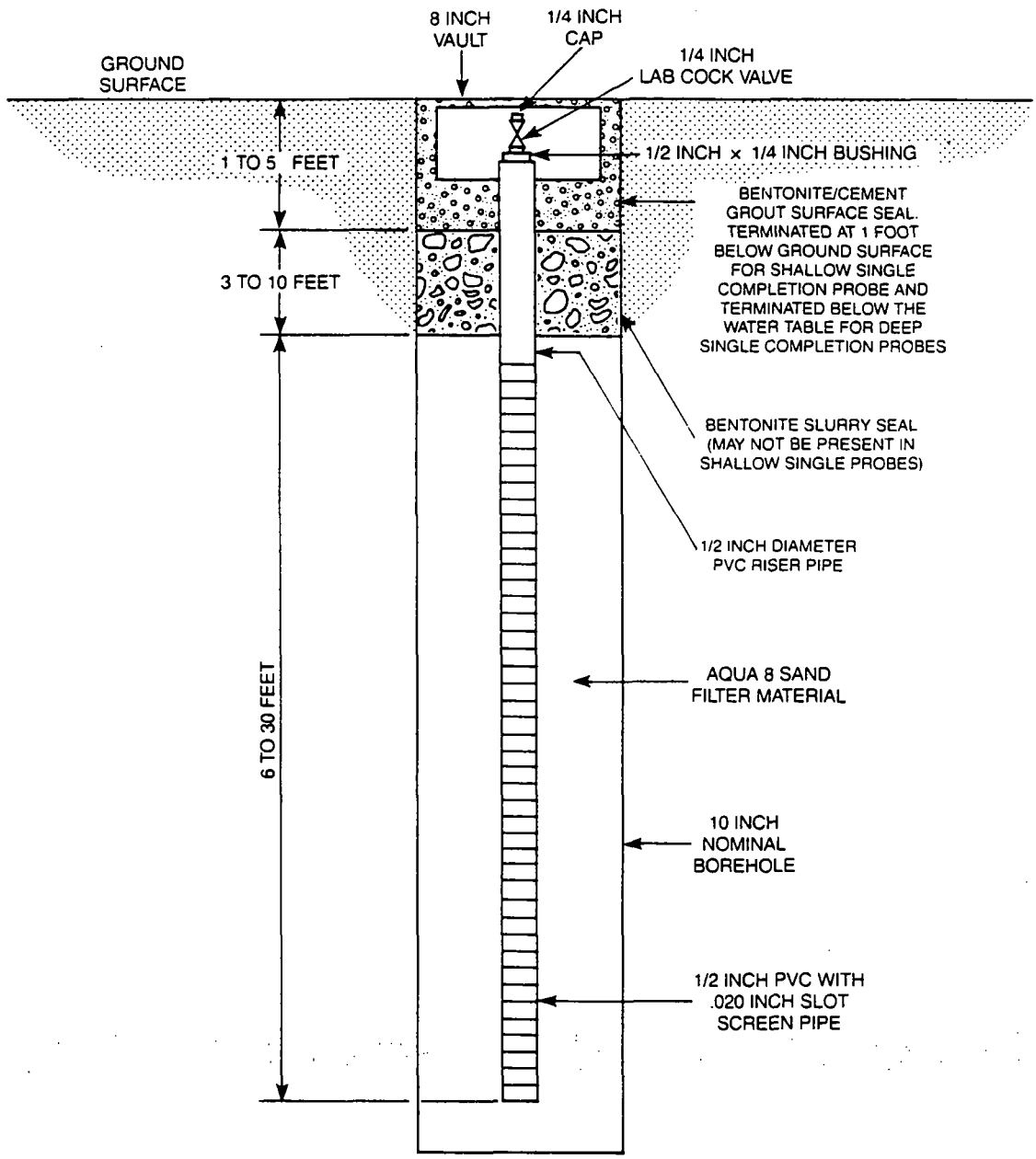


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Figure B-3
Cross Section of a Typical Single Completion Monitoring Probe Installed by Ecology

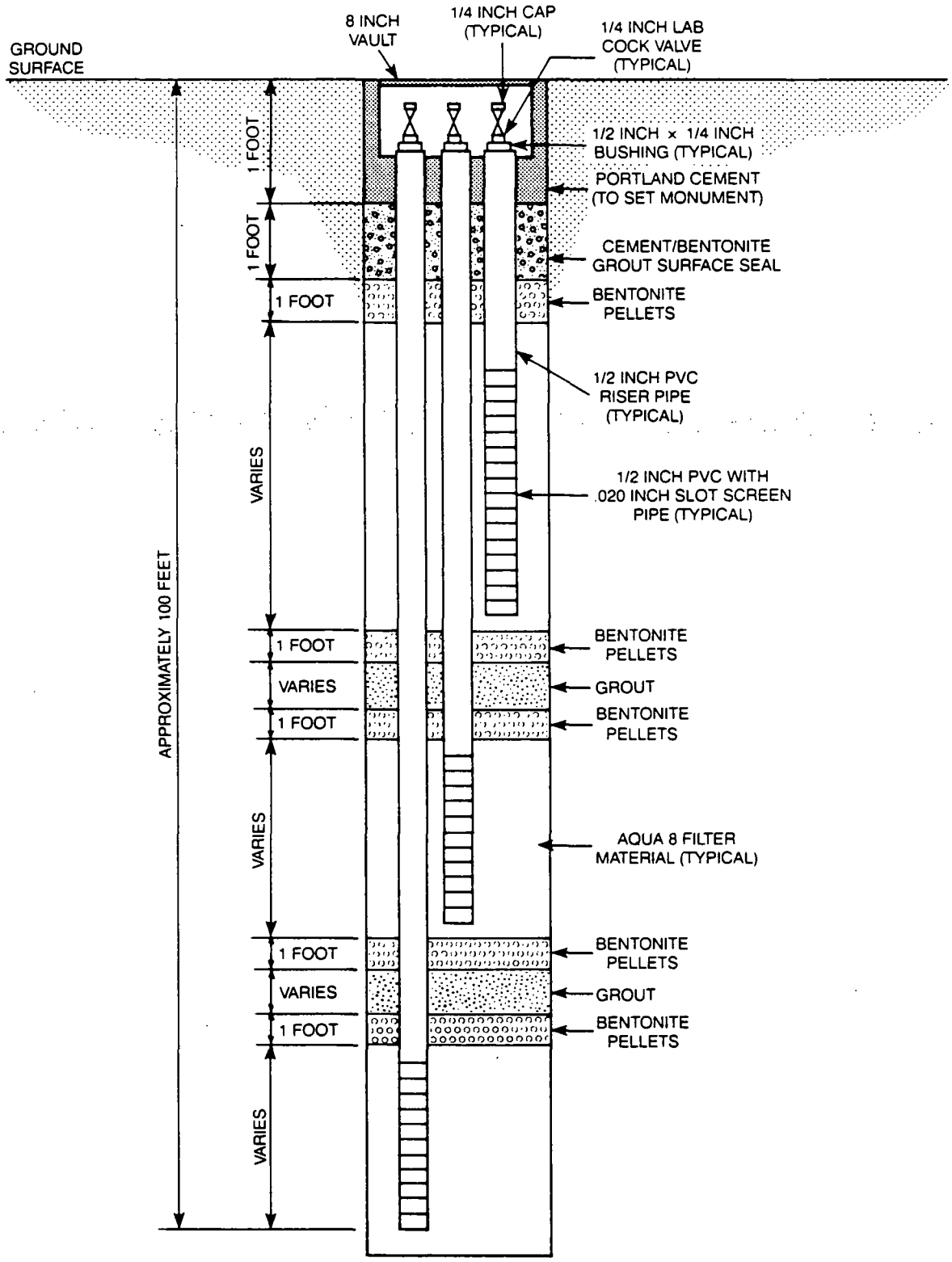

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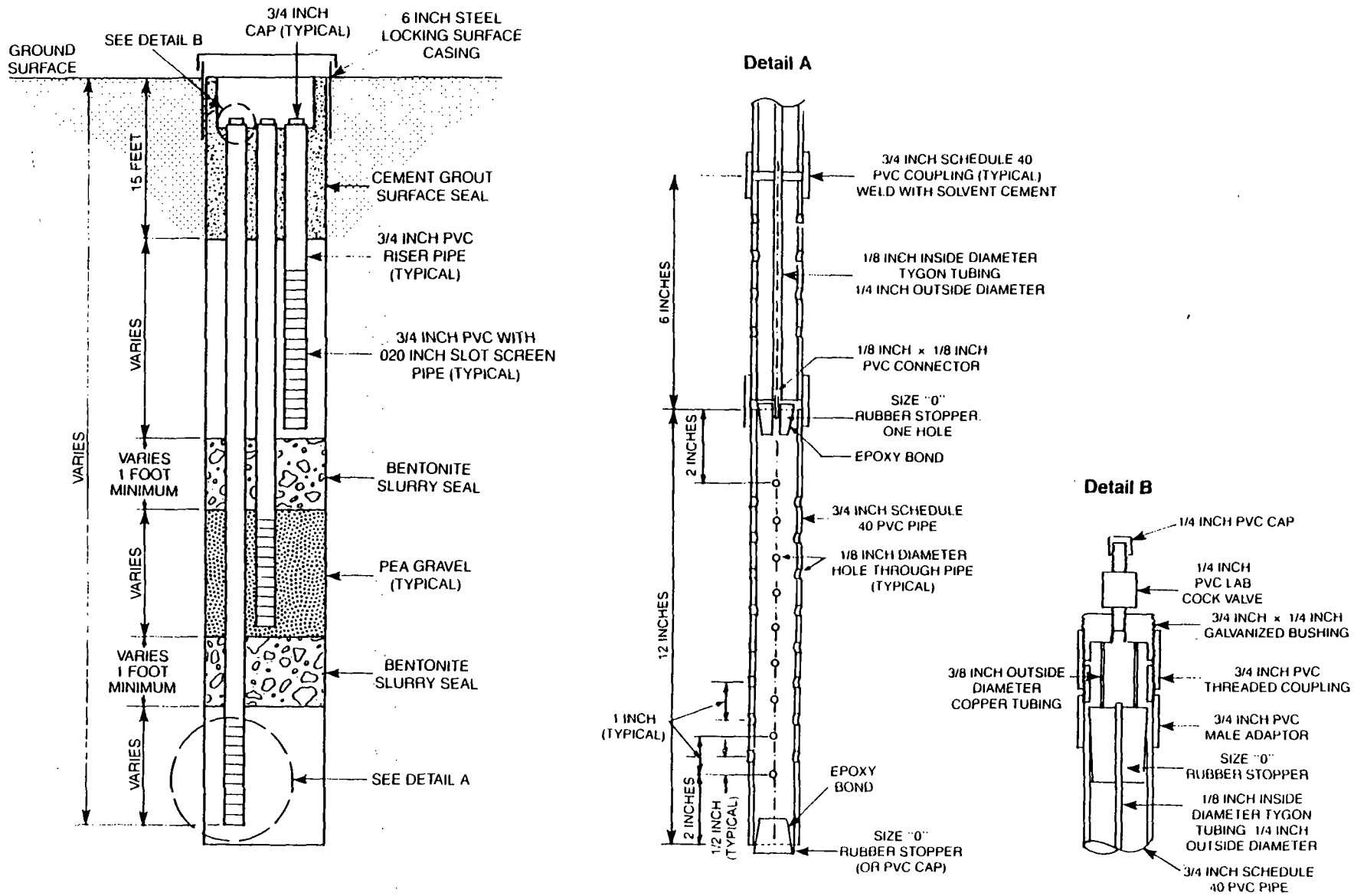
Figure B-4
Cross Section of a Typical Multi-Level Monitoring Probe Installed by Ecology



NOT TO SCALE

Figure B-5
Cross Section of a Multi-Level Monitoring Probe Installed by the City of Seattle Prior to the Remedial Investigation

To gather additional information near the peat bog located south-east of the landfill, the City contracted with Parametrix, Inc. to install three shallow single completion probes in the peat deposits. These probes are six to nine feet deep, hand augured holes. In each probe, pea gravel was installed to within one foot of the surface, and a bentonite surface seal was installed in the upper one foot. The probe is perforated in the pea gravel zone. These probes are shown on Figure B-1 and labeled "AS", "AT", and "AU".

4.2 Monitoring Equipment

The following is a list of the equipment used to monitor the offsite probes around the Midway Landfill:

a. "Dwyer Magnahelic" analog pressure gauges with ranges of 0 to .25 inches W.C., 0 to 1.0 inches W.C., 0 to 10.0 inches W.C., and 0 to 40 inches W.C.

b. "Bacharrach TLV Sniffer" combustible gas indicator with ranges of 0 to 100 parts per million (ppm), 0 to 1,000 ppm, and 0 to 10,000 ppm.

c. "Gastech Model NP-204" combustible gas indicator with ranges of 0 to 100% of the lower explosive limit (LEL), and 0 to 100% combustible gas by volume.

d. "Gastech Model IP-204" oxygen deficiency indicator with ranges of 0 to 5% oxygen by volume, and 0 to 25% oxygen by volume.

e. "Bacharach Fyrite" carbon dioxide indicator with ranges of 0 to 20% carbon dioxide by volume, and 0 to 60% carbon dioxide by volume.

f. "Brailsford Model TD-2N" evacuation pump capable of drawing up to 100 inches W.C. vacuum and 4 liters per minute.

4.3 Monitoring Procedure

Monitoring of offsite probes is accomplished by City of Seattle Field Technicians. Each day, the barometric pressure for the Midway area is recorded at four to six times in the day. This information is recorded to combine with the data collected at the individual monitoring probes for a specific day to note the effect of barometric conditions on the readings taken.

The following is the monitoring procedure followed by the field technicians at each offsite monitoring probe:

a. remove the vault cover from the prove vault
b. remove the cap from each completion level in the probe

c. insert the pressure gauge in one completion level of the probe
d. open the valve on the completion level that the pressure gauge is attached to and record the pressure
e. close the valve
f. repeat steps c, d, and e for each completion level
g. insert the evacuation pump in one completion level of the probe
h. open the valve on the completion level
i. evacuate the volume of the completion zone
j. remove the evacuation pump
k. attach the oxygen deficiency meter to the completion zone being sampled, draw and record the measurement. (note: this step is taken prior to measuring the amount of combustible gas, because the "TLV Sniffer" and the "Gastech Model NP-204" LEL range will not give a valid reading in gas samples where oxygen content is less than 10% by volume. If the oxygen content is less than 10% by volume, either the percent by volume range of the "Gastech Model NP-204", or a Flame Ionization Detector (FID) with a sample diluter should be used to measure the amount of combustible gas.
l. attach the appropriate combustible gas indicator to the completion zone being sampled, draw and record the measurement.
m. attach the CO_2 indicator to the completion zone being sampled, draw and record the measurement
n. close the valve
o. repeat steps g, h, i, j, k, l, m, and n on each completion level
p. replace the caps on each completion level
q. replace and secure the vault cover

4.4 Schedule of Measurements

As monitoring probes are installed, they are monitored daily until a certain confidence in the readings and trends in the probes are ascertained. If the readings indicate that unacceptable levels of combustible gas are present, the probe will continue to be monitored more frequently than those which do not indicate high levels of combustible gas. Also, probes nearer the landfill will generally be monitored more frequently than those further away. This makes it possible to quickly determine if landfill gas is escaping from the landfill and take appropriate measures with the onsite migration control system.

Currently, the monitoring schedule for probes around the Midway landfill is as follows:

TWO TIMES WEEKLY (evenly spaced)

A, C, I, J, K, L, M, AB, AF, AH, AM, AN, AO, AP, AQ, AR, AS, AT, AU, AV, AW, 37, 39, 44, 45, 48, 49, 50, 56, 59, 60, 61, 78, 79, 81, 82, 85, 87, MW-21, MW-23, MW-15, MW-24, MW-27

ONE TIME WEEKLY

B, D, E, H, N, O, R, V, Y, AA, AC, AD, AG, AI, AJ, AK, AL, 2, 10, 13, 17, 18, 64, 66, 69, 76, 84, 88, 90, MW-8, MW-10, MW-14, MW-20, MW-29

MONTHLY

P, Q, S, T, U, W, X, Z, 5, 6, 7, 8, 9, 12, 20, 21, 22, 26, 27, 29, 31, 32, 33, 34, 35, 40, 41, 43, 46, 47, 51, 52, 53, 54, 57, 58, 67, 70, 72, 73, 74, 75, 77, 80, 83, 86, 89, 91, 92, BARHOLES

5.0 RESULTS

5.1 Probe Logs and Subsurface Conditions

The probe logs for the probes drilled for this investigation are included in this report in Appendix B-1. A complete listing of all probes installed around the Midway Landfill is included as Table B-2 of this report. Generally, the sedimentary units encountered in the gas probe borings indicate a silty, sandy gravel layer overlying outwash and ice contact deposits. The contact between these two main sediment types is an erosional unconformity, indicating a gap in time between periods of deposition. The upper layers consist of a sandy and silty gravel while the lower deposits are comparatively looser and more water bearing than the till. Both deposits are generally poorly sorted. Occasionally, layers of silt and clay were noted, in all cases beneath the till layer.

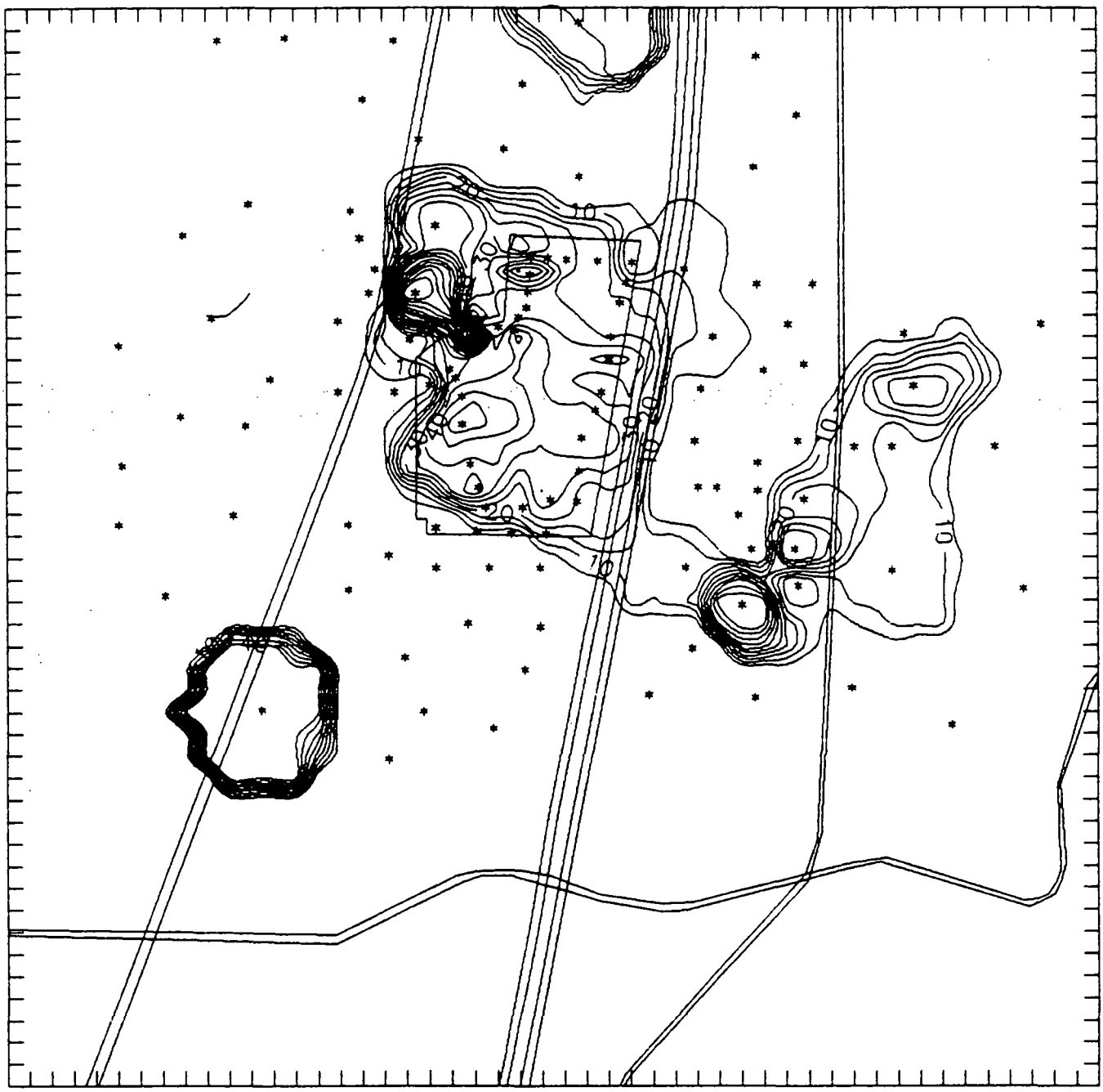
Data from previous studies indicate that below the reach of the gas probes installed for this study are sedimentary layers which are more massive, continuous, and easily correlatable from the data provided from the deeper groundwater wells.

5.2 Gas Concentration Isopleths

Data recorded from the monitoring probes installed for this investigation, along with monitoring probes installed prior to this investigation was compiled and input to a computer to generate gas concentration isopleths. These maps show gradient lines of gas concentrations around the Midway Landfill.

As seen on Figure B-6, which is an isopleth of the shallow soil zone for February, 1986, methane was detected north-west of the landfill in concentrations over 75%, north of the landfill in concentrations over 25%, east of the landfill in concentrations over 40%, and south-west of the landfill in concentrations over 40%. Figure B-7, a deep soil zone isopleth for February, 1986, shows that methane was detected in all directions away from the landfill and in concentrations over 90% in some areas. These two isopleths represent the status of landfill gas migration from the landfill at the time that the completed Phase I onsite gas migration control system was put in continuous operation. The effect of the offsite control wells placed in various locations in the neighborhoods east of the landfill can be seen on Figure B-6. This figure shows a deep soil zone east of Interstate 5, surrounded on three sides with concentrations of gas above 5%. However, the areas near the offsite control wells do not indicate concentrations of gas over 5% by volume in the shallow soil zone.

Figures B-8 and B-9 depict maximum shallow and deep gas concentrations during the first half of September, 1986. This represents the status of migrated



Note: All sets of probes and wells may not be shown.

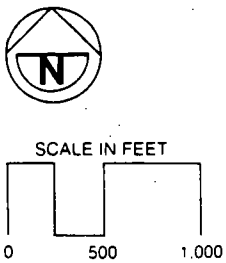
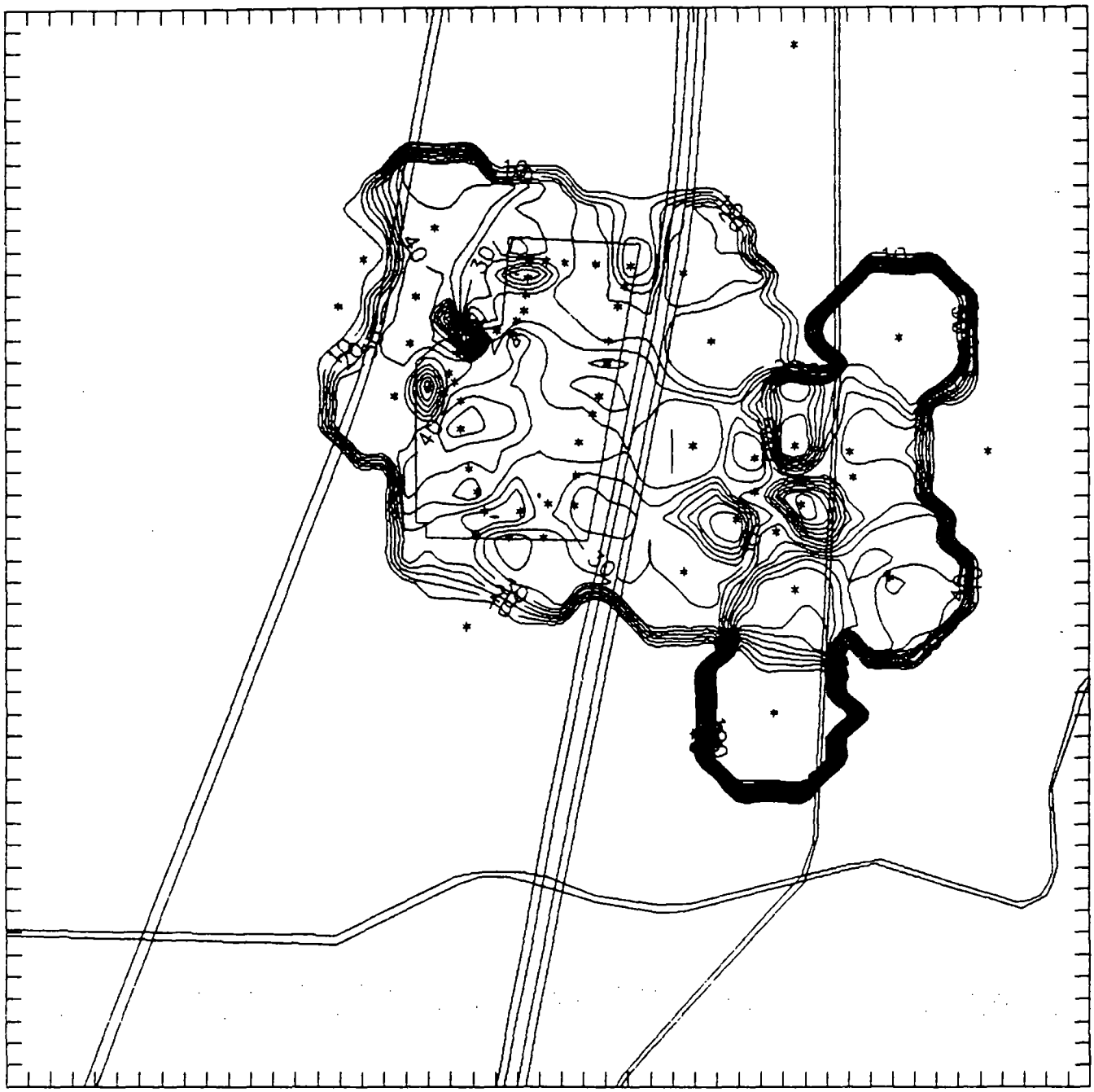


Figure B-6
Shallow Gas Concentration Isopleth, February, 1986



Note: All sets of probes and wells may not be shown.

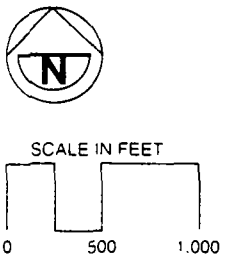
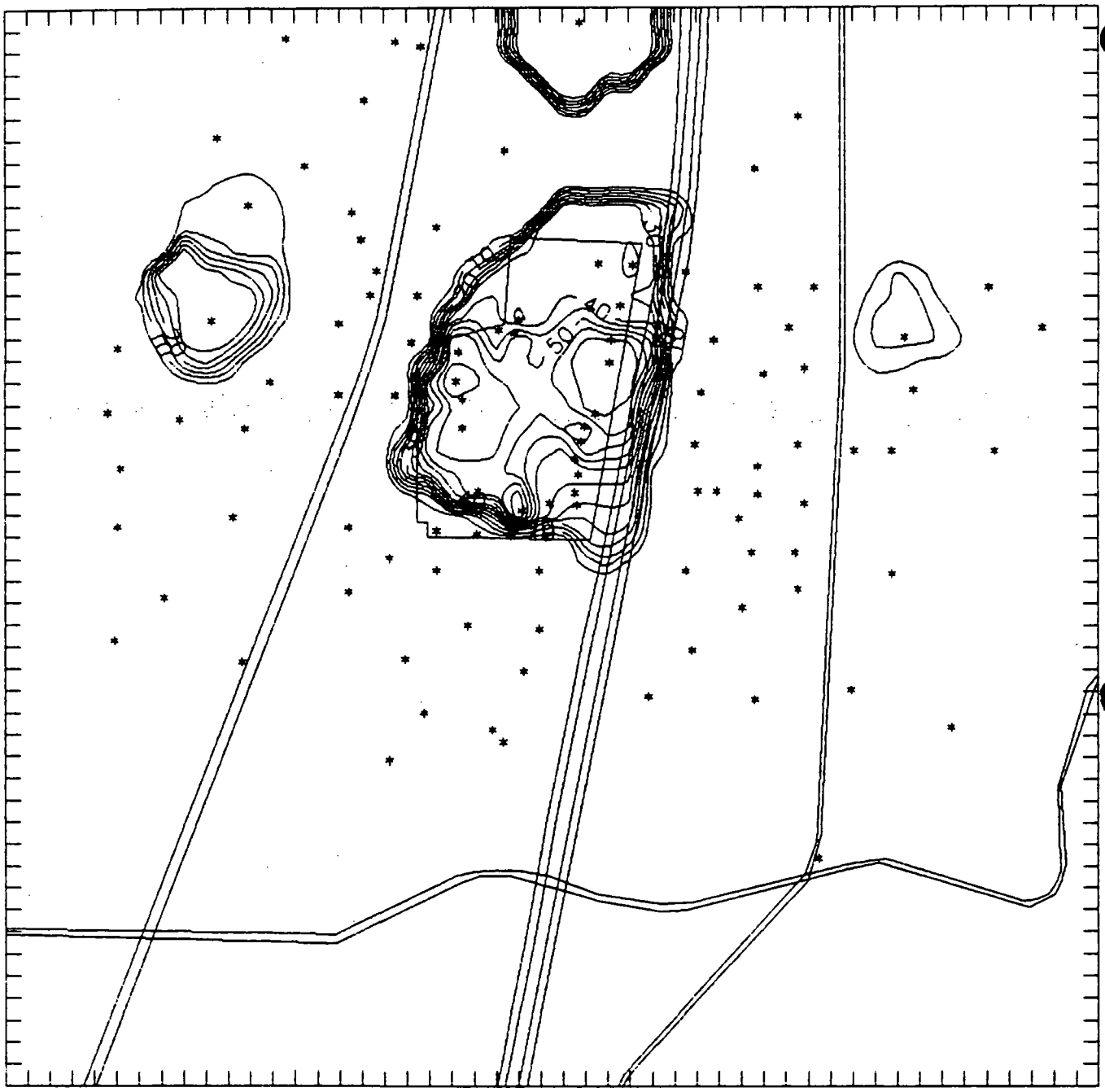


Figure B-7
Deep Gas Concentration Isopleth, February, 1986



Note: All sets of probes and wells may not be shown.

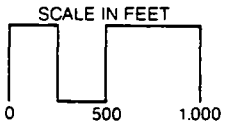


Figure B-8
Shallow Gas Concentration Isopleth, September 1986

Note: All sets of probes and
wells may not be shown.

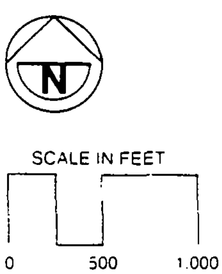


Figure B-9
Deep Gas Concentration Isopleth, September 1986

TABLE B-2
OFFSITE MONITORING PROBE COMPLETION DETAILS

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
A-S	03/15/85	GA	CITY	13.5	14.0	0.5
A-D	03/15/85	GA	CITY	58.4	59.0	0.6
A1-S	03/21/85	GA	CITY	13.5	14.0	0.5
A1-M	03/21/85	GA	CITY	37.4	38.0	0.6
A1-D	03/21/85	GA	CITY	58.5	59.0	0.5
B-S	03/14/85	GA	CITY	12.5	13.0	0.5
B-M	03/14/85	GA	CITY	32.5	33.0	0.5
B-D	03/14/85	GA	CITY	57.5	58.0	0.5
C-S	03/22/85	GA	CITY	24.0	24.5	0.5
C-M	03/22/85	GA	CITY	40.5	41.0	0.5
C-D	03/22/85	GA	CITY	56.0	56.5	0.5
D-S	03/18/85	GA	CITY	13.5	14.0	0.5
D-M	03/18/85	GA	CITY	43.5	44.0	0.5
D-D	03/18/85	GA	CITY	74.0	74.5	0.5
E-S	03/20/85	GA	CITY	13.5	14.0	0.5
E-M	03/20/85	GA	CITY	41.5	42.0	0.5
E-D	03/20/85	GA	CITY	67.4	68.0	0.6
H-S	03/01/85	GA	CITY	9.5	10.0	0.5
H-M	03/01/85	GA	CITY	33.5	34.0	0.5
H-D	03/01/85	GA	CITY	65.5	66.0	0.5
I-S	03/02/85	GA	CITY	11.4	12.0	0.6
I-M	03/02/85	GA	CITY	40.5	41.0	0.5
I-D	03/02/85	GA	CITY	69.5	70.0	0.5
J-S	03/04/85	GA	CITY	12.0	12.5	0.5
J-M	03/04/85	GA	CITY	43.8	44.5	0.7
J-D	03/04/85	GA	CITY	72.5	73.0	0.5
K-S	03/11/85	GA	CITY	12.2	13.0	0.8
K-M	03/11/85	GA	CITY	49.2	50.0	0.8
K-D	03/11/85	GA	CITY	79.8	80.5	0.7
L-S	06/27/85	GA	CITY	12.7	14.0	1.3
L-M	06/27/85	GA	CITY	53.7	55.0	1.3
L-D	06/27/85	GA	CITY	96.0	97.5	1.5
M-S	07/01/85	GA	CITY	12.7	14.5	1.8
M-M	07/01/85	GA	CITY	62.9	64.5	1.6
M-D	07/01/85	GA	CITY	102.1	103.5	1.4
N-S	03/21/85	GA	CITY	12.5	13.0	0.5
N-M	03/21/85	GA	CITY	50.5	51.0	0.5
N-D	03/21/85	GA	CITY	86.5	87.0	0.5
O-S	04/17/85	GA	CITY	12.2	13.0	0.8
O-M	04/17/85	GA	CITY	39.2	40.0	0.8
O-D	04/17/85	GA	CITY	73.3	74.0	0.7
P-S	03/26/85	GA	CITY	12.5	13.0	0.5
P-M	03/26/85	GA	CITY	28.5	29.0	0.5
P-D	03/26/85	GA	CITY	46.5	47.0	0.5
Q-S	09/02/86	TERRA	CITY	10.0	30.0	20.0
Q-M	09/02/86	TERRA	CITY	35.0	85.0	50.0

TABLE B-2
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
Q-D	09/02/86	TERRA	CITY	100.0	197.0	97.0
R-S	09/05/86	TERRA	CITY	8.0	30.0	22.0
R-M	09/05/86	TERRA	CITY	40.0	100.0	60.0
S-S	08/28/86	TERRA	CITY	9.0	19.0	10.0
S-M	08/28/86	TERRA	CITY	30.0	51.0	21.0
S-D	08/28/86	TERRA	CITY	70.0	80.0	10.0
T-S	09/22/86	TERRA	CITY	10.0	22.0	12.0
T-M	09/22/86	TERRA	CITY	33.0	63.0	30.0
U-S	09/17/86	TERRA	CITY	6.0	17.0	11.0
U-M	09/17/86	TERRA	CITY	20.0	55.0	35.0
U-D	09/17/86	TERRA	CITY	60.0	99.0	39.0
V-S	09/19/86	TERRA	CITY	7.0	15.0	8.0
V-M	09/19/86	TERRA	CITY	18.0	36.0	18.0
V-D	09/19/86	TERRA	CITY	40.0	84.0	44.0
W-S	09/27/86	TERRA	CITY	10.0	20.0	10.0
W-M	09/27/86	TERRA	CITY	30.0	102.0	72.0
X-S	09/29/86	TERRA	CITY	8.0	27.0	19.0
X-M	09/29/86	TERRA	CITY	34.0	75.0	41.0
X-D	09/29/86	TERRA	CITY	88.0	121.0	33.0
Y1-S	11/11/86	TERRA	CITY	10.0	20.0	10.0
Y1-M	11/11/86	TERRA	CITY	44.0	54.0	10.0
Y1-I	11/11/86	TERRA	CITY	58.0	68.0	10.0
Y1-D	11/11/86	TERRA	CITY	98.0	147.0	49.0
Y2-S	11/19/86	TERRA	CITY	13.0	37.0	24.0
Y2-M	11/19/86	TERRA	CITY	49.0	75.0	26.0
Y2-I	11/19/86	TERRA	CITY	87.0	107.0	20.0
Y2-D	11/19/86	TERRA	CITY	118.0	147.0	29.0
Z-S	12/19/86	TERRA	CITY	7.0	17.0	10.0
Z-M	12/19/86	TERRA	CITY	25.0	35.0	10.0
Z-D	12/19/86	TERRA	CITY	45.0	137.0	92.0
01-M	09/25/85	HC	DOE	19.0	48.5	29.5
02-S	11/07/85	HC	DOE	5.8	10.8	5.0
02-M	06/05/86	HC	DOE	27.7	49.3	21.6
02-D	06/03/86	HC	DOE	67.9	100.7	32.8
03-M	09/27/85	HC	DOE	27.0	51.5	24.5
04-M	09/30/85	HC	DOE	25.0	59.0	34.0
05-S	12/12/85	HC	DOE	6.4	11.4	5.0
06-S	11/08/85	HC	DOE	6.1	11.1	5.0
07-S	11/08/85	HC	DOE	5.0	10.0	5.0
08-S	11/08/85	HC	DOE	6.0	11.0	5.0
09-S	11/12/85	HC	DOE	8.8	13.8	5.0
10-S	11/12/85	HC	DOE	5.5	10.5	5.0
11-S	11/11/85	HC	DOE	5.8	10.8	5.0
12-S	11/11/85	HC	DOE	5.7	10.7	5.0
13-S	11/11/85	HC	DOE	6.0	11.0	5.0
13-M	06/10/86	HC	DOE	44.3	58.8	14.5

TABLE B-2
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
14-S	11/06/85	HC	DOE	6.4	11.4	5.0
15-S	11/07/85	HC	DOE	5.0	10.5	5.5
16-S	11/15/85	HC	DOE	6.0	11.0	5.0
17-S	11/14/85	HC	DOE	3.0	5.2	2.2
18-S	11/13/85	HC	DOE	5.8	10.8	5.0
19-S	11/13/85	HC	DOE	5.4	5.4	10.4
20-S	11/14/85	HC	DOE	6.2	11.2	5.0
21-S	11/14/85	HC	DOE	6.1	11.1	5.0
22-S	12/11/85	HC	DOE	6.1	11.1	5.0
23-M	11/05/85	HC	DOE	23.5	57.5	34.0
25-S	11/11/85	HC	DOE	6.0	11.0	5.0
26-S	11/15/85	HC	DOE	6.1	11.1	5.0
27-S	11/13/85	HC	DOE	5.9	10.9	5.0
28-S	11/13/85	HC	DOE	5.7	10.7	5.0
29-S	12/12/85	HC	DOE	3.6	6.4	2.8
30-S	11/18/85	HC	DOE	8.5	13.5	5.0
31-S	11/19/85	HC	DOE	5.5	10.5	5.0
32-S	11/18/85	HC	DOE	3.4	7.4	4.0
33-S	11/18/85	HC	DOE	3.3	7.3	4.0
34-S	11/15/85	HC	DOE	4.5	9.5	5.0
35-S	11/19/85	HC	DOE	6.0	11.0	5.0
36-S	11/20/85	HC	DOE	6.0	11.0	5.0
37-S	02/13/86	HC	DOE	4.3	7.8	3.5
37-M	02/13/86	HC	DOE	30.0	40.0	10.0
37-D	02/13/86	HC	DOE	58.0	88.0	30.0
38-S	11/20/85	HC	DOE	6.0	11.0	5.0
39-S	12/10/85	HC	DOE	6.2	11.2	5.0
40-S	12/05/85	HC	DOE	6.1	11.1	5.0
41-S	12/04/85	HC	DOE	9.9	14.9	5.0
42-S	12/04/85	HC	DOE	6.4	11.4	5.0
43-S	11/26/85	HC	DOE	6.3	11.3	5.0
44-S	11/25/85	HC	DOE	6.3	11.3	5.0
44-M	11/25/85	HC	DOE	20.0	40.0	20.0
44-D	11/25/85	HC	DOE	72.0	101.0	29.0
45-S	11/26/85	HC	DOE	6.1	11.1	5.0
45-M	11/26/85	HC	DOE	20.0	40.0	20.0
45-D	11/26/85	HC	DOE	27.5	92.5	65.0
46-S	11/26/85	HC	DOE	6.4	11.4	5.0
47-S	11/27/85	HC	DOE	6.1	11.1	5.0
48-S	12/02/85	HC	DOE	6.3	11.3	5.0
49-S	12/02/85	HC	DOE	6.2	11.2	5.0
50-S	01/11/86	HC	DOE	6.3	11.3	5.0
50-M	01/11/86	HC	DOE	20.0	40.0	20.0
50-D	01/11/86	HC	DOE	70.3	100.3	30.0
51-S	12/03/85	HC	DOE	6.1	11.1	5.0
52-S	12/03/85	HC	DOE	6.3	11.3	5.0

TABLE B-2
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
53-S	12/03/85	HC	DOE	6.0	11.0	5.0
54-S	12/03/85	HC	DOE	6.0	11.0	5.0
55-S	12/09/85	HC	DOE	6.1	11.1	5.0
56-S	12/09/85	HC	DOE	6.2	11.2	5.0
57-S	12/04/85	HC	DOE	6.3	11.3	5.0
58-S	12/04/85	HC	DOE	6.2	11.2	5.0
59-S	12/04/85	HC	DOE	6.0	11.0	5.0
59-M	01/14/86	HC	DOE	20.0	40.0	20.0
59-D	01/14/86	HC	DOE	67.5	99.5	32.0
60-S	12/06/85	HC	DOE	6.2	11.2	5.0
61-S	12/11/85	HC	DOE	6.3	11.3	5.0
62-S	11/19/85	HC	DOE	5.6	10.6	5.0
63-S	12/12/85	HC	DOE	5.3	10.3	5.0
64-S	12/13/85	HC	DOE	6.3	11.3	5.0
65-S	11/07/85	HC	DOE	5.4	10.4	5.0
66-S	12/06/85	HC	DOE	6.3	11.3	5.0
67-S	11/08/85	HC	DOE	5.8	10.8	5.0
68-S	11/15/85	HC	DOE	5.9	10.9	5.0
69-S	12/13/85	HC	DOE	6.3	11.3	5.0
70-S	11/25/85	HC	DOE	6.0	11.0	5.0
71-S	11/25/85	HC	DOE	6.0	11.0	5.0
72-S	12/09/85	HC	DOE	6.4	11.4	5.0
73-S	11/27/85	HC	DOE	6.2	11.2	5.0
74-S	12/10/85	HC	DOE	6.1	11.1	5.0
75-S	12/17/85	HC	DOE	6.1	11.1	5.0
76-S	01/16/86	HC	DOE	6.3	11.3	5.0
76-M	01/16/86	HC	DOE	20.0	40.0	20.0
76-D	01/16/86	HC	DOE	70.5	100.5	30.0
77-S	12/16/85	HC	DOE	6.0	11.0	5.0
78-S	12/16/85	HC	DOE	6.4	11.4	5.0
79-S	01/30/86	HC	DOE	6.0	8.0	2.0
79-M	01/30/86	HC	DOE	36.0	51.0	15.0
79-D	01/30/86	HC	DOE	67.5	100.0	32.5
80-M	02/07/86	HC	DOE	10.0	22.5	12.5
80-D	02/07/86	HC	DOE	68.0	98.0	30.0
81-M	01/24/86	HC	DOE	30.0	48.5	18.5
81-D	01/24/86	HC	DOE	64.0	79.0	15.0
82-S	02/05/86	HC	DOE	8.5	13.5	5.0
82-M	02/05/86	HC	DOE	20.0	49.0	29.0
82-D	02/05/86	HC	DOE	78.0	93.0	15.0
83-M	02/24/86	HC	DOE	15.5	35.5	20.0
84-S	06/30/86	HC	DOE	9.0	17.0	8.0
84-M	06/30/86	HC	DOE	43.9	63.1	19.2
84-D	06/30/86	HC	DOE	80.7	100.0	19.3
85-M	07/02/86	HC	DOE	44.0	63.9	19.9
85-D	07/02/86	HC	DOE	78.4	98.6	21.2

TABLE B-2
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
86-S	06/15/86	HC	DOE	7.7	15.4	7.7
86-M	06/15/86	HC	DOE	54.1	63.7	9.6
87-S	06/20/86	HC	DOE	8.1	13.2	5.1
87-M	06/20/86	HC	DOE	25.6	44.3	18.7
87-D	06/20/86	HC	DOE	68.9	93.4	24.5
88-S	06/13/86	HC	DOE	5.4	10.4	5.0
88-M	06/13/86	HC	DOE	19.9	34.8	14.9
88-D	06/13/86	HC	DOE	53.8	69.3	15.5
89-S	06/23/86	HC	DOE	10.4	15.7	5.7
89-M	06/23/86	HC	DOE	25.3	45.0	19.7
90-M	06/27/86	HC	DOE	52.5	57.8	5.3
91-S	07/09/86	HC	DOE	9.5	19.2	9.7
91-M	07/09/86	HC	DOE	30.6	50.0	19.4
92-S	07/11/86	HC	DOE	10.2	19.9	9.7
92-M	07/11/86	HC	DOE	29.5	49.2	19.7
AA-S	01/08/87	TERRA	CITY	8.0	38.0	30.0
AA-M	01/08/87	TERRA	CITY	49.0	69.0	20.0
AA-D	01/08/87	TERRA	CITY	77.0	99.0	22.0
AB-S	01/16/87	TERRA	CITY	7.0	28.0	21.0
AB-M	01/16/87	TERRA	CITY	30.0	34.0	4.0
AB-D	01/16/87	TERRA	CITY	50.0	60.0	10.0
AC-S	01/26/87	TERRA	CITY	9.0	28.0	19.0
AC-M	01/26/87	TERRA	CITY	35.0	50.0	15.0
AC-D	01/26/87	TERRA	CITY	60.0	75.0	15.0
AD-S	02/13/87	TERRA	CITY	9.0	28.0	19.0
AD-D	02/13/87	TERRA	CITY	35.0	100.0	65.0
AE-S	03/05/87	TERRA	CITY	7.0	26.0	19.0
AE-M	03/15/87	TERRA	CITY	31.0	49.0	18.0
AF-S	03/02/87	TERRA	CITY	8.0	27.0	19.0
AF-M	03/02/87	TERRA	CITY	35.0	75.0	40.0
AF-D	03/02/87	TERRA	CITY	95.0	150.0	55.0
AG-S	03/12/87	TERRA	CITY	6.0	26.0	20.0
AG-M	03/12/87	TERRA	CITY	33.0	50.0	17.0
AH-S	03/26/87	TERRA	CITY	10.0	23.0	13.0
AH-M	03/26/87	TERRA	CITY	28.0	67.0	39.0
AH-D	03/26/87	TERRA	CITY	75.0	105.0	30.0
AI-S	06/09/87	PMX	CITY	26.0	37.0	11.0
AI-M	06/09/87	PMX	CITY	47.5	82.5	35.0
AI-D	06/09/87	PMX	CITY	93.0	118.0	25.0
AJ-S	06/15/87	PMX	CITY	24.0	34.0	10.0
AJ-M	06/15/87	PMX	CITY	46.0	76.0	30.0
AJ-I	06/15/87	PMX	CITY	85.0	110.0	25.0
AJ-D	06/15/87	PMX	CITY	117.5	142.5	25.0
AJ-W	06/15/87	PMX	CITY	183.0	203.0	20.0
AK-S	06/25/87	PMX	CITY	23.0	43.0	20.0
AK-M	06/25/87	PMX	CITY	52.0	92.0	40.0

TABLE B-2
OFFSITE MONITORING PROBE COMPLETION DETAILS (CONT.)

PROBE	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DEPTH TO SCRN TOP	DEPTH TO SCRN BOT	LENGTH OF SCREEN
AK-I	06/25/87	PMX	CITY	101.0	136.0	35.0
AK-D	06/25/87	PMX	CITY	152.0	192.0	40.0
AK-W	06/25/87	PMX	CITY	206.0	239.0	33.0
AL-S	07/01/87	PMX	CITY	23.0	43.0	20.0
AL-M	07/01/87	PMX	CITY	53.0	82.0	29.0
AL-I	07/01/87	PMX	CITY	96.0	136.0	40.0
AL-D	07/01/87	PMX	CITY	144.0	179.0	35.0
AL-W	07/01/87	PMX	CITY	188.0	233.0	45.0
AM-S	08/04/87	PMX	CITY	25.0	40.0	15.0
AM-M	08/04/87	PMX	CITY	52.5	72.5	20.0
AM-D	08/04/87	PMX	CITY	83.0	118.0	35.0
AN-S	09/14/87	PMX	CITY	6.0	21.0	15.0
AN-M	09/14/87	PMX	CITY	22.0	32.0	10.0
AN-I	09/14/87	PMX	CITY	37.0	42.0	5.0
AN-W	09/14/87	PMX	CITY	75.0	85.0	10.0
AO-S	09/23/87	PMX	CITY	5.0	20.0	15.0
AO-M	09/23/87	PMX	CITY	21.0	51.0	30.0
AO-W	09/23/87	PMX	CITY	73.0	98.0	25.0
AP-S	09/24/87	PMX	CITY	5.0	20.0	15.0
AP-M	09/24/87	PMX	CITY	30.0	50.0	20.0
AP-I	09/24/87	PMX	CITY	58.0	88.0	30.0
AP-W	09/24/87	PMX	CITY	97.0	112.0	15.0
AQ-S	09/14/87	PMX	CITY	6.0	19.0	13.0
AQ-M	09/14/87	PMX	CITY	23.0	48.0	25.0
AQ-I	09/14/87	PMX	CITY	57.0	67.0	10.0
AQ-D	09/14/87	PMX	CITY	74.0	89.0	15.0
AR-S	09/21/87	PMX	CITY	5.0	20.0	15.0
AR-M	09/21/87	PMX	CITY	20.0	45.0	25.0
AR-I	09/21/87	PMX	CITY	61.0	66.0	5.0
AR-D	09/21/87	PMX	CITY	73.0	93.0	20.0
AS-S	09/01/87	PMX	CITY	2.0	7.0	5.0
AT-S	09/03/87	PMX	CITY	2.0	6.0	4.0
AU-S	09/03/87	PMX	CITY	2.0	6.0	4.0
AV-S	09/29/87	PMX	CITY	21.0	45.0	24.0
AV-M	09/27/87	PMX	CITY	52.0	82.0	30.0
AV-D	09/27/87	PMX	CITY	95.0	125.0	30.0
AV-W	09/27/87	PMX	CITY	135.0	150. 0	15.0

landfill gas seven months after the phase I onsite migration control system was put into continuous operation.

As shown on Figure B-8, shallow gas concentrations to the east, south, and west of the landfill have been greatly reduced. This is due not only to the influence of the onsite gas migration control system, but also to the operation of the offsite control wells. Gas concentrations over 25% by volume were detected 1300 feet west of the landfill. However, this is believed due to gas being generated in a peat bog located in that area and not to migrating landfill gas. Shallow gas concentrations over 30% by volume were detected north of the landfill during this time period. Without sufficient probe data north of the landfill, it is difficult to determine whether this is due to migrating landfill gas or if it is being generated by an offsite source of decomposing material.

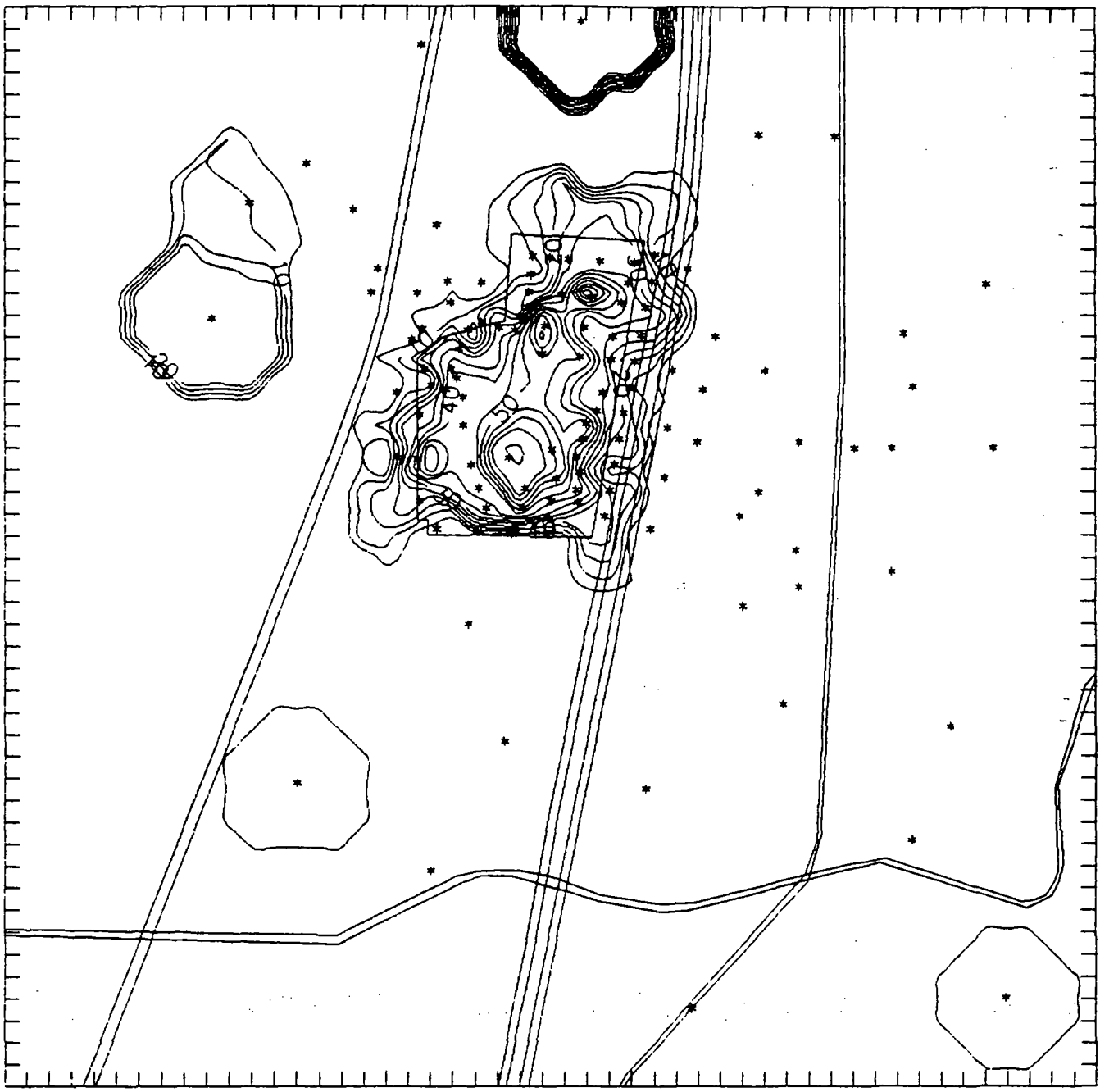
Figure B-9 (a gas concentration isopleth for September, 1986) shows significant reductions in deep gas concentrations west of the landfill from that recorded in February. Also, the concentrations of gas to the north, east, and south have been greatly reduced (from over 90% by volume in some areas to 35% by volume east of the landfill). It is not possible to ascertain the exact extent of offsite landfill migration due to the lack of offsite probe data.

Figures B-10 and B-11 show even further reductions in offsite gas concentrations. The gas previously detected in shallow soil zones to the west of the landfill has been determined to be a product of the peat bog located in that area. Gas concentrations in shallow soil zones north of the landfill are still causing concern and further actions are underway to determine the source and alleviate this problem.

As seen in Figure B-11, gas concentrations in the deep soil zones east and south of the landfill have been reduced from the levels recorded in September, 1986. However, this is proving to be a slow process. Additional probe data provided by a gas probe installed in groundwater monitoring well MW-21, indicated high level of offsite gas to the north-west of the landfill. This high concentration has been reduced over time due to the operation of control well C-11, and onsite migration wells PA-1 and PC-8 (see Figure B-13).

Figure B-14 shows a pressure gradient isopleth around the Midway Landfill for December, 1987. This isopleth is used in conjunction with shallow and deep gas concentration isopleths to determine the effectiveness of the onsite migration control system and the offsite control wells.

Pressure gradients emanating from the onsite extraction system are studied to determine if the vacuums created onsite are pulling previously migrated gas back to the landfill or if gas is being allowed to migrate offsite. Gas will tend to flow perpendicular to pressure gradients through the path of least resistance. In other words, if gas is present within the zone of influence



Note: All sets of probes and wells may not be shown.

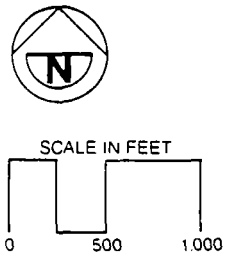
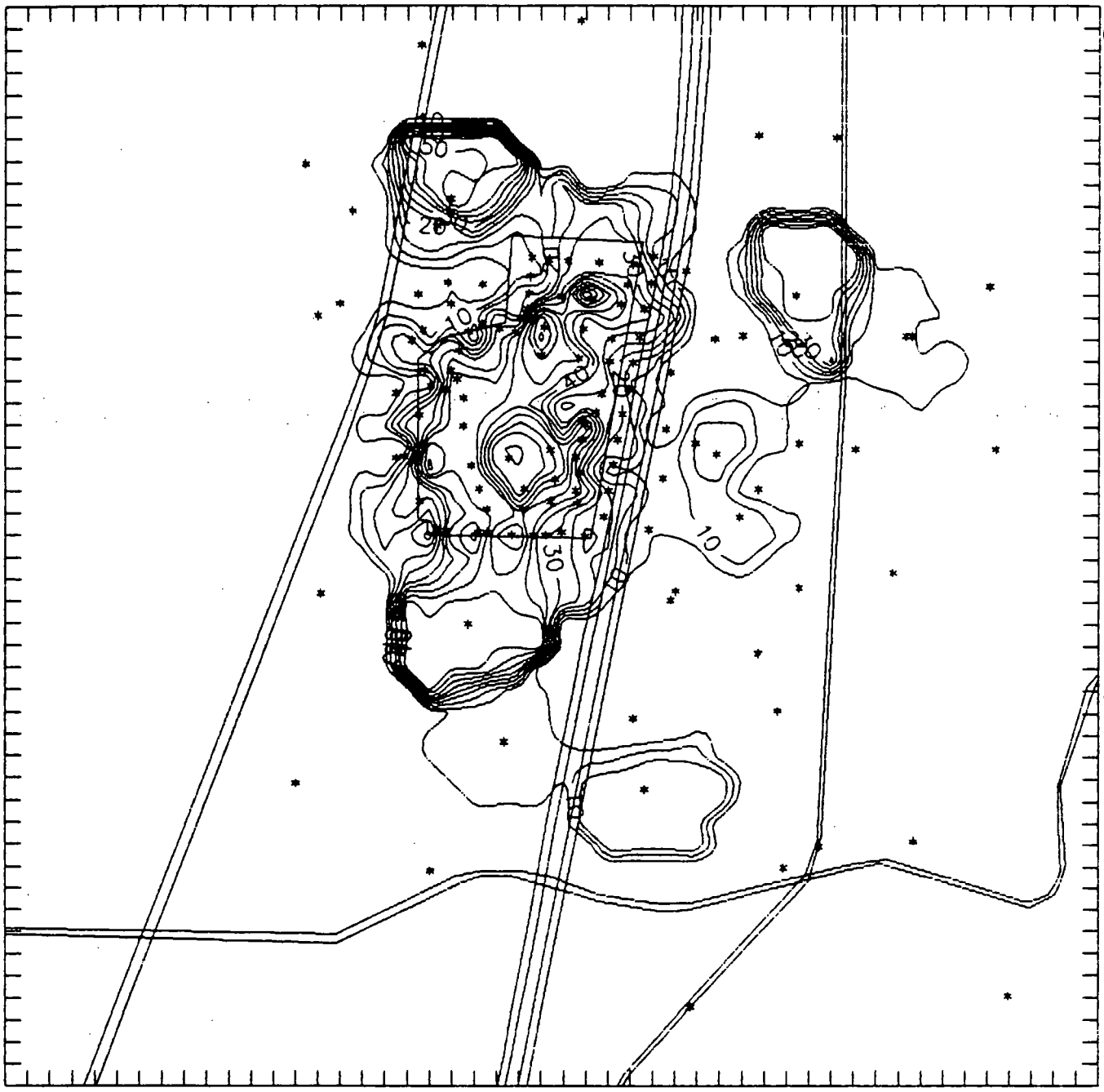


Figure B-10
Shallow Gas Concentration Isopleth, July 1987



Note: All sets of probes and wells may not be shown.

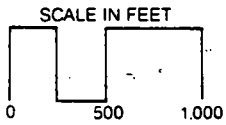


Figure B-11
Deep Gas Concentration Isopleth, July 1987

Note: All sets of probes and wells may not be shown.

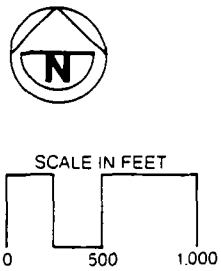


Figure B-12
Shallow Gas Concentration Isopleth, December 1987

Note: All sets of probes and wells may not be shown.

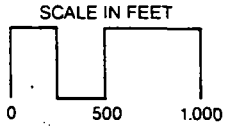
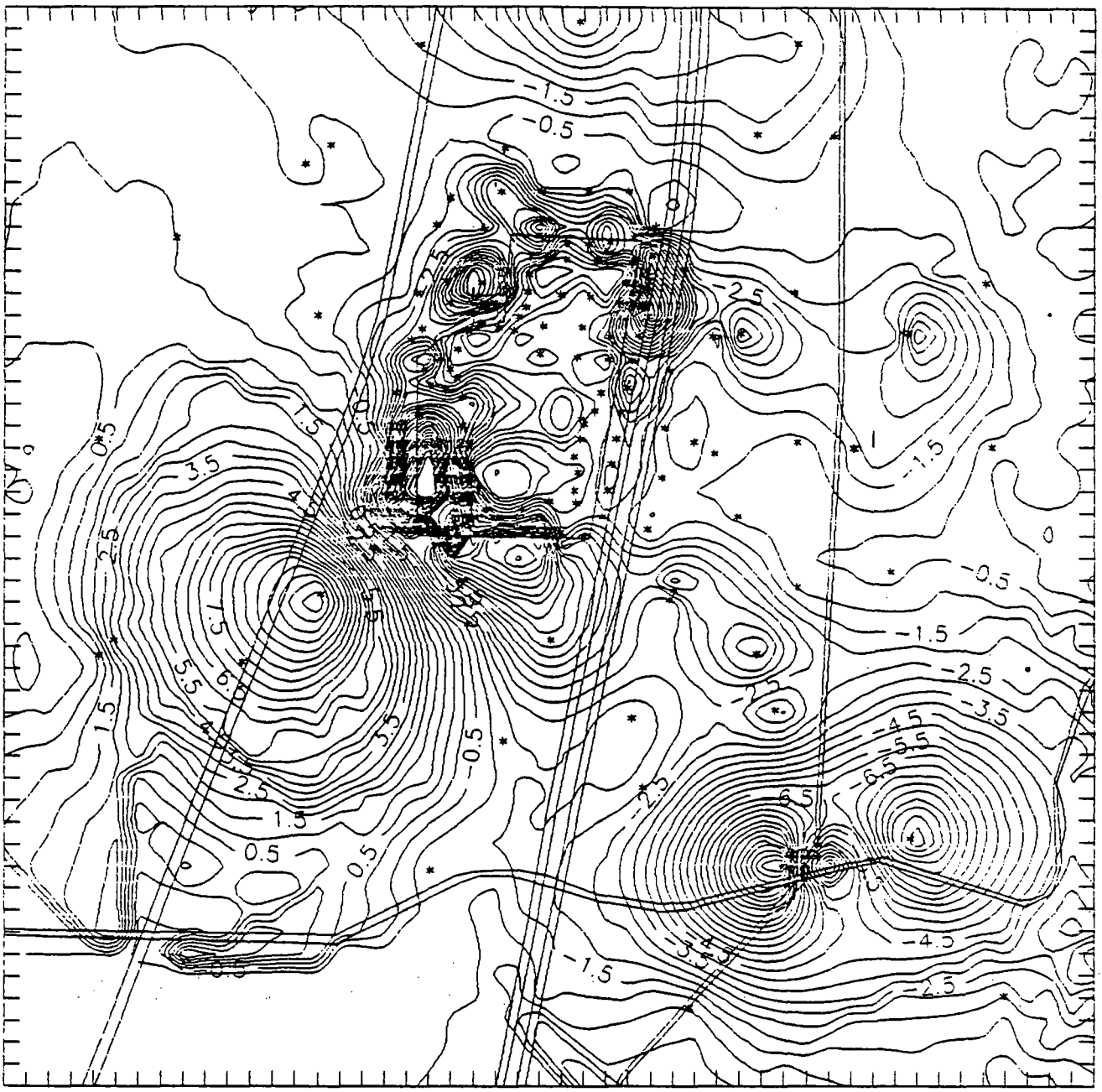


Figure B-13
Deep Gas Concentration Isopleth, December 1987



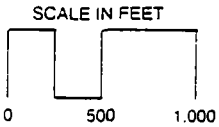


Figure B-14
Pressure Gradients
December 1987

of an induced vacuum point (i.e. an extraction well), that gas will tend to flow toward that point.

As shown in Figure B-14, pressure gradients at the present time indicate that gas, if present offsite, is effectively being pulled back toward the landfill. The vacuum being induced in the southeast corner of the landfill is not as great as the vacuum in the other areas; however, by studying Figure B-14, the pressure gradient toward the landfill becomes apparent.

5.3 Changes Over Time

As seen in the isopleths in Section 5.2, gas levels have been reduced around the landfill since the implementation of the onsite gas migration control system and the offsite gas extraction wells. Probes installed over time have helped to further define the extent of offsite gas migration which assists in determining the proper measure to be implemented both onsite and offsite to eliminate the offsite gas reservoirs which have accumulated over time.

6.0 CONCLUSIONS

The installation of monitoring probes Y, Z, and AG, in conjunction with probes drilled during a study at the Kent Highlands Landfill for gas migration control in 1986 and 1987 by Parametrix, Inc. have not shown any subsurface conduits for landfill gas migration between the Midway and Kent Highlands Landfill. The installation of probes AA and AB to the north and northwest of the site have helped to further define the extent of landfill gas migration to the north of the landfill and probes AC, AD, AE, and AH have helped to define the extent of gas migration to the south of the landfill (see Figures B-10 and B-11).

As seen in Figure B-10, probes AC and AE have shown levels of combustible gas present in the shallow soil zones. Comparing this with the data obtained from other monitoring probes nearby, this appears to be a localized phenomena. Further studies are underway in these areas to determine the source of this gas and appropriate measures to be taken. It should be noted that the "shallow" zone of probe AC is actually completed at seven to twenty-six feet below ground surface. Therefore, it is not valid to assume that the gas present in the probe is actually shallow or surface gas. It is possible that fractionated methane in the probe volume is being measured rather than an indicative sample of the methane present in the soil being sampled. A review of monitoring procedures should be implemented.

The initial reduction of high levels of gas in shallow soil zones and in basements and crawlspaces of structures around the site by the onsite migration control system, coupled with the offsite extraction well performance was quite fast. The decline in gas concentrations since has been gradual. With the addition of new probes from this and other studies, the extent of gas migration away from the site and potential subsurface conduits for landfill gas migration have been fairly accurately identified. The appropriate measures for controlling offsite migration as well as drawing migrated gas back to the landfill are being implemented.

REFERENCES

Eaton, D. L. 1986 (April). Evaluation of Potential Health Effects Associated with Off-Site Gas Extraction Systems at the Midway Landfill. Ad Hoc Committee on Midway Landfill Hazards, Department of Environmental Health, University of Washington, Seattle, Washington.

APPENDIX B-1

WELL LOGS FOR MONITORING PROBES INSTALLED FOR THE REMEDIAL INVESTIGATION

TERRA ASSOCIATES, Inc.
Geotechnical Consultants

June 10, 1987
Project No. T-250-4

Mr. James Braddock
Parametrix, Inc.
13020 Northup Way, Suite 8
Bellevue, Washington 98005

Subject: Off-Site Gas Monitor Wells
Midway Landfill Remedial Investigation
Subcontract Agreement PMX 55-1550-11

Dear Mr. Braddock:

We have completed the ten gas monitor wells required by Exhibit A of our subcontract agreement. This report describes the work accomplished by our firm. Eleven wells were actually installed. The eleventh well, Y2, is a replacement for Well Y1, which is partially blinded by 80 feet of steel casing inadvertently left in the borehole. Each of the eleven wells contains two, three or four gas collecting probes.

SUMMARY

Eleven gas monitor wells were installed at the approximate locations shown on the Gas Monitoring Well Location Plan, Figure 1. The well locations were selected by Parametrix and the City of Seattle. Ten wells are on street rights-of-way. Well AC is located on private property. Street addresses and other information to locate the gas monitor wells are provided on Table I.

Terra Associates, Inc. was assigned the task of installing the gas monitor wells. Our work included:

1) developing an approved Health and Safety Plan;

2) assuring that the boreholes would clear all utilities;

3) drilling the necessary boreholes and obtaining samples of in-place soil at five-foot intervals;

4) reporting the subsurface conditions encountered;

5) providing and installing slotted-screen probes and gravel pack; and

6) providing and installing cast iron security covers.

15301 N.E. 90th Street • Redmond, Washington 98052 • Phone: 881-5570
Mailing Address: P.O. Box 3338 • Redmond, Washington 98073

Gas and water sampling was included in our work only to the extent necessary to confirm that the safe working conditions required by the Health and Safety Plan were being maintained. Soil analysis performed by our firm was limited to visual classification of the samples recovered.

All our work was carefully coordinated with Parametrix and the City. The soil samples recovered, copies of field notes, and the well installation logs were delivered to Parametrix weekly.

Drilling began on November 3, 1986. Three wells were completed using a top-drive rotary drill rig. Because the soil sampling slowed the rotary rig more than expected, a cable-tool rig was mobilized to complete the work. The last hole was completed on March 26, 1987.

The following table, figure and appendices are included and complete this report. The appendices describe in more detail the work assigned to Terra Associates, Inc.

Table	I	Gas Monitoring Well Locations
Figure	1	Gas Monitoring Well Location Plan
Appendix	A	Drilling Equipment and Procedures
Appendix	B	Gas Monitor Well Installations
Appendix	C	Subsurface Conditions

We appreciate the opportunity to assist you on this project. Please contact us whenever we may be able to help and please call if you have any questions concerning the work reported herein.

Sincerely,

TERRA ASSOCIATES, INC.

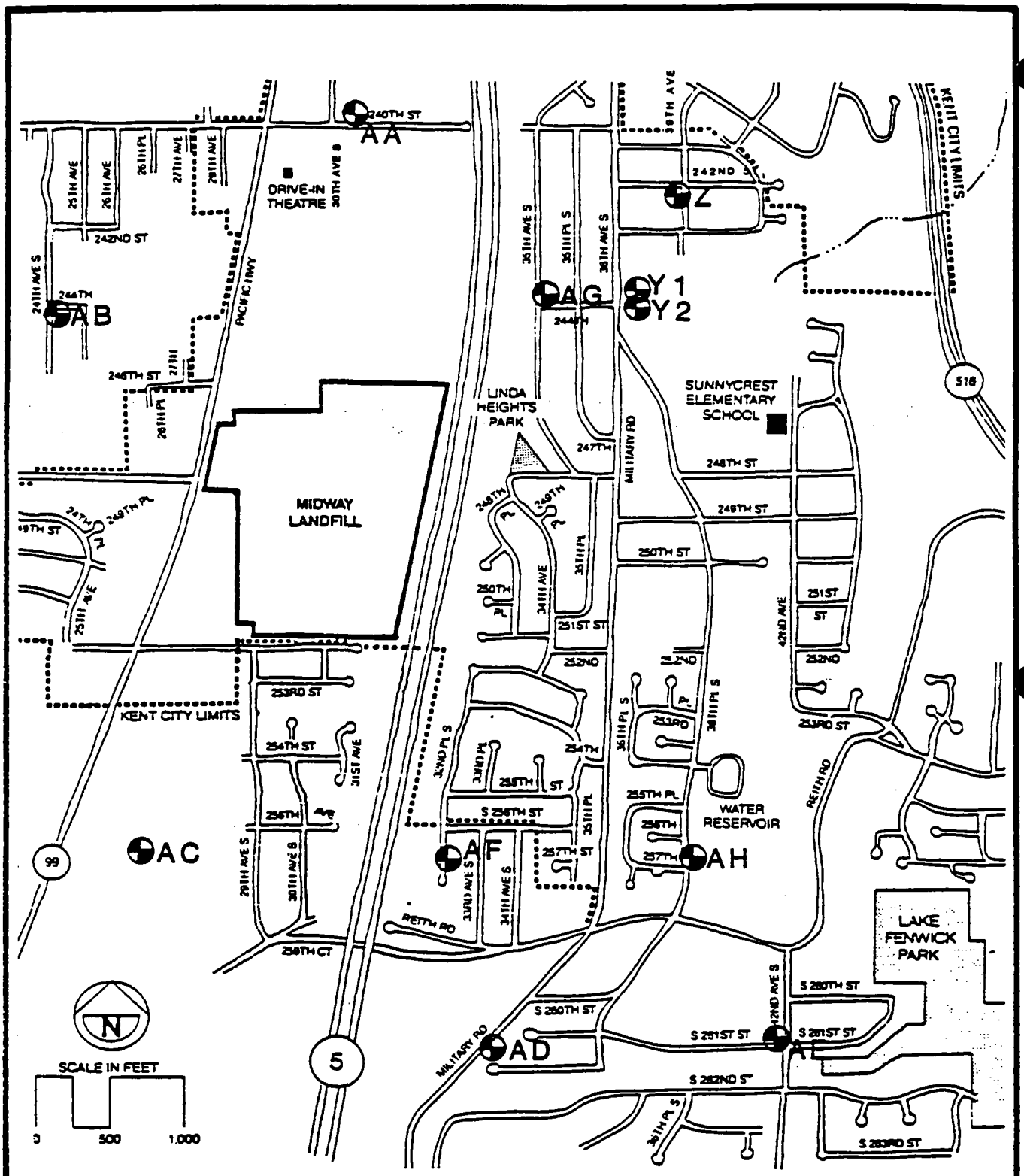
Anil Butail, P.E.
President

WAB/AB:pk
Enclosures

TABLE I

GAS MONITOR WELL LOCATIONS

Well No	Location
Y1	East side of Military Road S at S 244th St
Y2	About seven feet south of Y1
Z	East side of 39th Ave S, about 50 feet south of S 242nd St
AA	North side of S 240th St, about 200 feet east of 30th Ave S
AB	S 244th St at 24th Ave S, about 20 feet east of southeast corner
AC	In the planter near the SE corner of Cedarwood Shopping Center, approx 25650 Pacific Hwy S
AD	Approx 26060 Military Road S, east side
AE	S 261st St, north side, about 30 feet west of 42nd Ave S
AF	25620 32nd Place S, east side
AG	35th Ave S at 244th St, northeast corner
AH	38th Ave S, east side, about 50 feet north of S 257th St



AA Approximate location and letter of monitoring well

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LOCATION PLAN
GAS MONITORING WELLS
MIDWAY REMEDIAL INVESTIGATION

Proj. No. 250-4	Date 5-87	Figure 1

APPENDIX A

DRILLING EQUIPMENT AND PROCEDURES

Eleven gas monitor wells eight inches in diameter were installed to complete our work under Subcontract Agreement PMX-55-1550-11. Drilling the boreholes and installing the in-ground wells was subcontracted to Richardson Well Drilling Company of Tacoma, Washington. All their work was closely supervised by an experienced engineering geologist from Terra Associates, Inc.

A top-drive rotary drill rig was used to drill and sample the first three boreholes: Y1, Y2 and Z. Compressed air and water mist were used to remove the cuttings. To support the boreholes, eight-inch-diameter steel casing was driven using a pneumatic hammer. Soil samples were taken at five-foot intervals using a tube sampler driven with the casing hammer.

Due mostly to the time required to take the soil samples, work progress with the rotary drill rig proved to be much slower than expected. Consequently, the rotary rig was assigned to other Midway Landfill work and a cable-tool drill rig was mobilized to complete the remaining eight gas monitor wells required by this subcontract.

The cable-tool rig advances casing by driving it with a dead-weight hammer. The drill tool is lowered into the casing on steel cable. Borehole is made below the casing by dropping a heavy drill tool repeatedly onto the material at the bottom of the borehole. Water is added as needed to produce muddy, fluid cuttings. The cuttings are removed from the borehole with a trap-door bailer lowered into the casing after the drill tool is removed.

The borehole was advanced five feet at a time. Once the borehole was bailed free of cuttings, the sampling tube was inserted in the borehole and driven with a down-the-hole hammer operated by the cable. The hammer weighed about 2500 pounds. The sampler used with the cable-tool drill rig had an inside diameter of about five inches. It was usually driven one to two feet once in every five feet of borehole.

The cable-tool rig was not significantly faster than the rotary rig. It was preferred over the rotary rig primarily because the cost of keeping it on the site was lower. In addition, the cuttings removed by the bailer were easier to control than the air-blown cuttings from the rotary rig. Consequently, the site-cleanup problem with the cable-tool rig was much easier.

The steel casings were removed from the boreholes as the boreholes were backfilled with well screen and gravel pack. Usually the casings could be pulled by wrapping a choker around the casing and pulling with the winch. When the casing was too tightly embedded to be removed by pulling, the air hammer on the rotary drill rig could be reversed and the casing bumped out. The cable-tool rig could also bump casing by inserting the drill tool in the casing and hammering against a cap welded to the top of the casing.

To assure the boreholes would not collapse while the casings were being withdrawn, the pea gravel level was kept a few feet inside the casings, except when the seals were being placed.

At each well, our engineering geologist maintained a log of each borehole, collected the soil samples required by the subcontract, and supervised the installation of the gas collecting probes. All the cuttings were removed and taken to Kent Highlands Landfill for disposal.

The soil samples and the cuttings were visually classified in accordance with the Unified Soil Classification System, placed in closed containers and delivered weekly to Parametrix. The well installation logs in Appendix B report the results of this visual classification. Appendix C contains a general description of the subsurface conditions encountered in the boreholes.

While the gas monitor wells were being installed, methane was detected only at Well AF. The quantity of gases venting through the borehole was small. Maintaining the safe working environment prescribed by the Health and Safety Plan was never a problem.

APPENDIX B

GAS MONITOR WELL INSTALLATIONS

Schematic drawings of the as-built well installations are presented in this appendix. The approximate gas monitor well locations are described by Table I and Figure 1 in the main body of this report.

The gas monitor wells consist of either two, three or four gas probes packed in pea gravel collection zones. Each probe uses Schedule 80 PVC slotted pipe within the collection zones and solid-wall PVC riser pipe to bring the gases collected to the ground surface. The slot width is either two hundredths or four hundredths of an inch. All joints are threaded and flush. No glues or solvents were used. The probes are closed on the bottom end with either slip caps or threaded caps. The top of each probe is threaded and closed off with a Schedule 80 1/4-inch PVC ball valve and a threaded cap.

In each well, the deepest probe is 3/4-inch-diameter pipe and the shallower probes are 1/2-inch-diameter pipe. Because it was anticipated that the deep probes might encounter the regional groundwater table, the larger pipe was used to make it easier to insert the sensor used to locate the water level in the wells.

In each probe, pea gravel for the collection zone was installed to a point at least a few feet above the uppermost slots. The seals separating adjacent collection zones vary in thickness from about two to five feet. The seals were made from bentonite pellets, except for the deepest deal in Well AF, where concrete grout was used. At least 100 pounds of pellets were used for the bentonite seals. Once in place, water was added to swell the pellets and activate the seals.

To exclude surface water from the wells, a seal was placed at the ground surface. These seals were either concrete grout over a layer of bentonite pellets, or concrete grout mixed with a few percent of bentonite powder.

Each well was secured at the ground surface with a cast iron locking cover twelve inches in diameter.

The following figures are included and complete this appendix:

Figure B.1	Gas Monitor Well Y1
Figure B.2	Gas Monitor Well Y2
Figure B.3	Gas Monitor Well Z
Figure B.4	Gas Monitor Well AA
Figure B.5	Gas Monitor Well AB
Figure B.6	Gas Monitor Well AC
Figure B.7	Gas Monitor Well AD
Figure B.8	Gas Monitor Well AE
Figure B.9	Gas Monitor Well AF
Figure B.10	Gas Monitor Well AG
Figure B.11	Gas Monitor Well AH

GAS MONITORING WELL Y1

Logged By JJ

Date 11-11-86

ELEV. 448±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Gray, silty, gravelly SAND, iron staining, moist.	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55		concrete grout; bentonite pellets; 1/2" dia. pvc 0.040" slot 10'-20'; bentonite pellets; 1/2" pvc 0.040"slot (44'-54'); probable top of steel casing; bentonite pellets
	SP	Brown SAND with some silt and a trace of gravel, damp.			
	SM	Brown-gray, silty, gravelly SAND.			
	SP	Brown SAND with some silt.			

(cont.)

note: Seals are 3/8 inch bentonite pellets and water;
No methane detected while drilling;
Sampling done with 5 inch steel tube attached to drill rod and driven with a 7200 ft-lbs air hammer.

Sheet 1 of 3

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No.250-4	Date 12/86	Figure B.1a

GAS MONITORING WELL Y1

Logged By JJ

Date 11-11-87

ELEV. 448±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SP	Brown SAND with silt, moist.	65		1/2" dia. pvc 0.040" slot (58'-68') threaded end-cap
			70		bentonite pellets
			75		
		(Saturated)	80		caved section
	ML	Tan SILT, hard, moist, organics			
	SM GM	Gray-brown silty, gravelly SAND to silty, sandy GRAVEL, iron-stained, moist.	85		pea gravel filter
			90		steel casing
		(Increasing cobbles)	95		
		(Increasing water)	100		3/4" dia. pvc 0.040" slot (97'-147')
	GP	Brown, sandy GRAVEL, trace silt, wet	105		
	ML	Tan, sandy, clayey SILT, damp.	110		
	GM	Brown silty, sandy GRAVEL, wet.	115		
	SM	Brown, silty, gravelly SAND.			

(cont.)

note: 80 feet of casing left in borehole probably occupying section between 55 feet and 135feet

Sheet 2 of 3

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4	Date 12/86	Figure B.1b

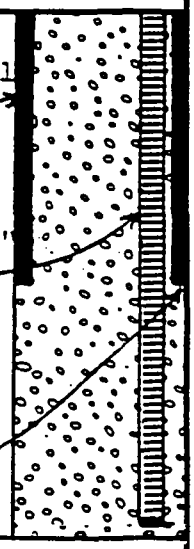
GAS MONITORING WELL Y1

Logged By JJ

Date 11/11/86

ELEV. 448 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, silty, gravelly SAND, wet.			pea gravel filter
	GM / GP	Brown sandy GRAVEL with some silt and occasional cobbles, wet.	125 130 135		3/4" dia. pvc 0.040" slot (97'-147')
	GP	Brown, sandy GRAVEL with some cobbles, trace silt, moist.	140 145		probable bottom of steel casing



note: Well completed at 148½ feet;
No methane detected during or shortly after drilling.

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REMEDIAL INVESTIGATION
KING COUNTY, WA

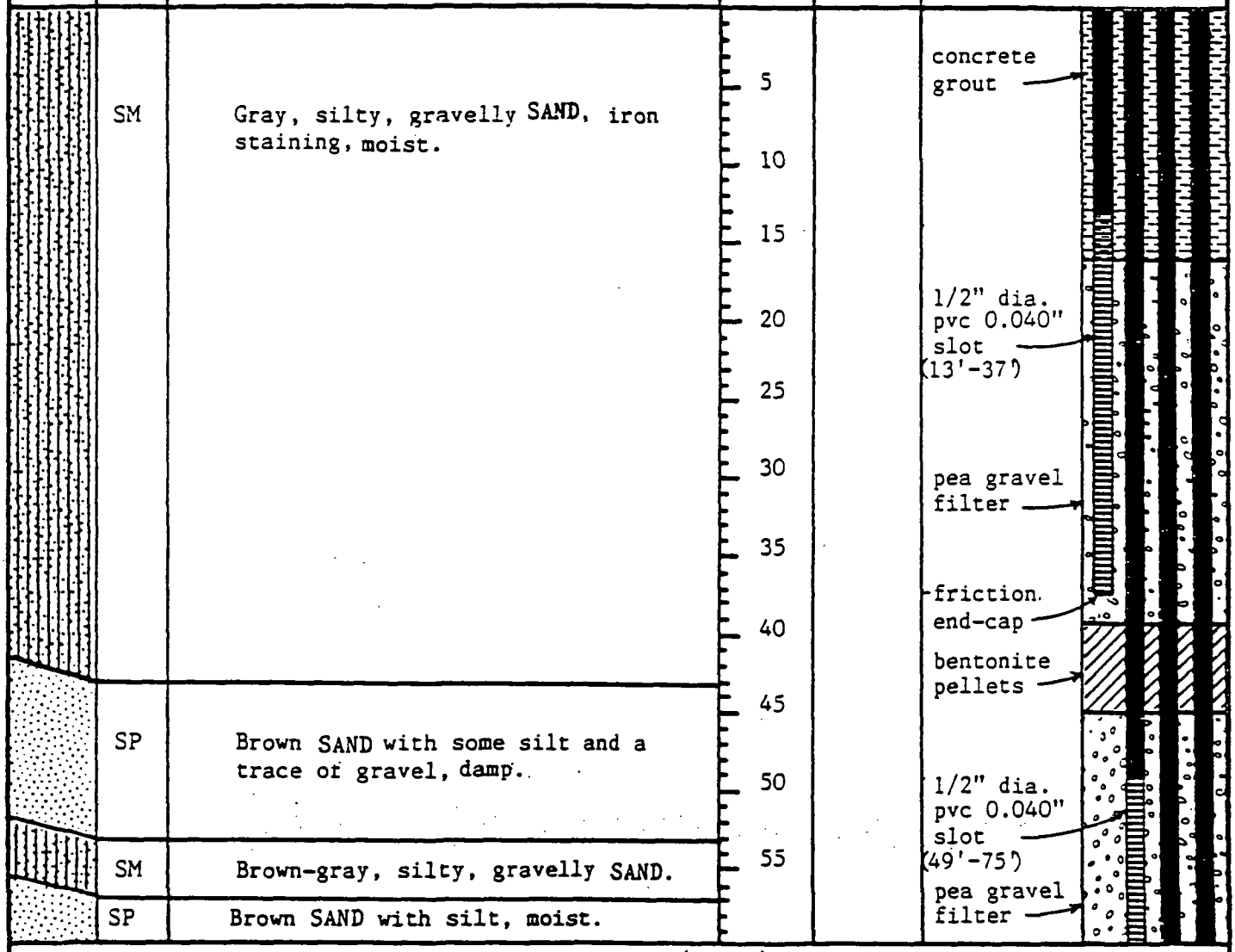
Proj. No. 250-4	Date 12/86	Figure B.1c

GAS MONITORING WELL Y2

Logged By JJ
Date 11-19-87

ELEV. 448+

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Gray, silty, gravelly SAND, iron staining, moist.	5, 10, 15, 20, 25, 30, 35, 40		concrete grout; 1/2" dia. pvc 0.040" slot (13'-37'); pea gravel filter; friction end-cap; bentonite pellets
	SP	Brown SAND with some silt and a trace of gravel, damp.	45, 50		1/2" dia. pvc 0.040" slot (49'-75'); pea gravel filter
	SM	Brown-gray, silty, gravelly SAND.	55		
	SP	Brown SAND with silt, moist.			



note: Y2 drilled 7½ feet south of Y1; (cont.)
Shallow probe is plugged by grout from the top seal;
Cuttings sampled at 5 foot intervals, soils described by correlating with Y1.

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4	Date 12/86	Figure B.2a

GAS MONITORING WELLY2

Logged By JJ

Date 11-19-87

ELEV. 448 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SP	Brown SAND with silt, moist.	65		
			70		
			75		friction end-cap
		Saturated	80		bentonite pellets
	ML	Tan SILT, moist, organics.			
	SM GM	Gray-brown silty, gravelly SAND to silty, sandy, GRAVEL, moist. (TILL)	85		
			90		1/2" dia. pvc 0.040" slot (87'-107')
		Increasing cobbles.	95		
		Increasing water.	100		pea gravel filter
	GP	Brown, sandy GRAVEL, trace silt, wet.	105		threaded end-cap
	ML	Tan, sandy, clayey SILT, damp.	110		bentonite pellets
	GM	Brown silty, sandy GRAVEL, wet.	115		
	SM	Brown, silty, gravelly SAND, wet.			

(cont.)

note: Cuttings sampled at approximately 5 foot intervals.

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Proj. No. 250-4 | Date 12/86 | Figure B.2b

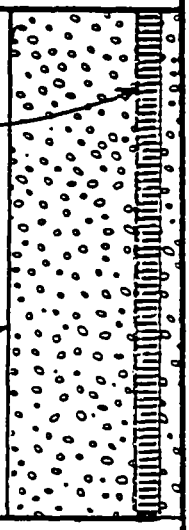
GAS MONITORING WELL Y2

Logged By JJ

Date 11-19-87

ELEV. 448 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, silty, gravelly SAND, wet.			3/4" dia. pvc .040" slot (118'-148')
	GM / GP	Brown sandy GRAVEL with some silt and occasional cobbles, wet.	125 130 135		pea gravel filter
	GP	Brown, sandy GRAVEL with some cobbles, trace silt, moist.	140 145		



note: Well completed at 148 feet;
No methane detected during or shortly after drilling;
Cuttings sampled at 5 foot intervals.

Sheet 3 of 3

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

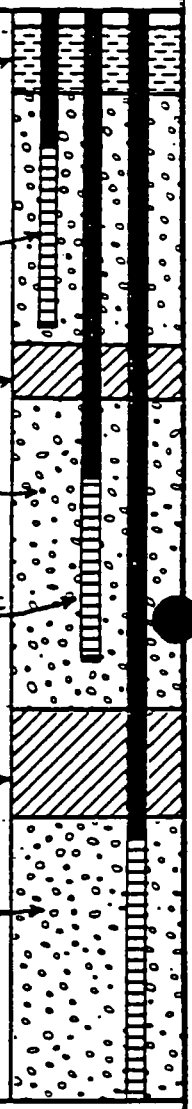
Proj. No. 250-4 | Date 12/86 | Figure B.2c

GAS MONITORING WELL Z

Logged By JJ
Date 12-19-87

ELEV. 400±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, silty, gravelly SAND, trace wood debris, very moist. (FILL)	5		concrete grout
	SM	Gray, silty, gravelly SAND, moist. (TILL)	10, 15		½" dia. pvc 0.020 slot (7'-17')
	SP	Brown SAND with some silt, trace gravel, moist.	20, 25, 30, 35		bentonite pellets; pea gravel; ½" pvc 0.020" slot (25'-35')
	GW	Brown sandy GRAVEL some silt, moist.	40		bentonite pellets
	SM	Gray, silty, gravelly SAND, wet to very moist. (TILL)	45		pea gravel
	GM	Gray, silty, sandy GRAVEL, damp to moist.	50, 55	NR	
	GW	Gray, sandy GRAVEL, wet.			



(cont.)

note: No methane detected during drilling;
Water encountered at 34 feet;
NR= no sample recovery.

sheet 1 of 3

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4	Date 4/87	Figure B.3a

GAS MONITORING WELL Z

Logged By JJ
Date 12-19-87

ELEV. 400 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GW	Gray, sandy GRAVEL with some silt, wet.	60		pea gravel filter
	SM	Gray, silty, gravelly SAND, moist. (TILL)	65, 70, 75		
	GM	Brown, silty, sandy GRAVEL with some cobbles, iron stained, wet.	80, 85, 90, 95	NR, NR	
	GM /GP GW	Brown, sandy GRAVEL with some silt, occasional cobbles, wet, dense. Interbedded, brown, sandy GRAVEL, trace silt, wet.	100, 105, 110, 115	NR	3/4" pvc 0.020" slot (45'-137')

(cont.)

note: No methane detected during drilling;
NR= no sample recovery

sheet 2 of 3

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KING COUNTY, WA

Proj. No. 250-4 | Date 4/87 | Figure B.3b

GAS MONITORING WELL Z

Logged By JJ

Date 12-19-87

ELEV. 400 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM /GP	Brown, sandy GRAVEL with some silt, occasional cobbles, wet.	120, 125, 130		3/4" pvc 0.020" slot (45'-137')
	ML	Blue-gray, sandy SILT, moist.	135		
	SM	Brown to gray, silty, gravelly SAND, some iron staining, moist to wet.	140, 145, 150		pea gravel

note: Well completed at 152 feet;
No methane detected during drilling;
Some seepage at 125 feet;
Casing drive shoe cut off at 137 feet.

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REMEDIAL INVESTIGATION
KING COUNTY, WA

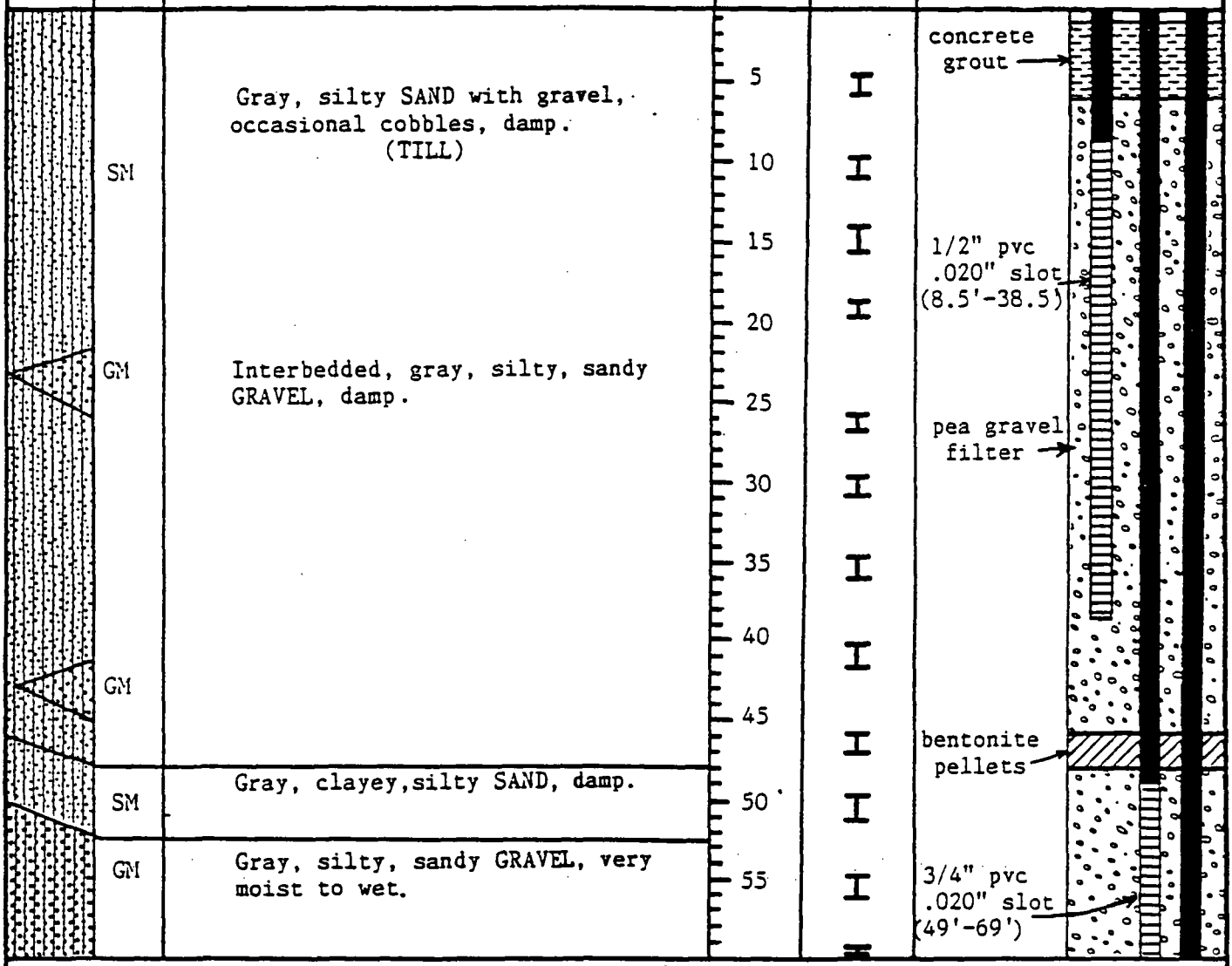
Proj. No. 250-4	Date 4/87	Figure B.3c

GAS MONITORING WELL AA

Logged By JJ
Date 1-8-87

ELEV. 387 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Gray, silty SAND with gravel, occasional cobbles, damp. (TILL)	5, 10, 15, 20		concrete grout; 1/2" pvc .020" slot (8.5'-38.5')
	GM	Interbedded, gray, silty, sandy GRAVEL, damp.	25, 30, 35, 40, 45		pea gravel filter; bentonite pellets
	GM				
	SM	Gray, clayey, silty SAND, damp.	50		
	GM	Gray, silty, sandy GRAVEL, very moist to wet.	55		3/4" pvc .020" slot (49'-69')



(cont.)

note: No methane detected during drilling; water at 48'-50'.

sheet 1 of 2

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KING COUNTY, WA

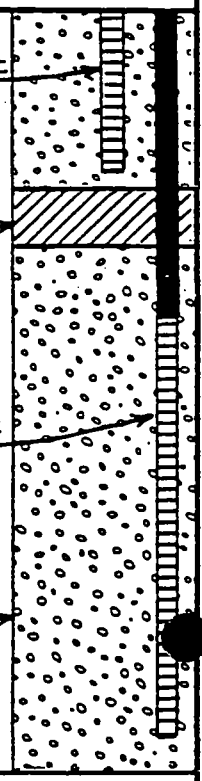
Proj. No. 250-4	Date 4/87	Figure B.4a

GAS MONITORING WELL AA

Logged By JJ
Date 1-8-87

ELEV. 387 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM	Brown to gray, sandy GRAVEL with some silt, very moist to wet.			3/4" pvc 0.020"slot (49'-69')
	SP	Brown SAND with some silt and gravel very moist to wet.	65	I	
			70	I	bentonite pellets
	GM	Brown, sandy GRAVEL with silt and occasional cobbles, very moist.	75	I	
	GW	Brown, sandy GRAVEL trace silt, iron stained, wet.	80	I	3/4" pvc .020" slot (77'-100')
			85	I	
			90	NR	pea gravel filter
	GM	Gray to brown, silty, sandy GRAVEL, some cobbles, very moist.	95	I	
			100	I	



note: Well completed at 101½ feet;
note: No methane detected during drilling;
Seepage at 71 feet,
Seepage at91 feet ;
NR= no sample recovery.

sheet 2 of 2

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4 | Date 4/87 | Figure B.4b

GAS MONITORING WELL AB

Logged By JJ
Date 1-16-87

ELEV. 278±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, silty SAND, wet.(FILL)			concrete grout
	SM	Brown, silty SAND, wet.	5		
	SM	Gray to brown, gravelly, silty SAND, some clay, wet. (TILL)	10		1/2" pvc .020 slot (7'-23')
	SP	Brown SAND with some silt, trace gravel, wet.	15		
			20		pea gravel filter
			25		bentonite pellets
	SM	Gray, silty, gravelly SAND, patchy iron staining, very moist.	30		
	GM	Brown, silty, sandy GRAVEL, wet.	35		1/2" pvc .020" slot (30'-35')
			40		bentonite pellets
	SP	Interbedded, brown SAND, wet.	45		caved section
	GM		50		3/4" pvc 0.020"slot (50'-60')
			55		
	SP	Brown SAND ,wet.	60		pea gravel filter
	ML	Gray, sandy SILT, moist.			

note: Well completed at 63 feet on 1-15-87;
No methane detected during drilling:
Water and heaving sand at 12-25 feet;
Seepage below 38 feet, heavy seepage at 60 feet.

sheet 1 of 1

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

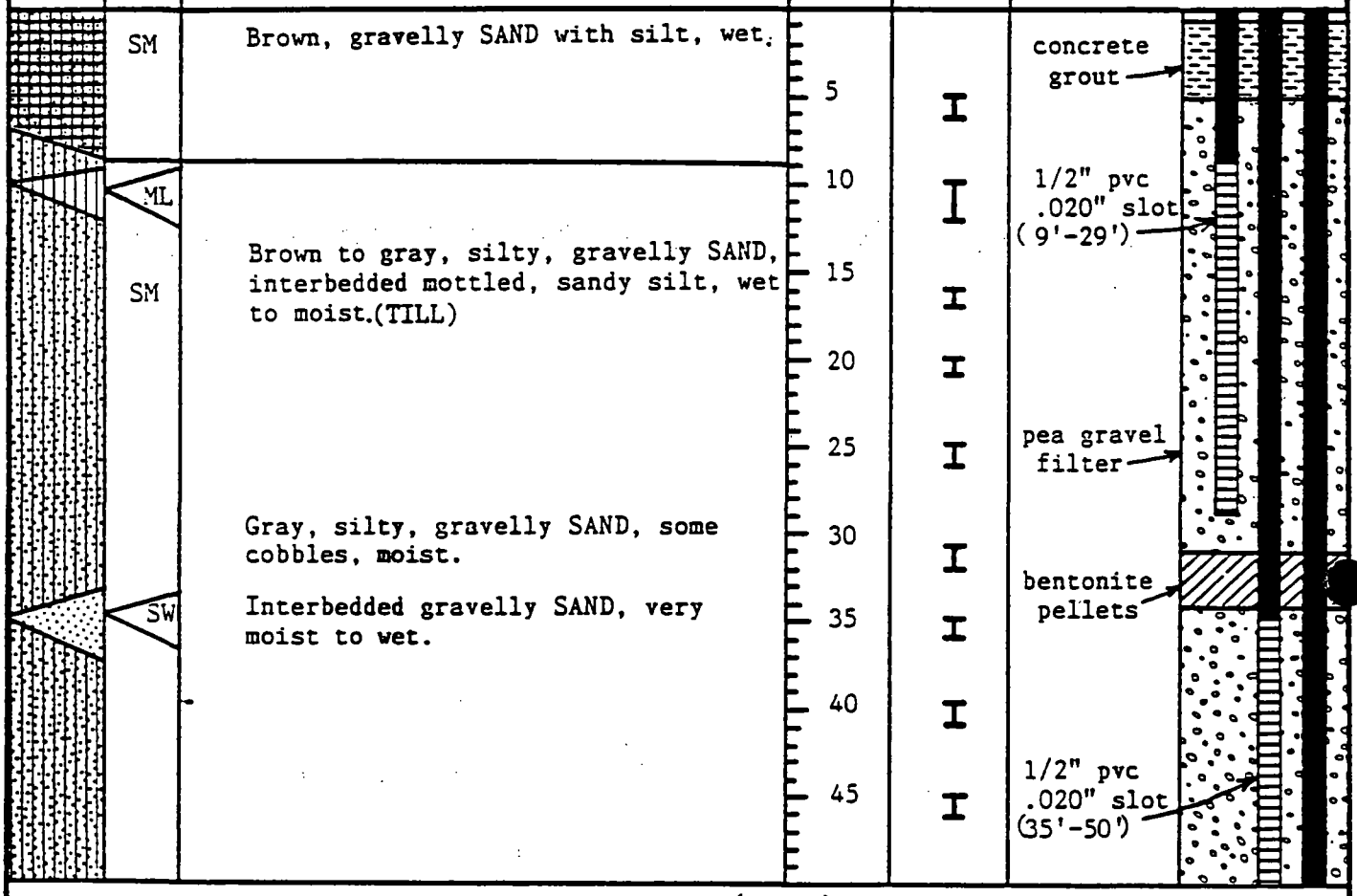
Proj. No. 250-4	Date 4/87	Figure B.5

GAS MONITORING WELL AC

Logged By JJ
Date 1-26-87

ELEV. 316±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, gravelly SAND with silt, wet.	5	I	concrete grout
	ML		10	I	1/2" pvc .020" slot (9'-29')
	SM	Brown to gray, silty, gravelly SAND, interbedded mottled, sandy silt, wet to moist.(TILL)	15	I	
			20	I	
			25	I	pea gravel filter
		Gray, silty, gravelly SAND, some cobbles, moist.	30	I	
	SW	Interbedded gravelly SAND, very moist to wet.	35	I	bentonite pellets
			40	I	
			45	I	1/2" pvc .020" slot (35'-50')



(cont.)

note: No methane detected during drilling;
Seepage at 4';
Seepage at 31';
Seepage at 43'.

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4 | Date 4/87 | Figure B.6a

GAS MONITORING WELL AC

Logged By JJ
Date 1/26/87

ELEV. 316 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Gray, gravelly, silty SAND, moist.	55 60 65		bentonite pellets pea gravel filter
	GM	Gray-brown, weathered, sandy GRAVEL with silt and occasional cobbles, wet.	70		3/4 " pvc .020" slot (60'-75')
	SP	Brown SAND with some silt, wet.	75		

Well completed at 77 feet on 1-23-87;
No methane detected during drilling;
Seepage at 50';
Seepage at 63';
Seepage at 75'.

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4 | Date 4/87 | Figure B.6b

GAS MONITORING WELL AD

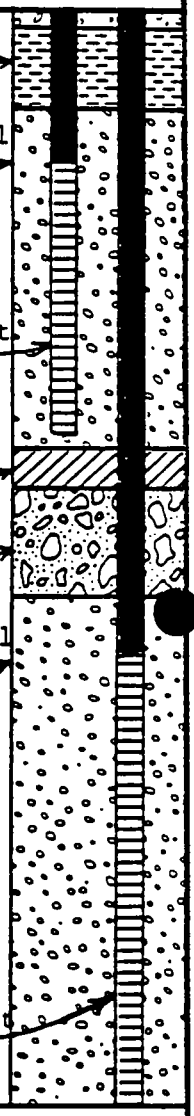
Logged By JJ

Date 2-13-87

ELEV. 375±

Graph	US CS	Soil Description	Depth (ft.)	Sample
	SM	Brown, silty gravelly SAND, wet(FILL		
	SM	Brown, gravelly SAND, wet.		
	SW	Brown SAND ,moist.	5	I
	SM / SP	Gray, silty, gravelly SAND interbedded with poorly graded sand,moist.	10	I
	GW	Brown, sandy GRAVEL, moist to wet.	15	I
			20	I
			25	I
	GM	Tan and gray, silty, sandy GRAVEL, wet.	30	I
		Interbedded, weathered, silty, sandy GRAVEL.	35	NR
			40	I
	GW	Tan and gray, sandy GRAVEL with some silt and cobbles,wet.	45	I
	GM	Interbedded, weathered,silty, sandy GRAVEL.	50	I
			55	I

Well Installation



(cont.)

note: No methane detected during drilling;
Seepage at 20'-25';
NR= no sample recovery.

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

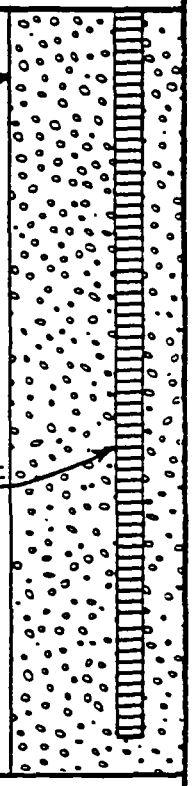
Proj. No. 250-4 | Date 4/87 | Figure B.7a

GAS MONITORING WELL AD

Logged By JJ
Date 2-13-87

ELEV. 375±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GW	Brown, sandy GRAVEL, very moist.	65, 70		pea gravel filter
	GM	Brown- multicolored, silty, sandy GRAVEL with cobbles, moist.	75, 80		
	GW	Brown- gray, sandy GRAVEL with silt and occasional cobbles, moist to wet	85, 90		3/4" pvc .020" slot (35'-100')
	GM	Multicolored, silty, sandy GRAVEL, moist.	95, 100		



note: Well completed at 102 feet on 2-4-87;
No methane detected during drilling;
No seepage noticed during drilling.

sheet 2 of 2

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

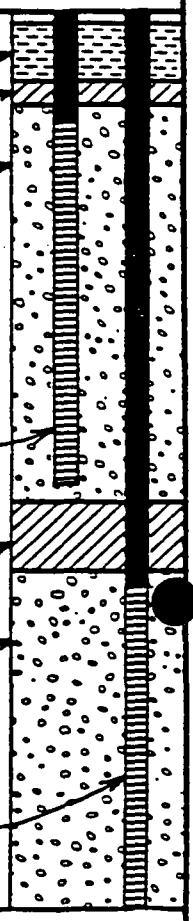
Proj. No. 250-4	Date 4/87	Figure B.7b

GAS MONITORING WELL AE

Logged By JJ
Date 3-5-87

ELEV. 296 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GW	Brown, sandy GRAVEL with some silt, trace organics, wet. (FILL)	5		concrete grout; bentonite; pea gravel filter
	ML	Gray, sandy SILT, trace gravel, wet.	10, 15		
	SM	Interbedded, gray, silty, gravelly SAND, wet.	20		1/2" pvc .020 slot (6'-26')
	SM	Gray, fine-grained, silty SAND, very moist.	25		bentonite pellets
	ML	Gray, laminated SILT with sand, damp.	30		
	SM	Gray, silty SAND with gravel, moist. (TILL)	35, 40		pea gravel filter; 3/4" pvc .020" slot (31'-49')
	SW	Gray, gravelly SAND, wet.	45		
	SM	Gray, silty SAND with gravel (TILL)			



note: Well completed at 49 feet on 3-5-87;
No methane detected during drilling;
Boulder hit at 49 feet.

sheet 1 of 1

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4	Date 4/87	Figure B.8

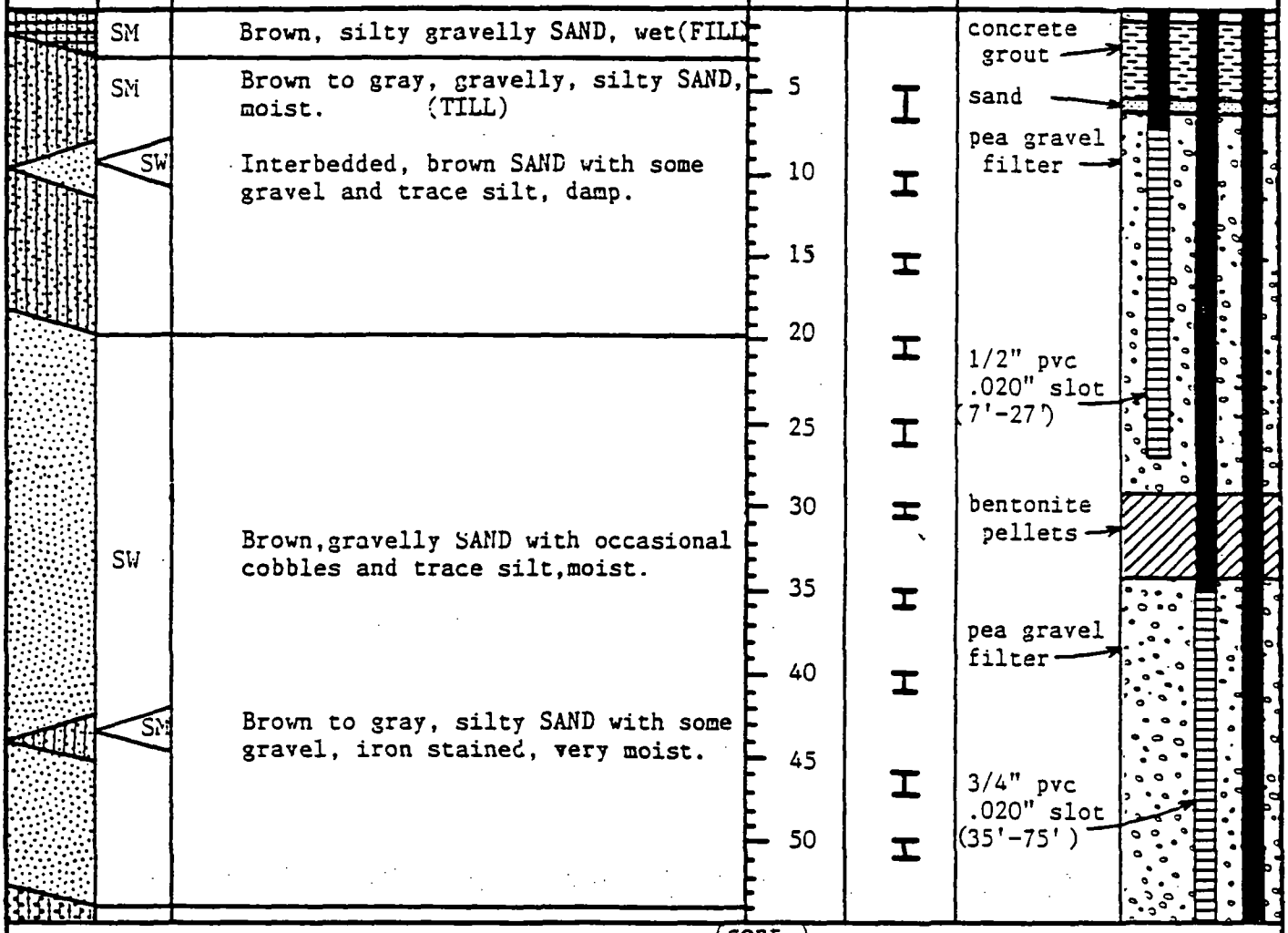
GAS MONITORING WELL AF

Logged By JJ

Date 3-2-87

ELEV. 408 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, silty gravelly SAND, wet(FILL)			concrete grout
	SM	Brown to gray, gravelly, silty SAND, moist. (TILL)	5		sand
	SW	Interbedded, brown SAND with some gravel and trace silt, damp.	10		pea gravel filter
			15		
			20		1/2" pvc .020" slot (7'-27')
			25		
			30		bentonite pellets
	SW	Brown,gravelly SAND with occasional cobbles and trace silt,moist.	35		
			40		pea gravel filter
	SM	Brown to gray, silty SAND with some gravel, iron stained, very moist.	45		3/4" pvc .020" slot (35'-75')
			50		



(cont.)

note: No methane detected during drilling;
Minor seepage at 35 feet.

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4	Date 4/87	Figure B.9a

GAS MONITORING WELL AF

Logged By JJ
Date 3-2-87

ELEV. 408±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM	Brown, multicolored, weathered, sandy GRAVEL with silt, wet.	60		pea gravel filter
	SW/ GW	Brown, gravelly SAND with trace silt and occasional cobbles, wet. Interbedded, gray-brown, sandy GRAVEL, wet.	65, 70		3/4" pvc .020" slot (35'-75')
	ML, SP	Gray to brown SAND with some gravel and trace silt, heaving, wet, interbedded tan, sandy SILT, wet.	75, 80		sand filter
	ML	Blue-gray, laminated SILT, damp.	85		pumped concrete grout
	GM	Tan, multicolored, weathered, silty, sandy GRAVEL, wet.	90, 95		sand filter; pea gravel filter
	GW	Interbedded brown, sandy GRAVEL, moist.	100, 105		3/4" pvc .020" slot (95'-150')

(cont.)

note: No methane detected during drilling to 105';
Artesian groundwater encountered at 62'
Heaving sand encountered at 72'-84'.

sheet 2 of 3

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4 | Date 4/87 | Figure B. 9b

GAS MONITORING WELL AF

Logged By JJ

Date 3-2-87

ELEV. 408 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM/ GP	Brown, multicolored, weathered sandy GRAVEL with silt and occasional cobbles, wet.	115 120 125 130 135 140 145 150		pea gravel filter 3/4" pvc .020" slot (95'-150')

note: Well completed at 152 feet on 2-25-87;
Methane detected at 138 feet, up to 168% LEL;
Trace H_2S detected at 150 feet, up to 2ppm;
Methane again detected at 150 feet, up to 164% LEL.

sheet 3 of 3

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REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4 | Date 4/87 | Figure B.9c

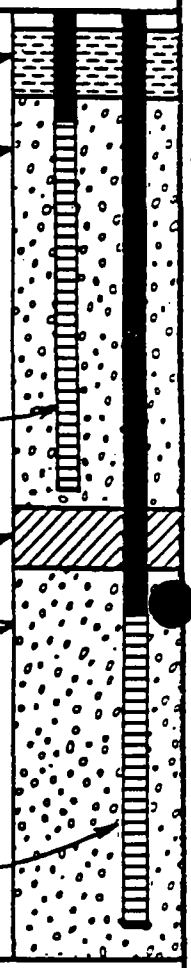
GAS MONITORING WELL AG

Logged By JJ

Date 3-12-87

ELEV. 418 ±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown and tan, silty SAND with gravel, damp to wet.	5, 10, 15, 20		concrete grout; pea gravel filter
	SP	Brown SAND trace silt, wet.	25		1/2" pvc .020" slot (6'-26')
	GP/GM, SM, SP	Brown, multicolored, weathered, sandy GRAVEL with silt and occasional cobbles, very moist. Interbedded silty SAND with gravel, and brown SAND, moist.	30, 35, 40, 45		bentonite pellets; pea gravel filter; 3/4" pvc .020" slot (33'- 50')
	CL	Light gray, silty clay, damp.	50		



note: Well completed at 51½ feet on 3-12-87;
No methane detected during drilling;
Seepage at 15 feet;
Seepage at 20 feet.

sheet 1 of 1

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250- 4 | Date 4/87 | Figure B.10

GAS MONITORING WELL AH

Logged By JJ

Date 3-26-87

ELEV. 359±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, silty SAND with gravel, wet. (FILL)	5		concrete grout
	SM	Brown, silty SAND with gravel, moist to wet. (TILL)	10		sand filter; pea gravel filter
	GM/ GP	Brown, multicolored, weathered, sandy GRAVEL with silt and occasional cobbles, moist.	15, 20		1/2" pvc .020" slot (9'-23')
	GW	Interbedded, sandy GRAVEL, trace silt.	25, 30, 35		bentonite pellets; pea gravel filter
	GW/ SW	Brown, sandy GRAVEL, trace silt, occasional cobbles and brown, gravelly SAND, wet.	40, 45		1/2" pvc .020" slot (28'2"-67'6")
	GM / GP	Brown, multicolored, weathered, sandy GRAVEL with silt and occasional cobbles, moist to wet.	50		

(cont.)

note: No methane detected during drilling
Artesian groundwater encountered at 45 feet

sheet 1 of 2

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

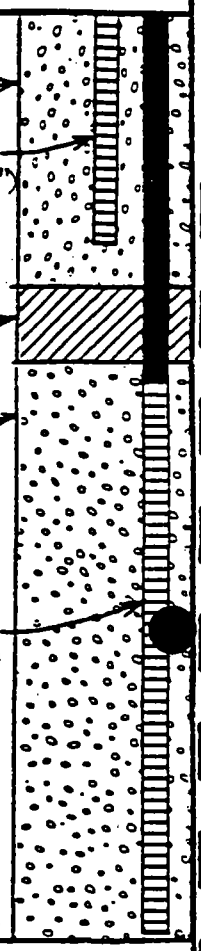
Proj. No. 250-4 | Date 4/87 | Figure B.11a

GAS MONITORING WELL AH

Logged By JJ
Date 3-26-87

ELEV. 359±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM / GP	Brown, multicolored, weathered, sandy GRAVEL with silt and some cobbles, moist to wet. Interbedded brown, gravelly SAND, wet.	60, 65		pea gravel filter; 1/2" pvc .020" slot (28'2"-67'6")
	ML	Dark gray SILT with some sand, trace gravel, very moist to damp.	70		bentonite pellets
	SM	Brown, silty SAND with some gravel, moist.	75, 80		pea gravel filter
	GM / GP	Brown, multicolored, weathered sandy GRAVEL with silt and occasional cobbles, very moist. Interbedded gravelly SAND, wet and silty SAND with gravel.	85, 90, 95, 100, 105	NR	3/4" pvc .020" slot (75'-105'4")



note: Well completed at 106 feet on 3-24-87;
No methane detected during drilling
Seepage at 100 feet;
Artesian groundwater encountered at 106 feet;
NR= no sample recovery.

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MIDWAY LANDFILL
REMEDIAL INVESTIGATION
KING COUNTY, WA

Proj. No. 250-4 | Date 4/87 | Figure B.11b

APPENDIX C

SUBSURFACE CONDITIONS

Visual classifications of the soils encountered in the gas monitor well boreholes are included on the well installation logs in Appendix B.

In general, the soils encountered in the well boreholes are tills underlain by advance outwash. The lowest unit encountered is a multicolored, silty, sandy gravel of uncertain origin. All units are interbedded with thin layers of lacustrine silt.

The natural tills are gravelly silty sands with cobbles. Because these soils were laid down beneath a glacier, the various grain sizes are thoroughly mixed and the material is dense and generally has low permeability. The tills that could be identified ranged up to 60 feet in thickness.

The advance outwash soils are believed to have been deposited by glacial melt-water streams. Consequently, they exhibit the grain-size sorting characteristic of fluvial soils. Because they were overridden by the glacier after they were deposited, they typically are nearly as dense as the tills.

Outwash material observed in the boreholes ranged from silts to sandy gravels with occasional cobbles. The finer-grained material generally was observed closer to the overlying till. Because the deeper, coarser-grained sandy gravels may be the principal gas-bearing strata, penetration of such strata by the gas monitor wells was considered desirable.

Groundwater was encountered in almost all the boreholes, often at more than one depth. Perched water tables and seepage zones were noted in all of the units described above. Based on water levels observed in the deep probes, the regional water table in this vicinity probably lies at about Elevation 250 to 300 feet.

APPENDIX C

OFFSITE CONTROL WELLS
TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM

FOR

THE MIDWAY LANDFILL RI

OFFSITE CONTROL WELLS

Prepared for:

SEATTLE ENGINEERING DEPARTMENT
SOLID WASTE UTILITY

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

March 24, 1988
PMX #55-1550-11 (Task 2.5.3)

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1.0 INTRODUCTION

The Midway Landfill is located within the City of Kent approximately 15 miles south of the City of Seattle. The landfill occupies a 60 acre site located between Interstate 5 and Highway 99, north of 252nd Street. In January 1966, the City of Seattle leased the site and began using it as a landfill. The landfill received demolition debris from commercial haulers and wood wastes and yard trimmings from the City's transfer stations. Records beginning in 1978 indicate that some industrial wastes also were deposited with the approval of the Seattle-King County Health Department. Information included in EPA's Emergency and Remedial Response Information System (ERRIS) files indicates that the landfill may have received industrial liquid and sludge wastes before 1980. It was closed in 1983, although clean soil materials from excavation projects are still accepted at the site to assist in final grading and cover. During the course of operations at the landfill, an estimated 3 million cubic yards of solid wastes were deposited. The waste covers approximately 40 acres and is over 100 feet deep in places.

Beginning in September 1985, the City of Seattle and the Department of Ecology began emergency remedial measures to prevent methane from reaching explosive levels in structures around the site. Included in these remedial measures was the installation of several offsite gas extraction wells. Nineteen of these wells have been installed. Due to reductions in gas concentrations over time, only five of these control wells are still in operation. Their locations are shown on Figure C-3. A table, indicating blower horsepower, depths, screened intervals, and operating status is shown on Table C-1.

TABLE C-1
CONTROL WELL INFORMATION

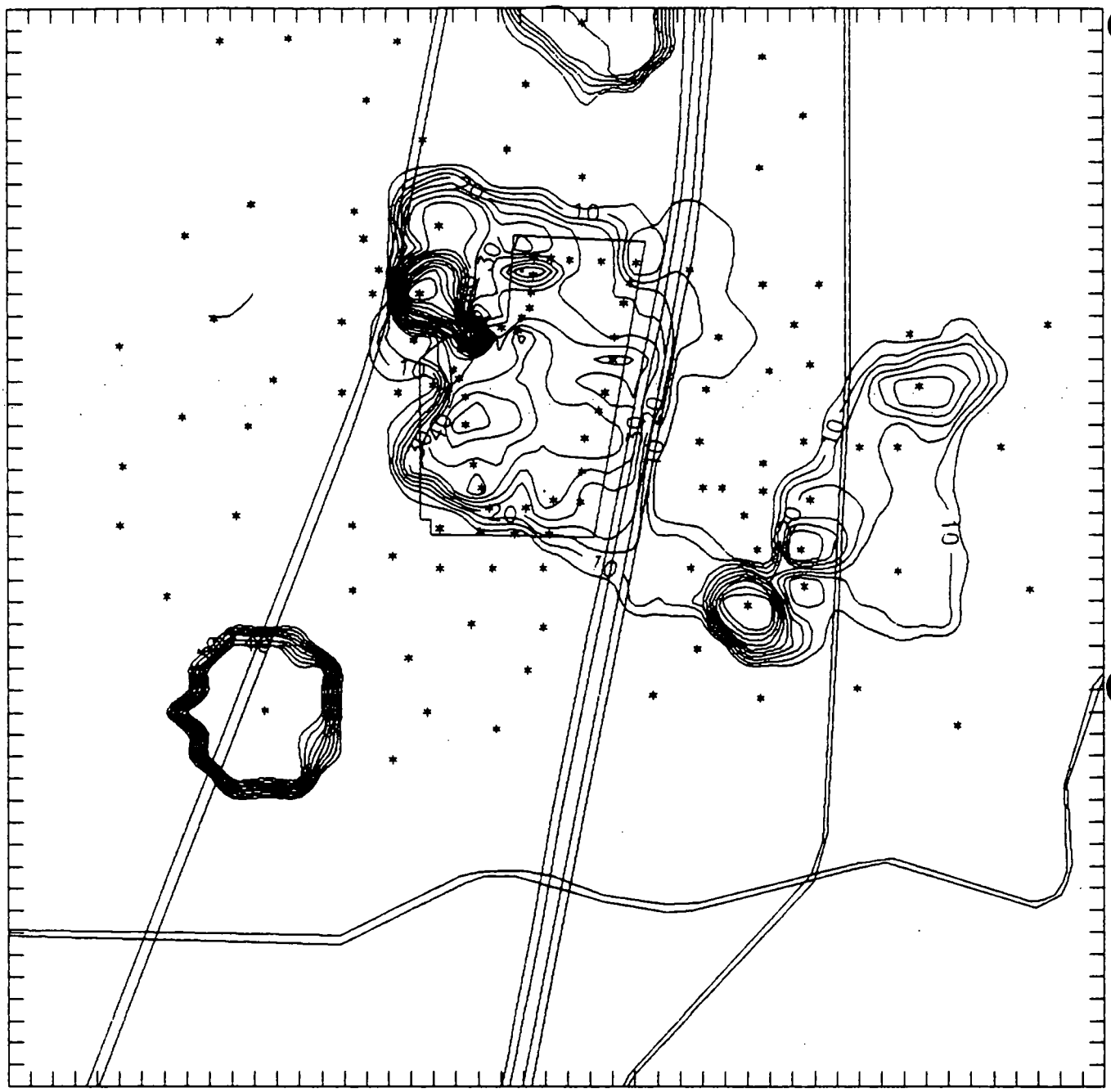
WELL	DATE COMPLETED	INSTALLED BY	INSTALLED FOR	DIST TO SCRN TOP	DIST TO SCRN BOT	LGT OF SCRN	BLWR SIZE	CASG SIZE	STATUS
C-1	12/23/85	TERRA	CITY	7	55	48	1.5	3"	OFF
C-2	12/31/85	TERRA	CITY	10	58	48	1.5	3"	OFF
C-3	12/30/85	TERRA	CITY	10	58	48	1.5	3"	OFF
C-4	01/21/86	TERRA	CITY	9	58	49	1.5	3"	OFF
C-5	02/03/86	TERRA	CITY	8	76	68	1.5	3"	OFF
C-6	05/14/86	TERRA	CITY	8	95	87	1.5	3"	*T*
C-7	05/16/86	TERRA	CITY	11	79	68	1.5	3"	*T*
C-8	05/19/86	TERRA	CITY	10	66	56	1.5	3"	OFF
C-9	05/20/86	TERRA	CITY	11	59	48	1.5	3"	OFF
C-10	05/22/86	TERRA	CITY	9	77	68	1.5	3"	OFF
C-11	06/02/86	TERRA	CITY	5	73	68	1.5	3"	OFF
C-12	06/04/86	TERRA	CITY	10	67	57	1.5	3"	ON
C-13	08/26/86	TERRA	CITY	21	101	80	5.0	4"	OFF
C-14	09/09/86	TERRA	CITY	40	95	55	5.0	4"	OFF
C-15	09/16/86	TERRA	CITY	29	93	64	5.0	4"	OFF
C-16	11/25/87	PMX	CITY	20	120	100	*A*	4"	*A*
C-17	11/19/87	PMX	CITY	20	120	100	1.5	4"	*T*
E-1	N/A	HART/CRO	DOE	N/A	N/A	N/A	5.0	4"	OFF
E-2	01/23/86	HART/CRO	DOE	20	83	63	5.0	4"	OFF

A = Well is drilled, but is not attached to a blower yet.
T = Well is throttled to a low vacuum.

2.0 EXISTING CONDITIONS

Prior to this remedial investigation, in the winter of 1986, landfill gas was found to have migrated extensively from the landfill to the north-west creating offsite reservoirs of gas in shallow soil zones in concentrations over 80% by volume, see Figure C-1. Landfill gas was also found to have migrated in shallow soil zones to the north, west, south-west and to the east in concentrations over 40% by volume. This shallow gas reservoir was found to be seeping into the basements and crawl spaces of some residences and businesses in the area. Eleven homes were evacuated in November, 1985, due to levels of methane gas above acceptable limits.

Landfill gas was also found to have migrated offsite in deep soil zones in concentrations over 70% by volume to the east of the landfill and over 55% by volume in other areas around the site during this same time period, see Figure C-2.



Note: All sets of probes and wells may not be shown.

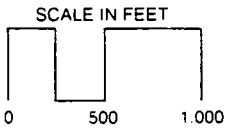
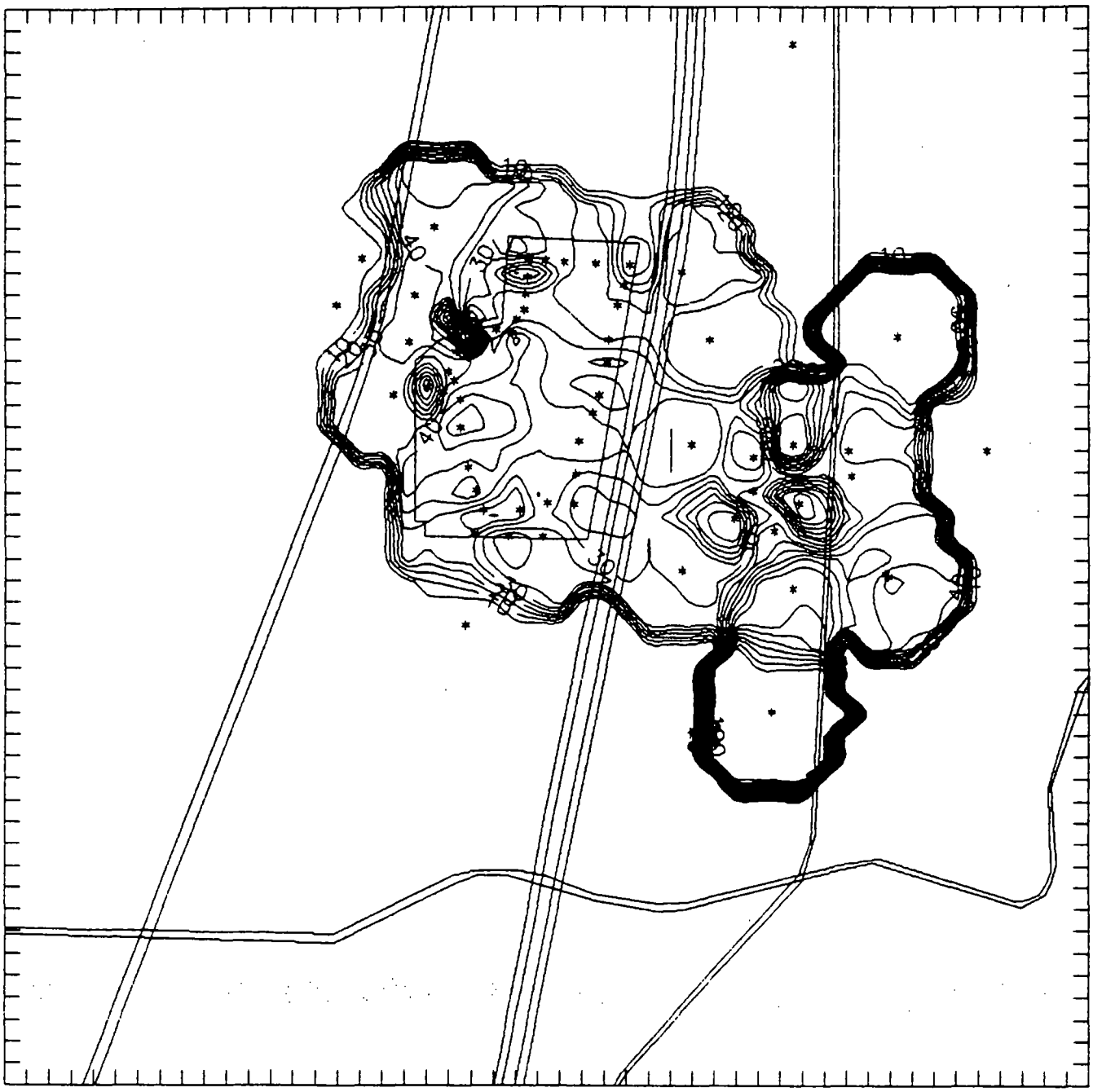


Figure C-1
Shallow Gas Concentration Isopleth, February, 1986



Note: All sets of probes and wells may not be shown.

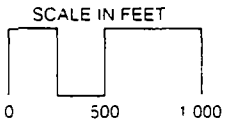


Figure C-2
Deep Gas Concentration Isopleth, February, 1986

3.0 OBJECTIVE

3.1 Attempt to Reduce Offsite Gas Concentrations

Results of monitoring programs conducted by the City and WDOE revealed that an extensive reservoir of gas had accumulated off-site from the landfill. This accumulation had caused gas concentrations above acceptable limits in several neighborhood homes and businesses structures. Offsite control wells were installed to reduce methane concentrations in these homes and businesses and to remove the gas from the surrounding soil.

As shown on Figure C-3, 19 offsite control wells were installed by the City and WDOE in various locations around the landfill. These sites were chosen because of the unacceptable levels of methane detected near the surface or in nearby structures, or in the case of C-16 and C-17, over 40 feet deep in the soil. The control wells are designed to remove gases from the well's radius of influence and discharge them through an activated charcoal filter to the atmosphere. Analysis of the discharge from these wells has shown that no health hazard are created by venting them to the atmosphere. See Table C-2.

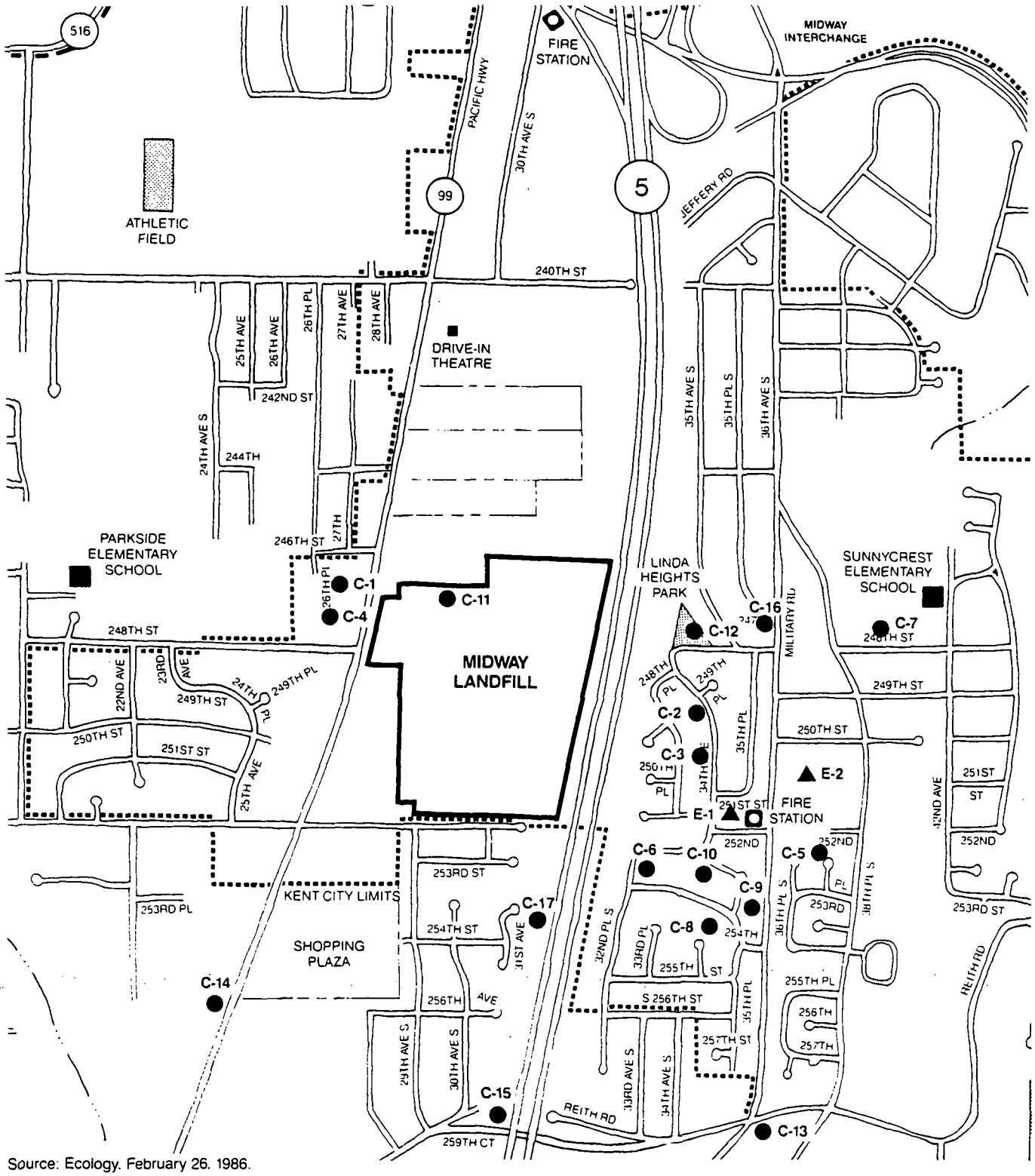
3.2 Evaluate Effectiveness of Offsite Gas Control Wells

An evaluation of the effectiveness of offsite control wells in reducing gas concentrations in structures and in shallow soil near the offsite control wells was accomplished by studying the gas measurements recorded in structures and in monitoring probes near the offsite control wells prior to and after the start-up of the offsite control wells. These readings made it possible to determine the need if any for additional offsite control wells and to ascertain the point at which the offsite control wells had effectively removed the gas within their radius of influence and could be shut down.

It is possible for offsite control wells to draw landfill gas away from the landfill. To help prevent this, an on-site migration control system must be in operation before offsite control wells are started up. It is important to study the field data recorded in the monitoring probes between the landfill and the offsite control well to assure that this phenomena does not occur.

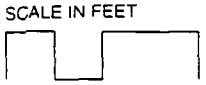
3.3 Determine the Zone of Influence of Selected Offsite Gas Control Wells

Selected offsite control wells and probes near those wells were monitored upon start-up to determine the area of influence of the control wells and provide engineering data for the design and location of additional control wells. A further discussion of these investigations is included in Section 4.4 of this report.



Source: Ecology, February 26, 1986.

SCALE IN FEET



E-1▲ Ecology Extraction Well

C-1● City of Seattle Extraction Well

Figure C-3
Location of Offsite Control Wells

TABLE C-2
CONCENTRATIONS OF ORGANIC COMPOUNDS IN SAMPLES COLLECTED FROM THE DISCHARGE TO ATMOSPHERE OF CONTROL WELLS IN THE VICINITY OF THE MIDWAY LANDFILL
ALL RESULTS REPORTED AS uL/L (ppm)

	CONTROL WELL				
COMPOUND	**C-1**	**C-2**	**C-3**	**C-4**	**C-5**
Vinyl Chloride	<1.0	<1.0	1.0	<1.0	<1.0
Chloroethane	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethylene	0.04	<0.005	<0.005	<0.005	<0.005
Methylene Chloride	<0.005	0.02	<1.0	<0.005	0.02
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	0.04	<0.01	<0.01	0.04	0.04
Carbon Tetrachloride	<0.01	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethane	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethylene	0.04	<0.01	0.02	<0.01	0.04
Acetone	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon Disulfide	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	<0.5	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene/Styrene	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene

Note: This is a complete list of all compounds analyzed.

TABLE C-2 (cont.)
CONCENTRATIONS OF ORGANIC COMPOUNDS IN SAMPLES COLLECTED FROM THE DISCHARGE TO ATMOSPHERE OF CONTROL WELLS IN THE VICINITY OF THE MIDWAY LANDFILL
ALL RESULTS REPORTED AS uL/L (ppm)

	CONTROL WELL				
COMPOUND	**C-6**	**C-7**	**C-8**	**C-9**	**C-10**
Vinyl Chloride	<1.0	<1.0	<1.0	1.0	<1.0
Chloroethane	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.0	<1.0	<1.0	<1.0	<1.0
1,1-Dichloroethylene	<0.005	<0.005	<0.005	<0.005	<0.005
Methylene Chloride	0.05	<1.0	<1.0	0.2	0.05
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	0.08	<0.01	<0.01	<0.01
Carbon Tetrachloride	<0.01	<0.01	<0.01	0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethane	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethylene	0.02	<0.01	0.02	<0.01	0.02
Acetone	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon Disulfide	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	20	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene/Styrene	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene

Note: This is a complete list of all compounds analyzed.

TABLE C-2 (cont.)
CONCENTRATIONS OF ORGANIC COMPOUNDS IN SAMPLES COLLECTED FROM THE DISCHARGE TO ATMOSPHERE OF CONTROL WELLS IN THE VICINITY OF THE MIDWAY LANDFILL
ALL RESULTS REPORTED AS uL/L (ppm)

	CONTROL WELL		
COMPOUND	**C-12**	**C-13**	**C-15**
Vinyl Chloride	<1.0	<1.0	3.0
Chloroethane	<0.5	<0.5	<0.5
Chloromethane	<1.0	<1.0	<1.0
1,1-Dichloroethylene	<0.005	0.1	<0.005
Methylene Chloride	<1.0	<1.0	<1.0
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	0.1	0.1
Carbon Tetrachloride	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	0.04	<0.01
1,1,2,2-Tetrachloro-ethane	<0.01	<0.01	<0.01
1,1,2,2-Tetrachloro-ethylene	<0.01	<0.01	<0.01
Acetone	<0.5	<0.5	<0.5
Carbon Disulfide	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2
Toluene	<0.5	20	<0.5
p-Xylene	<0.5	<0.5	<0.5
o-Xylene/Styrene	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5

* - Based on response for toluene

Note: This is a complete list of all compounds analyzed.

4.0 METHODOLOGY

4.1 Offsite Control Well Location Determination

After a few months of operating the onsite control wells, it became apparent that the reservoir of gas offsite was not going to be pulled back to the landfill quickly. The body of gas in the soil in residential neighborhoods was still causing concern because of the potential for gas migrating through basements and structure slabs into those structures.

In early 1986, the first five of these wells were installed adjacent to structures with severe gas infiltration problems. The first five wells created a negative pressure in the soil underneath the structures, creating a flow of gas away from the structures. They were 60 feet deep with 1.5 HP motor blowers and created vacuums of 8.5 inches WC.

At that time, the Department of Ecology began installing two similarly designed but larger offsite control wells in the same vicinity. These wells were 100 feet deep with 5 HP motor blowers; they created vacuums near 40 inches water column (W.C.).

Meanwhile, based on the good performance of the initial five control wells, the City contracted with Parametrix to install up to ten more control wells, nine in the neighborhood east of the landfill and one directly west of the landfill. The first seven of these were 80 to 100 feet deep with a 1.5 HP motor blower. After observing the ability of the larger Ecology control wells to remove large quantities of gas from ann extensive area, the City and Parametrix decided to make the last three wells of the larger design. These wells are labeled C-13, C-14 and C-15.

Due to continuing high gas concentrations south and north east of the landfill in the summer of 1987, the City contracted with Parametrix, Inc. to drill two additional offsite control wells. C-16 was drilled north east of the site (see Figure C-3) in November 1987. Negotiations with the homeowner on whose property the control well is located have delayed the connection of a motor blower to this well. C-17 was drilled south of the site (see Figure C-3) in November 1987. A temporary 1.5 HP motor blower was installed on the well to test gas concentrations and the effect, if any, that the control well will have on the reservoir of migrated gas in the area. From this test, a determination will be made as to the need for a permanent 5 HP motor blower installation.

4.2 Well Drilling and Mechanical Equipment Installation

Fifteen gas control wells eight inches in diameter were drilled and completed for the City by Parametrix, Inc. The work of drilling the boreholes and completing the in-ground wells was subcontracted to Richardson Well Drilling

Company. All their work was supervised by an engineering geologist from Terra Associates, Inc., also under subcontract to Parametrix. Two gas control wells with ten inch diameter boreholes were drilled and completed for the Department of Ecology by Black & Veatch. The work of drilling the boreholes and completing the in-ground wells was subcontracted to Hart Crowser & Associates Inc.

The boreholes for the City control wells were advanced using a top-drive rotary drill rig. Compressed air was used to remove the cuttings. To support the boreholes, eight-inch-diameter steel casing was driven using a pneumatic hammer. The wells were installed to depths ranging from 63 to 105 feet, five wells (C-13, 14, 15, 16 and 17) being drilled in the range of 100 feet. A log of each borehole can be seen in Appendices C-1 and C-2 of this report.

Methane was not detected in significant quantities at any well location until after the drilling had been completed, because gas-bearing strata penetrated by the boreholes may be closed off by the casings and because the large volumes of compressed air pumped down the holes while the boreholes are being advanced suppress the evolution of other gasses that may be present.

In general, the soils encountered in the well boreholes are silty, sandy gravels underlain by advance outwash (At Wells C-1, C-4, C-9 and C-11, a few feet of subsurface filling was identified). The natural tills are gravelly silty sands and cobbles. Because these soils were laid down beneath a glacier, the various grain sizes are thoroughly mixed and the material is dense with low porosity. The tills that could be identified ranged up to 46 feet in thickness. In several wells, the till either was missing or could not be distinguished from the underlying silty outwash materials.

Boreholes that penetrated to sufficient depth encountered what is either an extensive perched water table or the regional water table at approximately Elevation 265 to 280 feet. The water was usually observed in a semi-confined aquifer encountered near the bottom of the boreholes. In several boreholes, slight seepage from perched water tables was also observed.

Wells C-1 through C-12 were completed with a single three-inch-diameter PVC casing with flush threaded couplings. No solvents or glues were used in the completion of these wells. The wells were packed with pea gravel. A bentonite seal was placed from approximately five feet below ground surface to approximately seven feet below ground surface. A cement grout cap was then placed between the bentonite seal and ground surface. The three-inch PVC casing was slotted with 0.10 inch slots below the bentonite seal.

Wells C-13, 14, 15, 16, 17 and WDOE Wells E-1 and E-2 were completed similarly to wells C-1 through C-12 except that a four-inch-diameter casing was used.

Control Wells C-1 through C-12 are operated by a 1.5 H.P. 110/240 volt AC electric driven motor blower. The blower is capable of producing 8.5 inches W.C.. The flowrates in these control wells will vary greatly depending upon the permeability of the surrounding soil. The discharge of these blowers include an underground water trap to remove any entrained water. The discharge flows through an activated charcoal filter that filters out any organic contaminants and then is released to atmosphere. In wells C-6 through C-12, the mechanical equipment is covered by galvanized steel shelters. The discharge vent stack is either supported by a power pole or is attached to a nearby structure. In wells C-1 thru C-5, , the motor blower is installed in a partially buried vault. A typical schematic representation of control wells C-1 through C-12 is shown on Figure C-4.

Wells C-13, 14, and 15 were completed with a five H.P. 220 volt AC electric driven motor blower capable of producing up to 65 inches W.C. vacuum. The discharge of these blowers flow through a large above ground water trap which removes any entrained water in the gas stream. From the water trap, the discharge flows through a large activated charcoal filter and is then vented to atmosphere. The entire mechanical facilities are enclosed in a locked fenced area. These blowers are not installed near structures, therefore, noise suppression was not a concern in the installation. A typical schematic representation of control wells C-13, 14, and 15 is shown on Figure C-5. Well C-17 has been temporarily hooked up to a 1.5 HP motor blower to assess available flow rates and gas concentrations. Well C-16 will be similarly connected after negotiations with the property owner. A more permanent installation may be made depending on the information obtained during the temporary operation.

WDOE control wells E-1 and E-2 are built similarly to City control wells C-13, 14, and 15, however, the WDOE control wells were originally equipped with two electric driven motor blowers. These wells have since gone to the one blower design. A typical schematic representation of control wells E-1 and E-2 is shown on Figure C-6. A complete listing of the control wells and their screened intervals, blower size, etc. is included in Table C-1.

4.3 Operation and Monitoring

The offsite control wells operate continuously, 24 hours per day, seven days per week. The mechanical equipment at each control well has proved quite reliable with a minimum of downtime due to mechanical failure.

When the control wells were first put on line, they were monitored at least daily. In control wells where the gas concentrations were quickly reduced to near zero and remained at that level for several weeks, the frequency of monitoring was reduced to approximately once per week. As the confidence in the data recorded increased, the frequency of monitoring reduced accordingly.

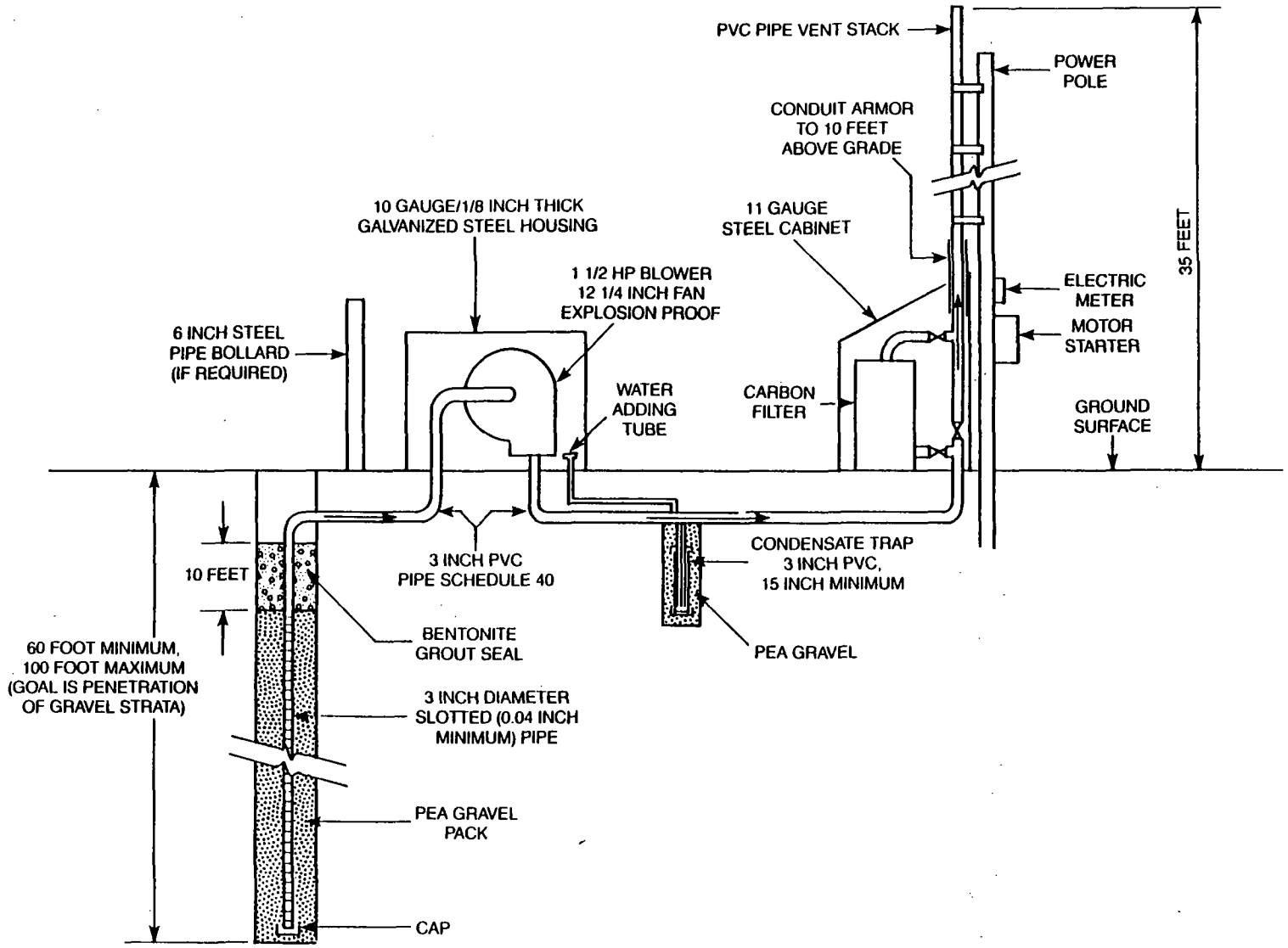
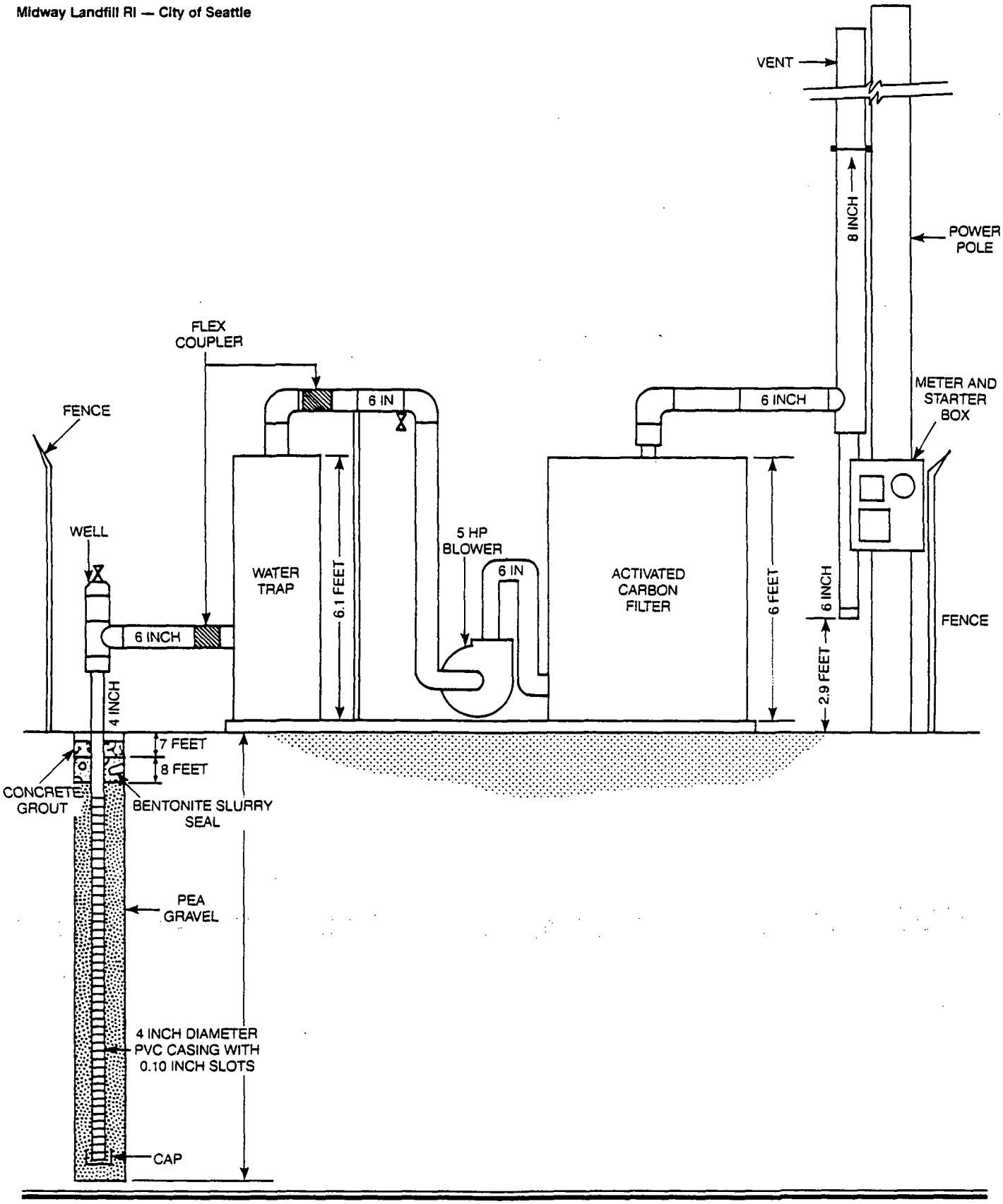


Figure C-4
Typical Schematic Cross Section of a City Off-Site Control Well with 1/2 H[illegible]otc[illegible]we[illegible]

NOT[illegible]ALE



NOT TO SCALE

Figure C-5
Typical Schematic Cross Section of a City Off-Site Control Well with a 5 HP Motor Blower

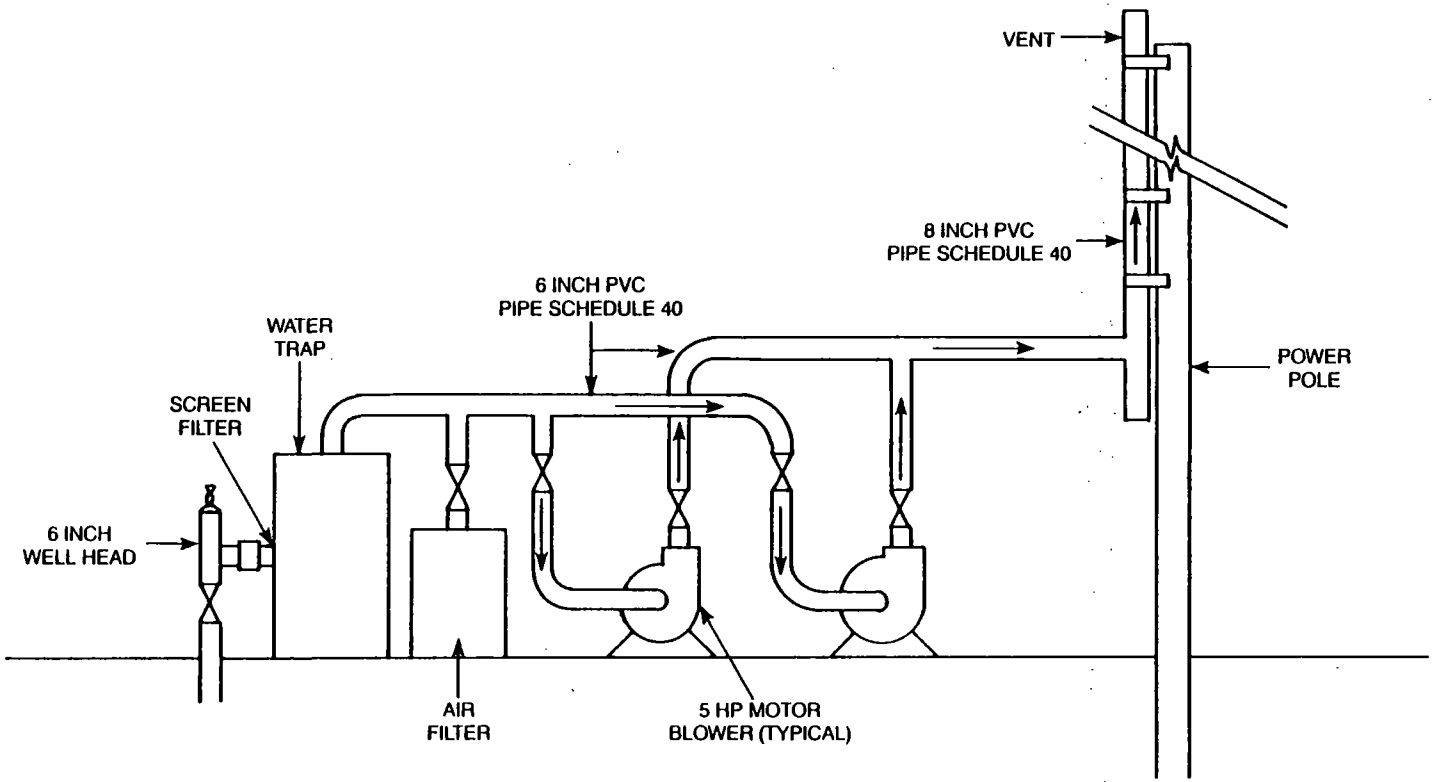


Figure C-6
Typical Schematic Cross Sectio[redacted]
[redacted]of a[redacted]olc[redacted] HP[redacted]Sit[redacted]ntrc[redacted]ll

NOT[redacted]ALE

Measurements normally taken at offsite control wells include:

- o Combustible gas (percent, parts per million, or percent LEL)
- o Oxygen (percent)
- o Carbon Dioxide (percent)
- o Hydrogen Sulfide (parts per million)
- o Static Pressure (vacuum in the well)
- o Velocity

Nitrogen is assumed to be the balance of the chemical makeup in the gas stream. The velocity is pressure taken at the inlet to the blower and then converted to flow mathematically. The static pressure measurement, accompanied with the flow measurement, are used to evaluate the wells relative sphere of influence.

4.4 Shut Down of Specific Control Wells and Intensive Monitoring

On February 6, 1986, a pumping test was performed on extraction well EW-2 located on the property of the Landgren Memorial Baptist Church at the corner of Military Road and 250th Street South in Kent, Washington by Hart Crowser & Associates Inc. The test involved measuring the pressure drawdowns in the extraction well and in observation probe 82 as a function of time while the extraction well was pumped at a constant rate. The locations of the observation probe and it's relationship to control well EW-2 is shown in Appendix A of this report.

After the above test, selected offsite controls wells and probes near these wells were monitored upon start-up to determine the area of influence of these controls wells and provide engineering data for the design of additional control wells. This intensive monitoring program was conducted by Parametrix, Inc. The original plan was to monitor several times a day for a week or more. This was performed in the first test period from June 24, 1986 to June 30, 1986. Evaluation of monitoring results showed very rapid probe pressure swings due to barometric changes. Monitoring of the probes several times per day was not often enough to give defined curves for pressure-time relationships. A second test period was planned during which probes were monitored every ninety minutes for twenty four hours. The second series of tests were performed from July 22, 1986 to July 23, 1986.

In June, 1987, due to continuous low gas reading in gas probes near control wells C-1, C-2, C-3, C-5, E-1, and E-2, it was determined that these wells had accomplished their task of removing gas from their sphere of influence and were therefore shut off. Monitoring probes near these wells were monitored with increased frequency immediately before and for weeks after the shut down. Wells near control well E-2 were monitored intensively by Parametrix for approximately 48 hours following it's shut down. This

increased monitoring schedule was implemented to determine whether or not gas was likely to return to the area surrounding these control wells following their shut down, or if gas had been effectively removed from the area. Static pressures, combustible gas concentrations, and oxygen were read in the monitoring probes during this study.

The results of both the Hart Crowser and Parametrix tests described above are discussed in Section 5.4 of this report.

There is a significant piezometric head associated with the regional groundwater table which was intercepted in the drilling of control wells C-13, 14, and 15. This piezometric head had blocked the screened intervals of control wells C-14 and 15. Therefore, since no influence of the surrounding soils was taking place in the operation of these control wells, C-14 and 15 were shut down in May, 1987. In the summer months of 1987, a drop in the water level was recorded in control well C-14 exposing approximately 10 feet of the screened interval. Therefore, control well C-14 was temporarily turned back on. The low permeability of the surrounding soil near C-14 severely inhibits the flow of gas from the well and thereby greatly reduces the wells projected radius of influence. No methane was detected in the vent air, and the well was turned off again.

5.0 RESULTS

5.1 Prevention of Gas in Structures

Several residences adjacent to control well installations typically recorded levels of methane above 10,000 ppm despite repeated efforts to seal the foundations of those structures until the control wells were turned on. According to City gas monitoring data, all gas was effectively removed from these structures within one day of the start up of the offsite control wells. Further, gas has remained out of structures in the vicinity of the landfill since the implementation of the offsite control wells. Combustible gas above 100 parts per million has not been recorded in a structure in the vicinity since November, 1986.

5.2 Reduction of Gas Concentrations

As seen in the isopleth shown on Figure C-1 of this report, prior to the implementation of the offsite control wells, landfill gas was present at shallow depths north-west and south-west of the landfill at levels of up to 40 percent by volume, and east of the site at levels up to 55 percent. The full extent of shallow depth gas migration east and south of the site could not be accurately determined due to lack of monitoring probes in these areas.

As seen in the isopleth shown on Figure C-2 of this report, prior to the start up of the offsite control wells, landfill gas was present in deep soil zones east of the site in concentrations up to 70 percent by volume, and in concentrations up to 55 percent in the vicinity of the landfill. Again, accurate determinations of the full extent of deep landfill gas migration could not be made due to lack of deep monitoring probes to the north, east and south of the landfill.

After the installation of the offsite control wells, reductions in shallow and deep soil zone gas concentrations were observed in areas near the control wells within one month of the control well start up. It should be noted that the onsite migration control system was also on line at this time and was also having an effect on the reductions of gas levels east of the landfill. The results of the implementation of the offsite control wells can be seen on Figures C-7 and C-8. These figures show isopleths of gas concentrations in shallow and deep soil zones approximately six months after the start up of the first control wells. Studying these isopleths with Figures C-1 and C-2, the reduction in gas concentration to the west and the east of the landfill can be seen.

5.3 Effect on Gas Movement

Control wells are installed to remove a reservoir of gas which has accumulated offsite. In this capacity, offsite control wells have proven quite

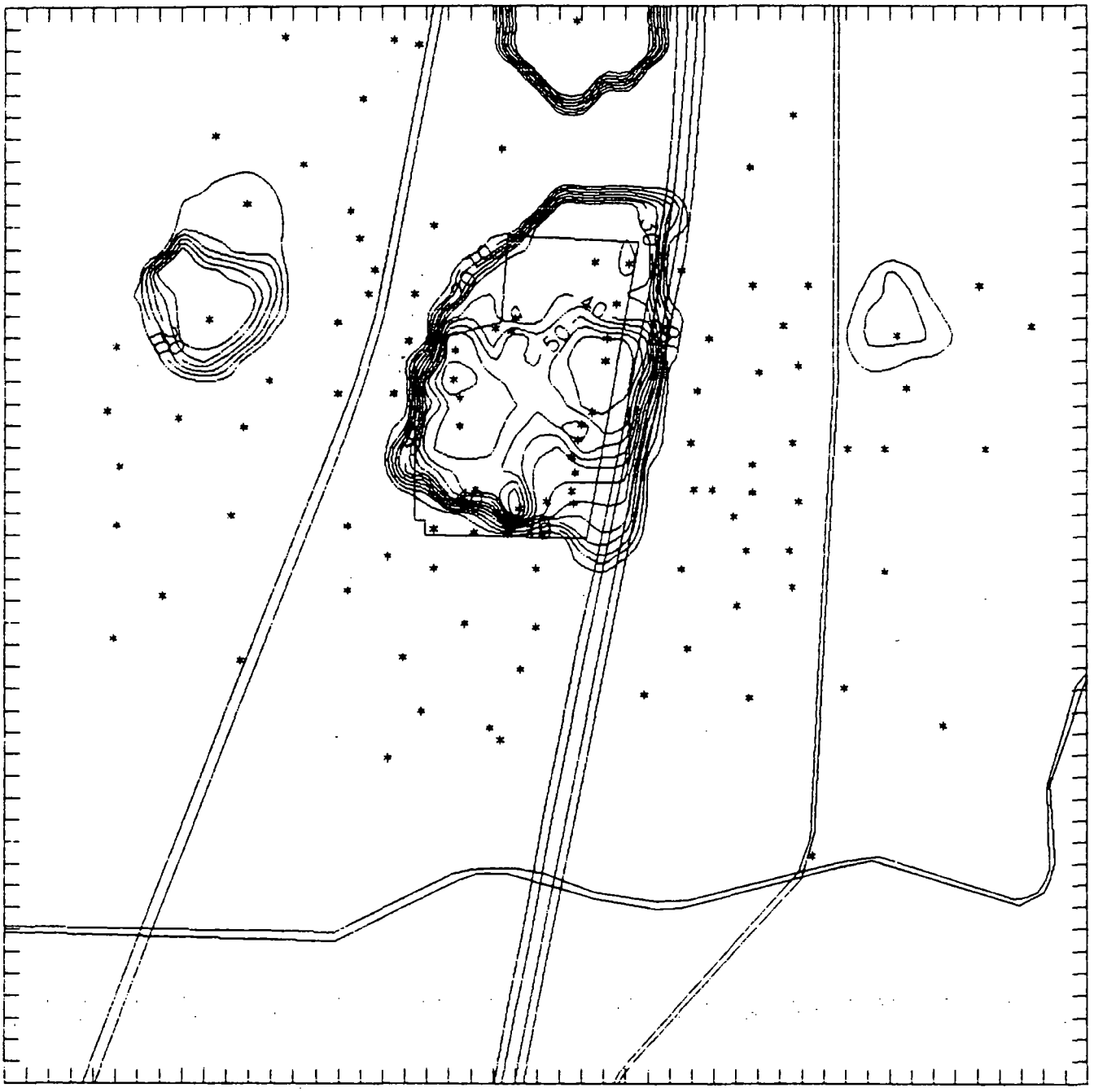
successful. Once the reservoir of gas surrounding the offsite control well has been eliminated, the control well should be shut down. The effect of leaving an offsite control well operating after this point can be a migration of gas from the landfill toward the offsite control well. This effect can be minimized by the proper operation of the onsite migration control system, but, this forces operation of the onsite system to create a greater vacuum curtain around the landfill than would otherwise be necessary.

5.4 Results of Offsite Control Well Shut Down

Tests were performed by Hart Crowser and Associates, Inc. in February, 1986, and performed by Parametrix, Inc. in June and July of 1986, (refer to Section 4.4 of this report). They indicate that offsite control wells have a weak vacuum effect in the shallow soils where air exchange with the atmosphere is quicker, and pressures equalize faster. Offsite control wells have an increasingly stronger vacuum effect proportional to the depth of measurement in the soil. It can be approximated that for a typical 1.5 horsepower blower producing 30 cubic feet per minute, a relationship between the horizontal distance from the offsite control well and the pressure in the surrounding soil exists as shown in Table C-3.

The soil vacuum produced by the 1.5 horsepower blower well system protects structures from gas infiltration, by preventing gas from moving from the soil to the inside of the structure. It is effective within a radius of influence of 200 to 300 feet. More recently, the prime objective of the installation of the offsite control wells has been to remove pockets of gas. The 1.5 horsepower system has some ability to remove gas from the soil surrounding it. It takes roughly two months to remove gas from the soil in a 200 foot radius, and 12 months to remove gas from 500 feet. A 12 month time-frame to remove gas from 500 feet is unnecessarily long. A five horsepower blower producing 250 cfm will remove gas from the soil in a 500 foot radius in approximately 1.5 months, and will also protect structures within a 500 foot radius.

The results of the test performed by Parametrix, Inc. in June, 1987, during the shut down of selected offsite control wells (reference Section 4.4 of this report), indicate that shallow and deep level gas has been effectively removed from the areas surrounding these control wells and that the wells can remain shut down. Probes near these wells are still monitored at least weekly. If in the future gas levels are found to be rising, the control well will be turned back on. See Table C-4 for results of this intensive monitoring program.



Note: All sets of probes and wells may not be shown.

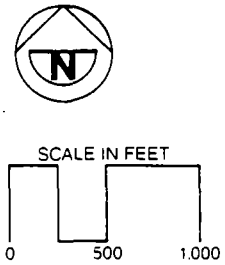


Figure C-7
Shallow Gas Concentration Isopleth, September 1986

Note: All sets of probes and wells may not be shown.

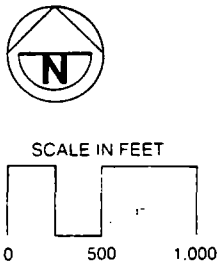


Figure C-8
Deep Gas Concentration Isopleth, September 1986

TABLE C-3
PRESSURE DRAWDOWN RELATED TO DISTANCE FROM
OFFSITE CONTROL WELLS
(1.5 H.P. MOTOR BLOWER)

DISTANCE	PRESSURE DRAWDOWN (inches W.C., measured at least 50 feet below ground surface)
50 ft.	1.0
100 ft.	0.7
200 ft.	0.4
500 ft.	0.1

TABLE C-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987

PROBE 46 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.)	CH4
6/29/87	-60	0700	0745	-0.06	100
6/29/87	0	0800	0800	--	--
6/29/87	1	0801	0809	-0.08	--
6/29/87	3	0803	0803	--	--
6/29/87	6	0806	0806	--	--
6/29/87	10	0810	0810	--	--
6/29/87	15	0815	0815	--	--
6/29/87	20	0820	0823	-0.085	--
6/29/87	25	0825	0825	--	--
6/29/87	30	0830	0830	--	--
6/29/87	45	0845	0850	-0.06	100
6/29/87	60	0900	0906	-0.08	100
6/29/87	100	0940	0946	-0.075	100
6/29/87	160	1040	1051	-0.06	100
6/29/87	300	1300	1312	-0.05	100
6/29/87	500	1620	1626	-0.025	80
6/29/87	740	2020	2034	-0.04	100
6/30/87	980	0020	0026	-0.075	80
6/30/87	1180	0340	0344	-0.07	180
6/30/87	1420	0740	0808	-0.045	200
6/30/87	1660	1140	1150	-0.055	100
6/30/87	1900	1540	1540	-0.04	200
6/30/87	2140	1940	2040	-0.06	180
6/30/87	2300	2340	2330	-0.08	200
7/01/87	2620	0340	0345	-0.08	200
7/01/87	2880	0800	0845	-0.1	240

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4	O2
6/29/87	2034	0	16
6/30/87	0808	0	16
6/30/87	2040	0	16
7/01/87	0845	0	16

TABLE C-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 50 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.) PROBE S	PRESSURE (IN. W.C.) PROBE M	PRESSURE (IN. W.C.) PROBE D	CH4 PROBE S	CH4 PROBE M	CH4 PROBE D
6/29/87	-60	0700	0710	-0.48	-1	-2.2	--	--	--
6/29/87	0	0800	0800	--	--	--	--	--	--
6/29/87	1	0801	0801	-0.52	-1.1	-2	--	--	--
6/29/87	3	0803	0803	-0.52	-1.1	-2	--	--	--
6/29/87	6	0806	0806	--	-1.1	-2	--	--	--
6/29/87	10	0810	0810	--	-1.1	-2	--	--	--
6/29/87	15	0815	0815	--	-1.1	-2	--	--	--
6/29/87	20	0820	0820	-0.54	-1.1	-2	--	--	--
6/29/87	25	0825	0825	-0.55	-1.1	-2	--	--	--
6/29/87	30	0830	0830	-0.55	-1.2	-1.9	--	--	--
6/29/87	45	0845	0845	-0.58	-1.2	-1.9	46	46	16
6/29/87	60	0900	0900	-0.54	-1.2	-1.8	64	64	20
6/29/87	100	0940	0940	-0.49	-1	-1.5	64	64	20
6/29/87	160	1040	1040	-0.32	-0.75	-1.3	75	75	30
6/29/87	300	1300	1300	-0.12	-0.27	-0.65	90	90	320
6/29/87	500	1620	1622	0.1	0.22	-0.215	82	82	1200
6/29/87	740	2020	2017	-0.05	-0.115	-0.7	90	90	6000
6/30/87	980	0020	0019	-0.225	-0.5	-1.2	58	58	9000
6/30/87	1180	0340	0340	-0.23	-0.6	-1.3	90	90	6000
6/30/87	1420	0740	0804	-0.26	-0.87	-1.7	100	100	4000
6/30/87	1660	1140	1140	-0.17	-0.45	-1.4	150	150	84
6/30/87	1900	1540	1530	-0.11	-0.29	-1.1	120	120	90
6/30/87	2140	1940	2020	-0.17	-0.42	-1.2	100	100	84
6/30/87	2300	2340	2319	-0.3	-0.8	-1.8	100	100	16
7/01/87	2620	0340	0340	-0.37	-0.9	-1.9	140	140	15
7/01/87	2880	0800	0840	-0.49	-1.2	-2.3	140	140	4000

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4 PROBE S	O2 PROBE S	CH4 PROBE M	O2 PROBE M	CH4 PROBE D	O2 PROBE D
6/29/87	2017	0	19	0	19	12	9
6/29/87	2115	--	--	--	--	14	9
6/30/87	0019	--	--	--	--	18	9
6/30/87	0340	--	--	--	--	12	9
6/30/87	0804	0	19	0	19	8	11
6/30/87	2020	0	19	0	19	0	21
7/01/87	0840	0	19	0	19	8	11

TABLE C-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 66 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.)	CH4
6/29/87	-60	0700	0715	-0.18	220
6/29/87	0	0800	0800	--	--
6/29/87	1	0801	0807	-0.19	--
6/29/87	3	0803	0803	--	--
6/29/87	6	0806	0806	--	--
6/29/87	10	0810	0810	--	--
6/29/87	15	0815	0815	--	--
6/29/87	20	0820	0821	-0.17	--
6/29/87	25	0825	0825	--	--
6/29/87	30	0830	0830	--	--
6/29/87	45	0845	0845	-0.19	190
6/29/87	60	0900	0903	-0.14	110
6/29/87	100	0940	0940	-0.11	150
6/29/87	160	1040	1046	-0.07	140
6/29/87	300	1300	1325	-0.02	140
6/29/87	500	1620	1635	0.07	140
6/29/87	740	2020	2047	0.025	120
6/30/87	980	0020	0037	-0.06	100
6/30/87	1180	0340	0357	-0.05	200
6/30/87	1420	0740	0816	-0.045	200
6/30/87	1660	1140	1200	0	200
6/30/87	1900	1540	1550	0.055	200
6/30/87	2140	1940	2059	-0.03	100
6/30/87	2300	2340	2347	-0.09	200
7/01/87	2620	0340	0352	-0.05	200
7/01/87	2880	0800	0852	-0.09	200

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4	O2
6/29/87	2047	0	16
6/30/87	0816	0	17
6/30/87	2100	0	17
7/01/87	0852	0	17

TABLE C-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 76 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.) PROBE S	PRESSURE (IN. W.C.) PROBE M	PRESSURE (IN. W.C.) PROBE D	CH4 PROBE S	CH4 PROBE M	CH4 PROBE D
6/29/87	-60	0700	0722	-0.045	-0.25	-0.075	--	--	--
6/29/87	0	0800	0800	--	--	--	--	--	--
6/29/87	1	0801	0802	-0.01	-0.22	-0.065	--	--	--
6/29/87	3	0803	0803	--	--	--	--	--	--
6/29/87	6	0806	0806	--	--	--	--	--	--
6/29/87	10	0810	0810	--	--	--	--	--	--
6/29/87	15	0815	0815	--	--	--	--	--	--
6/29/87	20	0820	0820	--	--	--	--	--	--
6/29/87	25	0825	0825	--	--	--	--	--	--
6/29/87	30	0830	0830	--	--	--	--	--	--
6/29/87	45	0845	0848	-0.01	-0.23	-0.07	--	--	--
6/29/87	60	0900	0900	-0.005	-0.21	-0.04	--	--	--
6/29/87	100	0940	0942	-0.04	-0.21	-0.06	--	--	--
6/29/87	160	1040	1041	0.01	-0.11	-0.03	--	--	--
6/29/87	300	1300	1328	0.055	0.07	0.13	--	--	--
6/29/87	500	1620	1640	0.095	0.15	0.165	--	--	--
6/29/87	740	2020	2102	0	-0.095	0.02	92	100	88
6/30/87	980	0020	0054	-0.065	-0.26	-0.12	--	--	--
6/30/87	1180	0340	0405	-0.06	-0.24	-0.1	--	--	--
6/30/87	1420	0740	0819	-0.05	-0.19	-0.085	140	200	100
6/30/87	1660	1140	1205	0.06	0.03	0.1	--	--	--
6/30/87	1900	1540	1555	0.07	0.06	0.12	--	--	--
6/30/87	2140	1940	2106	-0.05	-0.22	-0.26	130	200	100
6/30/87	2300	2340	2355	-0.09	-0.32	-0.165	--	--	--
7/01/87	2620	0340	0359	-0.065	-0.25	-0.13	--	--	--
7/01/87	2880	0800	0858	-0.105	-0.33	-0.185	180	240	100

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4 PROBE S	O2 PROBE S	CH4 PROBE M	O2 PROBE M	CH4 PROBE D	O2 PROBE D
6/29/87	2102	0	18	0	18	0	18
6/30/87	0819	0	18	0	16	0	19
6/30/87	2109	0	18	0	18	0	19
7/01/87	0858	0	18	0	16	0	18

TABLE C-4
RESULTS OF INTENSIVE MONITORING DURING THE SHUT-DOWN OF CONTROL WELL E-2, JUNE 1987 (CONT.)

PROBE 82 (all CH4 readings in PPM)

DATE	TIME MIN	TIME MIL	TIME ACT	PRESSURE (IN. W.C.) PROBE S	PRESSURE (IN. W.C.) PROBE M	PRESSURE (IN. W.C.) PROBE D	CH4 PROBE S	CH4 PROBE M	CH4 PROBE D
6/29/87	-60	0700	0722	-0.9	-4.5	-3.2	66	14	15
6/29/87	0	0800	0800	--	--	--	--	--	--
6/29/87	1	0801	0801	-1.2	-4.4	-3.2	--	--	--
6/29/87	3	0803	0803	-1.2	-4.6	-3.4	--	--	--
6/29/87	6	0806	0806	-1.2	-4.6	-3.2	--	--	--
6/29/87	10	0810	0810	-1.2	-4.5	-3	--	--	--
6/29/87	15	0815	0815	-1.2	-4.2	-2.8	--	--	--
6/29/87	20	0820	0820	-1.2	-3.9	-2.5	--	--	--
6/29/87	25	0825	0825	-1.1	-3.6	-2.4	--	--	--
6/29/87	30	0830	0830	-1.1	-3.4	-2.2	--	--	--
6/29/87	45	0845	0845	-0.9	-2.6	-1.8	62	14	13
6/29/87	60	0900	0900	-0.72	-2.2	-1.5	72	14	19
6/29/87	100	0940	0940	-0.4	-1.3	-1	75	16	80
6/29/87	160	1040	1040	-0.2	-0.8	-0.72	72	33	90
6/29/87	300	1300	1300	0	-0.07	-0.015	76	54	90
6/29/87	500	1620	1632	0.15	0.34	0.26	68	68	90
6/29/87	740	2020	2040	0.05	0.04	-0.1	46	40	78
6/30/87	980	0020	0034	-0.13	-0.43	-0.6	66	40	100
6/30/87	1180	0340	0352	-0.13	-0.45	-0.62	100	70	140
6/30/87	1420	0740	0812	-0.12	-0.57	-0.64	100	72	140
6/30/87	1660	1140	1155	-0.02	-0.18	-0.3	100	80	160
6/30/87	1900	1540	1545	0.025	-0.045	-0.185	90	82	160
6/30/87	2140	1940	2047	-0.11	-0.3	-0.45	100	100	160
6/30/87	2300	2340	2337	-0.2	-0.7	-0.8	120	100	200
7/01/87	2620	0340	0348	-0.9	-0.6	-0.18	210	100	120
7/01/87	2880	0800	0850	-0.245	-0.92	-1.1	140	140	200

CH4 check with Gastech model 1939-OX (LEL scale)

DATE	TIME MIL	CH4 PROBE S	O2 PROBE S	CH4 PROBE M	O2 PROBE M	CH4 PROBE D	O2 PROBE D
6/29/87	2040	0	18	0	19	0	19
6/30/87	0812	0	18	0	19	0	19
6/30/87	2047	0	18	0	20	0	18
7/01/87	0850	0	18	0	19	0	18

6.0 CONCLUSIONS

The offsite control wells installed in the surrounding neighborhood of the Midway Landfill have proven successful in protecting nearby structures from the seepage of migrated landfill gas. The offsite control wells, especially the larger ones, have also been successful in reducing the concentrations of methane gas which has migrated from the landfill to form large reservoirs offsite.

As a result of this, many offsite control wells have been shut down due to extremely low methane concentrations recorded over the past several months in monitoring probes nearby. Due to the influence of the onsite migration control system, it is not expected that landfill gas will return to these areas causing the offsite control wells to be turned back on. These probes will continue to be monitored however, and the control wells turned back on if any significant rise in methane levels is detected.

REFERENCES

Eaton, D. L. 1986 (April). Evaluation of Potential Health Effects Associated with Off-Site Gas Extraction Systems at the Midway Landfill. Ad Hoc Committee on Midway Landfill Hazards, Department of Environmental Health, University of Washington, Seattle, Washington.

APPENDIX C-1

WELL LOGS FOR CONTROL WELLS C-1 THRU C-5

TERRA ASSOCIATES, Inc.
Geotechnical Consultants

March 5, 1987
Project No. T-250

Mr. Clyde Moore
Parametrix, Inc.
13020 Northup Way, Suite 8
Bellevue, Washington 98005

Subject: Off-Site Gas Control Wells
Midway Landfill Gas Migration Control System
Subcontract Agreement PMX 55-1550-09 (Task 5)

Dear Clyde:

Supplement No. 1 to Agreement No. G85-19 between Parametrix, Inc., and the Engineering Department of the City of Seattle required the design and installation of five gas control wells in the community neighboring the Midway Landfill. By Subcontract Agreement PMX 55-1550-09, Parametrix assigned part of the work under Supplement No. 1 to Terra Associates, Inc. This report describes the work accomplished by our firm.

SUMMARY

Five gas control wells, C-1 through C-5, were installed at the approximate locations shown on the Vicinity Map, Figure 1. All five wells are located on private property, three at single-family residences and two at the rear of commercial buildings. The well locations were selected by Parametrix and the City after negotiating with the respective property owners. At each site, the exact well location was determined with the consent of the owner after the drill rig arrived.

The work of installing the gas control wells was assigned to Terra Associates, Inc. Our work included:

1) Assuring that the boreholes would clear all utilities;
2) Drilling the necessary boreholes and sampling the soil removed;
3) Reporting the subsurface conditions encountered;
4) Providing and installing slotted well screen and gravel pack;
5) Providing and installing vaults, fans and vent pipe; and
6) Providing and installing all necessary electrical equipment.

15301 N.E. 90th Street • Redmond, Washington 98052 • **Phone: 881-5570**
Mailing Address: P.O. Box 3338 • Redmond, Washington 98073

The scope of our work did not include gas or water sampling, or soil analyses. All our work was carefully coordinated with Parametrix, Inc.

Figure 2 shows a typical gas control well and its associated draft fan, vent pipe and power supply. The fans are housed in plastic electrical vaults with locked covers. In order to reduce noise levels and increase security, the vaults were placed partially below ground. The well heads are connected to the suction side of the fans. The gases collected from the wells are blown through vent pipes that extend five or more feet above the roof eaves. Each fan has metered power. A cut-off switch has been placed at a convenient location within sight of each fan vault.

The drilling work required to install the gas control wells began on December 23, 1985. The fifth well installation was substantially complete by February 7, 1986.

The Appendices to this summary report describe in more detail the work assigned to Terra Associates, Inc. Appendix A contains a description of the drilling methods used to make the eight-inch-diameter boreholes. Subsurface conditions encountered at the five boreholes are described in Appendix B. The gas control wells are described in Appendix C. Schematics of each well, fan and vent installation are presented in Appendix D.

The following figures and appendixes are included and complete this report:

Figure 1	Gas Control Wells Location Plan
Figure 2	Schematic Diagram - Gas Control Well
Appendix A	Drilling Equipment and Procedures
Appendix B	Subsurface Conditions
Figures B.1 through B.5B	Gas Migration Logs
Appendix C	Gas Control Wells
Appendix D	Gas Control System Installations
Figure D.1	Location Plan
Figures D.2 through D.6	Gas Control Well Logs

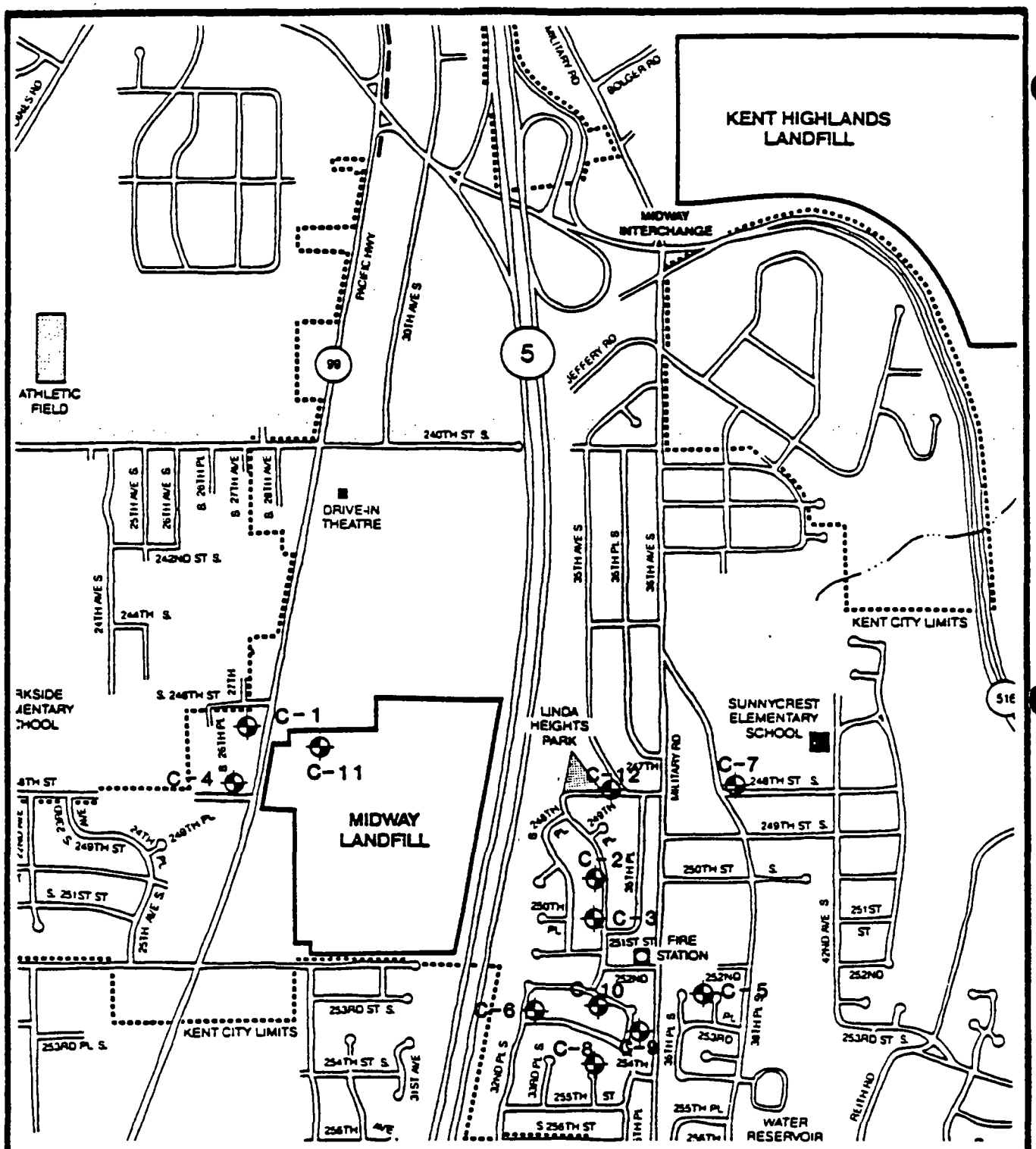
We appreciate the opportunity to assist you on this project. Please contact us whenever we may be able to help and please call if you have any questions concerning our work reported in this letter.

Sincerely yours,

TERRA ASSOCIATES, INC.

Anil Butail, P.E.
President

WB/AB:mf
enclosures



LOCATION PLAN

C-5 Gas Control Well Location

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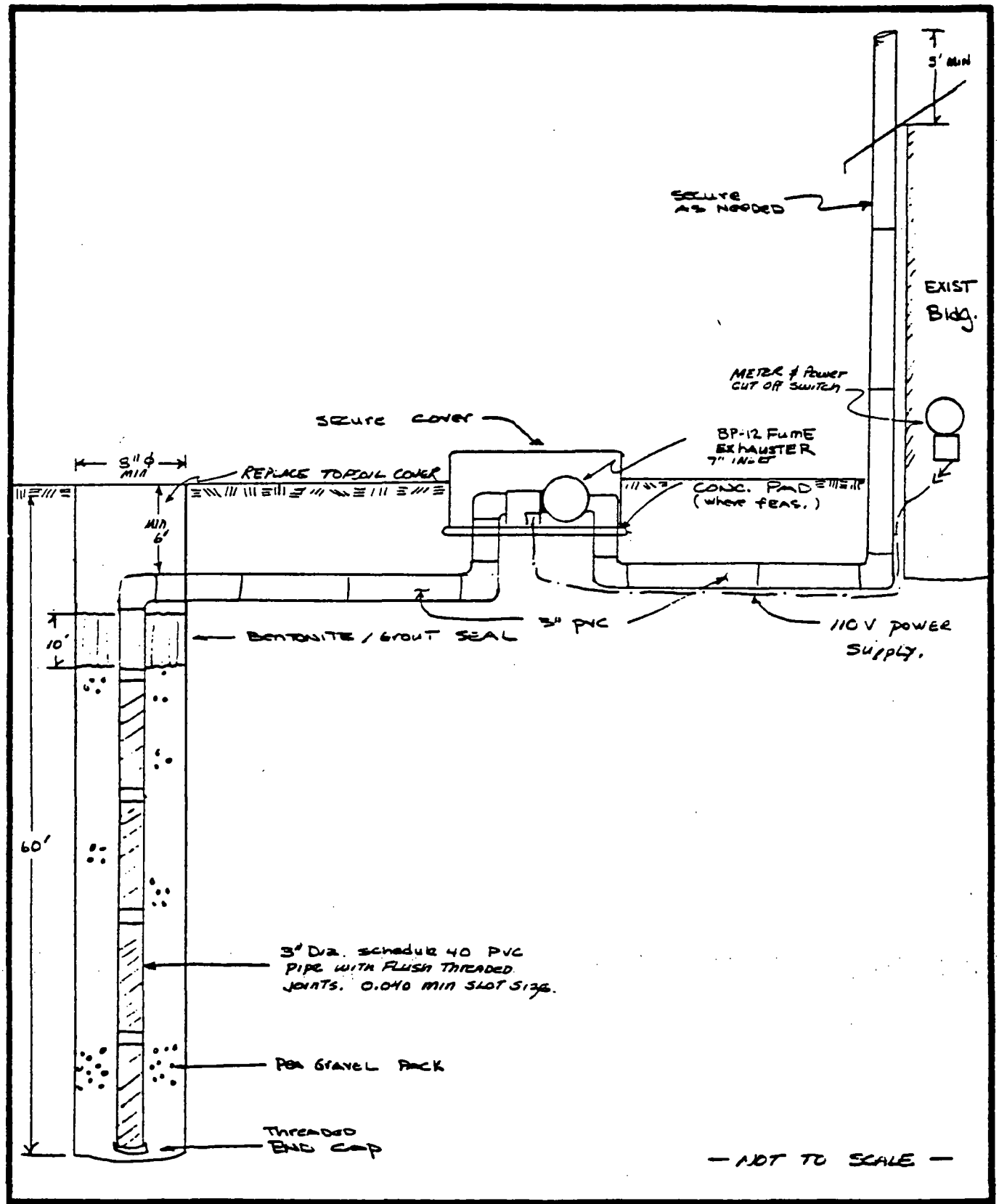
GAS CONTROL WELLS
MIDWAY, Wa.

Proj. No. 250	Date Feb.85	Figure 1



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SCHEMATIC DIAGRAM GAS CONTROL WELL MIDWAY Wa.

Proj. No. 250	Date Feb. 85	Figure 2

A P P E N D I X A

DRILLING EQUIPMENT AND PROCEDURES

APPENDIX A

DRILLING EQUIPMENT AND PROCEDURES

Five gas control wells eight inches in diameter were completed during this phase of the work under Subcontract Agreement PMX 55-1550-09. The tasks of drilling the boreholes and completing the in-ground well installations were subcontracted to Tacoma Pump and Drilling, Inc. All their work was closely supervised by an experienced engineering geologist from Terra Associates, Inc.

The boreholes were advanced using a top-drive rotary drill rig. Compressed air was used to remove the cuttings. To support the boreholes, eight-inch-diameter steel casing was driven using a pneumatic hammer. The wells were installed to depths of sixty feet or more. As the boreholes were backfilled with well screen and gravel pack, the air hammer was reversed and used to pull the casing. To assure the boreholes would not collapse as the casings were being withdrawn, the pea gravel level was maintained a few feet inside the casings.

Our engineering geologist maintained a log of each borehole, collected samples of cuttings, and supervised the installation of each well. At each location, the cuttings were removed and taken to Midway Landfill for disposal.

The samples of cuttings taken were visually classified in accordance with the Unified Soil Classification System, placed in closed containers and taken to our laboratory for storage. The borehole logs in Appendix B report the results of this visual classification. No further examination or testing of the soil samples has been authorized.

Because gas-bearing strata penetrated by the boreholes may be closed off by the casings and because the large volumes of compressed air pumped down the holes while the boreholes are being advanced suppress the evolution of other gasses that may be present, methane was not detected in significant quantities at any well location until after the drilling had been completed.

A P P E N D I X B

SUBSURFACE CONDITIONS

APPENDIX B

SUBSURFACE CONDITIONS

No samples of in-place soil were obtained during the performance of this work. At each gas control well borehole, an engineering geologist from Terra Associates, Inc. observed the cuttings blowing from the casing exhaust port and periodically classified representative samples. Borehole logs based on only the cuttings are reported on Figures B.1 through B.5. Because the cuttings cannot show abrupt changes in the soil, the strata lines shown on the logs are only approximations.

In general, the soils encountered in the well boreholes are tills underlain by advance outwash. At Well C-1, the till is overlain by about 15 feet of sandy fills with wood. The soils at this location to depths of 25 feet or more have a noticeable petroleum odor.

The tills are gravelly silty sands with cobbles. Because these soils were laid down beneath a glacier, the various grain sizes are thoroughly mixed and the material is dense with low porosity. The tills encountered ranged in thickness from seven to 15 feet.

The advance outwash soils are believed to have been deposited by glacial melt-water streams. Consequently, they exhibit the grain-size sorting characteristic of fluvial soils. Because they were overridden by the glacier after they were deposited, they also typically are very dense.

Outwash material observed in the borehole cuttings ranged from silty sands to sandy gravels with occasional cobbles. The finer-grained material generally was observed closer to the overlying till. It was also noted that the sandy gravels occurred at greater depth in the boreholes east of Midway Landfill than in the boreholes to the west. Because the coarser-grained sandy gravels may be the principal gas-bearing strata, penetration of such strata by the gas control wells was considered desirable. For this reason, Well C-5 was drilled 20 feet beyond its intended maximum depth.

The regional groundwater table was not observed in any of the boreholes. At Well C-3, perched water was encountered within the upper few feet of weathered till. No additional groundwater was observed after the casing was advanced below depth ten feet.

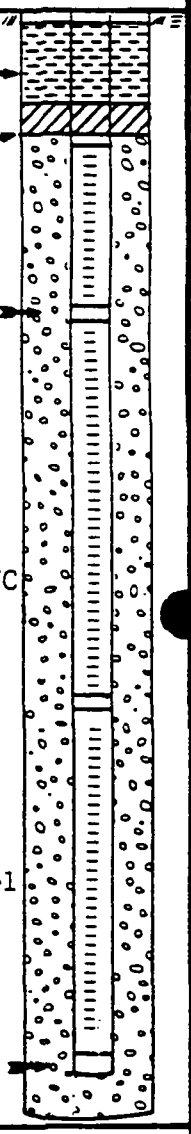
GAS CONTROL WELL NO.1

Logged By DW

Date 12-23-85

Surface Elev. 330

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
		2 inches Asphaltic Concrete			
	SM	Brown, silty, gravelly SAND with wood. (Fill) Strong petroleum odor	5, 10		Cement Grout; Bentonite Seal
	SM	Grey, gravelly, silty SAND. Petroleum odor	15		Flush Threaded Coupling
	SM	Brown, gravelly, silty SAND. Petroleum odor	20, 25		
	GM GP	Brown, silty, sandy GRAVEL with cobbles to slightly silty, sandy GRAVEL with cobbles.	30, 35, 40, 45, 50, 55		3" Dia.PVC Slotted Screen; Pea Gravel Pack; Threaded End Cap



Well terminated at Elevation 269.5 on 12-30-85.

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GAS MIGRATION CONTROL PROJECT MIDWAY, Wa.

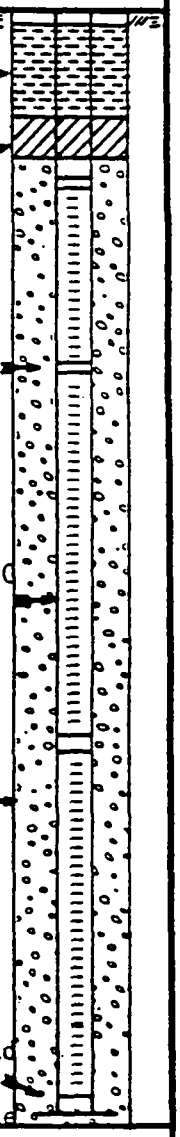
Proj. No. 250	Date Jan 87	Figure B.1

GAS CONTROL WELL NO.2

Logged By DW
Date 12-31-85

Surface Elev. 420 Approx.

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
		Topsoil			Cement Grout
	SM	Grey, gravelly, silty SAND	5		Bentonite Pellets
			10		
			15		
	SM	Brown/tan, silty, fine to medium SANDS with occasional gravel.	20		Flush Threaded Coupling
			25		
			30		3" Dia. Slotted 0.10 PVC Screen
			35		
			40		Pea Gravel Pack
			45		
			50		
			55		Threaded End Cap Keeper Plate
	GM	Grey, sandy GRAVEL with silt.			



Well terminated at 60.0 feet below existing grade.

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GAS MIGRATION CONTROL PROJECT
MIDWAY, Wa.

Proj. No. 250	Date Jan 87	Figure B.2

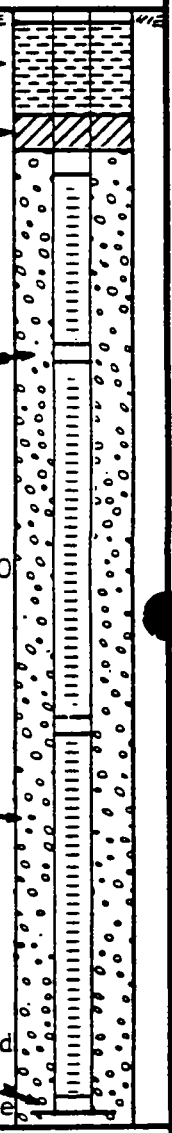
GAS CONTROL WELL NO.3

Logged By DW

Date 12-30-85

Surface Elev. 425 Approx.

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
		Grass/Sod			Cement Grout
	SM	Grey, gravelly, silty SAND	5		Bentonite Pellets
			10		
	SP	Grey/brown, clean, fine to medium SAND, with occasional gravel.	15		Flush Threaded Coupling
			20		
	GP	Grey, sandy GRAVEL	25		
			30		3" Dia. 0.10 Slotted PVC Screen
			35		
	SM/SP	Brown, slightly silty to clean SAND with occasional gravel.	40		Pea Gravel Pack
			45		
			50		
			55		Threaded End Cap Keeper Plate
	GM	Brown, sandy gravel with some silt.			



Well terminated at 60.0 feet below existing grade.

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GAS MIGRATION CONTROL PROJECT MIDWAY, Wa.

Proj. No. 250	Date Jan 87	Figure B.3

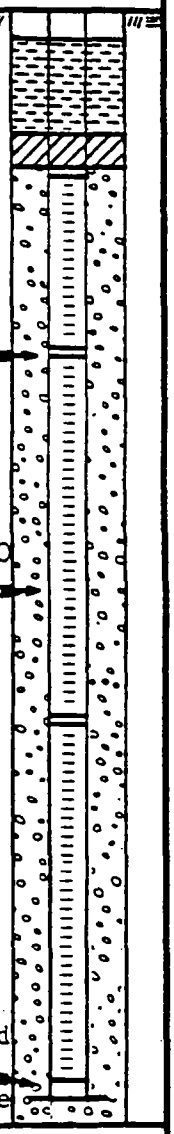
GAS CONTROL WELL NO.4

Logged By DW

Date 1-21-86

Surface Elev. 350 Approx.

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
		Sod - Topsoil			Cement Grout
	SM	Grey, gravelly, silty SAND. (Till)	5		Bentonite Pellets
	SM	Grey/brown, silty, fine to medium SAND with occasional gravel to silty, sandy GRAVEL with cobbles.	10, 15, 20, 25, 30		Flush Threaded Coupling; 3" Dia. 0.10 Slotted PVC Screen
	SM	Grey, gravelly, silty SAND.	35		
	SM /GM	Brown, slightly silty, fine to medium SAND to silty, sandy GRAVEL.	40, 45		Pea Gravel Pack
	GM	Tan, silty, sandy GRAVEL with cobbles and occasional boulder.	50, 55		Threaded End Cap; Keeper Plate



Well terminated at 60.0 feet below existing grade.

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GAS MIGRATION CONTROL PROJECT MIDWAY, Wa.

Proj. No. 250	Date Jan 87	Figure B.4

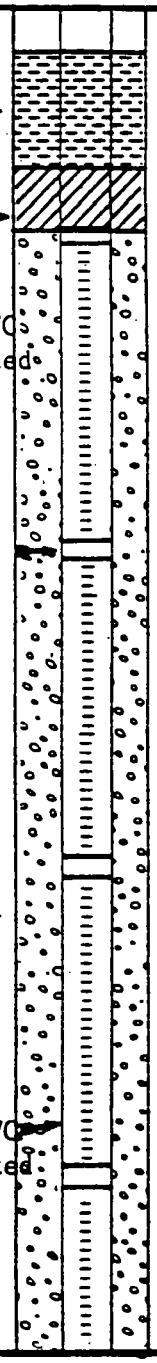
GAS CONTROL WELL NO.5

Logged By DW

Date 2-3-86

Surface Elev. 420 Approx.

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown becomes grey, gravelly, silty SAND with cobbles. (Till)	5, 10		Cement Grout; Bentonite Seal; 3" Dia. PVC .028 Slotted Screen
	GM	Grey, silty and sandy GRAVELS.	15		Flush Threaded Coupling
	SM/SP	Grey, slightly silty, fine to medium SAND with gravel.	20, 25, 30		Pea Gravel Pack
	SM	Brown, silty, fine to medium SAND with occasional gravel.	35, 40		3" Dia. PVC 0.10 Slotted Screen



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GAS MIGRATION CONTROL PROJECT MIDWAY, Wa.

Proj. No. 250	Date Jan 87	Figure B.5A

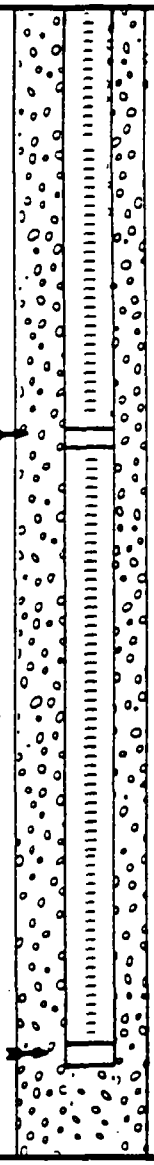
GAS CONTROL WELL NO.5 CONT.

Logged By DW

Date 2-3-86

ELEV. 420 Approx.

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown, silty, fine to medium SAND with occasional gravel.	45 50 55		Flush Threaded Coupling
	GM	Grey, silty, sandy GRAVEL and cobbles.	60 65 70 75		Pea Gravel Pack Threaded End Cap



Well terminated at 80.0 feet below existing grade.
Groundwater not encountered.

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Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY, Wa.

Proj. No. 250	Date Jan 87	Figure B.5B

APPENDIX C

GAS CONTROL WELLS

APPENDIX C

GAS CONTROL WELLS

Sketches of the as-built well installations are shown on the borehole logs in Appendix B.

The gas control wells consist of schedule 40 PVC slotted screen three inches in diameter packed in pea gravel. All joints are threaded and flush. The upper section of well pipe is unslotted PVC casing. Wells C-1 through C-4 have fifty feet of screen with slots 0.10 inches wide and six to eight feet of solid pipe at the top. Well C-5 has seven feet of solid casing, 20 feet of screen with 0.028-inch slots and 50 feet of screen with 0.10-inch slots.

The pea gravel well packing was installed to a point a few feet above the uppermost well screen slots. A seal about two feet long made with 50 pounds of bentonite pellets was placed above the pea gravel. Water was added to swell the pellets. Cement grout was placed above the pellets to within approximately one foot of the existing grade.

Although little methane was observed while the boreholes for the gas control well were being drilled, significant amounts were noted after the steel well casings were withdrawn and the wells were being developed. Compressed air was used to dilute the methane until the well could be capped and the gas exhaust system connected.

A P P E N D I X D

GAS CONTROL SYSTEM INSTALLATIONS

APPENDIX D

GAS CONTROL SYSTEM INSTALLATIONS

Figure D.1 shows the approximate location and provides a street address for each of the five gas exhaust systems installed under Subcontract Agreement PMX 55-1550-09. A sketch of each as-built gas exhaust system is presented on Figure D.2 through D.6.

Each gas control well is directly attached to the suction side of a draft fan. PB-12 fans manufactured by Cincinnati Fan and Ventilator Company, Inc., have been used on all installations. The fans have spark-resistant cast aluminum scrolls and impellers. They are driven by 1.5-horsepower sparkproof 110 volt electric motors manufactured by Reliance Electric Company, Inc. The fans and their motors are attacted to steel pedestals using wood and rubber shock mounts.

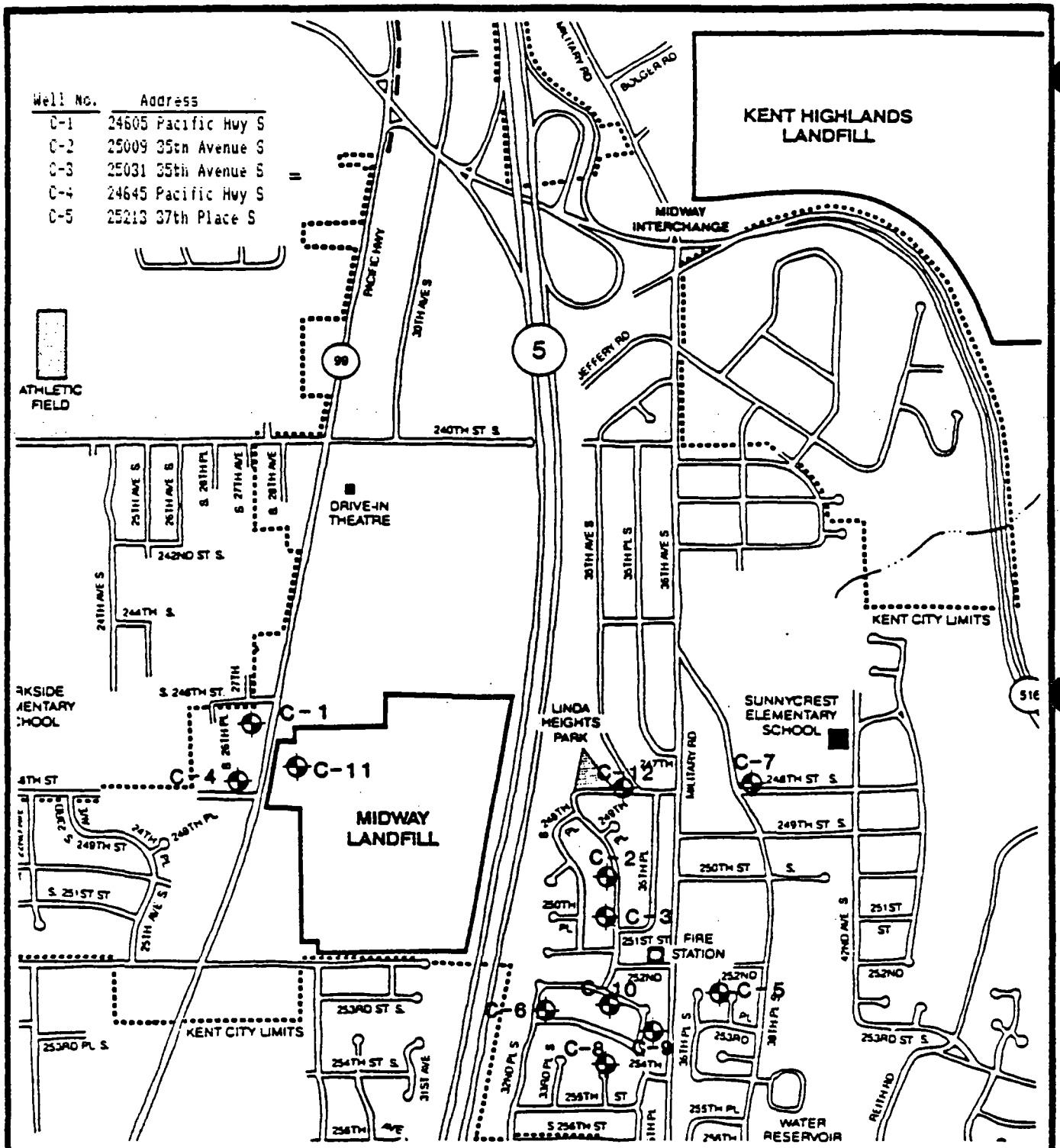
The fans are housed in plastic vaults with lockable covers. For improved noise control and better security, the vaults have been installed partially below the ground surface.

The gas control wells connect to the fan suctions using 3-inch-diameter PVC pipe that runs underground. Rubber reducers are used to connect the pipe to the 7-inch fan inlet flanges. The 5.5-inch fan discharge flanges connect to 3-inch-diameter PVC vent pipes using similar rubber reducers. The reducers attach to the fans and to the pipes with stainless steel hose clamps.

The vent pipes have been secured to nearby building walls using rubber shock mounts. The vents rise at least five feet above the roof eaves. At C-1 and C-2, in order to add to the overall stability of the vent stack, the underground vent pipes were embedded in concrete.

Each fan installation receives power from an existing source. No new power poles were needed. Power meters have been installed, as required by the contract. An electrical cutoff switch has been provided within sight of each vault.

The fan casings have been provided with drains so that condensate and other liquids may be periodically removed. At C-1 through C-4, small drain cocks are located at the bottom of the rubber reducer at the fan discharge. These cocks should be opened occasionally so that any liquids that have collected in the systems may be blown out. C-5 has been fitted with an automatic liquid trap that should require little or no maintenance. Any liquid expelled will drain to a pea gravel sump at the north side of the vault.



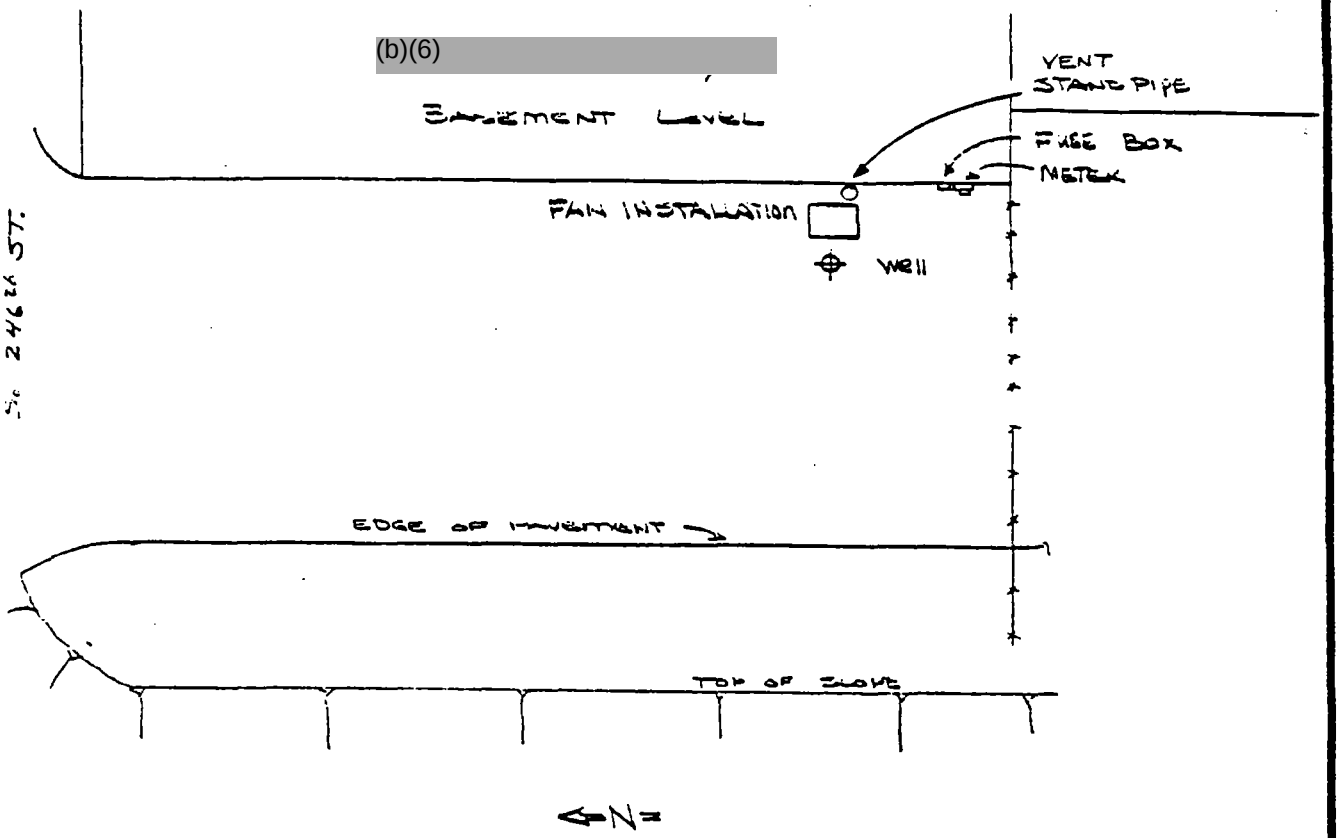
LOCATION PLAN

C-5 Gas Control Well Location

TERRA ASSOCIATES
Geotechnical Consultants

GAS CONTROL WELLS
MIDWAY, Wa.

Proj. No. 250	Date Feb. 86	Figure D.1



AS-BUILT SKETCH

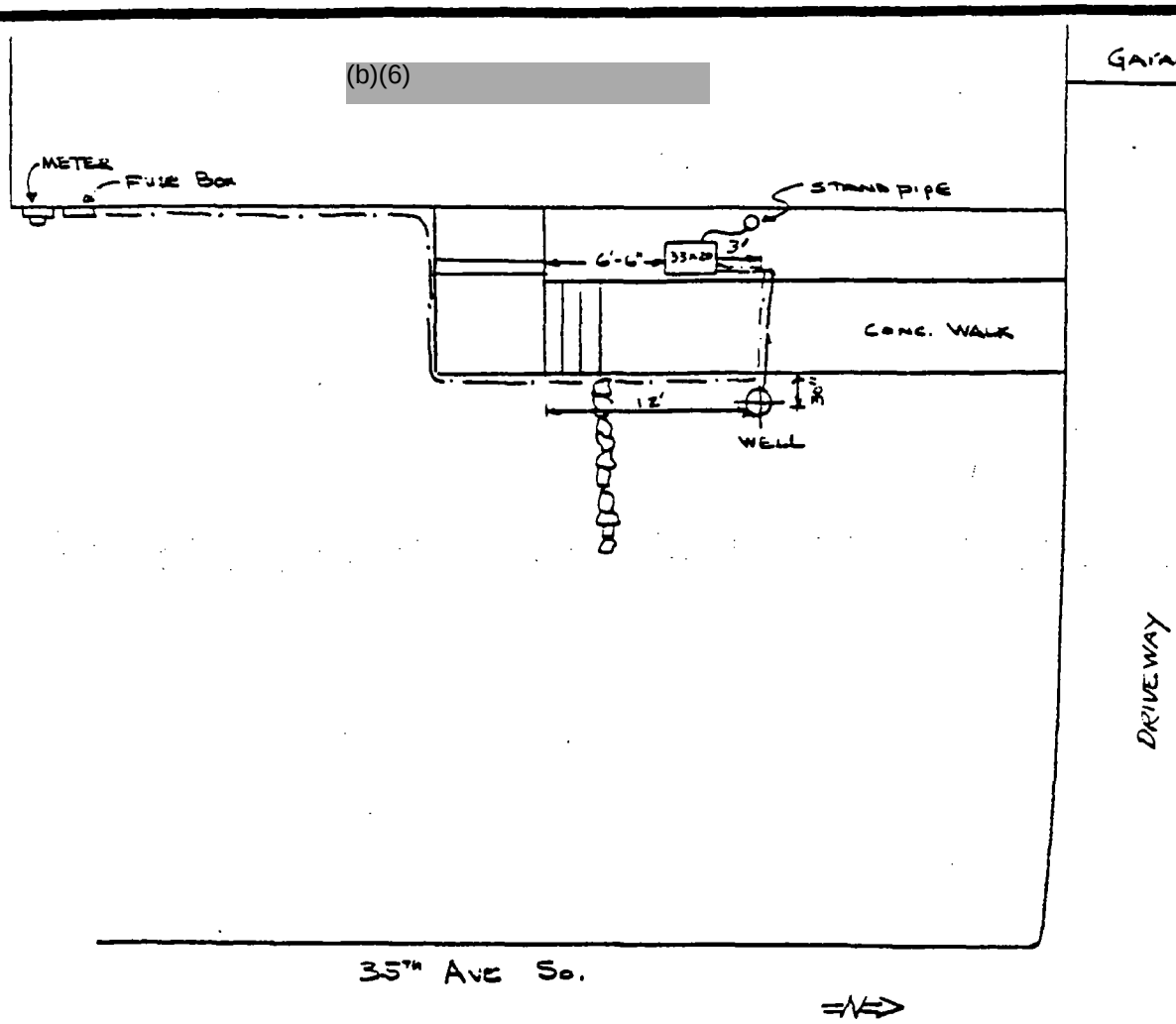
NOTES:

1) FAN WIRED TO 110 VOLT CIRCUIT LOCATED IN PANEL, LAST BAY - SOUTH, North WALL ADJACENT TO ENTRY

2) DRAIN COCK VALVE LOCATED BENEATH OUTLET Rubber REDUCER IN SIDE FAN INSTALLATION

3) Pull - FUSE OPERATES AS FAN ELECTRICAL CUT OFF Requires 1-20 amp delay Type cartridge fuse.

TERRA ASSOCIATES Geotechnical Consultants	GAS CONTROL WELL NO. C-1 MIDWAY, Wa.		
	Proj. No. 250	Date Feb. 86	Figure D.2



AS-BUILT SKETCH

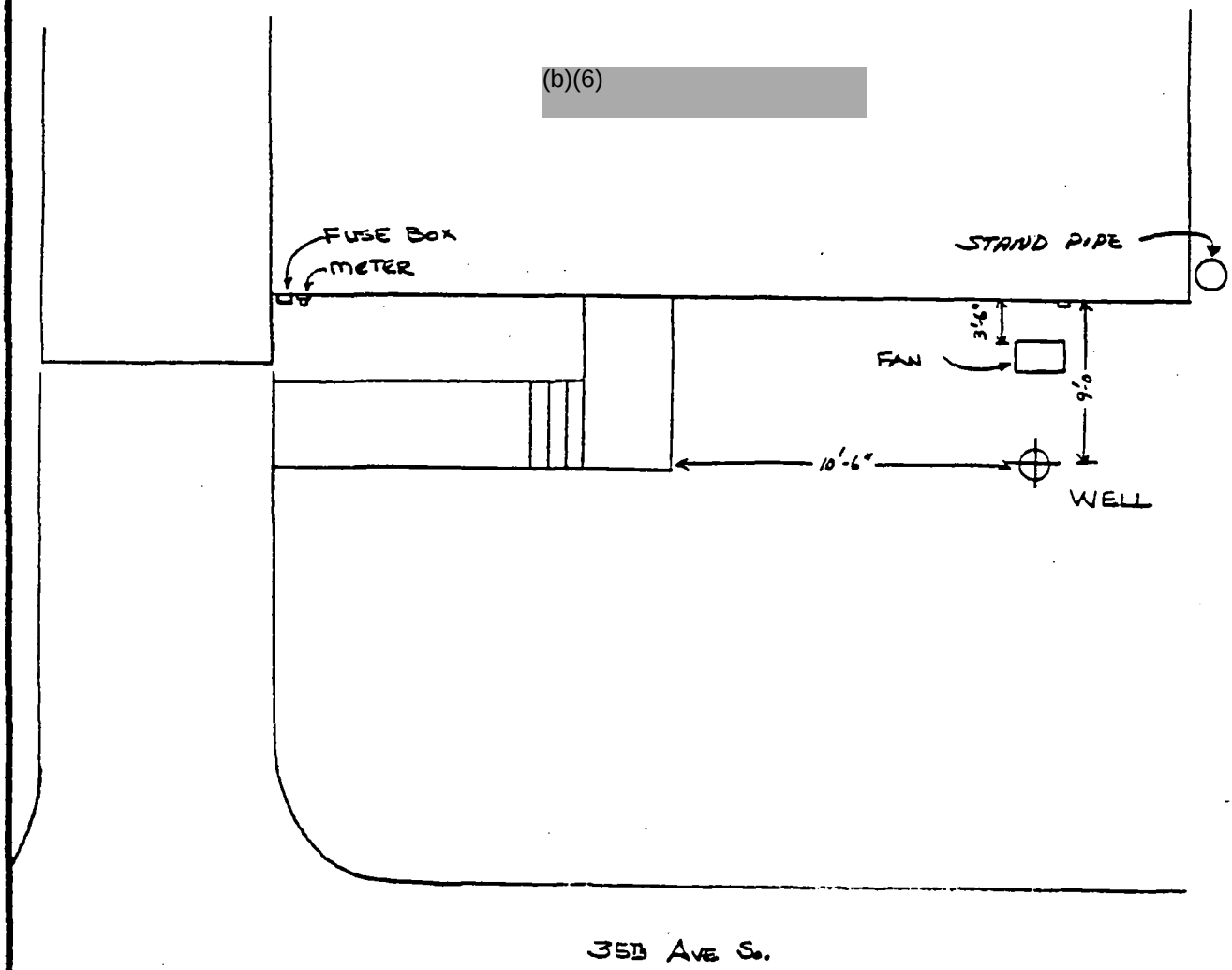
NOTES

1) FAN INSTALLATION WIRED TO HOUSE CIRCUIT PANEL LOCATED IN SOUTH EAST CORNER OF BASEMENT

2) INSTALLATION DRAINCOCKS LOCATED AT OUTLET RUBBER REDUCER AND INLET PIPE ON THE LOWER SIDES.

3) PULL FUSE OPERATES AS ELECTRICAL CUT-OFF REQUIRES 1-20 AMP DELAY ACTION FUSE.

TERRA ASSOCIATES Geotechnical Consultants	GAS CONTROL WELL NO. C-2 MIDWAY, Wa.		
	Proj. No. 260	Date Feb.86	Figure D.3



AS-BUILT SKETCH

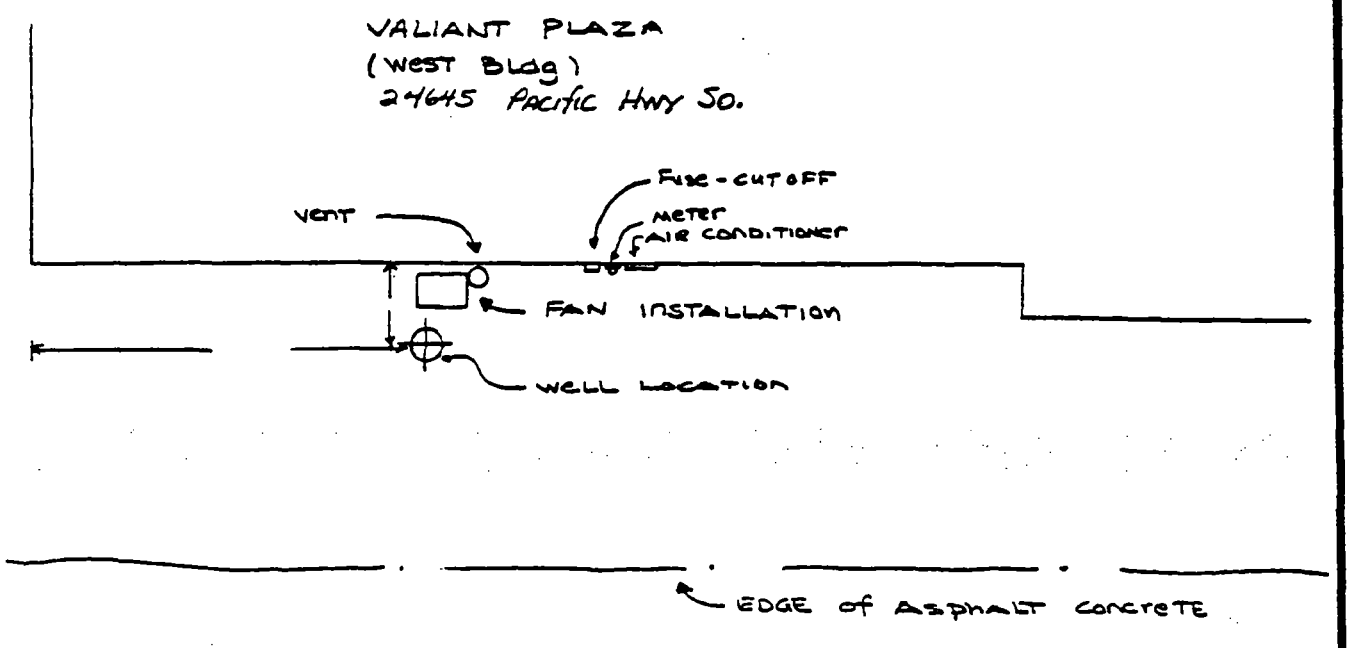
NOTES:

1) FAN INSTALLATION WIRED TO 110 V CIRCUIT & PANEL LOCATED AT SOUTH EAST CORNER OF RESIDENCE

2) DRAIN COCK VALVE LOCATED BENEATH OUTLET (LOWER) RUBBER REDUCER IN SIDE VAULT BOX.

3) PULL FUSE OPERATES AS ELECTRICAL CUT-OFF. REQUIRES 1 - 20 AMP DELAY ACTION CARTRIDGE FUSE

TERRA ASSOCIATES Geotechnical Consultants	GAS CONTROL WELL NO. C-3 MIDWAY, Wa.		
	Proj. No. 250	Date Feb. 86	Figure D.4



AS-BUILT SKETCH

NOTES:

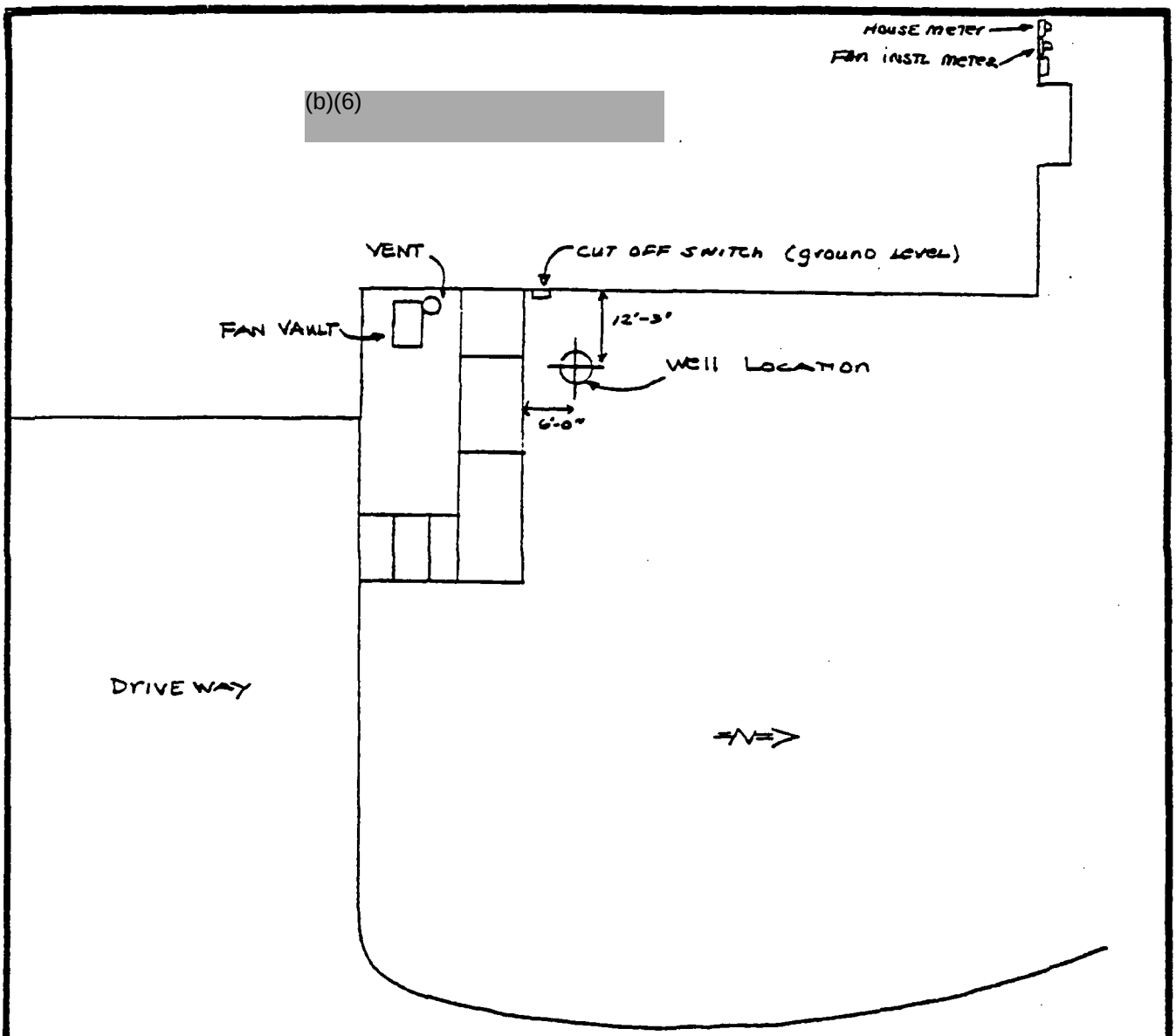
1) FAN WIRED TO 110 V CIRCUIT BREAKER LOCATED IN WEST BUILDING ELECTRICAL SPACE EAST SIDE of BLDG. (Approx CTR) EASTERN MOST PANEL, CIRCUIT BREAKER MARKED.

2) DRAIN COCK LOCATED AT LOWEST POINT, beneath OUTLET RUBBER REDUCER IN SIDE FAN VAULT.

3) TIME DELAY 20 AMP FUSE (1-Required) AND CIRCUIT BREAKER IN MAIN PANEL operates AS CUT-OFF. FAN WIRED TO 110V CIRCUIT.

TERRA ASSOCIATES Geotechnical Consultants	GAS CONTROL WELL NO. C-4 MIDWAY, Wa.		
	Proj. No. 250	Date Feb.86	Figure D.5

(b)(6)



37th PLACE SOUTH

AS-BUILT SKETCH

NOTES:
1) FAN INSTALLATION WIRED TO 220 VOLT HOUSE CIRCUIT BREAKER PANEL, LOCATED AT NORTH WALL OF BASEMENT
2) INSTALLATION HAS SELF DRAINING CONSTANT WATER LEVEL DRAIN TRAP FIXED TO LOWER RUBBER OUTLET COUPLING.
3) CUT OFF SWITCH LOCATED ADJACENT TO NORTH CORNER OF FRONT DOOR STEP.

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GAS CONTROL WELL NO. C-5 MIDWAY, Wa.

Proj. No. 250	Date Feb. 86	Figure D.8

APPENDIX C-2

WELL LOGS FOR CONTROL WELLS C-6 THRU C-13

TERRA ASSOCIATES, Inc.
Geotechnical Consultants

March 5, 1987
Project No. T-250-1

Mr. Clyde Moore
Parametrix, Inc.
13020 Northup Way, Suite 8
Bellevue, Washington 98005

Subject: Off-Site Gas Control Wells
Midway Landfill Gas Migration Control System
Subcontract Agreement PMX 55-1550-09 (Task 7)

Dear Clyde:

Supplement No. 2 to Agreement No. G85-19 between Parametrix, Inc., and the Engineering Department of the City of Seattle required the design and installation of ten gas control wells in the vicinity of the Midway Landfill. By an amendment to Subcontract Agreement PMX 55-1550-09, Parametrix assigned part of the work under Supplement No. 2 to Terra Associates, Inc. This report describes the work accomplished by our firm.

SUMMARY

Ten gas control wells, C-6 through C-15, were installed at the approximate locations shown on the Gas Control Well Location Plan, Figure 1. Well locations were selected by Parametrix and the City. Two wells are on private property. The other seven are on street right-of-way or on property owned by the City. Table I provides street addresses or other information to locate the wells.

The work of installing the gas control wells was assigned to Terra Associates, Inc. Our work included:

1) Assuring that the boreholes would clear all utilities;
2) Drilling the necessary boreholes and sampling the soil removed;
3) Reporting the subsurface conditions encountered; and
4) Providing and installing slotted well screen and gravel pack.

The scope of our work did not include gas or water sampling, soil analyses, or the installation of fans and vent pipes. All our work was carefully coordinated with Parametrix, Inc.

15301 N.E. 90th Street • Redmond, Washington 98052 • **Phone: 881-5570**
Mailing Address: P.O. Box 3338 • Redmond, Washington 98073

The drilling for Well C-6 began on May 14, 1986. All the wells through C-12 were completed by June 4, 1986. After a delay of eleven weeks, work began on Well C-13. The last well, C-15, was completed on September 16, 1986.

The Appendices to this summary report describe in more detail the work assigned to Terra Associates, Inc. Appendix A contains a description of the drilling methods used to make the eight-inch-diameter boreholes. Subsurface conditions encountered at the ten boreholes are described in Appendix B. The gas control wells are described in Appendix C.

The following table, appendixes and figures are included and complete this report:

Table	I	Gas Control Well Locations
Appendix	A	Drilling Equipment and Procedures
Appendix	B	Subsurface Conditions
Figure	1	Gas Control Well Location Plan
Figure	B.1a through B.10b	Gas Control Well Logs
Appendix	C	Gas Control Wells

We appreciate the opportunity to assist you on this project. Please contact us whenever we may be able to help and please call if you have any questions concerning the work reported herein.

Sincerely yours,

TERRA ASSOCIATES, INC.

Anil Butail, P.E.
President

WB/AB:mf

ANIL BUTAIL
STATE OF WASHINGTON
REGISTERED
PROFESSIONAL ENGINEER

Mr. Clyde Moore
March 5, 1987

TABLE I

GAS CONTROL WELL LOCATIONS

WELL NO	LOCATION
C-6	3310 South 253rd Street
C-7	South 248th Street, north shoulder of roadway, 65 feet east of 38th Avenue South
C-8	25406 34th Place South
C-9	25310 35th Place South
C-10	3431 South 252nd Place
C-11	Northeast of Midway Landfill, behind 24700 Pacific Highway South
C-12	3407 South 248th Street
C-13	Military Road at Reith Road 70 feet south of southeast corner
C-14	25447 Pacific Highway South South of Sleep-Aire parking lot
C-15	3014 259th Court, south side of roadway

A P P E N D I X A

DRILLING EQUIPMENT AND PROCEDURES

APPENDIX A

DRILLING EQUIPMENT AND PROCEDURES

Ten gas control wells eight inches in diameter were completed during this phase of the work under Subcontract Agreement PMX 55-1550-09 (Task 7). The work of drilling the boreholes and completing the in-ground wells was subcontracted to Richardson Well Drilling Company. All their work was closely supervised by an experienced engineering geologist from Terra Associates, Inc.

The boreholes were advanced using a top-drive rotary drill rig. Compressed air was used to remove the cuttings. To support the boreholes, eight-inch-diameter steel casing was driven using a pneumatic hammer. The wells were installed to depths that ranged from 63 to 105 feet. As the boreholes were backfilled with well screen and gravel pack, the air hammer was reversed and used to pull the casing. To assure the boreholes would not collapse while the casings were being withdrawn, the pea gravel level was maintained a few feet inside the casings.

Our engineering geologist maintained a log of each borehole, collected samples of cuttings, and supervised the installation of each well. At each location, the cuttings were removed and taken to Midway Landfill for disposal.

The samples of cuttings taken were visually classified in accordance with the Unified Soil Classification System, placed in closed containers and taken to our laboratory for storage. The borehole logs in Appendix B report the results of this visual classification. No further examination or testing of the soil samples has been authorized.

Because gas-bearing strata penetrated by the boreholes may be closed off by the casings and because the large volumes of compressed air pumped down the holes while the boreholes are being advanced suppress the evolution of other gasses that may be present, methane was not detected in significant quantities at any well location until after the drilling had been completed.

A P P E N D I X B

SUBSURFACE CONDITIONS

APPENDIX B

SUBSURFACE CONDITIONS

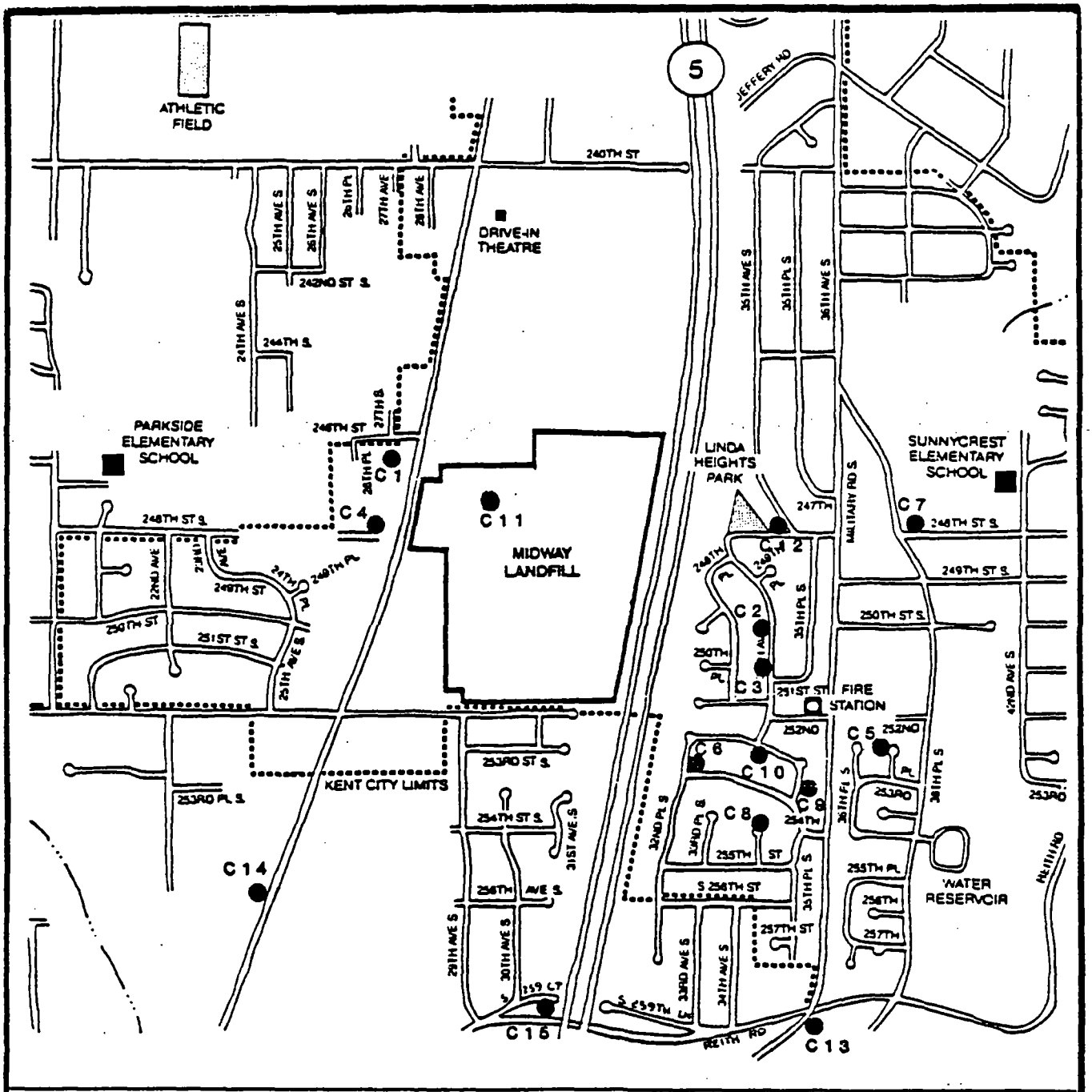
At each gas control well borehole, an engineering geologist from Terra Associates, Inc. observed the cuttings blowing from the casing exhaust port and periodically classified representative samples. No samples of in-place soil were obtained. Borehole logs based on only the cuttings are reported on Figures B.1 through B.10. Because samples taken from the cuttings cannot show abrupt changes in the soil, the strata lines shown on the logs are only approximations.

In general, the soils encountered in the well boreholes are tills underlain by advance outwash. At Wells C-9 and C-11, a few feet of surface fills were identified. The natural tills are gravelly silty sands with cobbles. Because these soils were laid down beneath a glacier, the various grain sizes are thoroughly mixed and the material is dense with low porosity. The tills that could be identified ranged up to 46 feet in thickness. In several wells, the till either was missing or could not be distinguished from the underlying silty outwash materials.

The advance outwash soils are believed to have been deposited by glacial melt-water streams. Consequently, they exhibit the grain-size sorting character-istic of fluvial soils. Because they were overridden by the glacier after they were deposited, they typically are nearly as dense as the overlying till.

Outwash material observed in the borehole cuttings ranged from silts to sandy gravels with occasional cobbles. The finer-grained material generally was observed closer to the overlying till. It was also noted that the sandy gravels occurred at greater depth in the boreholes east of Midway Landfill than in the boreholes to the west. Because the coarser-grained sandy gravels may be the principal gas-bearing strata, penetration of such strata by the gas control wells was considered desirable. For this reason, several wells were drilled to greater depth then anticipated.

Boreholes that penetrated to sufficient depth encountered what is probably the regional water table at approximately Elevation 265 to 280 feet. The water was usually observed in a semi-confined aquifer encountered near the bottom of the boreholes. In several boreholes, slight seepage from perched water tables was also observed.



GAS CONTROL WELL LOCATION PLAN

N

SCALE IN FEET

0 1,000 2,000

● C4 GAS CONTROL WELL LOCATION

TERRA ASSOCIATES

Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT
MIDWAY LANDFILL
KING COUNTY, WASHINGTON

Proj. No 250-1	Date 1-87	Figure 1

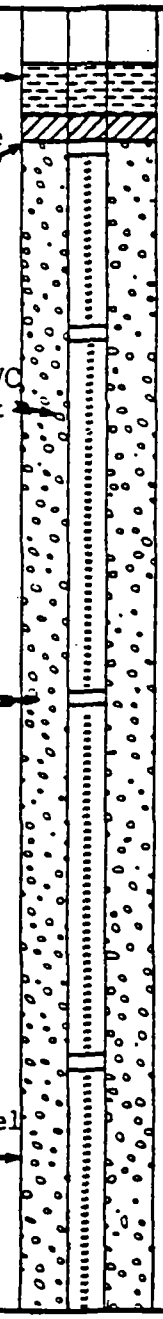
GAS CONTROL WELL NO.6

Logged By DW

Date 5-14-86

ELEV. 430+

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Grey gravelly silty SAND (Till)	5, 10, 15, 20, 25, 30		Cement grout; Bentonite seal; 3" Dia.PVC 0.10 Slot
	SM	Grey/tan silty fine to medium SAND with gravel.	35, 40, 45, 50, 55, 60, 65		Flush Threaded Coupling; Pea Gravel Pack



Well log continued

TERRA ASSOCIATES

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GAS MIGRATION CONTROL PROJECT MIDWAY WA.

Proj. No. 250-1	Date 1-87	Figure B.1a

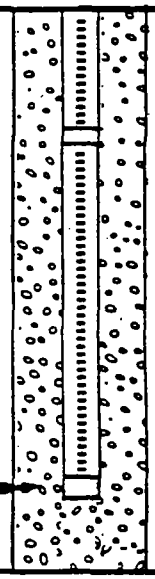
GAS CONTROL WELL NO.6

Logged By DW

Date 5-14-86

ELEV. 430+

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Grey/tan silty fine to medium SAND with some gravel.	75 80		
	GM	Grey silty sandy GRAVEL to clean sandy GRAVEL with cobbles.	85 90 95		Threaded End Cap



Well terminated at 100 feet below existing grade.
Groundwater not encountered.

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GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.1b

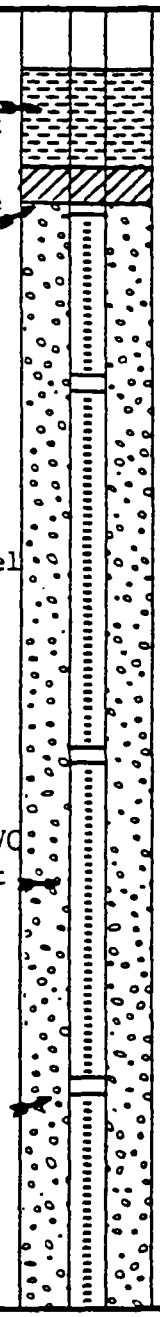
GAS CONTROL WELL NO.7

Logged By DW

Date 5-16-86

ELEV. 435±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Grey silty gravelly SAND, grades to silty fine to medium SAND with some gravel.	5, 10, 15, 20, 25, 30		Cement grout; Bentonite seal; Pea Gravel Pack
	SM	Brown/tan silty fine to medium SAND	35, 40, 45, 50, 55, 60		3" Dia.PVC 0.10 Slot; Flush Threaded Coupling
	GM	Grey silty sandy GRAVELS	65		



Well log continued

TERRA ASSOCIATES

Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.2a

GAS CONTROL WELL NO.7

Logged By DW

Date 5-16-86

ELEV. 435±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
		Brown silty sandy GRAVEL with cobbles.	75 80		Threaded End Cap Keeper Plate

Well terminated at 83 feet below existing grade.
Groundwater not encountered.

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GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.2b

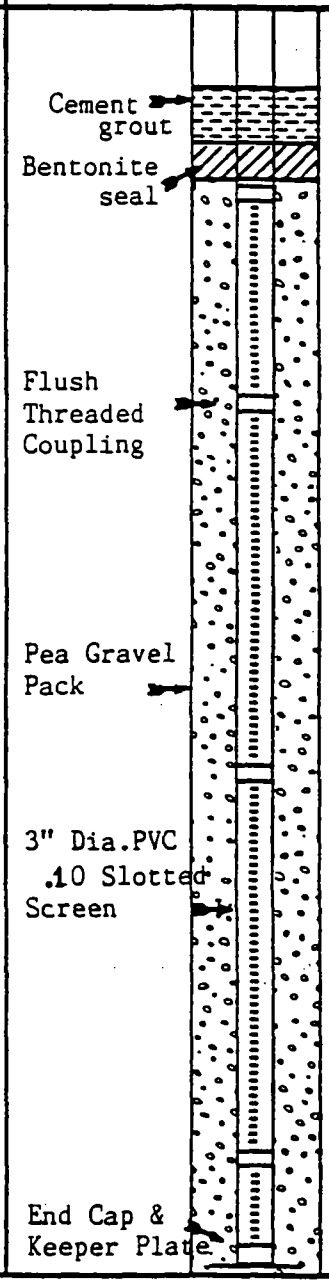
GAS CONTROL WELL NO.8

Logged By DW

Date 5-19-86

ELEV. 430±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Grey gravelly silty SAND. (Till)	5, 10, 15, 20		Cement grout; Bentonite seal; Flush Threaded Coupling
	SM	Brown silty fine to medium SAND with occasional gravel.	25, 30, 35, 40, 45		Pea Gravel Pack; 3" Dia.PVC .10 Slotted Screen
	GM	Brown silty sandy GRAVEL with cobbles.	50, 55, 60, 65		End Cap & Keeper Plate



Well terminated at 68.0 feet.
Groundwater not encountered.

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Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.3

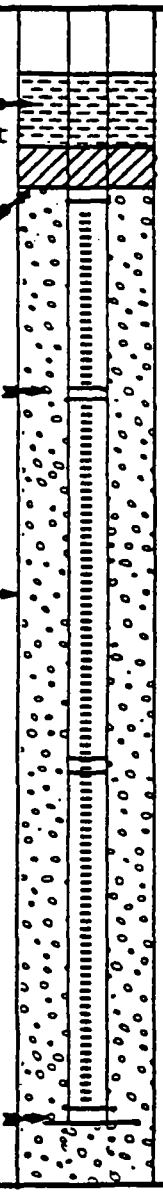
GAS CONTROL WELL NO.9

Logged By DW

Date 5-20-86

ELEV. 410±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
		Brown/tan sandy SILT with clay to silty gravelly SAND (Fill).	5		grout
	SM	Brown silty SAND with gravel, wet.	10, 15, 20, 25, 30, 35, 40, 45		Bentonite seal; Flush Threaded Coupling; Pea Gravel Pack
	SM / GM	Brown silty gravelly SAND to silty sandy GRAVEL with cobbles.	50, 55, 60		Threaded End Cap Keeper Plate



Well terminated at 62'9".
Groundwater not encountered.

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GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

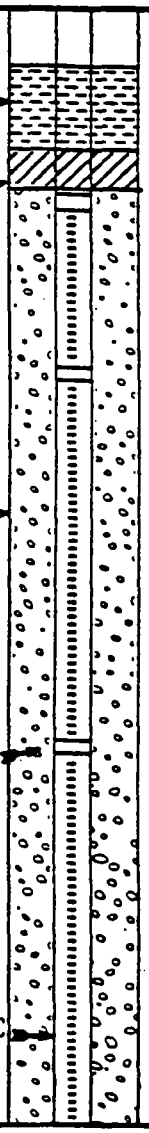
Proj. No. 250-1	Date 1-87	Figure B.4

GAS CONTROL WELL NO.10

Logged By DW
Date 5-22-86

ELEV. 430±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Grey gravelly silty SAND (Till)	5, 10, 15, 20, 25, 30, 35		Cement grout; Bentonite seal; Pea Gravel Pack
	SM	Brown silty fine to medium SAND	40, 45, 50, 55		Flush Threaded Coupling; 3" Dia.PVC 0.10 Slot



Well log continued

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Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.5a

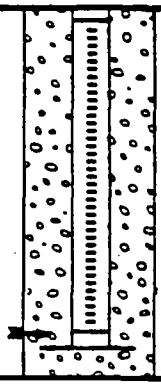
GAS CONTROL WELL NO.10

Logged By DW

Date 5-22-86

ELEV. 430±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown silty fine to medium SAND	65		
	GM	Brown becomes grey slightly silty sandy GRAVEL with occasional cobbles.	70 75		End Cap Keeper Plate



Well terminated at 80 feet below existing grade.
Groundwater not encountered.

TERRA ASSOCIATES
Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.5b

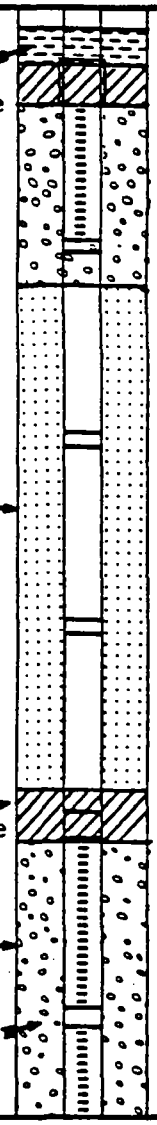
GAS CONTROL WELL NO.11

Logged By DW

Date 6-2-86

ELEV. 350±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Grey silty gravelly SAND (Fill) Grey/tan gravelly silty SAND, wet to silty gravelly SAND. Light seepage encountered between 20 and 40 feet.	5 10 15 20 25 30 35 40		Cement grout Bentonite seal Native Sandy Silt and Clay Backfill
	ML	Brown/tan gravelly sandy SILT	45		Bentonite seal
	ML	Blue/grey clayey SILT with sand and gravel.	50		Pea Gravel
	GM	Tan silty sandy gravel with occasional cobbles.	55		Threaded Joint



Well log continued

TERRA ASSOCIATES

Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.6a

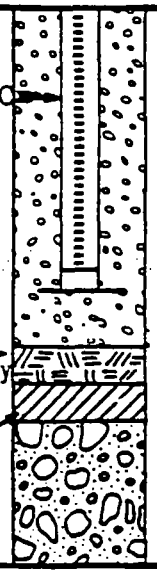
GAS CONTROL WELL NO.11

Logged By DW

Date 6-2-86

ELEV. 350±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM	Tan silty sandy GRAVEL with occasional cobbles.	65 70 75 80 85		3" Dia. Slotted PVC Native Clay Backfill Bentonite Seal Native Gravel
	GP	Clean sandy GRAVEL			



Well terminated at 90 feet below existing grade.
Groundwater encountered at 88 feet during drilling rising to 73 feet.

TERRA ASSOCIATES
Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.6b

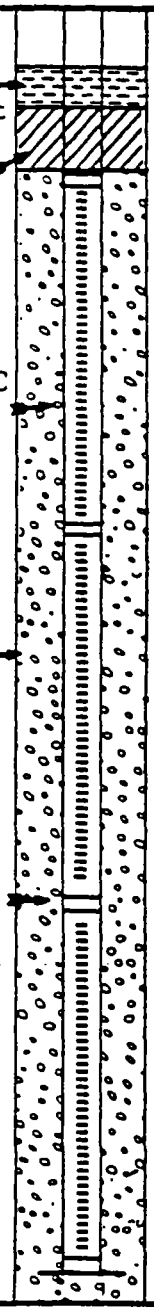
GAS CONTROL WELL NO. 12

Logged By DW

Date 6-4-86

ELEV. 385±

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown silty SAND with gravel Light groundwater seepage at 20 feet	5, 10, 15, 20, 25		Cement grout Bentonite seal 3" Dia.PVC 0.40 Slot
	GM	Grey slightly silty sandy GRAVEL with occasional cobbles at depth	30, 35, 40, 45, 50, 55		Pea Gravel Flush Threaded Joint
	GP	Brown clean sandy GRAVEL with cobbles	60, 65		



Well terminated at 70.0 feet below existing grade.

TERRA ASSOCIATES

Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa.

Proj. No. 250-1	Date 1-87	Figure B.7

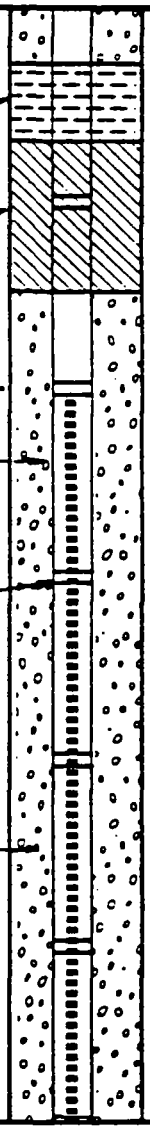
GAS CONTROL WELL NO. 13

Logged By DW

Date ~~8/26/86~~

ELEV. 370

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
		Brown silty SAND with gravel (Fill)	5		Cement Grout
	SM	Brown-tan slightly silty to silty gravelly SAND (Till)	10, 15, 20, 25, 30, 35, 40, 45		Bentonite Seal; 4" Dia. pvc sched. 40 0.040 slot; Threaded coupling; Pea Gravel Filter
	GM	Tan silty sandy GRAVEL, damp.	50, 55		



Well log continued.

TERRA ASSOCIATES

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GAS MIGRATION CONTROL PROJECT MIDWAY Wa

Proj. No. 250-1	Date 10/86	Figure B.8a

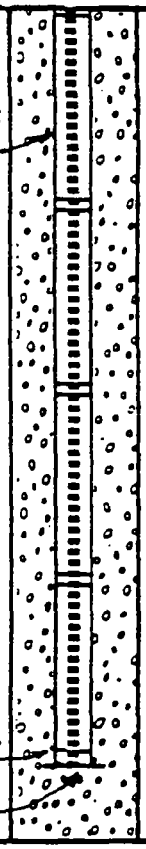
GAS CONTROL WELL NO. 13

Logged By UW

Date 8-26-86

ELEV. 370

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM/ GP	Tan slightly silty sandy GRAVEL with cobbles	65		4" Dia. pvc sched 40 slot .040
			70		
			75		
			80		Pea gravel filter
		3' thick tan silty SAND strata at 97'	85		
			90 ▼	9/9/86	
			95		
			100		Threaded end cap
					Keeper Plate



Well terminated at 105 feet.
Groundwater not observed at time of drilling.
Subsequently measured at 90.0 feet on September 9, 1986.
No methane detected upon completion of well installation.

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GAS MIGRATION CONTROL PROJECT MIDWAY Wa

Proj. No. 250-1	Date 10/86	Figure B.8b

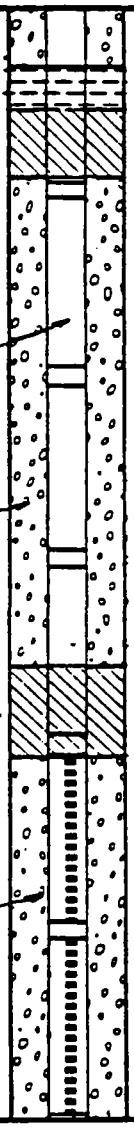
GAS CONTROL WELL NO.14

Logged By DW

Date 9/9/86

ELEV. 320

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	SM	Brown-tan silty SAND with gravel to gray silty gravelly SAND with cobbles. Damp, becomes wet.	5, 10, 15, 20, 25		Cement grout; Bentonite seal; 4" Dia. pvc sched 40; pea gravel backfill
	GP	Gray clean to slightly silty sandy GRAVEL. Seepage encountered below 25'	30, 35		
	SM/ GM	Gray silty sandy GRAVEL to silty gravelly SAND with cobbles.	40, 45, 50, 55 ▽	9/9/86	Bentonite seal; 4" Dia. pvc Sched 40 0.10 slot
	ML	Dark gray clayey sandy SILT			



Well log continued.

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GAS MIGRATION CONTROL PROJECT MIDWAY Wa

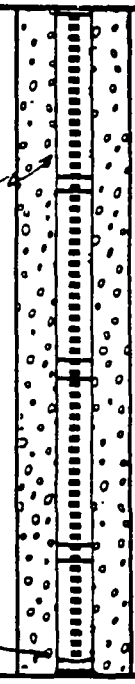
Proj. No. 250-1	Date 1-87	Figure B.9a

GAS CONTROL WELL NO. 14

Logged By DW
Date 9/9/86

ELEV. 320

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	ML				
	GM	Dark gray silty sandy GRAVEL with some clay, damp to wet Grades to: Dark gray silty SAND with some gravel.	65 70 75 80 85 90 95		4" Dia. pvc sched 40 slot 0.10 Pea gravel filter End cap



Well terminated at 96.0 feet.
Groundwater observed at 55.0 feet at completion of drilling.
Methane not observed upon completion of drilling.

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GAS MIGRATION CONTROL PROJECT
MIDWAY Wa

Proj. No. 250-1	Date 1-87	Figure B.9b

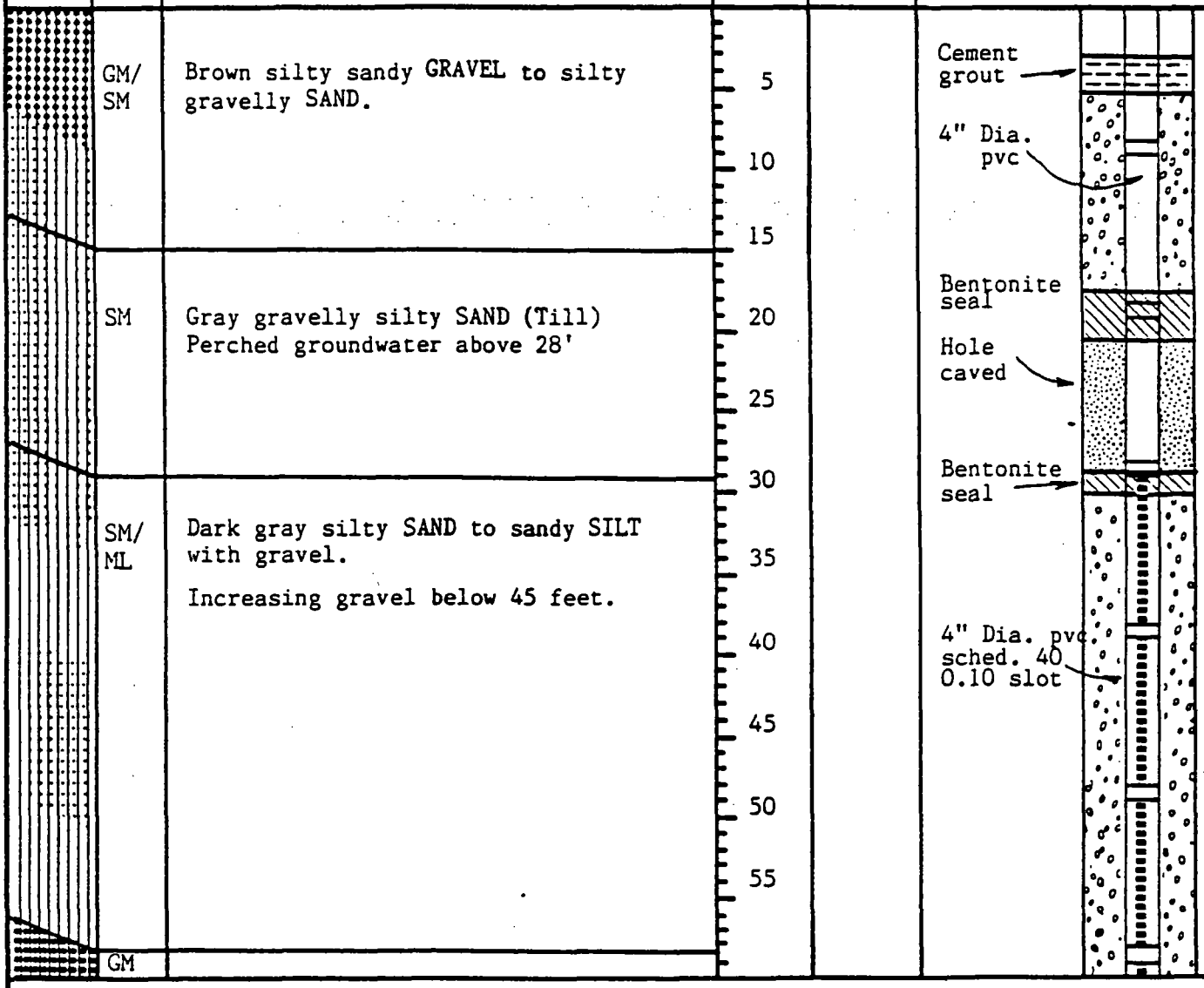
GAS CONTROL WELL NO.15

Logged By DW

Date 9/16/86

ELEV. _____

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM/ SM	Brown silty sandy GRAVEL to silty gravelly SAND.	5, 10, 15		Cement grout; 4" Dia. pvc
	SM	Gray gravelly silty SAND (Till) Perched groundwater above 28'	20, 25, 30		Bentonite seal; Hole caved; Bentonite seal
	SM/ ML	Dark gray silty SAND to sandy SILT with gravel. Increasing gravel below 45 feet.	35, 40, 45, 50, 55		4" Dia. pvc sched. 40 0.10 slot
	GM				



Well log continued.

TERRA ASSOCIATES

Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa

Proj. No250-1	Date 1-87	Figure B.10a

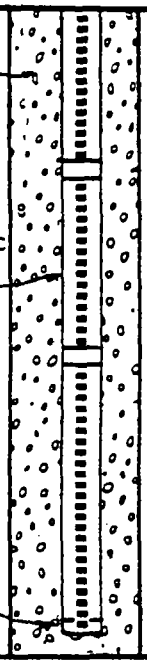
GAS CONTROL WELL NO.15

Logged By DW

Date 9/16/86

ELEV. _____

Graph	US CS	Soil Description	Depth (ft.)	Sample	Well Installation
	GM	Dark gray silty sandy GRAVEL, wet below 75 feet.	65		Pea gravel filter
			70		
		Dark gray silt lense at 76'	75 ▽		4" Dia. pvc Sched 40 0.10 slot
	SM	Dark gray silty sandy GRAVEL, grades to clean	80		
	GP	Sandy GRAVEL, wet.	85		
			90		Threaded end cap



Well terminated at 95 feet.
Groundwater measured at 90.0 feet at time of drilling.
Subsequent measurement at 74.0 feet.
Perched groundwater between 20 to 28 feet.
Methane not detected upon completion of installation.

TERRA ASSOCIATES
Geotechnical Consultants

GAS MIGRATION CONTROL PROJECT MIDWAY Wa

Proj. No. 250-1	Date 1-87	Figure B.10b

A P P E N D I X C

GAS CONTROL WELLS

APPENDIX C

GAS CONTROL WELLS

Sketches of the as-built well installations are shown on the borehole logs in Appendix B.

The gas control wells consist of schedule 40 PVC well screen and solid-wall casing packed in pea gravel. All joints are threaded and flush. The slot width on the well screen is 0.1 inch. Wells C-6 through C-12 have PVC well screen and casing three inches in diameter. Wells C-13, C-14 and C-15 were installed with four-inch-diameter PVC screen and casing. Unslotted PVC casing was used for the uppermost section at each well and at other depths within several wells where a special effort was made to exclude perched water from the wells.

The pea gravel well packing was installed to a point a few feet above the uppermost well screen slots. A seal about two feet long made with at least 50 pounds of bentonite pellets was placed above the pea gravel. Water was added to swell the pellets. Cement grout was placed above the pellets to within a few feet of the existing grade.

After the gas control wells were installed in the boreholes, the gas exhaust system installations were completed by Parametrix, Inc.

Although little methane was observed while the boreholes for the gas control well were being drilled, significant amounts were noted in several boreholes after the steel casings were withdrawn and the wells were being installed. Compressed air was used to dilute the methane until the well could be capped.

APPENDIX D

ONSITE MIGRATION CONTROL WELL SYSTEM TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM

FOR

THE MIDWAY LANDFILL RI

ONSITE MIGRATION CONTROL WELL SYSTEM

Prepared for:

SEATTLE ENGINEERING DEPARTMENT
SOLID WASTE UTILITY

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

March 24, 1988
PMX #55-1550-11 (Task 2.6)

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1.0 INTRODUCTION

The Midway Landfill is located within the City of Kent approximately 15 miles south of the City of Seattle. The landfill occupies a 60-acre site located between Interstate 5 and Highway 99, north of 252nd Street. In January 1966, the City of Seattle leased the site and began using it as a landfill. The landfill received demolition debris from commercial haulers and wood wastes and yard trimmings from the City's transfer stations. Records beginning in 1978 indicate that some industrial wastes also were deposited with the approval of the Seattle-King County Health Department. Information included in EPA's Emergency and Remedial Response Information System (ERRIS) files indicates that the landfill may have received industrial liquid and sludge wastes before 1980. It was closed in 1983, although clean soil materials from excavation projects are still accepted at the site to assist in final grading and cover. During the course of operations at the landfill, an estimated 3 million cubic yards of solid wastes were deposited. The waste covers approximately 40 acres and is over 100 feet deep in places.

From September 1985 through December 1987, the City of Seattle installed a series of gas migration control wells around the perimeter of the site as an emergency measure of final closure. These wells are connected by manifold piping to temporary motor blowers and flares. This system is under continuous operation and portions will be replaced by permanent facilities as part of final closure construction.

The system described in the following report was designed and installed outside of the scope of the Remedial Investigation and is reported in this document for reference.

2.0 EXISTING CONDITIONS

2.1 Offsite Migration of Landfill Gas

In the Fall of 1986, prior to the installation of the Phase II onsite migration control wells, landfill gas was found to have migrated up to 2800 feet from the landfill. Confidence was high that this was not landfill gas which had migrated offsite since the implementation of the Phase I migration control system, rather it was gas which had migrated prior to that time and had formed large reservoirs in the surrounding neighborhoods. The Phase I migration control wells were determined to be inadequate at drawing this migrated gas back to the landfill due to the distance which the gas had traveled and the estimated size of the offsite reservoirs.

The drilling of offsite probes described in Appendix B of this report has shown complex geological conditions around the site (see Appendix G). The landfill site had been an operating gravel pit. The sandy-gravel soils extend away from the site in all directions. In some areas there are sandy-silt layers interspersed. To the south and east there is a relatively low-permeability glacial material cap of silty, sandy gravel forty to sixty feet deep over the gravels. This till cap is also present to a lesser depth in some areas north and west of the site. There are peat deposits west and south-east of the site. The area west of the site and a portion of the freeway corridor east of the site were filled with gravels.

The sandy-gravel soils act as a low-resistance pathway for gas migration. The glacial material cap tends to keep the gas in the gravels, retarding the gas from venting to the atmosphere. The migration has been further pushed along by fluctuations in atmospheric pressure, which expand and contract the gas reservoir. Annual changes in the groundwater table also helped extend the migration.

3.0 OBJECTIVES

3.1 Installation of Gas Extraction Wells to Control Gas Migration

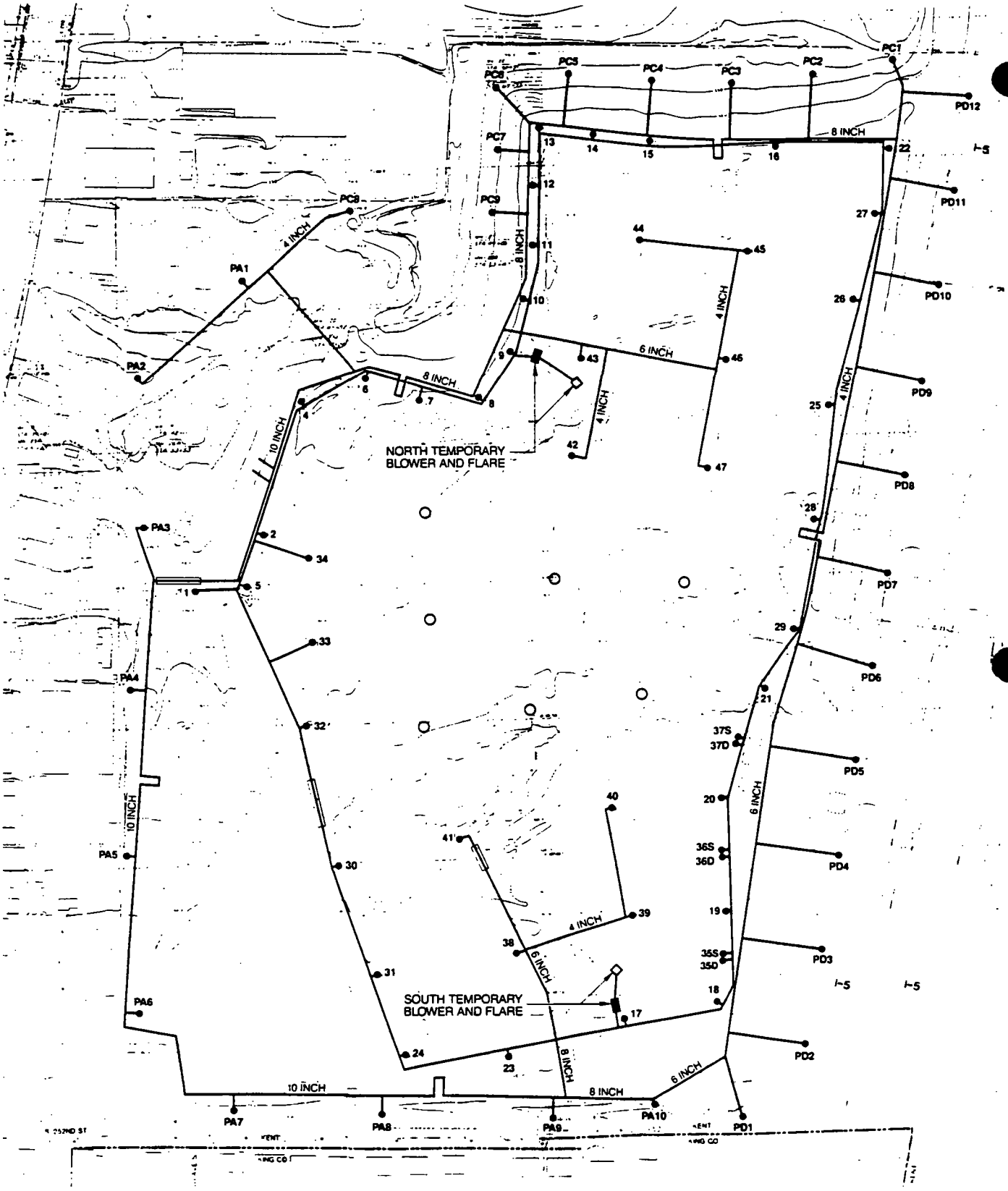
In climates such as the Puget Sound area, anaerobic decomposition and methane generation starts about a year after burial of wet or damp solid waste. The anaerobic bacteria produce methane as a byproduct of digestion of waste. This gas is expelled under slight positive pressure. The volume produced by individual bacterium is small, but many millions of bacteria over a period of time can create the volume and pressure sufficient to cause the gas to move away from the area where it is generated.

At Midway, methane gas was found to have migrated offsite into surrounding neighborhoods and business areas. Therefore, as an emergency remedial measure of final closure at the site, the City of Seattle engaged Parametrix, Inc. in September, 1985, to install several gas extraction vacuum wells along the perimeter of the landfill within the landfill's boundaries. They were connected to manifold piping, vacuum motor blowers and flares to extract the produced landfill gas before it could migrate offsite. Also, it was hoped that these wells would be capable of drawing previously migrated gas back to the landfill. These wells are referred to in this report as Phase I wells.

In September, 1986, the Phase I wells alone were determined to have certain weaknesses in creating an effective "vacuum curtain" around the landfill and thereby preventing landfill gas from migrating offsite. Also, the Phase I wells were unable to draw migrated gas back to the landfill in a reasonable amount of time. Therefore, from November 1986 through December 1987, a series of extraction wells drilled in native soil were installed around the perimeter of the site along with ten wells drilled in the interior of the landfill.

The philosophy of this Phase II design was two fold. The perimeter wells drilled in native soil could be drawn on at a higher vacuum than the Phase I wells drilled in waste. This creates a stronger vacuum curtain to not only prevent produced gas from escaping, but also to draw migrated gas back to the landfill. The ten new interior wells were installed to eliminate interior pressure against the vacuum curtain. The disadvantage of drawing on the wells drilled in native soil is that the concentration of combustible gas in the gas stream from these wells in not adequate to keep the flare lit. Therefore, the interior wells provided the added advantage that the higher BTU content from these wells would assist in maintaining the flare. Also the interior wells and the Phase I wells help in odor control at the site.

Figure D-1 shows the locations of the Phase I and Phase II extraction wells.



SCALE IN FEET

0 100 200

N

● Existing Wells

○ Proposed Wells

——— Existing Pipeline

Figure D-1
Location of Onsite Migration Control Wells

3.2 Extraction of Gas From the Landfill

The vacuum induced in the extraction wells draws the gas generated in the landfill toward the wells. The radius of influence of onsite extraction wells varies dependant upon the surrounding material/geology. Wells drilled in waste could have a large potential radius of influence due to the relative permeability of the in-place solid waste. However, because of the minimal cover currently in place at Midway and the occurrence of air infiltration into the landfill, the extraction wells are operated at a reduced vacuum and produce a limited effective radius of influence. Based on offsite probe data, the in-soil migration control wells have a large radius of influence.

The Phase I and Phase II interior wells and the Phase I wells extract the bulk of the landfill gas produced. The Phase II wells drilled in native soil are designed to extract any landfill gas which escapes the barrier produced by the Phase I wells. The Phase II native soil wells are also operated to draw the offsite reservoirs of migrated landfill gas back to the landfill. Once this migrated gas has been pulled back to the landfill, the vacuums in the Phase II native soil extraction wells can be lessened to a point where, although they are still effective in maintaining a vacuum curtain, the net effect of low BTU gas in the manifold system is reduced.

3.3 Elimination of Offsite Gas Migration

The elimination of offsite landfill gas migration is the primary purpose of the onsite gas migration control system. Generally, this has been accomplished in a four step process. As described above, the Phase I wells were installed in an emergency attempt to extract the bulk of the landfill gas produced. The Phase II interior wells were installed to reduce the "back pressure" on the Phase I wells by extracting the gas produced in the middle of the landfill before it reaches the Phase I perimeter wells and to help control odors. The Phase II native soil wells produce the final barrier against offsite gas migration. These wells are run at a much higher vacuum generally than the wells installed in refuse and therefore create an effective barrier against offsite gas migration.

The fourth step in this process is not actually an elimination of offsite gas migration, rather it is a cleanup of gas which has migrated a great distance offsite. This process involves the installation of offsite control wells in the neighborhoods surrounding the landfill. These wells were installed as emergency remedial measures to eliminate the methane discovered in the basements and crawlspaces of homes and businesses near the landfill. These offsite control wells are discussed in detail in Appendix C of this report. Briefly, the offsite control wells are individual wells attached to small motor blowers which produce a vacuum in the surrounding soil, protecting the structures they are placed near, and removing gas from the surrounding soil. The successful performance of these offsite control wells caused the City to install several larger control wells in areas where large reservoirs of

migrated landfill gas is present in an attempt to remove that gas from the ground.

3.4 Monitoring of Gas Levels and Temperatures

Methane gas and carbon dioxide are produced in the anaerobic decomposition of organic materials. Carbon dioxide, water, and heat are produced in the aerobic decomposition of organic materials. The major constituents of the gas in an onsite migration control well are monitored carefully to determine the amount of anaerobic and aerobic decomposition taking place in the surrounding waste. These data allow the operator to decide how to adjust the well to maintain its safe operation.

The temperature of the gas stream is an important characteristic to monitor in the migration control wells installed in waste. The heat produced in aerobic decomposition can cause the decomposing waste to combust spontaneously if it is not carefully monitored. However, temperature is not as useful an indicator in migration control wells drilled in native soil, because the soil acts to cool the gas stream before it can be sampled.

3.5 Burning Extracted Gas

To reduce the contaminants emitted to the atmosphere by the extraction of landfill gas, the extracted gas is flared. Currently on site, two temporary flares are in use. These flares will be replaced with permanent flares as part of the final landfill closure.

3.6 Avoiding Starting Fires in the Waste

In-waste gas migration control wells installed at the Midway Landfill are monitored at least weekly to assure their optimum performance with respect to control of offsite migration of landfill gas, and to assure that the operation of the well system is not "over stressing" the landfill, (extracting landfill gas too aggressively and thereby creating the potential for landfill fires).

The heat produced by aerobic decomposition can start an underground fire in the deposited solid waste. Therefore, the amount of aerobic decomposition taking place in the landfill is closely monitored to assure safe operation of the system. The safe operation of the system is accomplished by suppressing the amount of air allowed to be exposed to deposited solid waste.

4.0 METHODOLOGY

4.1 Onsite Gas Wells

4.1.1 Location

Thirty-four Phase I migration control wells (see Figure D-1) were installed in waste on 100- to 200-foot centers around the perimeter of the landfill. This spacing was designed to create overlapping spheres of influence between wells. However, many areas of the landfill lack sufficient clay cover to prevent air being drawn through the soil cover into the waste surrounding the wells. This air intrusion results in a low operational vacuum in the wells. Accordingly, these Phase I wells could not influence a large enough area to provide confidence that the vacuum barrier was being produced, especially along the eastern boundary. Therefore, three additional migration control wells, numbers 35, 36, and 37, were installed between existing migration control wells 18, 19, 20, and 21. These three new wells are double-completed, that is, they have two pipes of different depths so that gas flow can be adjusted to minimize air intrusion at the shallow level but maximize vacuum at the deeper level.

Because of the operational limitations of the Phase I migration control wells in preventing offsite migration of landfill gas, forty additional Phase II migration control wells were planned. Forty-one of these Phase II wells, also shown on Figure D-1, were installed between November, 1986 and December, 1987. Twelve of the Phase II migration control wells were installed in native soil on approximately 175-foot centers along the eastern border of the landfill. These wells are labeled PD-1 through PD-12.

Nineteen of the Phase II migration control wells were installed in native soil on approximately 300-foot centers along the north, west and south boundaries of the landfill. These wells are numbered PA-1 through PA-10 and PC-1 through PC-9.

Ten of the Phase II migration control wells were installed in waste in the interior of the landfill. Six wells were placed in the north half of the landfill and four in the south. These wells are numbered 38 through 47.

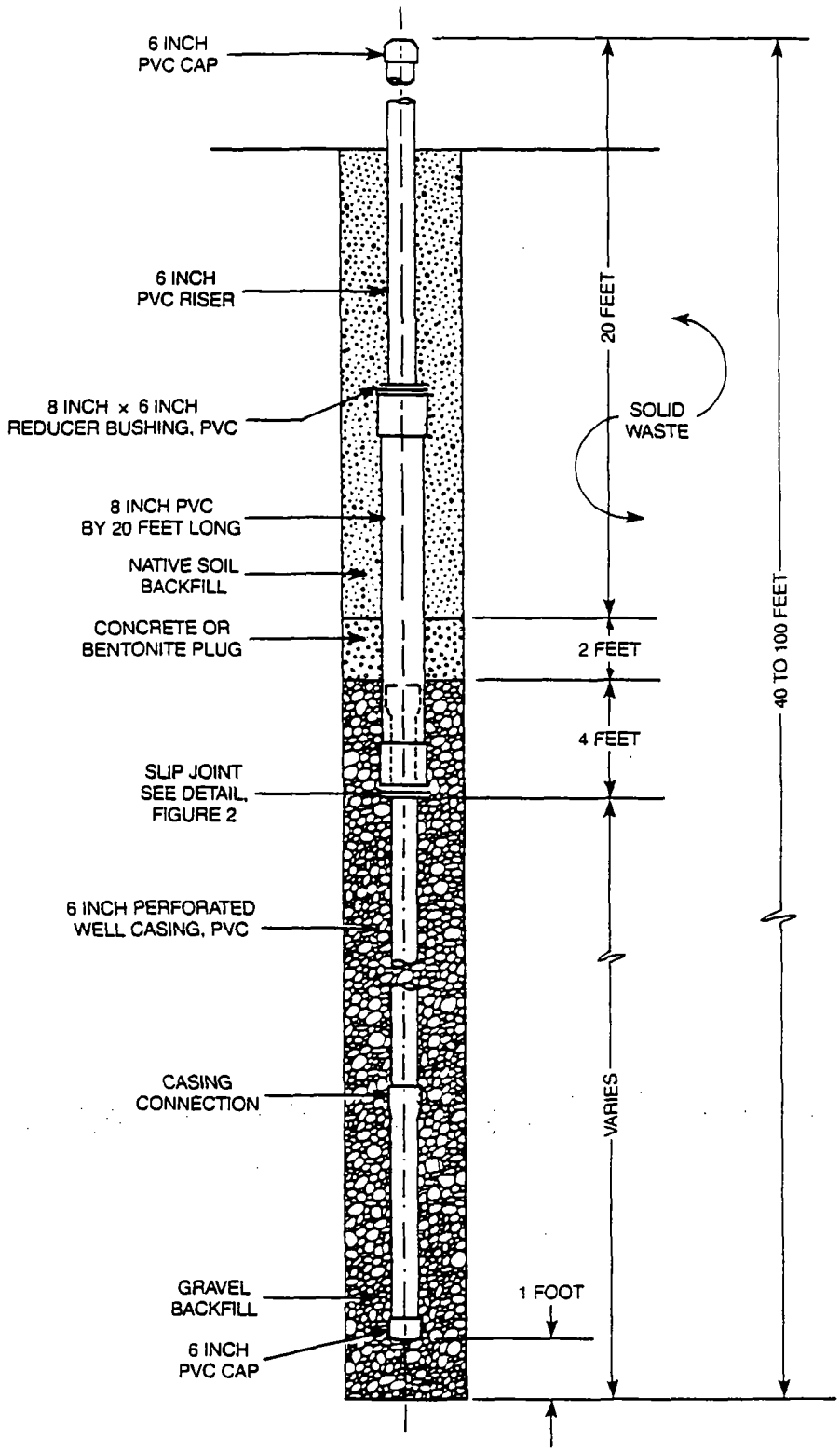
4.1.2 Migration Control Well Typical Installations

The thirty-four original Phase I migration control wells were installed in waste using a 24 to 30 inch auger. These wells were drilled to 80% of the depth of the landfill at that point. Generally, the wells were drilled between 40 and 100 feet deep. The wells are completed with a single 6-inch-diameter PVC casing which is perforated from between roughly 25 feet below ground surface to the bottom of the well. A 20 foot slip joint is installed between 5 and 25 feet below ground surface to allow for landfill settlement.

This slip joint is made of 8-inch diameter PVC with an 8"x6" slip bushing on the lower end. The well casing is inserted into this slip joint but not physically attached. As the landfill settles, the casing is designed to telescope in on itself. The well is filled with a gravel backfill up to 22 feet below ground surface. Above the gravel backfill is an approximate two foot thick bentonite or concrete plug. The remainder of the well is backfilled with native material. A cross section of a typical Phase I extraction well is shown on Figure D-2.

The Phase II interior migration control/odor control wells were installed in waste using a 24 to 30 inch auger. These wells also were drilled to 80% of the depth of the landfill, generally over 100 feet deep. These wells are double completed with one casing 6-inch-diameter PVC casing installed to approximately one half the total depth of the well. This "shallow completion" 6-inch casing is perforated between 25 feet from ground surface to the bottom of the completion. The second completion is an 8-inch-diameter PVC casing installed to the depth of the well. The 8-inch casing is perforated from below the bottom of the shallow completion to the bottom of the well. A two foot thick bentonite plug is placed between the shallow completion and the deep completion and above the screened interval of the shallow completion. The screened intervals for both completions are filled with a gravel backfill. Native soil is backfilled between the upper bentonite seal and ground surface. A slip joint is installed in both completions similar to that installed in the Phase I wells except that the deep completions of these wells require a 10-inch-diameter slip joint. The three additional Phase I wells installed after the original 34 were completed similarly to the Phase II interior wells except that both completions are 6-inch-diameter, see Figure D-3. A typical cross-section of a Phase II double completion migration control well is shown on Figure D-4. It is expected that at least six additional interior migration/odor control wells will be required to effectively control odor.

The Phase II native soil wells are drilled using a 12-inch diameter top drive rotary drill rig with compressed air to remove the cuttings. The completion of these wells are similar to that of the Phase II interior wells with the exception that both completions are 4-inch-diameter PVC casing and a slip joint is not required. A typical cross-section of a Phase II double completion well is shown on Figure D-5. The well head completion detail for Phase II native soil wells is shown on Figure D-6 for wells installed on the west boundary of the landfill (wells PA-1 thru PA-6, PA-10, and PC-1 through PC-9). These wellheads were completed simply by extending the casings above ground. The wellheads for Phase II native soil wells installed to the east and south of the landfill (wells PD-1 through PD-12 and PA-7 thru PA-9) were buried in a vault as shown on Figure D-7. The vault was required because the wells to the east were installed on the Interstate 5 southbound shoulder and the wells to the south, with the exception of PA-10, were installed outside the boundaries of the landfill on the right-of-way for South 252nd Street.



NOT TO SCALE

Figure D-2
Typical Cross Section of a Phase I Single Completion Extraction Well

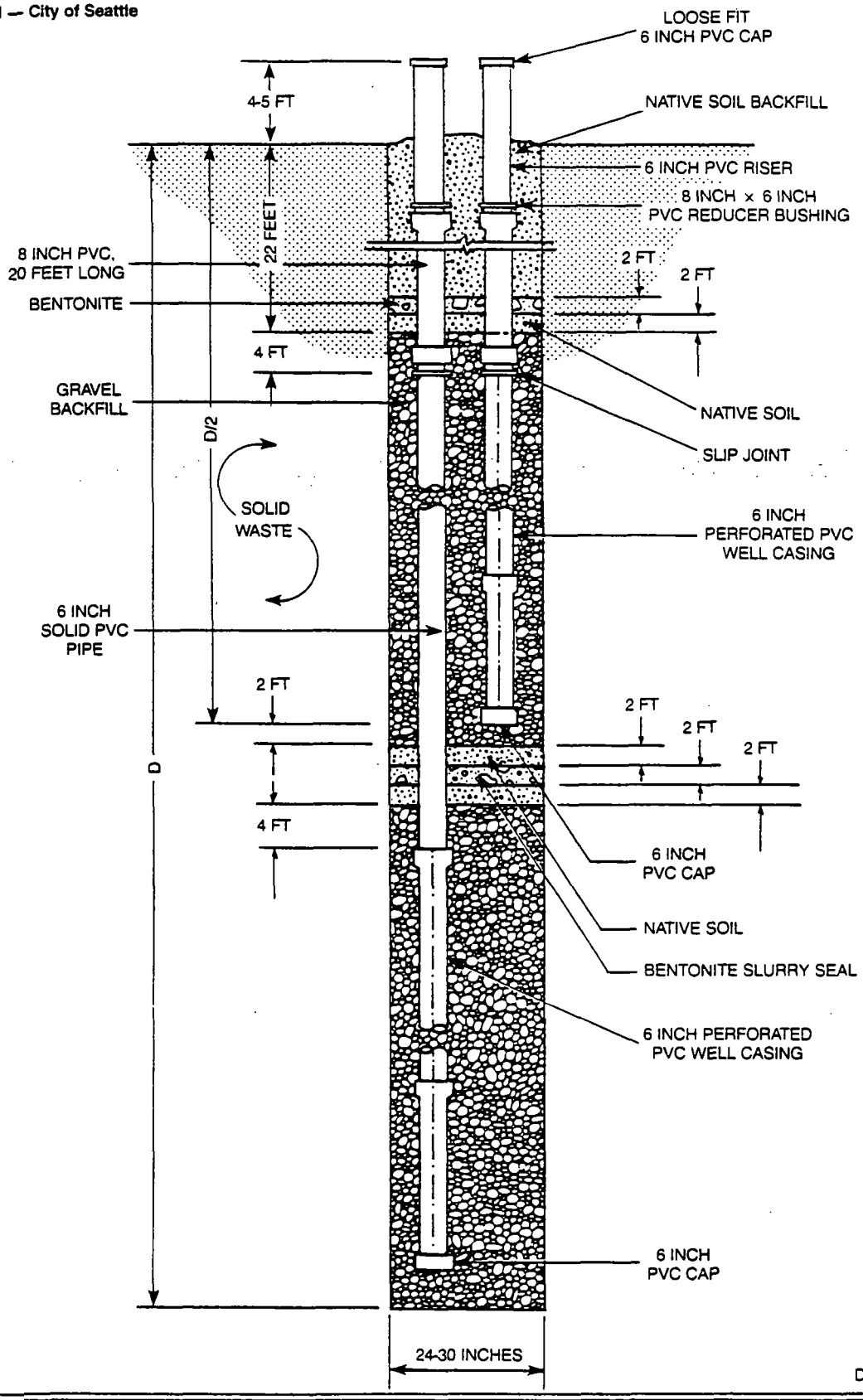
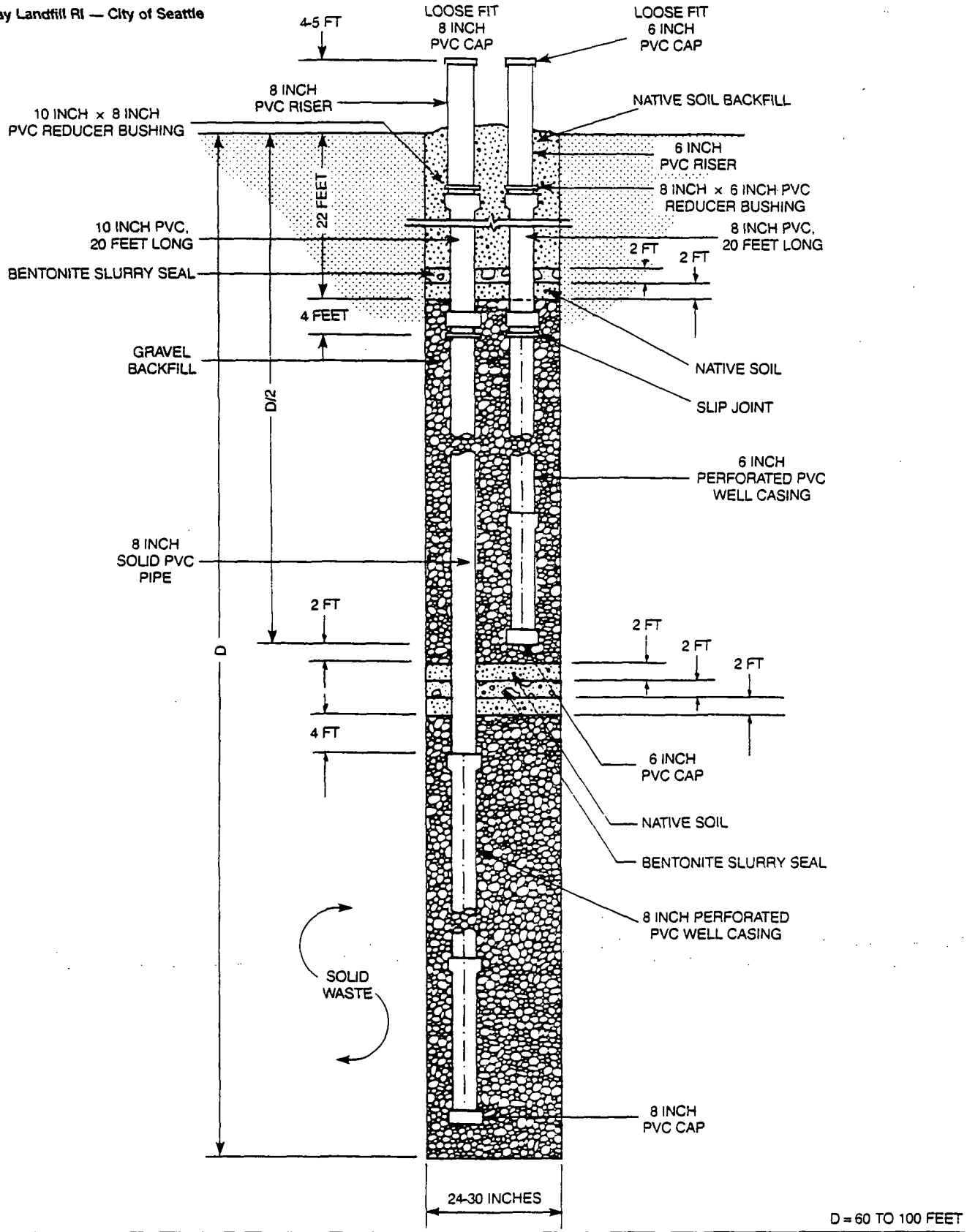


Figure D-3
Typical Cross Section of a Phase I Double Completion Extraction Well

NOT TO SCALE



NOT TO SCALE

Figure D-4
Typical Cross Section of a Phase II Interior Double Completion Extraction Well

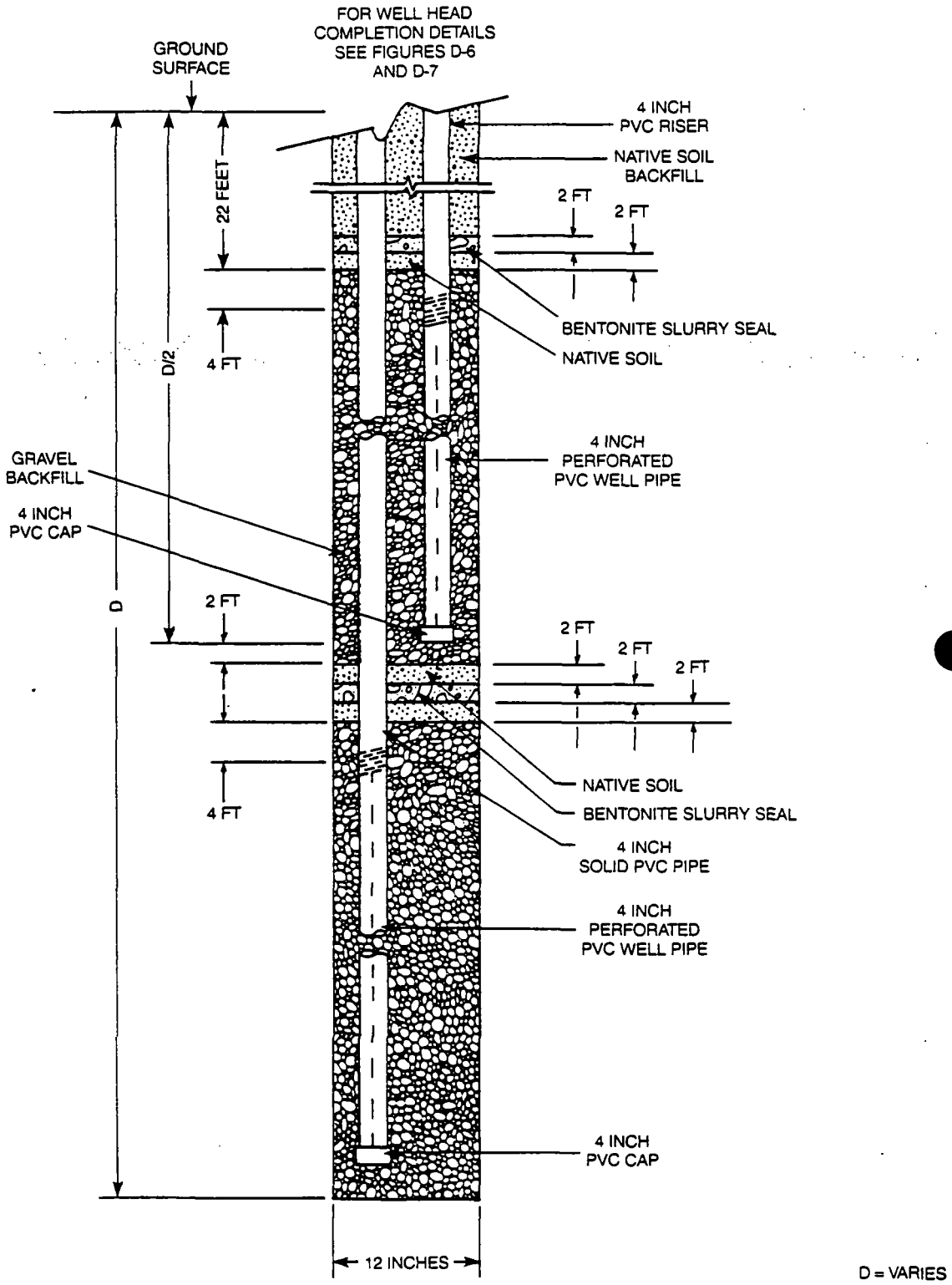


Figure D-5
Typical Cross Section of a Phase II Native Soil Double Completion Extraction Well

NOT TO SCALE

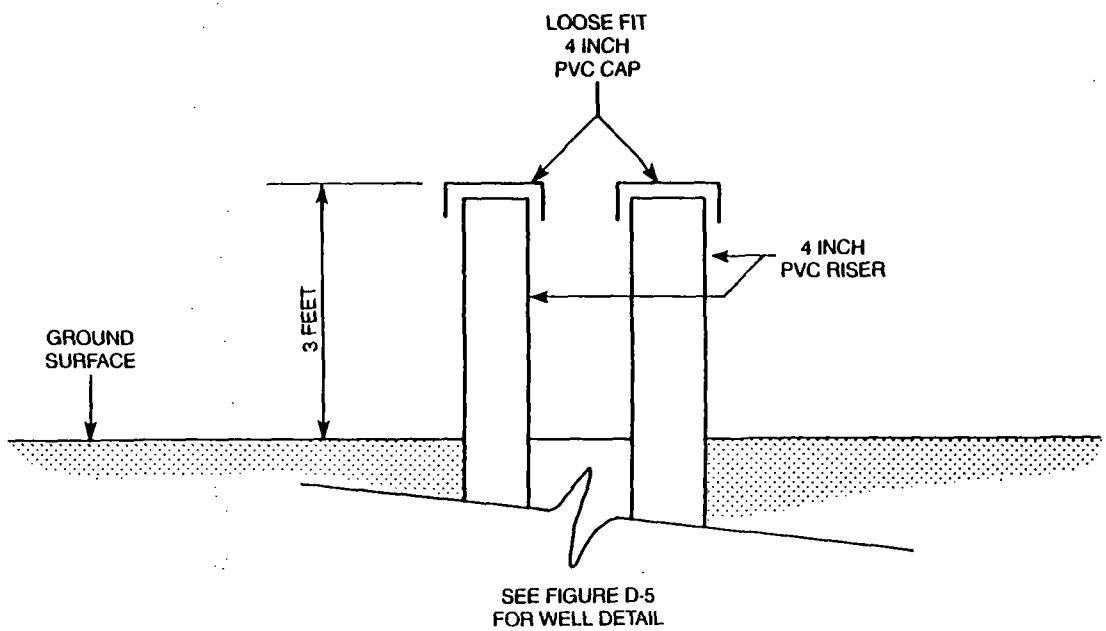


Figure D-6
Typical Cross Section of a Phase II Native Soil Well Head Detail for Well Located North and West of the Midway Landfill

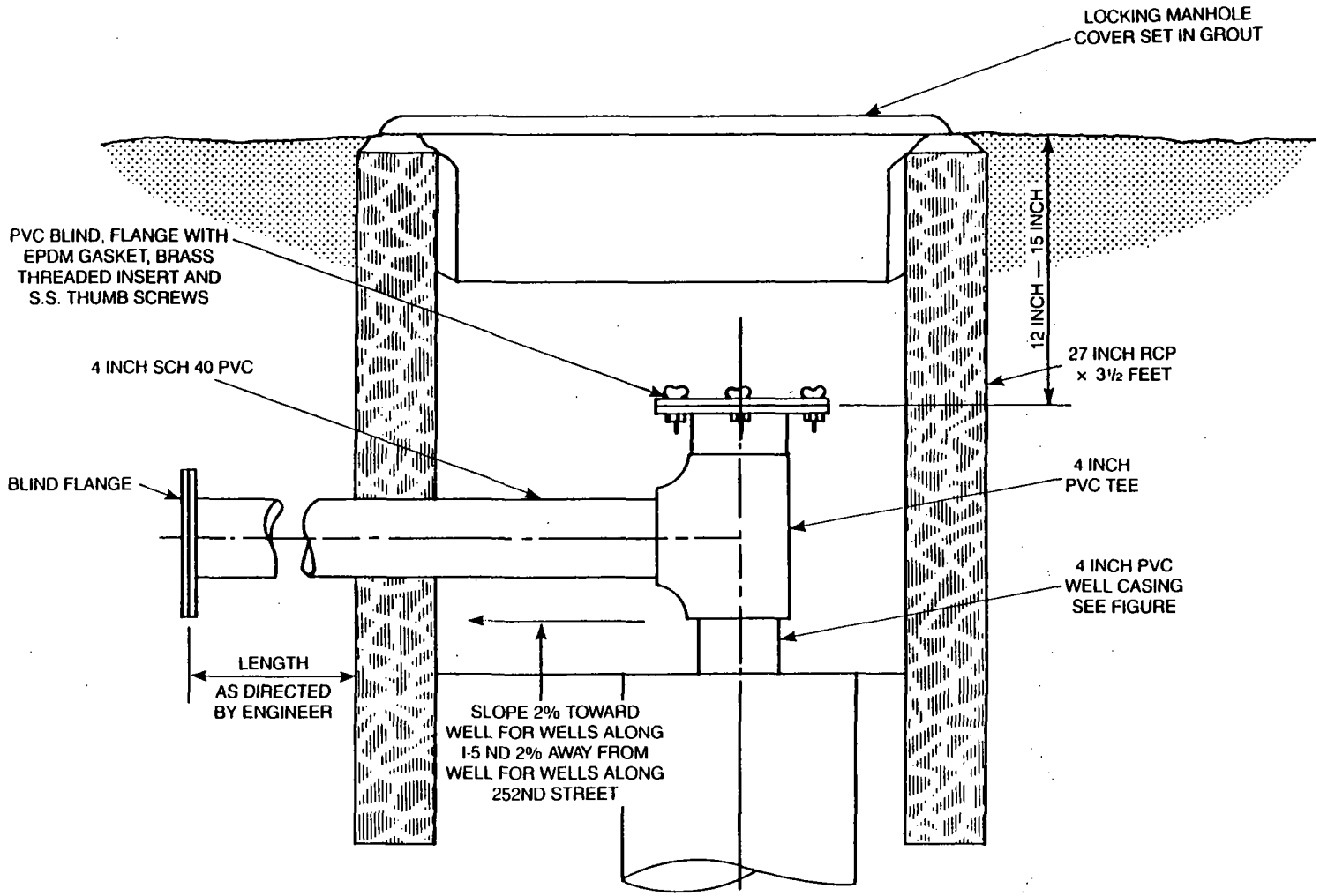


Figure D-7
Typical Cross Section of a Phase II Native Soil Well Head Detail for Wells Located Along I-5 and South 252nd Street

NOT SCALE

4.1.3 Water Levels in Migration Control Wells

A study was performed in the winter of 1985 to determine the levels of water in the Phase I migration control wells. Each well was tested using a sounder to determine the distance from ground surface to standing water in the extraction well.

A similar study was performed in February 1987 which included a test of the Phase II wells. The results of these tests are described in Section 5-6 of this report.

4.1.4 Manifold, Blowers and Flares

The manifold piping installed for the Phase I and Phase II wells was built using PVC piping sized for minimal pressure drops throughout the system, based on the expected flows from each well. The original portable diesel powered motor blowers were designed to move 1200 cubic feet per minute of air at 24 inches W.C. vacuum. In February, 1987, these blowers were replaced with electric blowers designed to provide a flow of 2200 cfm of air at a static vacuum of 45 inches W.C. This replacement was necessary as a result of the decision to install substantial portions of the Phase II extraction system wells prior to the landfill closure. Figure D-8 shows a typical schematic representation of the blower/flare system.

The temporary flares currently in use at Midway are each designed to maintain a flame in a flow of 500 cfm of 50 percent methane. These flares are of a fixed louver design for air induction. These flares will be replaced in the permanent facilities with four permanent flares (one spare) designed to meet the emissions requirements of PSAPCA. Recent study by the South Coast Air Quality District has shown that 1500 degree F temperature maintained for 0.3 seconds will eliminate most airborne pollutants. While the temporary flares currently at the site do not meet permanent flare requirements, the tests that have been performed have shown that this temperature is reached and there are no emissions problems.

4.2 Operation of In-Waste Wells

In-waste gas migration control wells installed at the Midway Landfill are monitored at least weekly to assure their optimum performance with respect to control of offsite migration of landfill gas, and to assure that the operation of the well system is not "over stressing" the landfill, (extracting landfill gas too aggressively and thereby creating the potential for landfill fires).

Anaerobic decomposition, or decomposition of organic materials in an oxygen depleted environment, is accomplished by anaerobic bacteria. The by-products of anaerobic decomposition are methane and carbon dioxide. The anaerobic bacteria require organic materials (in this case, solid waste), and water to

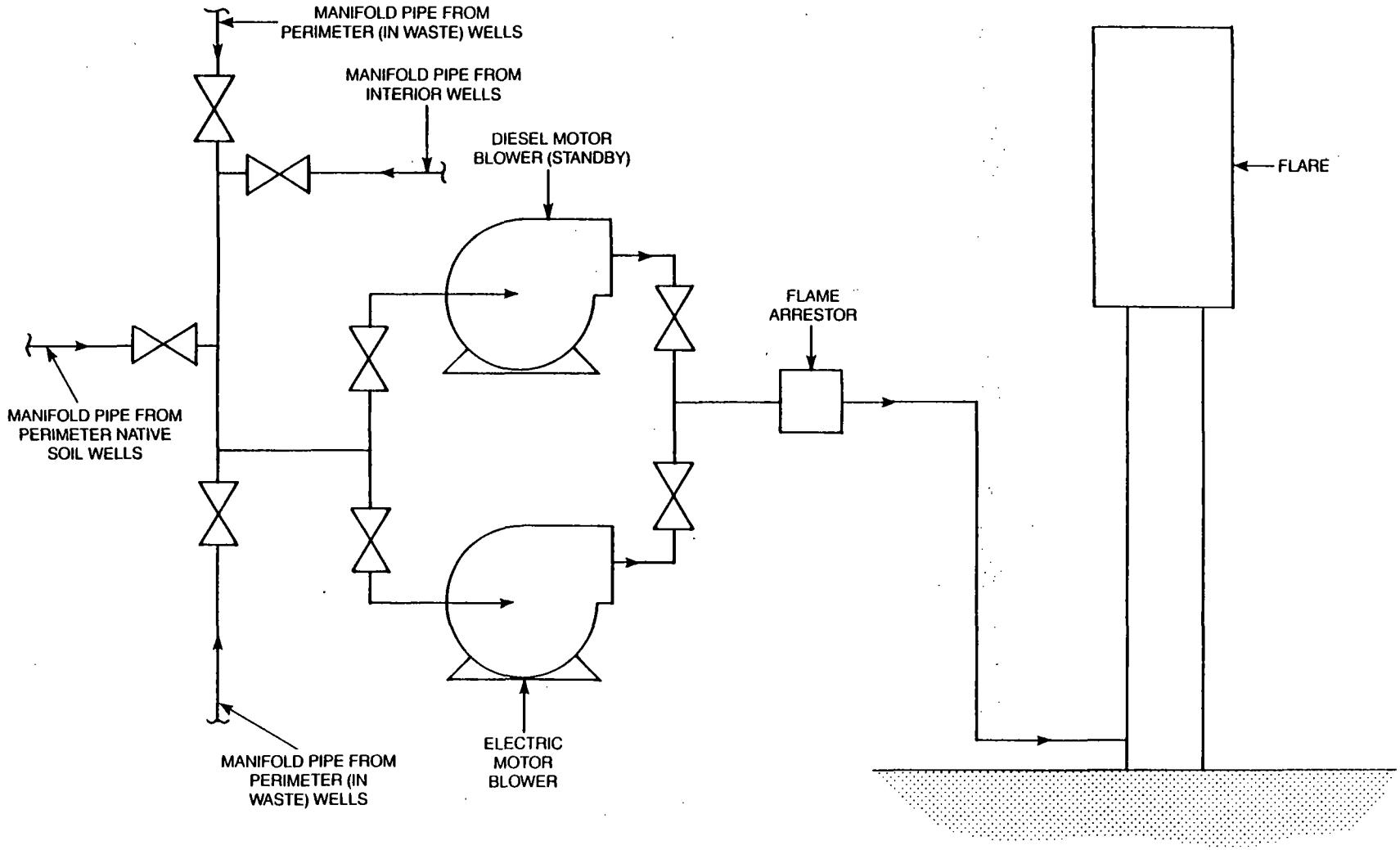


Figure D-8
Typical Temporary M[redacted]r
[redacted]er [redacted]fol[redacted]hem[redacted]

produce appreciable amounts of methane and carbon dioxide. Aerobic decomposition, or decomposition of organic materials in an oxygen rich environment, is accomplished by aerobic bacteria. The by-products of aerobic decomposition are carbon dioxide, water, and heat. The heat produced by aerobic decomposition can start an underground fire in the deposited solid waste. Therefore, the amount of aerobic decomposition taking place in the landfill is closely monitored to assure safe operation of the system. The safe operation of the system is accomplished by suppressing the amount of air allowed to be exposed to deposited solid waste. The following three steps are taken to assure that a minimum of aerobic decomposition is taking place in the landfill:

- Improve the landfill cover with low permeability material.
- Reduce the vacuum in the landfill so that less air is "sucked" through the cover to the solid waste.
- Closely monitor the amount of aerobic decomposition taking place in various areas of the landfill and adjust well vacuums accordingly.

To accomplish the system goals of gas control without refuse fires, the following information is gathered about the gas stream from each completion zone of each well in the field:

- Combustible Gas Percentage
- Oxygen Percentage
- Carbon Dioxide Percentage
- Static Pressure
- Temperature
- Velocity of Gas Stream in Well

The sum of concentrations of combustible gas, oxygen, and carbon dioxide in the sampled gas stream will always equal less than 100% of the total gas stream make-up. Experience has shown that the balance of the gas stream make-up consists of water vapor and nitrogen, except for trace quantities of various organic compounds. The percentage of water vapor in the gas stream can be calculated from the following formula:

$$\left(7.89 - \frac{3207}{395.43 + T}\right)$$

$$\%H_2O = \frac{10}{P_a + P_w} \times 100$$

Where -

T = Temperature in degrees Fahrenheit of the gas stream
P_a = Atmospheric Pressure in inches water column
P_w = Pressure (or vacuum) in inches water column in the well

The balance of the gas stream is nitrogen. In other words, 100% - % methane - % oxygen - % carbon dioxide - % water vapor = % nitrogen. Free (or breathing) air consists of approximately 21% oxygen and 79% nitrogen, which is a ratio of 1:3.76. So, by multiplying the percent of oxygen recorded in the field by 3.76, the amount of nitrogen associated with free air can be known.

As stated previously, aerobic decomposition consumes oxygen. It gets it's oxygen from air. The nitrogen associated with this consumed oxygen is not used in the chemical process of aerobic decomposition and is still present in the gas stream. This "carried over" nitrogen is considered "residual nitrogen". This residual nitrogen is the balance of nitrogen present in the gas stream after the nitrogen associated with free air is subtracted.

Example:

Readings taken in the field:

WELL#	CH4%	O2%	CO2%	TEMP	PRESS.	FLOW
X	21	7	18	48degF	-5.0"WC	22 CFM

Calculated Quantities:

H2O% (from above formula) = 1%
Total N2% (100% - CH4% - O2% - CO2% - H2O%) = 53%
N2 from free air (from ratio described above) = 26%
Residual N2% (diff. btwn. total N2 and N2 from free air) = 27%

Operational experience at Midway and other landfill sites has shown that a safe limit of aerobic decomposition in the waste surrounding an extraction well is indicated by a maximum of 30% residual nitrogen in the well gas stream. In consideration of this fact and the present goal to maximize flow and vacuum, wells in refuse are adjusted to allow no more than 30% residual nitrogen. Because heat is produced in aerobic decomposition, temperature is a very quick indicator of dangerous amounts of aerobic decomposition. Experience has shown that 108 degrees F in the well gas stream is a safe maximum temperature at which to operate an in-waste extraction well at the Midway site. Temperature is measured once a week, and more frequently if indicated.

The above calculations and parameters are used only to give the operator an idea of what bio-chemical processes are taking place in the area of influence of a particular well. Other variables such as ambient temperature vs. temperature in the well, barometric pressure, and influence of areas outside the landfill are also taken into consideration in the adjustment of migration control wells.

4.3 Operation of In-Soil Wells

The primary purpose of migration control wells installed in native soil around the landfill is to create a vacuum barrier that will prevent offsite migration. These wells also are used in conjunction with offsite control wells to remove reservoirs of gas that have accumulated over time.

In-soil wells are monitored and adjusted similarly to the wells installed in waste. Pressure in the onsite wells is measured and compared with pressure in the offsite probes to verify the effectiveness of the extraction wells. The chemical make-up of the gas is monitored to determine the amounts of aerobic and anaerobic decomposition taking place in the area of the landfill influenced by a particular in-soil extraction well. However, temperature in in-soil wells is not as quick an indicator of aerobic decomposition in the waste influenced by the well, because the landfill gas extracted by an in-soil well has cooled somewhat by migrating through native soil. Therefore, the operator must rely more heavily on the calculations of residual nitrogen described in 4.2 to determine adjustments to be made to the in-soil wells.

As with migration control wells installed in waste, these wells are monitored at least weekly.

4.4 Extraction Piping and Equipment

The manifold piping and blower are operated to maintain at least 10 inches W.C. in the extraction piping at the furthest point in the system from the blower. This is to allow flexibility in the adjustment of all migration control wells. The motor blowers operate on 460V 3 phase current and are operated continuously 24 hours per day seven days per week.

To maintain the flame in the flare, a target of 30% minimum methane in the manifold gas stream has been determined. The air induction is a fixed louver design on the temporary flares; therefore, there is little flexibility regarding methane to air flow ratios. The permanent flares to be installed as part of the final closure will have adjustable louvers and temperature sensing ports to allow for more flexibility. A typical schematic representation of the blower and flare facility are shown in Figure D-8.

5.0 RESULTS

5.1 Interception of Gas Bearing Strata

Based on the results of offsite probe monitoring data discussed in Appendix B of this report and the migration pathways report in Appendix G, confidence is high that the gas bearing strata which allowed the extensive offsite landfill gas migration at the Midway Landfill has been intercepted. Since the installation and continued operation of the onsite migration control system begun in early 1986, offsite migration of gas appears to have been significantly reduced if not eliminated. A major area of concern at this time is to the south-east where large reservoirs of migrated landfill gas have accumulated over time.

There is a strong possibility that the permeable gravel surrounding the site could allow enough air access from offsite into the landfill due to the induced vacuum even after the final cover is placed to present an "over-stressing" problem. Therefore, the installation of a final cover will probably not completely solve the air intrusion and subsequent aerobic decomposition problem. Careful monitoring and adjustment of all migration control wells will continue to be needed for the life of the system. Monitoring will be needed for at least 20 years, but will decrease in frequency with time. The data will be evaluated, and if any system weaknesses are indicated, wells can be added.

5.2 Gas Concentrations and Temperature

The average combined methane concentration throughout the migration control system is currently approximately 30% by volume. Many in-waste wells produce methane at levels over 40%. In contrast, most of the in-soil wells produce very low concentrations of methane mixed with free air. This is to be expected, because most of the landfill gas is extracted by the in-waste wells.

Many areas of the landfill lack the three feet of clay cover considered adequate to prevent intrusion of air into the waste when wells are installed and operated. For this reason, gas flow in several of the migration control wells must be restricted to prevent unsafe levels of aerobic decomposition near the wells. Normally-operating in-waste extraction wells are currently producing gas at temperatures between 90 and 100 degrees F. This temperature reflects the level of aerobic decomposition allowed to occur in the landfill as a compromise between optimum operation of the extraction wells and safe limits of heat.

5.3 Gas Flow

Prior to the installation of the Phase II wells, the average extracted gas flow throughout the landfill was approximately 900 to 1000 cfm of 35% to 50% methane. After the installation of the Phase II wells in February, 1987, an initial high flow of nearly 2000 cfm of 30% methane was measured as gas from the area was being drawn through the soil surrounding the in-soil extraction wells. Over the course of about one month, this flow was reduced to 1200 to 1400 cfm of 30% gas. Since then, the flow has gradually declined to 800 to 1000 cfm of 30% gas.

5.4 Change in Offsite Gas

As discussed in Appendices B and C of this report, landfill gas at shallow depths have been greatly reduced (from as high as 55% by volume in some areas to less than 5% by volume in all areas). This is due not only to the operation of the onsite migration control system but also to the offsite gas extraction wells which were installed concurrently.

Deep gas concentrations offsite have also been reduced from as high as 70% by volume in some areas down to less than 5% by volume west and north of the landfill and less than 40% by volume in areas east, south-east and south of the landfill. Evidence indicates that the areas where gas concentrations remain high in deep soil zones are caused by gas reservoirs which have accumulated over time. These areas are still causing concern and steps such as the installation of additional offsite control wells and additional in-soil migration control wells are being studied in an attempt to remove this gas.

5.5 Effect of Adjustments

When the influenced waste near a migration control well exhibits the characteristics of aerobic decomposition above safe limits, the flow from that well is reduced by use of the control valve installed on each completion of every well. Conversely, when readings taken indicate that a well can be drawn on harder and still be within safe limits, the flow is increased. In this way, wells eventually will be adjusted to a stable level of maximum safe flow. After this has been accomplished, the frequency at which a well is monitored can be reduced. The only future adjustments necessary should be due to seasonal changes in average barometric pressure, and the gradual decline of methane production in the landfill.

Adjusting the flow to achieve the optimum operating level in the migration control wells has proven to be quite effective. Generally, changes in gas concentrations can be witnessed within 24 hours, although sometimes this process can take weeks. Except for the effect of barometric changes, the flow in wells remains fairly constant between adjustments.

5.6 Results of Water Level Measurements

In a test performed in the winter of 1986, it was found that twelve of the migration control wells contained significantly high water levels, see Table D-1. The effectiveness of these wells was reduced depending on the ratio of well screen above and below the water table. Because these wells were clustered principally in three non-adjacent groups, and no water table was known to correlate with the water levels in the wells, it was concluded that these were local perched water tables within the refuse. By the summer of 1986, when it was decided to pump the wells down, they were dry again.

A second test performed in the winter of 1987 again found no evidence of a single continuous water table throughout the landfill. Table D-2 shows the results of the second study, including a list of the drill depths and completion levels of each migration control well.

TABLE D-1
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (WINTER, 1986)

WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
1	49.5	47	2.5
2	60.5	37.5	14.8
3	51.5	37	14.5
4	61	31.5	29.5
5	66	36	30
6	60.5	42.5	18
7	70.5	56.5	13.5
8	67.5	65	2.5
9	71	56.5	14.5
10	65.5	55	10.5
11	61.5	59	2.5
12	61.5	57	4.5
13	62	40.5	21.5
14	65.5	55	10.5
15	61	57.5	4.5
16	61	55	6
17	87	N/A	N/A
18	101	N/A	N/A
19	93.5	N/A	N/A
20	92.5	N/A	N/A
21	101	96.5	4.5
22	76.5	69	7.5
23	79	47.5	31.5
24	60.7	51	9.7
25	89	60.5	28.5
26	87.5	50	33.5
27	86	72.5	13.5
28	89.5	86	3.5
29	87	81.5	5.5
30	50	47	3
31	76.4	52.5	24.1
32	81	76	5
33	68	41	27
34	68	57	11

TABLE D-2
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (FEBRUARY 20, 1987)

WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
1	49.5	N/A	N/A
2	60.5	60.5	0
3	51.5	30.58	20.92
4	61	61	0
5	66	34.41	31.67
6	60.5	37.64	22.86
7	70.5	50.22	20.28
8	67.5	63.17	4.33
9	71	51.67	19.33
10	65.5	51.62	13.88
11	61.5	58.31	3.19
12	61.5	50.37	11.13
13	62	37.26	24.74
14	65.5	65.5	0
15	61	54.11	6.89
16	61	53.69	7.31
17	87	91	6
18	101	99	2
19	93.5	86	7.5
20	92.5	85	7.5
21	101	94	7
22	76.5	67.75	8.75
23	79	40	39
24	60.7	47	13.7
25	89	60	29
26	87.5	61	26.5
27	86	68.8	17.2
28	89.5	87	2.5
29	87	82	5
30	50	46.53	3.47
31	76.4	74	2.4
32	81	69	12
33	68	44.53	23.47
34	68	54.87	13.13
35S	42	41	1
35D	98	91	7
36S	46	42	4
36D	94	91	3
37S	48	48	0
37D	98	97	1
38S	56	56	0
38D	110	75	35
39S	64	64	0
39D	126	110	16
40S	64	64	0

TABLE D-2 (CONT.)
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (FEBRUARY 20, 1987)

WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
40D	126	110	16
41S	60	60	0
41D	118	91	27
42S	32	21.72	10.28
42D	62	62	0
43S	39	38.51	0.49
43D	78	48.5	29.5
44S	39	38.51	0.49
44D	79	51.15	27.85
45S	42	42	0
45D	82	57.01	24.99
46S	47.5	43.22	4.28
46D	93	53.05	39.95
47S	43.5	40.28	3.22
47D	85	52.24	32.76
PA1S	29	12	17
PA1D	67	56.66	10.34
PA2S	35	N/A	N/A
PA2D	67	N/A	N/A
PA3S	56	56	0
PA3D	93	93	0
PA4S	44	44	0
PA4D	98	98	0
PA5S	60	60	0
PA5D	118	118	0
PA6S	63	30	33
PA6D	120	55	65
PA7S	58	56	0
PA7D	117	74.9	42.1
PA8S	52	48.5	3.5
PA8D	112	109	3
PA9S	64	44.5	19.5
PA9D	138	138	0
PA10S	66	66	0
PA10D	133	133	0
PC8S	32	13	19
PC8D	76	59.27	16.73
PD1S	65	65	0
PD1D	130	128	2
PD2S	63	63	0
PD2D	130	130	0
PD3S	56	56	0
PD3D	113	113	0
PD4S	68	68	0
PD4D	130	130	0

TABLE D-2 (CONT.)
WATER LEVELS IN ONSITE MIGRATION CONTROL WELLS (FEBRUARY 20, 1987)

WELL #	DRILL DEPTH	DEPTH TO WATER FM. GRD.	HEIGHT OF WATER IN WELL
PD5S	60	60	0
PD5D	118	118	0
PD6S	50	50	0
PD6D	110	94	16
PD7S	58	56	2
PD7D	117	89	28
PD8S	46	46	0
PD8D	101.5	86	15.5
PD9S	44	44	0
PD9D	99.5	80.5	19
PD10S	51	47	4
PD10D	101.5	81	20.5
PD11S	51	51	0
PD11D	101	76	25
PD12S	38	38	0
PD12D	91	78	13

6.0 CONCLUSIONS

The current onsite migration control system is doing an effective job in eliminating the amount of offsite landfill gas migration. The addition of the final cover will allow for increased flows from both in-waste wells and in-soil wells, which should help to decrease the concentrations of methane gas that have accumulated offsite. In the future, if weaknesses in the system are found through data evaluation, it may be necessary to install additional wells to gain confidence in the system's ability to control migration.

The completion of the final cover onsite, and the rerouting of surface water runoff from Interstate 5 and areas east (which is now discharged into the landfill) will eliminate most of the variable water within the landfill. This will improve the efficiency of certain extraction wells.

APPENDIX E

CHARACTERIZATION OF ON-SITE AND OFF-SITE SUBSURFACE GAS

MIDWAY LANDFILL REMEDIAL INVESTIGATION

TECHNICAL MEMORANDUM

CHARACTERIZATION OF ON-SITE AND OFF-SITE SUBSURFACE GAS

Prepared for:

CITY OF SEATTLE ENGINEERING DEPARTMENT
SOLID WASTE UTILITY

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

March 23, 1988
PMX # 55-1550-11

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EXECUTIVE SUMMARY

This technical memorandum summarizes the findings of several studies that were conducted to characterize the chemical composition of subsurface gases in the vicinity of the Midway Landfill. These studies compare on-site subsurface gas from Midway Landfill with off-site subsurface gas to evaluate the possibility that components of the landfill subsurface gas have migrated off-site.

First, gas from individual on-site gas extraction wells was analyzed to describe its composition, with particular emphasis on substances known to be present at specific locations deep within the landfill, based on previous studies. Then, pre-combustion flare gas, composed of the combined gases extracted from the numerous individual on-site gas extraction wells, was analyzed to determine the "average" composition of gases extracted from the landfill. Finally, subsurface gas collected from off-site gas monitoring probes and off-site gas control wells was compared with subsurface gas collected on-site to evaluate the nature and extent of potential off-site migration of substances in the landfill subsurface gas.

The results of the gas characterization studies described in this technical memorandum showed that subsurface gas collected from the on-site gas extraction wells and flare manifolds contained a wide variety of substances, including numerous USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs). The compounds found most frequently and in the highest concentrations in the on-site subsurface gas included ethylbenzene, vinyl chloride, total xylenes, toluene, and benzene. The maximum concentrations of these compounds were in the low parts-per-million (ppm) range.

Subsurface gas from on-site gas extraction well 44D-0 was generally observed to have higher concentrations of HSL VOCs than gas from other on-site sampling points. Of the 23 HSL VOCs detected in on-site subsurface gas, the maximum concentrations reported for 13 of the compounds were observed at well 44D-0. One possible explanation is that well 44D-0 had a relatively low gas flow rate, 6 ft^3/min ("equilibrium flow"), at the time of sampling, which may have resulted in increased opportunity for these gas contaminants to accumulate in the relatively smaller, slower-moving volume of gas.

For the 23 HSL VOCs detected in the on-site subsurface gas, the <u>mean</u> on-site concentration for a given contaminant was typically less than 10% of the corresponding maximum on-site concentration. The maximum observed on-site concentration for any HSL VOC detected during sampling of subsurface landfill gas was 31 ppm of vinyl chloride, detected at gas extraction well 44D-0. The mean concentration of vinyl chloride across all on-site gas extraction well samples was slightly less than 3 ppm.

Benzene, toluene, and total xylenes are commonly referred to as the "BTX" group. Ethylbenzene and styrene were frequently found associated with this group of compounds. They all share similarities in chemical structure and properties and, for this reason, the five compounds have been treated and are

referred to collectively in this technical memorandum as "BTX-group" compounds.

Other HSL VOCs were found less frequently and in lower concentrations, generally in the parts-per-billion (ppb) range. The toxic inorganic gases hydrogen sulfide and carbon monoxide were also reported present in on-site subsurface gas in the low parts-per-million range. Hydrogen cyanide and hydrogen chloride were not detected in on-site subsurface gas.

Concentrations of HSL VOCs in subsurface gas were plotted on base maps of the site and surrounding area to evaluate the association between on- and off-site subsurface gas contaminant distribution. The results suggest that off-site migration of at least some of the on-site subsurface gas contaminants has occurred, possibly in all directions away from the Midway Landfill. This is thought to be particularly true with respect to the BTX-group compounds.

Vinyl chloride was frequently associated with the BTX-group compounds in on-site subsurface gas, but during sampling off-site it was found at only two of the gas monitor probe locations, both south of the landfill. In a separate study, conducted by Farr, Friedman & Bruya, Inc., under subcontract to Parametrix, vinyl chloride was also found at concentrations of up to 1-3 ppm at other locations to the east and south of Midway Landfill in the subsurface gas samples collected from off-site gas control wells. Factors affecting the distribution of vinyl chloride in subsurface gas in the vicinity of Midway Landfill may be different from those affecting the distribution of the BTX-group compounds; this is discussed in further detail in the Midway Landfill Remedial Investigation Summary Report (Parametrix, 1988).

Several HSL VOCs were detected in subsurface gas samples collected west of the landfill at off-site gas monitoring probe completions 88-S and 88-M, which were adjacent to a wetland area. It is difficult to determine solely from the gas characterization studies the degree to which compounds found at this location may be associated with materials present in the wetland, as opposed to being materials that have possibly migrated from Midway Landfill. Although some HSL VOCs were detected in off-site subsurface gas monitoring probes to the east, remedial investigation data do not suggest extensive migration of subsurface gas contaminants in this direction. None of the compounds reported at gas monitoring probe M-M appear to have migrated as far east as probe 50-S.

From the analysis presented in this technical memorandum, it was concluded that off-site migration of BTX-group compounds has occurred. This conclusion is based on the following:

- Comparison of the types of compounds found in on- and off-site subsurface gas samples,
- Mapping of the geographic distribution of the concentrations of specific compounds, and
- The likelihood of finding these compounds in association.

It was further concluded that the five BTX-group compounds described above (ethylbenzene, total xylenes, toluene, benzene, and styrene) comprise the best available "fingerprint" of USEPA HSL VOCs that are consistently present in both on-site and off-site subsurface gas. Off-site concentrations for the five BTX-group compounds were consistently lower than the corresponding on-site concentrations.

The gas characterization studies conducted for the Midway Landfill Remedial Investigation were not designed to identify the mechanisms responsible for observed attenuation of subsurface gas components; however, some possible mechanisms might be biodegradation, chemical interactions with water or soil components, adsorption onto soil organic matter, and the action of the on-site gas extraction system in drawing subsurface gas back toward the landfill.

Results of a study conducted outside the scope of the remedial investigation (Farr, Friedman, and Bruya, 1987) further indicated that evaluation of the ethane/methane and propane/methane ratios might be useful in distinguishing Midway Landfill gas from natural gas that is supplied by local utilities such as the Washington Natural Gas Company.

1.0 INTRODUCTION

This technical memorandum discusses studies that were conducted by Parametrix, Inc., to characterize the composition of subsurface landfill gas from Midway Landfill as part of the Midway Landfill Remedial Investigation required by the Washington State Department of Ecology. Data from previous studies are discussed and compared with the studies conducted specifically for the remedial investigation.

1.1. PREVIOUS REPORTS ON MIDWAY LANDFILL GAS COMPOSITION

Previous reports on the chemical composition of gases associated with the Midway Landfill include:

- Chemical Hazards in Gaseous Emissions from Municipal Landfills. University of Washington, Department of Environmental Health, Environmental Health Special Investigation EHSI 85-001. September 1985.

- Evaluation of Potential Health Effects Associated with Off-Site Gas Extraction Systems at the Midway Landfill. University of Washington, Department of Environmental Health, Ad Hoc Committee on Midway Landfill Hazards. April 1986.

1.1.1 THE CHEMICAL HAZARDS IN GASEOUS EMISSIONS FROM MUNICIPAL LANDFILLS REPORT

The September 1985 study conducted by the University of Washington Department of Environmental Health examined the concentrations of selected inorganic gases and volatile organic compounds in gas from the inlets of three of the numerous small on-site temporary gas flares. These small flares were used to control landfill gas emissions prior to the installation of the current on-site gas extraction system, which consists of on-site gas extraction wells, motor blowers, and two temporary gas flares. Data from this study are summarized in Tables 1-1 and 1-2. The findings of the 1985 report included the following observations:

- Combustible gas concentrations ranged from 34-36% by volume.

- Carbon monoxide concentrations ranged from 10-30 ppm.

- Hydrogen sulfide concentrations ranged from 0.9-18 ppm.

- Hydrogen cyanide concentrations were below the detection limits of 0.33 ppm and 0.03 ppm respectively at the two flares sampled for this compound.

- Numerous volatile organic compounds were detected, with concentrations of selected compounds or compound classes ranging up to approximately 45 ppm. Compounds detected included benzene,

Table 1-1. Inorganic gases detected at the Midway Landfill during University of Washington survey of 5/17/85.

Parameter Sampled	Sampling Method	Flare #5	Flare #25
Combustible gas	Explosimeter	34%	36%
Carbon monoxide (CO)	Drager tube	10 ppm	30 ppm
Hydrogen sulfide (H_2S)	Drager tube	1 ppm	18 ppm
Hydrogen sulfide (H_2S)	Impinger/colorimetry	0.9 ppm	17 ppm
Hydrogen cyanide (HCN)	Impinger/Ion chromatography		

Note: Sampling points were "mini-flares" in use prior to present gas control system; samples were taken of unburned gases.

Source: University of Washington, 1985.

Table 1-2. Volatile Organic Compounds (VOCs) detected at the Midway Landfill during University of Washington survey of 5/17/85.

CAS #	COMPOUND	Laucks Data (ppm)	Laucks Data (mg/m3)	Flare #5 (ppm)	Flare #5 (mg/m3)	Flare #13 (ppm)	Flare #13 (mg/m3)	Flare #25 (ppm)	Flare #25 (mg/m3)
67-64-1	acetone	0.28	0.67	0.47	1.11	0.27	0.63	0.93	2.22
107-06-2	1,2-dichloroethane	0.07	0.28	ND	ND	ND	ND	0.57	2.29
71-43-2	benzene	0.02	0.05	5.66	16.97	2.70	8.11	13.57	40.70
540-84-1	isooctane	NR	NR	0.83	3.89	0.36	1.67	1.98	9.31
79-01-6	trichloroethene	0.05	0.27	ND	ND	ND	ND	22.59	122.09
108-88-3	toluene	0.42	1.57	1.63	6.09	1.95	7.31	37.00	138.58
111-65-9	octane	NR	NR	2.45	11.86	1.14	5.51	4.32	20.89
127-18-4	tetrachloroethene	0.05	0.34	1.02	6.84	0.73	4.89	1.26	8.47
N/AP	* C-2 benzenes	0.63+0.57	5.22	20.38	88.62	5.18	22.50	43.79	190.40
111-84-2	nonane	NR	NR	6.20	32.45	4.17	21.85	6.01	31.49
79-34-5	1,1,2,2-tetrachloroethane	NR	NR	ND	ND	ND	ND	ND	ND
138-86-3	limonene	NR	NR	7.68	42.67	3.83	21.25	5.07	28.17
N/AP	C-(11,13,14,15) compounds	NR	NR	2.40	15.26	0.48	3.05	1.20	7.63
108-90-7	chlorobenzene	< 0.01	< 0.05	Trace	Trace	ND	ND	Trace	Trace
75-09-2	methylene chloride	0.17	0.59	0.76	2.66	0.46	1.60	3.05	10.65
108-10-1	4-methyl-2-pentanone	0.79	3.25	Trace	Trace	ND	ND	Trace	Trace
78-93-3	2-butanone	0.13	0.38	Trace	Trace	ND	ND	Trace	Trace
71-55-6	1,1,1-trichloroethane	0.17	0.93	ND	ND	ND	ND	ND	ND
75-00-3	chloroethane	0.04	0.10	ND	ND	ND	ND	ND	ND
67-66-3	chloroform	< 0.01	< 0.05	ND	ND	ND	ND	ND	ND
75-34-3	1,1-dichloroethane	0.18	0.73	ND	ND	ND	ND	ND	ND
156-60-5	trans-1,2-dichloroethene	0.21	0.83	ND	ND	ND	ND	Trace	Trace
75-35-4	1,1-dichloroethene	0.01	0.04	ND	ND	ND	ND	Trace	Trace
78-87-5	1,2-dichloropropane	0.01	0.05	ND	ND	ND	ND	ND	ND

Source: University of Washington (1985).

Notes:
Sampling points were "mini-flares" in use prior to present gas control system; samples were taken of unburned landfill gases.

ND = Not Detected (detection limit = 0.15 mg/m3 for 49 liter sample).
NR = Not Reported.
* C-2 benzenes include m,o,p-xylene isomers and ethylbenzene.

toluene, several chlorinated solvents, and numerous alkyl and aromatic hydrocarbons.

1.1.2 THE EVALUATION OF POTENTIAL HEALTH EFFECTS ASSOCIATED WITH OFF-SITE GAS EXTRACTION SYSTEMS AT THE MIDWAY LANDFILL REPORT

In April 1986, the University of Washington Department of Environmental Health Ad Hoc Committee on Midway Landfill Hazards evaluated the potential human health effects associated with the observed concentrations of compounds present in gases vented by the off-site gas control wells located in residential neighborhoods near Midway Landfill. [NOTE: This study used the term "off-site vent wells" to describe what Parametrix refers to as "off-site gas control wells" and the term "on-site vent wells" to describe what Parametrix refers to as "on-site gas extraction wells," including odor control wells and migration control wells.] The 1986 study concluded:

- Methane presents a fire and/or explosion hazard when its concentration in air reaches at least 4.5%. At very high concentrations (generally in excess of 50% methane in air), methane may cause asphyxiation by displacing oxygen in breathing air. There are essentially no other health hazards associated with methane gas.

- Carbon dioxide is not generally considered a toxic substance, but abnormally high concentrations in breathing air may result in transient but significant adverse health effects. Removal of exposed individuals to "fresh" air will result in rapid and complete recovery from symptoms.

- Benzene, at the concentrations observed at Midway Landfill, presents a hazard only where the possibility exists for chronic (i.e., repeated, long-term) exposure. Benzene is recognized by most regulatory agencies as a confirmed human carcinogen. Limited sampling of nearby residences has failed to find benzene even where relatively high levels of methane have been found, although the detection limits (0.1 ppm) used in the studies that were evaluated were not adequately low to detect statistically significant increases above background benzene concentrations.

- It was judged unlikely that ambient air monitoring for benzene or other organic vapors would produce any significant information about the contribution of landfill vent gas emissions [off-site gas control well emissions] to ambient levels of volatile organics such as benzene.

- Hydrogen sulfide (H_2S) is highly acutely toxic. Hydrogen sulfide is a highly reactive substance and will combine with water, forming insoluble sulfides and acid sulfates. For this reason, it would not be expected to migrate effectively through moist soil and would not be expected to occur in vent gases off-site much beyond the landfill area. In each of four samples of off-site gas analyzed, H_2S was below the limit of detection of 0.1 ppm and was not detectable in any of the residential basement gas samples collected

(although a higher detection limit, 1 ppm, based on a different field method, was used for this portion of the field surveys).

- Aromatic Hydrocarbons other than benzene (e.g., toluene and xylenes) were identified in the off-site gas control well emissions but were generally present at concentrations below what have been identified routinely in ambient air. Exposure to emissions from the off-site gas control wells could be expected to be totally insignificant relative to other common sources of these compounds.

- Methylene chloride was identified in samples at concentrations considerably above ambient levels but generally far below levels associated with any known adverse health effect. However, methylene chloride may be carcinogenic in experimental animals; the carcinogenicity of methylene chloride is still at issue.

- Trichloroethylene (trichloroethene, TCE) was identified at concentrations far below those known to produce any adverse health effects in humans and generally within the range reported for ambient indoor levels of TCE. TCE is generally classified as a potential human carcinogen, although further studies are necessary before a definite conclusion on the carcinogenicity of TCE in humans can be made.

- Acetone was identified in some off-site gas control well gas samples at "relatively low" concentrations (i.e., less than 0.2 ppm). Acetone is considered one of the safest of all organic solvents, and exposure to acetone at the levels identified poses no conceivable health risks.

- Vinyl chloride data were not analytically verified and, thus, were not included in the report. It was concluded that vinyl chloride may have been present in the emissions from the off-site gas control wells and that it would be important to further ascertain the actual concentrations of vinyl chloride in the vent gas. Vinyl chloride is recognized as a human carcinogen, based on epidemiological studies in worker populations with relatively high levels of exposure.

- For all gaseous emissions other than methane, considerably lower levels were found in off-site vent [gas control] wells relative to on-site vent [gas extraction] wells. Selective reduction in relative concentrations of gas components would be expected for those components that:

  (a) Are of lower volatility;
  (b) Are of higher water solubility;
  (c) Have reactive chemistry;
  (d) Have chemical affinity for solids and/or organic components of soil.

- Under "worst-case" atmospheric conditions, a minimum dilution factor of about 6,000 to 7,000 for emission gases in the breathing zone air would result at a point 40 to 70 meters from the stack. At distances closer or further away than this, the dilution factors are considerably greater.

- Based on estimates of compound concentrations and expected dilution factors, acute health effects from the potentially toxic gases and vapors identified in landfill gas emissions are extremely unlikely.

- Based on a quantitative risk assessment presented in the report, it was concluded that "it is very unlikely that even one additional case of cancer will ever occur in the Midway community as a result of these landfill gases . . . the estimated level of risk, even if viewed as unacceptable, is likely to be insignificant compared to the background cancer risk in the general population . . . risk estimates determined for landfill gases are insignificant compared to other common sources of potentially cancer-causing chemicals."

- The Summary and Conclusions section of the 1986 report concluded the following: "Based on the limited data available, none of the gaseous emissions in the off-site extraction [control] wells at the Midway landfill that have been identified to date, other than methane, appear likely to represent a significant direct threat to the health of the potentially exposed population. . . . This conclusion is not intended to minimize the seriousness of the methane gas problem."

1.1.3 SUMMARY OF POTENTIAL HEALTH AND SAFETY HAZARDS RELATED TO MIDWAY LANDFILL GAS CONSTITUENTS

Potential health and safety hazards related to compounds identified in Midway Landfill subsurface gas in the two University of Washington studies included:

- Fire or explosion due to the presence of methane and other combustible gases, particularly when sources of heat, ignition, and oxygen are available.

- Simple asphyxiation (suffocation) from breathing air where very high levels of landfill gas accumulate and oxygen is displaced (e.g., in low-lying areas during on-site drilling into landfill waste materials).

- Acute toxic effects resulting from short-term exposures to undiluted landfill gas. The primary compounds of concern with respect to short-term exposures include the toxic inorganic gases hydrogen sulfide (H_2S) and carbon monoxide (CO). The University of Washington researchers (1985, 1986) concluded that the observed concentrations of volatile organic compounds in subsurface gas vented from off-site gas control wells were far below levels expected to result in adverse health effects following acute exposures.

- Chronic toxic effects resulting from long-term exposures to certain volatile organic compounds, notably benzene and several chlorinated organic compounds known or suspected to cause cancer in humans.

Potential health effects associated with compounds identified in Midway Landfill subsurface gas are described in greater detail in the April 1986 University of Washington study cited above.

1.2 SUPPLEMENTAL STUDIES OF POTENTIAL HEALTH HAZARDS ASSOCIATED WITH MIDWAY LANDFILL GAS

Potential effects on public health of Midway Landfill subsurface gas are further evaluated in the Preliminary Endangerment Assessment (Parametrix, 1988) prepared as part of the Midway Landfill Remedial Investigation and currently in the Endangerment Assessment being prepared for the Midway Landfill Feasibility Study.

2.0 OBJECTIVES

The objectives for the on-site and off-site Midway Landfill subsurface gas characterization as part of the remedial investigation were to:

- Identify chemical components present in on-site subsurface landfill gas samples collected from:
  - On-site gas extraction wells.
  - Pre-combustion flare gas (flare inlet gas).
- Identify a list of on-site subsurface gas contaminants that comprise a potential "fingerprint" of Midway Landfill subsurface gas.
- Identify chemical components present in off-site subsurface gases.
- Evaluate the relationship between on-site subsurface gas composition and off-site subsurface gas composition.

The tasks above were completed in order to help fulfill the following broader objectives, as outlined in Section 2.3.1.1 of the Final Remedial Investigation Sampling and Analysis Plan for the Midway Landfill (Black & Veatch, 1986b):

- Expand the current landfill gas monitoring and sampling database.
- Better estimate the present extent of landfill gas migration.
- Identify migration conduits and landfill gas accumulation points.
- Determine predominant transport mechanisms.
- Determine compositional changes in gas as it migrates away from the landfill.
- Determine effectiveness of off-site subsurface gas extraction systems and determine the need for additional off-site controls.

By comparing data on the nature and extent of migration of gas components (eg., volatile organic compounds) with data on combustible gas migration, it might be possible to evaluate the degree of likelihood that gas at specific off-site locations originated from the Midway Landfill versus other potential sources.

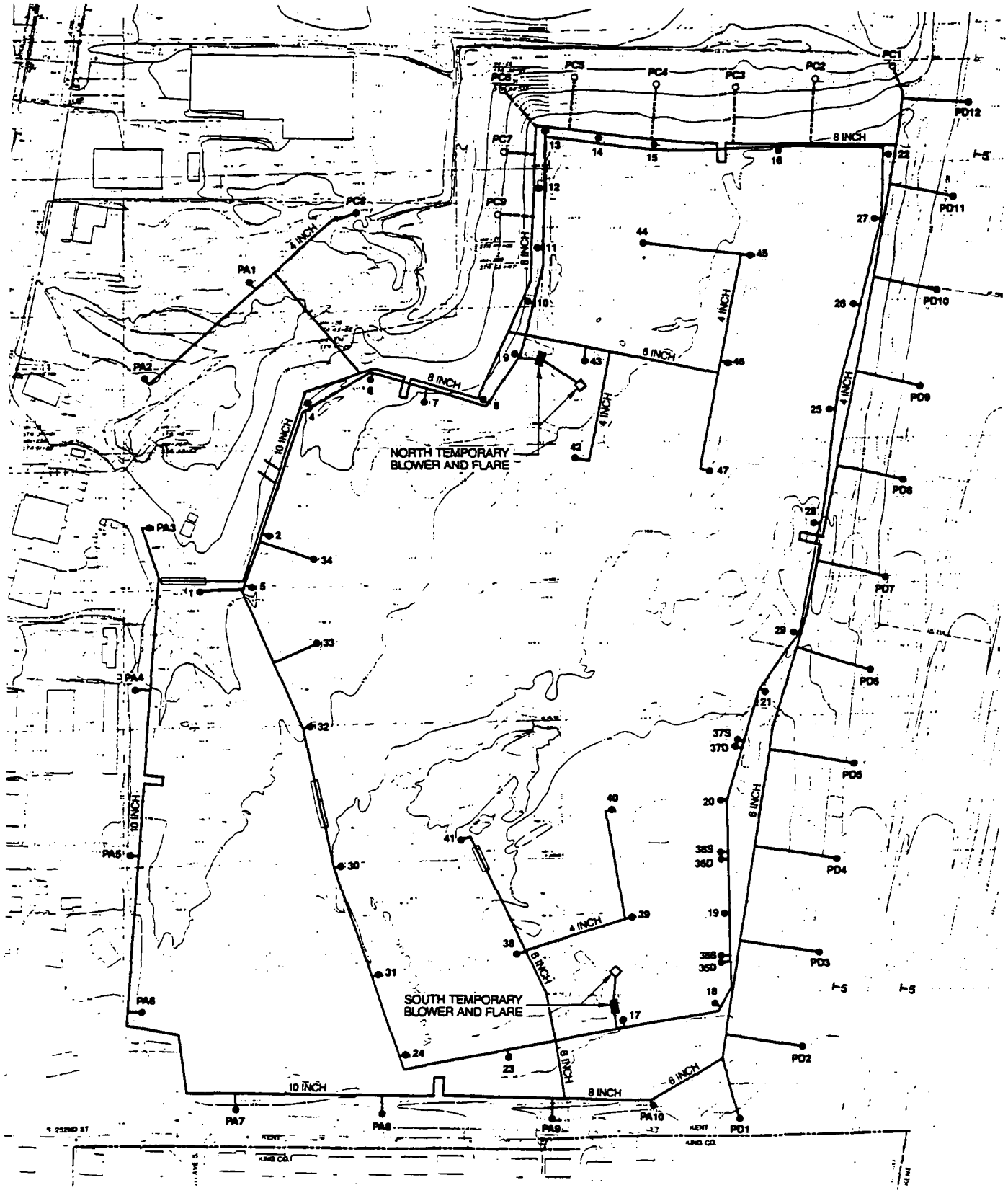
3.0 EXISTING CONDITIONS

Combustible gases are present in both on-site and off-site subsurface gas. These on-site combustible gases are currently being collected by a gas extraction well system and then burned at two temporary flare installations on-site. The locations of the on-site gas extraction wells and temporary flares are shown in Figure 3-1. The design and specifications for a permanent flare and motor blower installation are in the process of being finalized.

Off-site migration of landfill subsurface gas has been monitored at numerous gas monitoring probes and off-site gas control wells located in the communities near the landfill since mid-1985. Off-site combustible gases are being controlled using both the on-site gas extraction system and off-site gas control wells. The locations of existing off-site subsurface gas monitoring probes and off-site gas control wells are shown in Figure 3-2.

Toxic inorganic gases have also been detected in on-site subsurface gases. The major toxic inorganic gases detected are hydrogen sulfide and carbon monoxide. Hydrogen sulfide is a common product of anaerobic decomposition of landfill wastes. Carbon monoxide is a product of incomplete combustion that is associated with subsurface landfill fires, which may occur as a result of the intrusion of air into the landfill wastes. Although there are no subsurface landfill fires believed to be burning at present, there is a residual concentration of carbon monoxide in the range of 1-4 ppm, believed to be due at least in part to past subsurface fires. Subsurface landfill fires are suspected to exist if routine gas monitoring indicates carbon monoxide concentrations at or above 50 ppm.

The presence of numerous USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) at or below the low parts-per-million (ppm) range has been confirmed in both on-site and off-site subsurface gases by the results of several sampling and analysis studies conducted both prior to and concurrent with the Midway Landfill Remedial Investigation.



SCALE IN FEET

0 100 200

N

● Existing Wells

○ Proposed Wells

Existing Pipeline

Proposed Pipeline

Culvert

Figure 3-1. Location of Existing On-Site Gas Extraction Wells and Temporary Flare Installations.

Figure 3-2. Location of Off-Site Gas Monitoring Probes and Gas Control Wells

(See map that is Appendix A of
the Landfill Gas Technical Report.)

4.0 METHODOLOGY

This section describes the methods used to characterize the composition of on-site and off-site subsurface gas. Methods described include:

- o Field screening and monitoring methods
- o Sampling methods
- o Laboratory analytical methods
- o Data evaluation methods
  - Summary tables
  - Mapping of the geographic distribution of contaminants

Sampling activities that have been done to characterize gas composition include:

- o Sampling of gas from the on-site gas extraction system
- o Sampling of gas from inlets and exhaust flames of the temporary on-site flares
- o Preliminary screening for gas contaminants at off-site gas monitoring probes
- o Sampling of gas at selected off-site gas monitoring probes, based on screening results
- o Sampling of gas at off-site gas control wells

These gas characterization screening and sampling activities are summarized in Table 4-1. Table 4-1 shows that a large body of data exists regarding Midway Landfill gas composition. However, the various studies listed differed on a number of important factors:

- o Date of sampling (and, therefore, status of the gas control system and other remedial measures in effect at the time of sampling)
- o List of target compounds (parameters measured)
- o Sampling methods
- o Laboratory analytical methods

Table 4-1 shows that sampling has been done numerous times between May 1985 and the present. Various remedial activities have been implemented during this period and would be expected to have an effect over time on the landfill gas concentrations and composition and, therefore, on the sampling results. In addition, a variety of sampling and analytical methods were used to

Table 4-1. Summary of on-site and off-site gas characterization activities described in this Technical Task Memorandum.

Sampling Activity	Parameters Measured	Sample Type	Detection Method	Sampling Team	Sample Dates	Analytical Lab(s)
ON-SITE LANDFILL GAS SAMPLING ACTIVITIES:						
Initial Site Surveys	Combustible gas	Explosimeter	Wheatstone bridge	UW	05/17/85	(field)
	Carbon monoxide (CO)	Detector tube	Colorimetric	UW	05/17/85	(field)
	Hydrogen sulfide (H2S)	Detector tube	Colorimetric	UW	05/17/85	(field)
	Hydrogen sulfide (H2S)	Impinger	Colorimetric	UW	05/17/85	UW
	Hydrogen cyanide (HCN)	Impinger	Ion Chromatography	UW	05/17/85	UW
	Selected VOCs	Charcoal tube	GC/MS	UW	05/17/85	UW
	Selected VOCs	Cryogenic tank	GC/MS	UW	05/17/85	UW
On-Site Gas Extraction Wells	HSL VOCs	Tedlar bag	GC/MS	B & V	'85-'87	ATI
	HSL VOCs	Tedlar bag	GC/MS	PMX	06/87-07/87	ATI
	Total non-CH4 VOCs	HNu PI-101	PID	PMX	06/87-07/87	(field)
	Combustible Gas/H2S/O2	MSA 361	Wh. bridge; electrochem.	PMX	06/87-07/87	(field)
	Carbon dioxide (CO2)	Fyrite CO2 analyzer	Chemical	PMX	06/87-07/87	(field)
Flare Inlet Gas (pre-combustion)	Selected VOCs	Evacuated cylinder	GC/FID or GC/PID	FFB	03/87	FFB
	HSL VOCs	Tedlar bag	GC/MS	B & V	05/01/86	ATI
	HSL VOCs	Tedlar bag	GC/MS	PMX	06/18/86	ATI
	Hydrogen sulfide (H2S)	Detector tube	Colorimetric	PMX	11/19/86	(field)
	Hydrogen cyanide (HCN)	Detector tube	Colorimetric	PMX	11/19/86	(field)
	Hydrogen cyanide (HCN)	Impinger	Ion Specific Electrode	PMX	11/19/86	ATI
	HSL VOCs	Tedlar bag	GC/MS	TRC	06/87	RTL
	HSL VOCs	VOST	GC/MS	TRC	06/87	RTL
	Combustible Gas/H2S/O2	MSA 361	Wh. bridge; electrochem.	TRC	06/87	(field)
	Hydrogen cyanide (HCN)	Impinger	Ion Specific Electrode	TRC	06/87	RTL
	Hydrogen chloride (HCl)	Impinger	Ion Chromatography	TRC	06/87	RTL
Flare Outlet Gas (post-combustion)	Selected VOCs	Evacuated cylinder	GC/FID or GC/PID	FFB	03/87	FFB
	HSL VOCs	VOST	GC/MS	TRC	06/87	RTL
	Combustible Gas/H2S/O2	MSA 361	Wh. bridge; electrochem.	TRC	06/87	(field)
	Hydrogen cyanide (HCN)	Impinger	Ion Specific Electrode	TRC	06/87	RTL
	Hydrogen chloride (HCl)	Impinger	Ion Chromatography	TRC	06/87	RTL

(Continued ...)

(See also NOTES at end of this Table)

Table 4-1. (continued)
Page 2.

Sampling Activity	Parameters Measured	Sample Type	Detection Method	Sampling Team	Sample Dates	Analytical Lab(s)
OFF-SITE LANDFILL GAS SAMPLING ACTIVITIES:						
Off-Site Gas Probes (screening)	Total non-CH4 VOCs	HNu PI-101	PID	PMX	06/87	(field)
	Combustible Gas/H2S/O2	MSA 361	Wh. bridge; electrochem.	PMX	06/87	(field)
	Carbon dioxide (CO2)	Fyrite CO2 analyzer	Chemical	PMX	06/87	(field)
Off-Site Gas Probes (sampling; including off-site gas control wells)	Total non-CH4 VOCs	HNu PI-101	PID	PMX	06/87-07/87	(field)
	Combustible Gas/H2S/O2	MSA 361	Wh. bridge; electrochem.	PMX	06/87-07/87	(field)
	Carbon dioxide (CO2)	Fyrite CO2 analyzer	Chemical	PMX	06/87-07/87	(field)
	HSL VOCs	Tedlar bag	GC/MS	PMX	06/87-07/87	ATI
	HSL VOCs	Tedlar bag	GC/MS	B & V	'85-'87	ATI
Off-Site Gas Control Well Carbon Filter Drum Inlet/Outlet	HSL VOCs	Tedlar bag	GC/MS	B & V	'85-'87	ATI
	Selected VOCs	Evacuated cylinder	GC/FID or GC/PID	FFB	03/87	FFB

NOTES:

ATI = Analytical Technologies, Inc.
B & V = Black & Veatch (consultants to WA Dept. of Ecology)
FFB = Farr, Friedman & Bruya (subconsultants to Parametrix, Inc.)
GC/FID = Gas Chromatography/Flame Ionization Detection
GC/MS = Gas Chromatography/Mass Spectrometry
GC/PID = Gas Chromatography/Photoionization Detection
HSL VOCs = USEPA Hazardous Substances List Volatile Organic Compounds
PID = Photoionization Detector
PMX = Parametrix, Inc. (consultants to City of Seattle)
RTL = Research Triangle Laboratories, Inc.
Total non-CH4 VOCs = Volatile Organic Compounds detectable using HNu PI-101 with 10.2 eV probe (excludes methane)
TRC = TRC Environmental Consultants (subconsultants to Parametrix, Inc.)
UW = University of Washington, Dept. of Environmental Health
VOCs = Volatile Organic Compounds
VOST = Volatile Organic Sampling Train

characterize the gas in the various studies, as shown in Table 4-1; therefore, the results for each field activity are potentially influenced by the choice of sampling and analytical methods.

Each study focused on a different set of "target compounds," or list of "things to look for" in the gas, as shown in Table 4-2; therefore, each study would be expected to result in a somewhat different list of substances found in the gas. Comparisons among the various studies were easiest where there was overlap in the contents of the respective target compound lists. Factors such as the differences in the limits of detection achieved in each study had to also be considered when making comparisons among studies.

Studies of subsurface landfill gas composition conducted by Parametrix for the Midway Landfill Remedial Investigation included the following volatile organic target compounds:

- The "official" list of current USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) compiled by USEPA by combining the following:
  - Twenty-seven of the 29 VOCs included in the Clean Water Act CERCLA/RCRA Consent Order "Priority Pollutant" VOCs list (Fed. Reg., 1981). (Acrolein and acrylonitrile were later deleted from this group by USEPA in compiling the current Hazardous Substances List.)
  - Eight additional VOCs added at the time of compilation of the Hazardous Substances List
- Three additional VOCs that are not on the "official" Hazardous Substances List but results for which were routinely included in laboratory reports provided by Analytical Technologies, Inc.:
  - Tetrahydrofuran
  - Trichlorofluoromethane
  - Trichlorotrifluoroethane

For the purposes of this technical memorandum, the full list of 38 compounds described above is referred to as the "USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs)," excluding the two deleted HSL compounds and including the three non-HSL compounds reported by the laboratory.

4.1. SAMPLING AT INDIVIDUAL ON-SITE GAS EXTRACTION WELLS

Subsurface gas samples obtained from individual on-site gas extraction wells represent the gas present within the limited zone of influence of that well. Wells at various locations on-site were sampled to identify specific localized "hot spots" within the landfill waste that appear to contain relatively higher levels of contaminants than at other locations. Data on samples from these "hot spots" would then be compared with data on the pre-combustion flare gas, which was comprised of gas from numerous individual extraction

Table 4-2. Summary of target parameters studied during Midway Landfill gas monitoring and sampling activities.

CAS #	COMPOUND	USEPA Hazardous Substances List VOCs	UW	Midway RI S&A Plan List	B&V	PMX	FFB	TRC
USEPA Priority Pollutant VOCs:								
107-02-8	acrolein	1 *	NR	NR	NR	NR	NR	NR
107-13-1	acrylonitrile	2 *	NR	NR	NR	NR	NR	NR
71-43-2	benzene	3	X	X	X	X	X	X
75-27-4	bromodichloromethane	4	NR	NR	X	X	NR	NR
74-83-9	bromomethane (methyl bromide)	5	NR	NR	X	X	NR	NR
75-25-2	bromoform	6	NR	NR	X	X	NR	NR
56-23-5	carbon tetrachloride	7	NR	X	X	X	X	NR
108-90-7	chlorobenzene	8	X	X	X	X	NR	X
75-00-3	chloroethane	9	X	NR	X	X	X	X
110-75-8	2-chloroethylvinyl ether	10	NR	NR	X	X	NR	NR
67-66-3	chloroform	11	X	NR	X	X	X	NR
74-87-3	chloromethane (methyl chloride)	12	NR	NR	X	X	X	NR
124-48-1	dibromochloromethane	13	NR	NR	X	X	NR	NR
75-34-3	1,1-dichloroethane	14	X	NR	X	X	X	X
107-06-2	1,2-dichloroethane	15	X	NR	X	X	X	NR
75-35-4	1,1-dichloroethene	16	X	NR	X	X	X	NR
156-60-5	trans-1,2-dichloroethene	17	X	X	X	X	X	X
78-87-5	1,2-dichloropropane	18	X	X	X	X	NR	NR
10061-01-5	cis-1,3-dichloropropene	19	NR	NR	X	X	NR	NR
10061-02-6	trans-1,3-dichloropropene	20	NR	NR	X	X	NR	NR
100-41-4	ethylbenzene	21	NR	NR	X	X	X	X
75-09-2	methylene chloride	22	X	X	X	X	X	X
79-34-5	1,1,2,2-tetrachloroethane	23	X	NR	X	X	X	NR
127-18-4	tetrachloroethene (PCE)	24	X	X	X	X	X	X
108-88-3	toluene	25	X	X	X	X	X	X
71-55-6	1,1,1-trichloroethane	26	X	NR	X	X	X	NR
79-00-5	1,1,2-trichloroethane	27	NR	NR	X	X	NR	NR
79-01-6	trichloroethene (TCE)	28	X	X	X	X	X	X
75-01-4	vinyl chloride (chloroethene)	29	NR	X	X	X	X	X
USEPA Hazardous Substances List VOCs (added to Priority Pollutants list by CERCLA):								
67-64-1	acetone	30	X	NR	X	X	X	NR
78-93-3	2-butanone (methyl ethyl ketone; MEK)	31	X	NR	X	X	NR	NR
75-15-0	carbon disulfide	32	NR	NR	X	X	X	NR
591-78-6	2-hexanone (methyl n-butyl ketone)	33	NR	NR	X	X	NR	NR
108-10-1	4-methyl-2-pentanone (MIBK)	34	X	NR	X	X	NR	NR
100-42-5	styrene	35	NR	NR	X	X	X	NR
108-05-4	vinyl acetate	36	NR	NR	X	X	NR	NR
1330-20-7	xylenes (total)	37	NR	X	X	X	NR	NR

(See also NOTES at end of this Table.)

Table 4-2. (continued)
Page 2.

CAS #	COMPOUND	USEPA Hazardous Substances List VOCs	UW	Midway RI S&A Plan List	B&V	PMX	FFB	TRC
Additional parameters studied:								
124-38-9	carbon dioxide (CO2)	NR	NR	X	X	X	NR	X
630-08-0	carbon monoxide (CO)	NR	X	NR	NR	NR	NR	X
N/AP	combustible gas	NR	X	X	X	X	NR	X
N/AP	C-2 benzenes (m,o,p-xylenes + ethylbenzene)	NR	X	NR	NR	NR	NR	NR
N/AP	C-(11,13,14,15) compounds	NR	X	NR	NR	NR	NR	NR
75-71-8	dichlorodifluoromethane (Freon 12)	NR	NR	NR	NR	NR	NR	X
74-84-0	ethane	NR	NR	NR	NR	NR	X	NR
N/AP	gas flow rate (on-site gas wells)	NR	NR	X	NR	X	NR	X
7732-18-5	gas moisture content (H20)	NR	NR	X	NR	NR	NR	X
N/AP	gas pressure	NR	NR	X	X	X	NR	NR
N/AP	gas temperature (on-site gas wells)	NR	NR	X	NR	X	NR	X
7647-01-0	hydrogen chloride (HCl)	NR	NR	X	NR	NR	NR	X
74-90-8	hydrogen cyanide (HCN)	NR	X	X	NR	X	NR	X
7783-06-4	hydrogen sulfide (H2S)	NR	X	X	NR	X	NR	X
540-84-1	isooctane	NR	X	NR	NR	NR	NR	NR
138-86-3	limonene	NR	X	NR	NR	NR	NR	NR
74-82-8	methane	NR	NR	NR	NR	NR	X	NR
111-84-2	nonane	NR	X	NR	NR	NR	NR	NR
111-65-9	octane	NR	X	NR	NR	NR	NR	NR
7782-44-7	oxygen (O2)	NR	NR	X	X	X	NR	X
95-47-6	o-xylene	NR	NR	NR	NR	NR	X	NR
74-98-6	propane	NR	NR	NR	NR	NR	X	NR
106-42-3	p-xylene	NR	NR	NR	NR	NR	X	NR
109-99-9	tetrahydrofuran	NR	NR	NR	NR	X	NR	NR
75-69-4	trichlorofluoromethane (Freon 11)	NR	NR	NR	NR	X	NR	X
76-13-1	trichlorotrifluoroethane (Freon 113)	NR	NR	NR	NR	X	NR	NR

NOTES:

* Acrolein and acrylonitrile have been deleted from the USEPA Hazardous Substances List.
X = Compound is included in the indicated target parameter list.
NR = Compound was not reported as a target parameter on the indicated list.
VOCs = Volatile Organic Compounds
UW = University of Washington
S & A = Sampling and Analysis
B & V = Black & Veatch
PMX = Parametrix, Inc.
FFB = Farr, Friedman & Bruya Inc. Environmental Chemists
TRC = TRC Environmental Consultants

wells, and with data on off-site subsurface gas. These comparisons would help determine whether the contaminants detected at specific on-site "hot spots" potentially contribute to the composition of emissions from the flares or to migrating landfill subsurface gas.

Parametrix collected Tedlar bag samples from each of the 14 on-site gas extraction wells during one round of sampling conducted during June-July 1987. The on-site gas extraction wells sampled are listed in Table 4-3, and their locations are shown on Figure 3-1. Samples were sent to Analytical Technologies for analysis by GC/MS.

The 14 sampling points were selected using a combination of two methods that was designed to result in selection of equal numbers of randomly and non-randomly chosen sampling locations, as described below:

- Seven (7) of the fourteen sampling points were selected based on existing data that suggested the potential presence of elevated concentrations of landfill gas contaminants at these locations. These sampling points are referred to as "biased sampling points" because the selection process was non-random, i.e., biased toward selection of wells expected to have relatively higher contaminant levels.

- The remaining seven (7) sampling points were chosen randomly from among the remaining well locations. These sampling points are referred to as "random sampling points" and were expected to provide samples that were more representative of typical contaminant concentrations throughout the landfill.

Samples of subsurface gas were collected in Tedlar bags using either a bellows-type foot pump or a Brailsford TD-2N high-efficiency electric pump. The Brailsford pump was required when samples were taken from on-site gas extraction wells, where a relatively high vacuum was maintained in the well by the on-site gas control system. Tedlar bags were filled passively, such that sample gas did not come in contact with the pump, thus, reducing the possibility of sample contamination. The pump created a vacuum around the bag, which was contained within a sealed housing ("Peli-case"); gas was then drawn passively into the bag through a Teflon sampling line. New Teflon tubing was used for each sample to prevent cross-contamination. Field samples and the appropriate QA/QC samples were shipped to the laboratory at the end of each day of sample collection.

Sample analysis was performed by Analytical Technologies by gas chromatography/mass spectrometry (GC/MS) using cryogenic focusing techniques. Analyses followed USEPA Method 624 guidelines for Hazardous Substances List Volatile Organic Compounds (HSL VOCs). Where possible, samples were analyzed within 24 hours of receipt by the lab.

4.2. SAMPLING OF PRE-COMBUSTION FLARE GAS (FLARE INLET GAS)

Landfill gases collected by means of the numerous individual on-site gas extraction wells are combined in a manifold system and conveyed via PVC pipe

Table 4-3. On-site gas extraction wells sampled by Parametrix, Inc. during June-July 1987.

Type of Gas Extraction Well	Total # of Wells	Total Potential Sampling Points	Selected Biased Sampling Points	Selected Random Sampling Points	Total Selected Sampling Points
Perimeter of refuse (Wells #1--37)	37	40	4-0 12-0 21-0 25-0 36D-0	18-0 24-0 33-0 34-0	9
Interior of refuse (Wells #38--47)	10	20	41D-0	44D-0	2
Perimeter wells (Wells # PA-1 thru PA-10)	10	20	PA8D-O	(none)	1
Perimeter wells (Wells # PD-1 thru PD-12)	12	24	(none)	PD6D-0 PD12D-0	2
Perimeter well (Well # PC-8)	1	2	(none)	(none)	0
Perimeter well (Well # C-11)	1	1	(none)	(none)	0
TOTALS	71	107	7	7	14

to one or the other of the two temporary flares to be burned. Gas samples taken from the "feed line," or flare inlet, represent a weighted average of the gases collected by all the gas extraction wells supplying the flare. Thus, samples of these pre-combustion flare gases provide an overall picture of the average types and quantities of compounds present in gas extracted from the landfill.

Several studies summarized in this technical memorandum examined the chemical composition of pre-combustion flare gases. Target parameters included in each of the various studies are summarized in Table 4-2.

4.2.1. TRC ENVIRONMENTAL CONSULTANTS FLARE SAMPLING ACTIVITIES

TRC Environmental Consultants, Inc., were retained by Parametrix as sub-contractors to conduct sampling of the pre- and post-combustion flare gases from the two temporary on-site flares in operation during the Midway Landfill Remedial Investigation. TRC sampling activities were conducted during June 1987. The objectives of TRC's studies were to:

- Characterize the chemical composition of mixed gases collected by the on-site gas collection system.
- Characterize the chemical composition of post-combustion stack emissions from the two temporary on-site flares.
- Estimate the overall combustion efficiency of the two existing temporary flares.

Details of TRC's flare sampling methodology are contained in Section 3.4 and Appendix C of the Midway Landfill Air Quality Technical Report (Parametrix, 1988). Those portions of TRC's methodology that pertain to characterization of the pre-combustion flare gas composition are reproduced in this section.

Volatile organic compounds were sampled using two sampling methods. In the first method, a standard Volatile Organic Sampling Train (VOST) apparatus was used. Pre-combustion flare gases were sampled at the inlet of each flare using a stainless steel probe that was heated to maintain a sample gas temperature of approximately 130° C. Post-combustion flare gases were sampled within the zone of the flame using an Inconel probe, also heated to maintain a sample gas temperature of approximately 130° C. Each sample consisted of one pair of sample cartridges (Tenax resin cartridge followed by a Tenax/charcoal cartridge). Sampling at the flare inlets followed USEPA's Protocol for the Collection and Analysis of Volatile POHCs Using VOST (1984), using the slow-VOST procedure. Two samples were collected from each location. Samples were analyzed by Research Triangle Laboratories by Purge-Trap-Desorb Gas Chromatography/Mass Spectrometry (PTD-GC/MS) in accordance with USEPA Method 624.

In the second method, grab samples were collected in Tedlar bags from the flare inlets only and shipped to Research Triangle Laboratories for analysis of VOCs following USEPA Method 624 PTD-GC/MS procedures. Details of the analytical procedures are included as Appendices 1 and 2 of TRC's Meteoro-

logical Data and Air Quality Modeling Technical Memorandum, which comprises Appendix C of the Midway Landfill Air Quality Technical Report (Parametrix, 1988).

Hydrogen cyanide (HCN) and hydrogen chloride (HCl) samples were collected from both pre- and post-combustion gases using a midget impinger train. Samples were sent to Research Triangle Laboratories for analysis. Hydrogen cyanide analyses were performed by Ion Specific Electrode techniques according to NIOSH methods S250 and 7904. Hydrogen chloride analyses were performed by Ion Chromatography techniques according to NIOSH methods 7903 and S248. Details of the analytical procedures are included as Appendix 3 of TRC's technical memorandum.

Hydrogen sulfide (H_2S) was analyzed in the field using a Mine Safety Appliances MSA 361 gas analyzer provided by Parametrix. TRC's Interscan LD series H_2S analyzer was damaged during shipment to the site, and therefore was not used; however, both the MSA and Interscan instruments have similar limits of detection (approximately 1 ppm H_2S).

Flow velocity measurements were performed at each flare inlet duct at sampling points determined using USEPA Reference Method 1 and were measured using a standard pitot tube that was aligned with the direction of gas flow and coupled to an inclined manometer. Flare outlet flow rates were computed based on the inlet flow rates and gas composition. Exhaust flow rates were calculated using net theoretical heat release based on the lower heating value of the landfill gas according to methods described in Appendix 5 of TRC's technical memorandum.

Gas temperatures were measured using a digital pyrometer and Type K thermocouple according to USEPA Reference Method 2.

The molecular weight of the landfill gas was determined by measuring the volumetric percentage of methane, carbon dioxide, and oxygen in the gas streams. An integrated bag sample was collected during each test run and then analyzed using Fyrite gas analyzers, as described in USEPA Reference Method 3 for carbon dioxide and oxygen.

Moisture content of the gas was determined by gravimetric analysis of silica gel adsorbent integrated into the HCN/HCl midget impinger sampling train, as described in USEPA Reference Method 4.

4.2.2. PARAMETRIX FLARE SAMPLING ACTIVITIES

Prior to the remedial investigation, Parametrix had collected Tedlar bag samples of pre-combustion flare gas for other studies related to the Midway Landfill. Samples were collected from a sampling port located between the blower motor and the flare head (see Figure 4-1). Samples were shipped to Analytical Technologies for analysis by gas chromatography/mass spectrometry (GC/MS) according to USEPA guidelines for HSL VOCs using Method 624 and cryogenic focusing techniques.

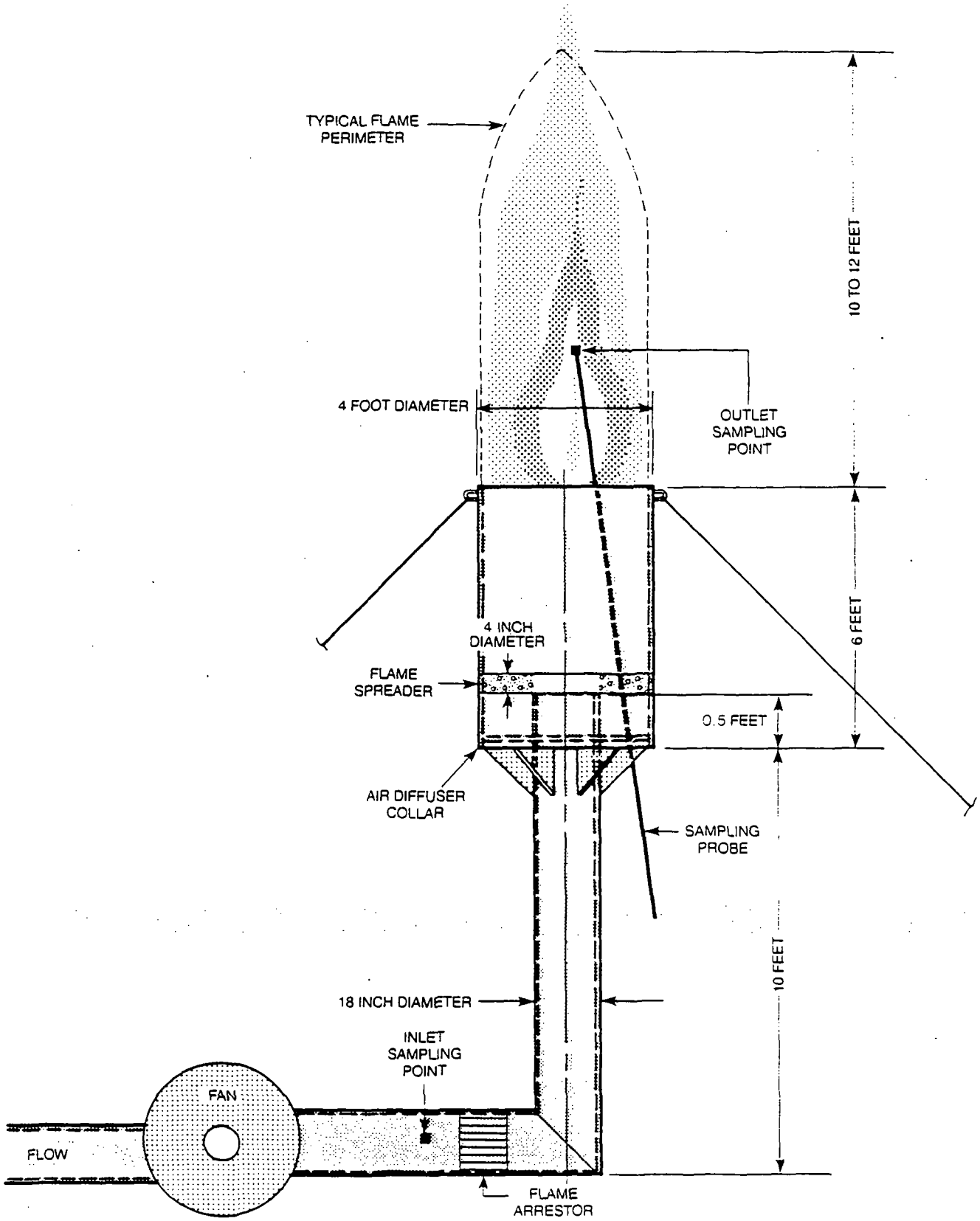


Figure 4-1.
Schematic Diagram of Temporary Gas Flare and Inlet Sampling Point

4.2.3. BLACK & VEATCH FLARE SAMPLING ACTIVITIES

Prior to and during the same time period as the remedial investigation, Black & Veatch also had conducted sampling of pre-combustion flare gases under the direction of the Washington State Department of Ecology. Samples were collected in Tedlar bags and sent to Analytical Technologies for analysis. Samples were analyzed by GC/MS according to USEPA guidelines for HSL VOCs using Method 624.

4.2.4. FARR, FRIEDMAN & BRUYA FLARE SAMPLING ACTIVITIES

In other studies related to Midway Landfill, Farr, Friedman & Bruya conducted sampling of pre- and post-combustion flare gases under the direction of Parametrix during March 1987. Samples of pre-combustion flare gases were collected in stainless steel evacuated cylinders from ports at the inlets to the flares. Samples of post-combustion flare gases were collected from within the zone of the flame.

Capillary tubing (approximately 0.025 mm I.D.) was inserted into the flame from underneath the flare head through openings in the bottom of the air diffuser collar (see Figure 4-1). The galvanized steel air diffuser collar is the top portion of the flare installation, in which the landfill gas is mixed with air to the extent required to support combustion. Sampling from underneath the flare was conducted for two primary reasons:

- It was desirable to protect field personnel as much as possible from potential hazards, including the possibility that shifting winds might cause exposure to hot exhaust gases from the open flame.

- The procedure ensured that the sampling probe was maintained at an elevated temperature over most of its length. An elevated probe temperature helped minimize potential problems related to condensation of materials inside the sampling apparatus without requiring additional equipment, e.g., electrically-heated probe lines.

Prior to collecting the samples, the capillary tubing was purged by drawing approximately one liter of gas through the tubing. The capillary tubing was then attached to the stainless steel evacuated cylinder, the cylinder valve was opened, and the sample was collected directly into the cylinder. The known vapor pressures of the target compounds indicated that a heated sampling line was not necessary to prevent condensation of vapors under these sampling conditions.

Sample analysis was performed by direct injection of gas from the cylinder, at atmospheric pressure, into a Hewlett-Packard 5890A Gas Chromatograph (GC). Target compound identification was based on GC retention time using Electron Capture Detection (ECD) and Flame Ionization Detection (FID). Internal standards were run daily for each target compound. Blanks were run daily as a quality assurance check.

4.3. SCREENING AT OFF-SITE GAS MONITORING PROBES FOR VOCs

Parametrix screened off-site gas monitoring probes during June 1987 for the potential presence of landfill subsurface gas contaminants using several portable direct-reading field instruments. These screening methods were designed to help select the off-site gas monitoring probes that were to be sampled for USEPA HSL VOCs. The subsequent identification of specific compounds present in the gas was done by collecting Tedlar bag samples for laboratory analysis by GC/MS; the probe sampling methods used are described in Section 4.4 of this memorandum.

Probes were selected for inclusion in the screening process based on past VOCs sampling and lab analysis results, past or current levels of combustible gas, or other criteria that suggested the presence of subsurface gases. Probes included in Parametrix' screening activities are listed in Table 4-4.

The probe screening activities conducted by Parametrix were designed as improvements to the field screening methods originally proposed for the remedial investigation. The Final Work Plan and Final Sampling and Analysis Plan (Black and Veatch, 1986b) and Parametrix' Scope of Work memo (Parametrix, 1986) had specified that a Foxboro Model OVA 128 Century Organic Vapor Analyzer (OVA 128) was to be used in the field in:

- Scan mode to detect the presence of volatile organic compounds (VOCs) in subsurface gas samples

- Gas Chromatographic (GC) mode to identify ("fingerprint") and quantify specific VOCs present in the subsurface gas samples.

The OVA 128 was not used for these purposes due to several technical considerations:

- The OVA 128 used in scan mode is unable to discriminate between VOCs and methane; therefore, methane would be expected to interfere with VOCs measurements. For this reason, photoionization detection(PID) instruments were used to quantify "total non-methane volatile organic vapor concentrations" for the purpose of implementing continuous air quality monitoring under the health and safety plans submitted by Parametrix and AGI, respectively.

- Existing gas characterization data obtained using Tedlar bag samples and laboratory analysis by GC/MS indicated the presence of numerous VOCs at highly variable concentrations in both on-site and off-site gas samples. It is extremely difficult to interpret accurately the results obtained using the OVA 128 in GC mode under these conditions, primarily because of the limited ability of the instrument's GC column in resolving the peaks for individual components of complex mixtures in the field.

- The OVA 128 used in GC mode requires the prior selection of high-purity standards for all compounds of interest in order to tentatively identify these compounds in a given sample.

Table 4-4. Off-site gas monitoring probes included in Parametrix, Inc. probe screening activities during June 1987.

Gas Probe	Date Screened
17-S	06/11/87
30-D	06/05/87
30-(?)	06/14/87
37-D	06/10/87
37-M,S	06/12/87
*44-D,M,S	06/05/87
44-M	06/11/87
45-D	06/05/87
45-M,S	06/12/87
50-D	06/05/87
50-M,S	06/12/87
61-M,S	06/05/87
70-S	06/14/87
78-S	06/14/87
79-D,M,S	06/12/87
80-D,M	06/12/87
81-D,M	06/11/87
85-D,M	06/12/87
86-M	06/05/87
87-D,M,S	06/12/87
88-D,S	06/11/87
89-M,S	06/14/87
AC-D,M,S	06/14/87
AE-D,S	06/14/87
AF-D	06/10/87
AF-M,S	06/12/87
J-D	06/10/87
J-M,S	06/11/87
M-D,M,S	06/12/87
T-D,S	06/14/87
Z-D,M,S	06/12/87

Screening was conducted by taking field measurements on Tedlar bag samples using an HNu PI-101, MSA 361, and Fyrite CO2 Analyzer.

*D, M, S, or D, M, etc., indicate multiple completion probes for which the indicated completions were included in the screening tests.

D = Deep completion
M = Medium completion
S = Shallow completion

- Evaluation of previous sampling data (Tedlar bag and GC/MS) suggested that many of the numerous compounds present in the on-site gas would, individually, be unlikely to exceed the OVA 128's compound-specific GC-mode detection limits under field conditions but would be likely to interfere with even tentative identification and quantification of compounds exceeding the OVA 128's detection limits.

After discussions involving Parametrix, the City of Seattle, and Ecology, it was decided that a preferred approach would place less emphasis on identifying individual compounds using field GC methods and greater emphasis on developing an effective alternative field screening method for monitoring for air emissions. Identification and quantification of individual gas components were to be supported by collection of gas samples for laboratory analysis by more sensitive and more reliable GC/MS methods.

Using the revised methods developed by Parametrix, total non-methane VOCs were measured in the field using an HNu PI-101 portable photoionization detector (PID) equipped with a 10.2 eV probe. This instrument was selected because of its relatively high sensitivity to a wide range of VOCs under field conditions and its lack of sensitivity to methane. The limit of detection for this instrument is approximately 1 ppm, comparable to that of the OVA 128 used in scan mode. However, the HNu PI-101 is not able to identify individual compounds (as can the OVA 128 when used in GC mode) and, thus, is useful mainly to identify locations where elevated levels of total non-methane VOCs exist. Additional field monitoring parameters were measured using a Mine Safety Appliances MSA 361 Portable Indicator (combustible gas, hydrogen sulfide, and oxygen), a Fyrite carbon dioxide analyzer, and a Magnehelic gas pressure gauge.

Gas samples used for the probe screening activities were obtained from the probes using either a bellows-type foot pump or a Brailsford TD-2N high-efficiency electric pump. The Brailsford pump was required when samples were taken from probes where a relatively high vacuum was maintained in the probe by nearby off-site gas control well blowers. Tedlar bags were filled passively by creating a vacuum around the bag contained within a sealed housing ("Peli-case") and allowing gas to enter the bag through Teflon tubing. Two 3-liter bags were filled and discarded; field instrument readings were obtained for gas from the third bag collected. This procedure ensured that the probes were adequately purged prior to taking field measurements, so that a representative sample of gas was drawn from the slotted portion of the probe completion.

For screening purposes, Tedlar bags were flushed with ambient air, emptied, and reused, unless the presence of condensed moisture was observed inside the bag; when condensation was present, the bag was discarded and replaced with a fresh bag. The known low levels (low ppb range) of HSL VOCs in ambient air near the Midway Landfill were several orders of magnitude below the concentrations that would be expected to interfere with the VOCs probe screening measurements.

4.4. SAMPLING AT OFF-SITE GAS MONITORING PROBES AND OFF-SITE GAS CONTROL WELLS

Samples collected from off-site gas monitoring probes and off-site gas control wells provided information on the potential extent and direction of landfill subsurface gas migration. Knowledge of the chemical constituents of off-site subsurface gas helped determine whether the off-site subsurface gas originated from the landfill or from unrelated off-site sources. If the chemical "fingerprint" of an off-site subsurface gas sample closely matched that of the on-site subsurface gas, there would be reason to suspect that the off-site gas contaminants may have migrated with methane and other major landfill subsurface gas constituents or have otherwise been transported from the site. In other cases, the chemical "fingerprint" might indicate that the off-site subsurface gas more likely originated from sources unrelated to the Midway Landfill, perhaps from utility leaks or from the decay of natural materials in sources such as wetlands or buried peat deposits, for example.

4.4.1. PARAMETRIX OFF-SITE GAS SAMPLING ACTIVITIES

Off-site subsurface gas monitoring probes were selected by the City of Seattle for sampling based on field data from the probe screening procedures described above and other criteria. Samples were collected from each of 12 off-site gas probes during two sampling rounds, for a total of 24 samples. Replicate samples and field blanks were also collected in accordance with QA/QC requirements. The off-site gas monitoring probes sampled by Parametrix during June 1987 are listed in Table 4-5.

The sample collection procedure was similar to that described for the probe screening activities, except that for each sample a single, 3-liter Tedlar bag was filled and emptied twice to purge the probe; the bag was then filled a third time and sealed and shipped to Analytical Technologies for analysis. Analytical procedures followed USEPA guidelines for GC/MS using cryogenic focusing and Method 624 for HSL VOCs. Where possible, samples were analyzed within 24 hours of receipt by the laboratory.

In addition to the sampling program described above for the remedial investigation, Parametrix collected Tedlar bag samples of gas from off-site gas control wells and from a limited number of off-site gas monitoring probes prior to the start of the remedial investigation. The procedures used were similar to those for the remedial investigation, with the following exceptions: 1) only the bellows pump was used to collect the samples, 2) probes were not purged prior to sampling, and 3) no attempt was made to achieve sample analysis within 24 hours of sample receipt by the laboratory. The sample analysis was conducted by Analytical Technologies; analytical procedures were similar to those used during the remedial investigation studies.

4.4.2. BLACK & VEATCH OFF-SITE GAS SAMPLING ACTIVITIES

Black & Veatch collected Tedlar bag samples of gas from off-site subsurface gas monitoring probes and off-site gas control wells. Samples were shipped to Analytical Technologies for analysis. Analytical procedures followed

Table 4-5. Off-site gas monitoring probes sampled by Parametrix, Inc. during June-July 1987.

Gas Probe Name	Date of First Sample	Date of Second Sample
2-S	06/22/87	06/30/87
37-D	06/22/87	06/30/87
44-D	06/15/87	06/23/87
50-S	06/23/87	07/09/87*
88-M	06/22/87	06/30/87
88-S	06/15/87	06/23/87
J-D	06/22/87	06/30/87
M-M	06/15/87	06/23/87
T-S	06/22/87	06/30/87
Z-S	06/23/87	06/30/87
AC-S	06/15/87	06/23/87
AF-D	06/15/87	06/23/87

*Sample originally collected 06/30/87 unusable due to leak in Tedlar bag; probe was re-sampled on 07/09/87.

USEPA guidelines for GC/MS using cryogenic focusing and Method 624 for HSL VOCs.

4.4.3. FARR, FRIEDMAN & BRUYA OFF-SITE GAS SAMPLING ACTIVITIES

Farr, Friedman & Bruya (FFB) conducted sampling of subsurface gas at selected off-site gas control wells and at a limited number of off-site gas monitoring probes under the direction of Parametrix as part of other studies of the Midway Landfill. This sampling activity was not conducted specifically for the remedial investigation; the methods used were somewhat different than those described for the remedial investigation sampling activities because the goals of the study were different.

Stainless steel evacuated cylinders were used to draw gas from the inlet and outlet sides of the carbon filter drums installed at the off-site gas control wells. The purpose of the carbon filter drums was to remove trace organics from the extracted gas prior to venting the gas to the atmosphere. Analytical methods used were similar to those described for FFB's flare sampling activities (see Section 4.2.4).

4.5. DATA EVALUATION METHODS

Data from the gas characterization studies were evaluated using summary tables showing contaminant concentrations at specific on- and off-site sampling locations. Maps of the distribution of Summed USEPA Hazardous Substances List Volatile Organic Compounds (Summed HSL VOCs) concentrations, as well as the distribution of individual HSL VOCs, were also prepared. Statistical summary values reported in the gas characterization summary tables for the remedial investigation included the total number of compounds detected at each sampling location, sums of the concentrations of compounds in each sample (Summed HSL VOCs), maximum values, arithmetic mean values, and the standard deviation of the arithmetic mean as an index of the degree of statistical variation in the data set. Concentrations of selected gas components were plotted on base maps of the site and surrounding areas to help evaluate the association between on- and off-site subsurface gas contaminant distribution.

5.0 RESULTS

Because of the large volume of data involved, the raw data and accompanying quality assurance/quality control data have not been included in this technical memorandum. These materials are available for public review at the Midway Landfill Remedial Investigation Data Repositories at the Kent and Des Moines public libraries or they may be acquired from the City of Seattle Department of Engineering, Solid Waste Utility for the cost of copying. The data are collectively referred to as the Parametrix Midway RI/FS Gas Analysis Data (8 vols.).

5.1. OVERVIEW OF SAMPLING RESULTS

Several USEPA HSL VOCs were found in both on-site and off-site subsurface gas samples. The compounds most frequently found together were the BTX-group compounds (benzene, toluene, total xylenes, ethylbenzene, and styrene). Vinyl chloride was very often associated with the BTX-compound group in on-site subsurface gas samples, but in off-site subsurface gas samples it was found much less frequently than the BTX group.

Maximum on-site concentrations for BTX-group compounds and vinyl chloride were in the 17 to 31 ppm range. All the maximum contaminant concentrations for BTX-group compounds and vinyl chloride were from one on-site gas extraction well (44D-0) that operated at a relatively low gas flow rate. Arithmetic mean on-site concentrations for these compounds were in the 2 to 4 ppm range.

Maximum off-site concentrations for the BTX-group compounds and vinyl chloride were less than 0.3 ppm. Arithmetic mean off-site concentrations were in the low parts-per-billion range, often near or below the detection limit.

Interpretation of results for other compounds is less clear for several reasons: 1) a lack of clear-cut patterns of geographic distribution, 2) extremely low concentrations reported, and 3) quality assurance/quality control issues related to trace contaminant levels present in laboratory blanks. These results are discussed in more detail in subsequent sections of this chapter.

Prediction of potential public health impacts associated with the observed concentrations of compounds present in subsurface gas is complex and considered beyond the scope of the Gas Characterization Technical Memorandum. Important factors in a public health analysis include detailed description of the numerous assumptions required to describe any potential exposure scenario, estimation of concentrations of specific compounds at the exposure point, and the intrinsic toxic properties of specific compounds to which human receptors are potentially exposed. These issues will be addressed in the Endangerment Assessment currently being prepared by ICF, Inc., for the Midway Landfill Feasibility Study.

5.1.1. PRIMARY COMPOUNDS DETECTED

5.1.1.1. Compounds detected in both on-site and off-site subsurface gas

Results of Parametrix' on-site and off-site subsurface gas sampling activities are summarized in Tables 5-1, 5-2, and 5-3. Several HSL VOCs were found in a high percentage of both on-site and off-site subsurface gas samples. These compounds, listed in decreasing frequency of on-site occurrence, include:

- Ethylbenzene
- Xylenes (total)
- Toluene
- Benzene

The compounds listed above were found in greater than 50% of both the on-site gas extraction well and off-site gas monitoring probe completions sampled. Styrene was frequently reported in low concentrations in on-site and off-site subsurface gas in association with the compounds listed above. Vinyl chloride was reported present in 86% of the on-site gas extraction well completions sampled but was found in only 17% of the off-site gas probe completions sampled. The HSL VOC 1,1,1-trichloroethane was reported present at 50% of the off-site gas monitoring probes sampled but not at any of the on-site gas extraction wells sampled by Parametrix during the remedial investigation. Other HSL VOCs were reported less frequently.

Overall, the group of compounds that includes benzene, toluene, total xylenes, ethylbenzene, and styrene is consistent with what laboratories call a "BTX" pattern. The term BTX describes a mixture of aromatic compounds whose major constituents include Benzene, Toluene, and any or all of the three Xylene isomers, often associated with other derivatives of simple aromatic compounds. (Note: the chemical term "aromatic compounds" includes benzene and other organic compounds that resemble benzene in chemical behavior. The chemical term "aromatic compounds" should not be confused with the common understanding of the phrase "odor-causing substances.") The BTX-group compounds share a number of characteristics with respect to chemical structure and behavior (see Figure 5-1).

BTX-type mixtures of aromatic compounds are found in a multitude of common materials, including petroleum-based motor and aviation fuels, solvents, thinners, paints, inks, cleaning fluids, and degreasers. They are also widely used as chemical building blocks and intermediates for the industrial synthesis of an even greater variety of chemical products.

Vinyl chloride (also called vinyl chloride monomer, VCM, or chloroethene) is not typical of BTX-type mixtures. Vinyl chloride shares structural and chemical characteristics with other chlorinated-ethene-based solvents, which differ from the BTX-group compounds described above (see Figure 5-1). Vinyl chloride monomer (VCM) is used industrially in the manufacture of polyvinyl chloride (PVC) plastics and other polymeric resins and to a lesser extent as a chemical intermediate and solvent. (Note: -"ethene" is the currently

Table 5-1. Summary of results (in ppb) for USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) in on-site and off-site subsurface gas samples collected by Parametrix, Inc. during June-July 1987.

			ON-SITE GAS EXTRACTION WELL COMPLETIONS SAMPLED No. of Sampling Rounds = 1 (N = 14 well completions; total of 16 samples)					OFF-SITE GAS MONITORING PROBE COMPLETIONS SAMPLED No. of Sampling Rounds = 2 (N = 12 probe completions; total of 27 samples)					
CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)*	HSL VOC #	# of Sampled Well Completions Where Reportable	% of Sampled Well Completions Where Reportable	Maximum Report-able Concen-tration (ppb)	Average (Arith. Mean) Concen-tration (ppb)	Std. Dev. of Mean Concen-tration (ppb)	# of Sampled Probe Completions Where Reportable	% of Sampled Probe Completions Where Reportable	Maximum Report-able Concen-tration (ppb)	Average (Arith. Mean) Concen-tration (ppb)	Std. Dev. of Mean Concen-tration (ppb)	Code
Compounds reported present both on-site and off-site:													
100-41-4	Ethylbenzene	21	13	93 %	16,610	2,825	4,133	11	92 %	127	44	41	1
75-01-4	Vinyl chloride	29	12	86 %	31,215	2,887	7,606	2	17 %	275	35	86	1
1330-20-7	Xylenes (Total)	37	11	79 %	29,195	3,419	7,208	9	75 %	106	19	26	1
108-88-3	Toluene	25	10	71 %	24,044	1,920	5,751	10	83 %	68	18	21	1
71-43-2	Benzene	3	10	71 %	1,384	318	394	8	67 %	185	28	46	1
100-42-5	Styrene	35	5	36 %	508	41	122	6	50 %	134	18	37	1
108-90-7	Chlorobenzene	8	5	36 %	258	34	68	1	8 %	56	2	10	1
127-18-4	Tetrachloroethene	24	4	29 %	80	10	23	1	8 %	4	0.2	1	1
75-09-2	Methylene chloride	22	2	14 %	2,648 E	220	662	2	17 %	2,489 E	169	681	1
109-99-9	Tetrahydrofuran	91 *	2	14 %	2,099	224	604	2	17 %	733	27	138	1
75-69-4	Trichlorofluoromethane	92 *	2	14 %	357	25	86	2	17 %	223	11	44	1
75-00-3	Chloroethane	9	2	14 %	708 E	45	171	1	8 %	1,192	44	225	1
67-64-1	Acetone	30	1	7 %	939	59	227	3	25 %	40,002	1,659	7,572	1
78-93-3	2-Butanone	31	1	7 %	183	11	44	3	25 %	486	31	100	1
76-13-1	Trichlorotrifluoroethane	93 *	1	7 %	106	9	26	2	17 %	3,000 E	125	568	1
75-35-4	1,1-Dichloroethene	16	1	7 %	112	7	27	1	8 %	7	0.3	1	1
Compounds reported present on-site only:													
79-01-6	Trichloroethene	28	4	29 %	97	7	23	0	0 %	ND	ND	ND	2
75-34-3	1,1-Dichloroethane	14	3	21 %	748	49	181	0	0 %	ND	ND	ND	2
108-05-4	Vinyl acetate	36	3	21 %	483	40	117	0	0 %	ND	ND	ND	2
156-60-5	trans-1,2-Dichloroethene	17	2	14 %	79	5	19	0	0 %	ND	ND	ND	2
107-06-2	1,2-Dichloroethane	15	1	7 %	126	8	31	0	0 %	ND	ND	ND	2
10061-01-5	cis-1,3-Dichloropropene	19	1	7 %	15	1	4	0	0 %	ND	ND	ND	2
108-10-1	4-Methyl-2-pentanone	34	1	7 %	6	0	1	0	0 %	ND	ND	ND	2

(Continued ...)

NOTE: Data presented in this table are not blank-corrected and therefore represent a conservative estimate of true values.
ND = Not Detected (detection limits vary by compound and as a function of matrix interferences).
R = Rejected data value (not seen in this Table); data rejected per Quality Assurance guidelines.
(data value) E = Estimated data value; estimate based on cryogenic system blank from date other than sample analysis date due to lab's loss of cryogenic blank data file.
ND and R values assumed to have a numerical value equal to zero for purposes of statistical computations; "E" (estimated) values used as shown.
(See also footnotes at end of this table)

Table 5-1. Summary of results (in ppb) for USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) in on-site and off-site subsurface gas samples collected by Parametrix, Inc. during June-July 1987.

			ON-SITE GAS EXTRACTION WELL COMPLETIONS SAMPLED No. of Sampling Rounds = 1 (N = 14 well completions; total of 16 samples)					OFF-SITE GAS MONITORING PROBE COMPLETIONS SAMPLED No. of Sampling Rounds = 2 (N = 12 probe completions; total of 27 samples)					
CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)*	HSL VOC #	# of Sampled Well Completions Where Reportable	% of Sampled Well Completions Where Reportable	Maximum Reportable Concentration (ppb)	Average (Arith. Mean) Concentration (ppb)	Std. Dev. of Mean Concentration (ppb)	# of Sampled Probe Completions Where Reportable	% of Sampled Probe Completions Where Reportable	Maximum Reportable Concentration (ppb)	Average (Arith. Mean) Concentration (ppb)	Std. Dev. of Mean Concentration (ppb)	Code
Compounds reported present both on-site and off-site:													
100-41-4	Ethylbenzene	21	13	93 %	16,610	2,825	4,133	11	92 %	127	44	41	1
75-01-4	Vinyl chloride	29	12	86 %	31,215	2,087	7,606	2	17 %	275	35	86	1
1330-20-7	Xylenes (Total)	37	11	79 %	29,195	3,419	7,288	9	75 %	106	19	26	1
108-88-3	Toluene	25	10	71 %	24,044	1,920	5,751	10	83 %	68	18	21	1
71-43-2	Benzene	3	10	71 %	1,384	318	394	8	67 %	185	28	46	1
100-42-5	Styrene	35	5	36 %	588	41	122	6	50 %	134	18	37	1
108-90-7	Chlorobenzene	8	5	36 %	258	34	68	1	8 %	56	2	10	1
127-18-4	Tetrachloroethene	24	4	29 %	88	10	23	1	8 %	4	0.2	1	1
75-09-2	Methylene chloride	22	2	14 %	2,648 E	220	662	2	17 %	2,489 E	169	681	1
109-99-9	Tetrahydrofuran	91 *	2	14 %	2,099	224	604	2	17 %	733	27	138	1
75-69-4	Trichlorofluoromethane	92 *	2	14 %	357	25	86	2	17 %	223	11	44	1
75-00-3	Chloroethane	9	2	14 %	708 E	45	171	1	8 %	1,192	44	225	1
67-64-1	Acetone	30	1	7 %	939	59	227	3	25 %	40,002	1,659	7,572	1
78-93-3	2-Butanone	31	1	7 %	183	11	44	3	25 %	486	31	100	1
76-13-1	Trichlorotrifluoroethane	93 *	1	7 %	106	9	26	2	17 %	3,000 E	125	568	1
75-35-4	1,1-Dichloroethene	16	1	7 %	112	7	27	1	8 %	7	0.3	1	1
Compounds reported present on-site only:													
79-01-6	Trichloroethene	28	4	29 %	97	7	23	0	0 %	ND	ND	ND	2
75-34-3	1,1-Dichloroethane	14	3	21 %	748	49	181	0	0 %	ND	ND	ND	2
108-05-4	Vinyl acetate	36	3	21 %	483	40	117	0	0 %	ND	ND	ND	2
156-60-5	trans-1,2-Dichloroethene	17	2	14 %	79	5	19	0	0 %	ND	ND	ND	2
107-06-2	1,2-Dichloroethane	15	1	7 %	126	8	31	0	0 %	ND	ND	ND	2
10061-01-5	cis-1,3-Dichloropropene	19	1	7 %	15	1	4	0	0 %	ND	ND	ND	2
108-10-1	4-Methyl-2-pentanone	34	1	7 %	6	0	1	0	0 %	ND	ND	ND	2

(Continued ...)

NOTE: Data presented in this table are not blank-corrected and therefore represent a conservative estimate of true values.
ND = Not Detected (detection limits vary by compound and as a function of matrix interferences).
R = Rejected data value (not seen in this Table); data rejected per Quality Assurance guidelines.
(data value) E = Estimated data value; estimate based on cryogenic system blank from date other than sample analysis date due to lab's loss of cryogenic blank data file.
ND and R values assumed to have a numerical value equal to zero for purposes of statistical computations; "E" (estimated) values used as shown.
(See also footnotes at end of this table)

Table 5-1. (continued)
Page 2.

CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)*	HSL VOC #	ON-SITE GAS EXTRACTION WELL COMPLETIONS SAMPLED — No. of Sampling Rounds = 1 (N = 14 well completions; total of 16 samples): # of Sampled Well Completions Where Reportable	% of Sampled Well Completions Where Reportable	Maximum Reportable Concentration (ppb)	Average (Arith. Mean) Concentration (ppb)	Std. Dev. of Mean Concentration (ppb)	OFF-SITE GAS MONITORING PROBE COMPLETIONS SAMPLED — No. of Sampling Rounds = 2 (N = 12 probe completions; total of 27 samples): # of Sampled Probe Completions Where Reportable	% of Sampled Probe Completions Where Reportable	Maximum Reportable Concentration (ppb)	Average (Arith. Mean) Concentration (ppb)	Std. Dev. of Mean Concentration (ppb)	Code
Compounds reported off-site only:													
71-55-6	1,1,1-Trichloroethane	26	0	0 %	ND	ND	ND	6	50 %	67	4	13	3
74-87-3	Chloromethane	12	0	0 %	ND	ND	ND	5	42 %	666	37	128	3
75-15-0	Carbon disulfide	32	0	0 %	ND	ND	ND	4	33 %	79	9	22	3
Compounds not detected/not reportable:													
75-27-4	Bromodichloromethane	4	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
74-83-9	Bromomethane	5	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
75-25-2	Bromoform	6	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
56-23-5	Carbon tetrachloride	7	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
110-75-8	2-Chloroethylvinyl ether	10	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
67-66-3	Chloroform	11	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
124-48-1	Dibromochloromethane	13	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
78-87-5	1,2-Dichloropropane	18	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
10061-02-6	trans-1,3-Dichloropropene	20	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
79-34-5	1,1,2,2-Tetrachloroethane	23	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
79-00-5	1,1,2-Trichloroethane	27	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4
591-78-6	2-Hexanone	33	0	0 %	ND	ND	ND	0	0 %	ND	ND	ND	4

(Continued ...)

NOTE: Data presented in this table are not blank-corrected and therefore represent a conservative estimate of true values.
ND = Not Detected (detection limits vary by compound and as a function of matrix interferences).
R = Rejected data value (not seen in this Table); data rejected per Quality Assurance guidelines.
(data value) E = Estimated data value; estimate based on cryogenic system blank from date other than sample analysis date due to lab's loss of cryogenic blank data file.
ND and R values assumed to have a numerical value equal to zero for purposes of statistical computations; "E" (estimated) values used as shown.
(See also footnotes at end of this table)

Table 5-1. (continued)
Page 3.

CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)*	HSL VOC #	ON-SITE GAS EXTRACTION WELL COMPLETIONS SAMPLED No. of Sampling Rounds = 1 (N = 14 well completions; total of 16 samples) # of Sampled Well Completions Where Reportable	% of Sampled Well Completions Where Reportable	Maximum Reportable Concentration (ppb)	Average (Arith. Mean) Concentration (ppb)	Std. Dev. of Mean Concentration (ppb)	OFF-SITE GAS MONITORING PROBE COMPLETIONS SAMPLED No. of Sampling Rounds = 2 (N = 12 probe completions; total of 27 samples) # of Sampled Probe Completions Where Reportable	% of Sampled Probe Completions Where Reportable	Maximum Reportable Concentration (ppb)	Average (Arith. Mean) Concentration (ppb)	Std. Dev. of Mean Concentration (ppb)	Code
FOOTNOTES:			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)

* HSL compounds Acrolein (#1) and Acrylonitrile (#2) deleted from HSL by USEPA.
Tetrahydrofuran (91*), Trichlorofluoromethane (92*), & Trichlorotrifluoroethane (93*)
not on HSL but reported on lab's list of target compounds.

For all compounds, sample values were reportable only when they exceeded lab system blanks by a factor of ten (10).
Where compounds were reportable, lab system blank values were subtracted from sample values to yield reported sample value.

(1) Number of sampled gas extraction well completions where compound was reportable under QA/QC protocol.
(2) Per cent of sampled gas extraction well completions where compound was reportable under QA/QC protocol.
= (# of well completions where reportable) / (14 well completions sampled) x 100
(3) Maximum reportable concentration (parts per billion, ppb), after blank correction
(4) Average (arithmetic mean) concentration (parts per billion, ppb)
- o based on (sum of 16 samples)/(16)
- o Not Detected (ND) and Rejected (R) values assumed to have numerical value of zero

(5) Standard deviation of mean concentration
- o based on 16 samples
- o Not Detected (ND) and Rejected (R) values assumed to have numerical value of zero

(6) Number of sampled gas monitoring probe completions where compound was reportable under QA/QC protocol.
(eg., 88-M and 88-S are considered two distinct probe completions)
(7) Per cent of sampled gas monitoring probe completions where compound was reportable under QA/QC protocol.
= (# of probe completions where reportable) / (12 probe completions sampled) x 100
(8) Maximum reportable concentration (parts per billion, ppb), after blank correction
(9) Average (arithmetic mean) concentration (parts per billion, ppb)
- o based on (sum of 27 samples)/(27)
- o Not Detected (ND) and Rejected (R) values assumed to have numerical value of zero

(10) Standard deviation of mean concentration
- o based on 27 samples
- o Not Detected (ND) and Rejected (R) values assumed to have numerical value of zero

(11) Compound-specific sampling results code
- 1 = Compound found both on-site and off-site
- 2 = Compound found on-site only
- 3 = Compound found off-site only
- 4 = Compound found neither on-site nor off-site

Table 5-2. Concentrations (in ppb) of USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) in subsurface gas samples from on-site gas extraction wells sampled by Parametrix, Inc. during June-July 1987.

CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)*	HSL VOC #	ON-SITE GAS EXTRACTION WELL COMPLETIONS SAMPLED — No. of Sampling Rounds = 1 (N = 14 well completions; total of 16 samples) 4-0	12-0	18-0	21-0	24-0	25-0	(#1 33-0	#2 33-0	#2R) 33-0	34-0	36D-0	41D-0	44D-0	PA8D-0	PD6D-0	PD12D-0	% of Sampled Well Completions Where Reportable	Maximum Reportable Concentration (ppb)	Average (Arith. Mean) Concentration (ppb)	Standard Deviation of Arith. Mean Concentration (ppb)
71-43-2	Benzene	3	102	381 E	ND	861	77	461	787	ND	ND	1,384	400	R	640	74	ND	R	71 %	1,384	318	394
75-27-4	Bromodichloromethane	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
74-83-9	Bromomethane	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
75-25-2	Bromoform	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
56-23-5	Carbon tetrachloride	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
108-90-7	Chlorobenzene	8	51	ND	ND	ND	44	139	ND	ND	ND	ND	ND	ND	258	45	ND	ND	36 %	258	34	68
75-00-3	Chloroethane	9	15	708 E	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14 %	708	45	171
110-75-8	2-Chloroethylvinyl ether	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
67-66-3	Chloroform	11	R	ND	ND	ND	R	R	ND	ND	ND	ND	ND	ND	ND	ND	ND	R	0 %	ND	ND	ND
74-87-3	Chloromethane	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
124-48-1	Dibromochloromethane	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
75-34-3	1,1-Dichloroethane	14	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	748	ND	ND	27	21 %	748	49	181
107-06-2	1,2-Dichloroethane	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	126	ND	ND	ND	7 %	126	8	31
75-35-4	1,1-Dichloroethene	16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	112	ND	ND	ND	7 %	112	7	27
156-60-5	trans-1,2-Dichloroethene	17	ND	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	79	ND	ND	ND	14 %	79	5	19
78-87-5	1,2-Dichloropropane	18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
10061-01-5	cis-1,3-Dichloropropene	19	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	ND	7 %	15	1	4
10061-02-6	trans-1,3-Dichloropropene	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
100-41-4	Ethylbenzene	21	2,467	2,444 E	2,240	6,744	371	1,924	5,544	ND	ND	566	5,205	R	16,610	430	634	16	93 %	16,610	2,825	4,133
75-09-2	Methylene chloride	22	R	2,648 E	R	R	R	R	R	R	877	R	R	R	R	R	R	R	14 %	2,648	220	662
79-34-5	1,1,2,2-Tetrachloroethane	23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
127-18-4	Tetrachloroethene	24	7	ND	ND	ND	12	80	ND	ND	ND	ND	ND	ND	57	ND	ND	ND	29 %	80	10	23
108-88-3	Toluene	25	235	125 E	ND	1,043	70	704	ND	ND	ND	417	2,105	1,961	24,044	22	ND	R	71 %	24,044	1,920	5,751
71-55-6	1,1,1-Trichloroethane	26	R	ND	ND	ND	R	R	ND	ND	ND	ND	ND	ND	R	R	ND	ND	0 %	ND	ND	ND
79-00-5	1,1,2-Trichloroethane	27	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
79-01-6	Trichloroethene	28	ND	ND	ND	ND	5	10	ND	ND	ND	ND	ND	ND	97	2	ND	ND	29 %	97	7	23
75-01-4	Vinyl chloride	29	21	204 E	730	1,538	25	111	8,457	ND	ND	461	1,568	ND	31,215	46	538	ND	86 %	31,215	2,807	7,606
67-64-1	Acetone	30	R	ND	R	R	R	R	R	R	939	R	R	R	R	R	R	R	7 %	939	59	227
78-93-3	2-Butanone	31	R	R	ND	R	R	R	R	R	ND	R	ND	ND	R	183	R	R	7 %	183	11	44
75-15-0	Carbon disulfide	32	R	ND	ND	ND	R	R	ND	ND	ND	ND	ND	ND	R	R	ND	R	0 %	ND	ND	ND
591-78-6	2-Hexanone	33	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
108-10-1	4-Methyl-2-pentanone	34	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	ND	7 %	6	0	1
100-42-5	Styrene	35	46	ND	ND	ND	37	53	ND	ND	ND	ND	ND	ND	508	17	ND	ND	36 %	508	41	122
108-05-4	Vinyl acetate	36	56	ND	ND	ND	ND	95	ND	ND	ND	ND	ND	ND	483	ND	ND	ND	21 %	483	40	117
1330-20-7	Xylenes (Total)	37	611	1,417 E	ND	2,965	104	1,743	4,323	7	ND	ND	11,090	3,168	29,195	72	ND	11	79 %	29,195	3,419	7,208
109-99-9	Tetrahydrofuran	91 *	R	1,493 E	ND	R	R	R	R	ND	ND	R	ND	ND	R	2,099	R	R	14 %	2,099	224	604
75-69-4	Trichlorofluoromethane	92 *	ND	ND	ND	ND	357	R	ND	ND	ND	ND	ND	ND	R	44	ND	R	14 %	357	25	86
76-13-1	Trichlorotrifluoroethane	93 *	R	R	ND	ND	ND	R	R	32	106	ND	ND	ND	R	R	ND	ND	7 %	106	9	26
	Total:		3,622	9,419	2,971	13,150	1,102	5,327	19,032	39	1,922	2,828	22,367	5,130	104,186	3,040	1,172	54	N/AP	N/AP	N/AP	N/AP
	Maximum:		2,467	2,648	2,240	6,744	371	1,924	8,457	32	939	1,384	11,090	3,168	31,215	2,099	634	27	93 %	31,215	3,419	7,606
	Mean:		95	248	78	346	29	140	501	1	51	74	536	135	2,742	80	31	1	18 %	2,947	318	724
	Std. Dev. of Mean:		403	640	374	1,191	83	421	1,716	5	203	252	1,961	589	7,942	340	131	5	26 %	7,892	852	1,927
	No. of Compounds Found:		11	8	2	5	10	11	4	2	3	4	5	2	15	12	2	3	(Total of 23 target VOCs detected)			

NOTE: Data presented in this table are not blank-corrected and therefore represent a conservative estimate of true values (i.e., true values are slightly lower than data presented here).

* HSL compounds Acrolein (#1) and Acrylonitrile (#2) deleted from HSL by USEPA.

Tetrahydrofuran (91*), Trichlorofluoromethane (92*), & Trichlorotrifluoroethane (93*) not on HSL, but reported on lab's list of target compounds.

ND = Not Detected (detection limits vary by compound and as a function of matrix interferences).

R = Rejected data value; QA/QC review indicated sample results not sufficiently higher than lab blank to report value.

ND and R values assumed to have a numerical value equal to zero for purposes of statistical computations.

(data value) E = Estimated data value; estimate based on cryogenic system blank from date other than sample analysis date due to lab's loss of blank data file.

Table 5-3. Concentrations (in ppb) of USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) in subsurface gas samples from off-site gas monitoring probes sampled by Parametrix, Inc. during June-July 1987.

CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)*	HSL VOC #	2-S (#1	2-S #1R	2-S #2)	37-D (#1	37-D #2)	44-D (#1	44-D #2)	50-S (#1	50-S #2)	88-M (#1	88-M #2)	88-S (#1	88-S #2)	J-D (#1	J-D #2)	M-M (#1	M-M #2)	T-S (#1	T-S #2)	Z-S (#1	Z-S #2	Z-S #2R)	AC-S (#1	AC-S #1R	AC-S #2)	AF-D (#1	AF-D #2)	% of Sampled Probes Where Reported	Maximum Report-able Concen-tration (ppb)	Average (Arith. Mean) Concen-tration (ppb)	Std. Dev. of Mean Concen-tration (ppb)
			OFF-SITE GAS MONITORING PROBE COMPLETIONS SAMPLED — No. of Sampling Rounds = 2 (N = 12 probe completions; total of 27 samples)																														
71-43-2	Benzene	3	43	49	58 E	166	ND	R	48	R	ND	R	ND	38	ND	185	ND	28	48	ND	ND	R	R	R	ND	ND	22	43	49	67 %	185	28	46
75-27-4	Bromodichloromethane	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
74-83-9	Bromomethane	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
75-25-2	Bromoform	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
56-23-5	Carbon tetrachloride	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
108-90-7	Chlorobenzene	8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	56	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8 %	56	2	10
75-00-3	Chloroethane	9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,192	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8 %	1,192	44	225
110-75-8	2-Chloroethylvinyl ether	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
67-66-3	Chloroform	11	ND	R	R	ND	ND	R	R	R	ND	R	R	R	ND	ND	ND	R	R	ND	ND	R	R	R	ND	R	R	ND	R	0 %	ND	ND	ND
74-87-3	Chloromethane	12	48	ND	ND	666	ND	ND	ND	ND	ND	114	ND	ND	ND	143	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17	ND	ND	42 %	666	37	128
124-48-1	Dibromochloromethane	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
75-34-3	1,1-Dichloroethane	14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
107-06-2	1,2-Dichloroethane	15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
75-35-4	1,1-Dichloroethene	16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	8 %	7	0.3	1
156-60-5	trans-1,2-Dichloroethene	17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
78-87-5	1,2-Dichloropropane	18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
10061-01-5	cis-1,3-Dichloropropene	19	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
10061-02-6	trans-1,3-Dichloropropene	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
100-41-4	Ethylbenzene	21	76	75	14 E	182	ND	57	8	R	ND	115	28 E	113	63	118	8 E	18	14	9	6 E	46	29 E	27 E	66	17	37	127	12	92 %	127	44	41
75-09-2	Methylene chloride	22	R	R	R	R	R	R	R	R	R	R	R	R	R	R	2,079 E	R	R	R	R	R	R	2,489 E	R	R	R	R	R	17 %	2,489	169	681
79-34-5	1,1,2,2-Tetrachloroethane	23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
127-18-4	Tetrachloroethene	24	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8 %	4	0.2	1
108-88-3	Toluene	25	47	68	ND	55	ND	13	ND	R	ND	38	ND	25	ND	16	12 E	16	25	ND	ND	16	8 E	ND	63	ND	52	27	8	83 %	68	18	21
71-55-6	1,1,1-Trichloroethane	26	ND	ND	ND	ND	ND	R	ND	8	ND	11	ND	5	ND	13	ND	R	ND	ND	ND	ND	ND	ND	5	9	ND	67	ND	50 %	67	4	13
79-00-5	1,1,2-Trichloroethane	27	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
79-01-6	Trichloroethene	28	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
75-01-4	Vinyl chloride	29	ND	ND	ND	269	252 E	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	275	154	17 %	275	35	86
67-64-1	Acetone	30	ND	ND	ND	ND	ND	R	R	66	R	ND	ND	R	ND	40,002	R	R	R	4,716	R	ND	R	R	R	R	ND	R	R	25 %	40,002	1,659	7,572
78-93-3	2-Butanone	31	ND	R	R	ND	ND	R	R	R	ND	ND	ND	197	ND	R	R	147	ND	R	ND	R	R	R	R	486	R	R	R	25 %	486	31	100
75-15-0	Carbon disulfide	32	R	R	ND	R	ND	R	R	R	ND	R	ND	30	R	79	ND	60	R	ND	ND	ND	R	R	ND	ND	R	71	R	33 %	79	9	22
591-78-6	2-Hexanone	33	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
108-10-1	4-Methyl-2-pentanone	34	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
100-42-5	Styrene	35	134	ND	ND	ND	ND	99	ND	ND	ND	ND	ND	ND	ND	104	ND	28	ND	ND	ND	ND	32 E	29 E	ND	ND	60	ND	ND	50 %	134	18	37
108-05-4	Vinyl acetate	36	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0 %	ND	ND	ND
1330-20-7	Xylenes (Total)	37	12	ND	R	106	ND	16	11	R	ND	25	61 E	18	77	24	26 E	14	48	R	R	R	R	ND	ND	9	20	17	24	75 %	106	19	26
109-99-9	Tetrahydrofuran	91 *	ND	8	ND	ND	ND	R	ND	ND	ND	ND	ND	R	ND	R	ND	R	ND	R	ND	ND	R	ND	ND	R	ND	R	733	17 %	733	27	138
75-69-4	Trichlorofluoromethane	92 *	ND	ND	ND	ND	ND	ND	ND	ND	ND	67	ND	ND	ND	ND	ND	223	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17 %	223	11	44
76-13-1	Trichlorotrifluoroethane	93 *	R	R	R	R	3,000 E	R	R	ND	ND	R	R	R	R	R	R	ND	ND	ND	R	R	R	ND	R	R	R	383	R	17 %	3,000	125	568
	Total:		360	200	72	1,364	3,252	185	59	74	ND	362	89	426	140	41,929	2,125	537	134	4,725	6	61	70	2,545	134	521	208	1,017	981	N/AP	49,899	2,281	N/AP
	Maximum:		134	75	58	666	3,000	99	40	66	ND	115	61	197	77	40,002	2,079	223	48	4,716	6	46	32	2,489	66	486	60	383	733	92 %	40,002	1,659	7,572
	Mean:		9	5	2	36	86	5	2	2	ND	10	2	11	4	1,103	56	14	4	124	0	2	2	67	4	14	5	27	25	17 %	1,313	60	255
	Std. Dev. of Mean:		27	17	10	117	481	18	7	11	ND	28	11	36	16	6,398	333	43	11	755	1	8	7	398	14	78	14	77	119	26 %	6,392	265	1,210
	No. of Compounds Found:		6	4	2	6	2	4	3	2	0	6	2	7	2	11	4	9	4	2	1	2	3	3	3	4	6	9	6	(Total of 19 target VOCs detected)			

NOTE: Data presented in this table are not blank-corrected and therefore represent a conservative estimate of true values (i.e., true values are slightly lower than data presented here).

* HSL compounds Acrolein (#1) and Acrylonitrile (#2) deleted from HSL by USEPA.

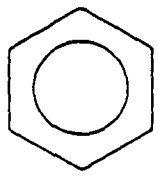
Tetrahydrofuran (91*), Trichlorofluoromethane (92*), & Trichlorotrifluoroethane (93*) not on HSL, but are reported on lab's list of target compounds.

ND = Not Detected (detection limits vary by compound and as a function of matrix interferences).

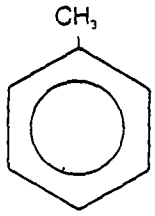
R = Rejected data value; QA/QC review indicated sample results not sufficiently higher than lab blank to report value.

ND and R values assumed to have a numerical value equal to zero for purposes of statistical computations.

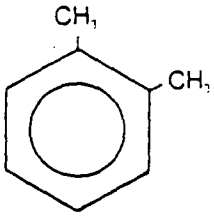
(data value) E = Estimated data value; estimate based on cryogenic system blank from date other than sample analysis date due to lab's loss of blank data file.



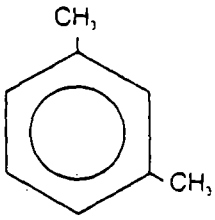
Benzene



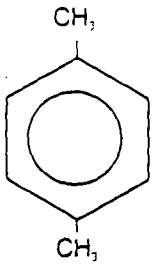
Toluene



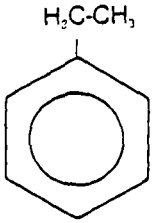
o-Xylene



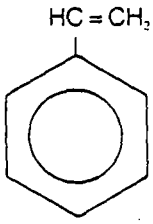
m-Xylene



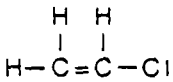
p-Xylene



Ethylbenzene



Styrene



Vinyl Chloride

Figure 5-1.
Chemical Structures of Selected Compounds Detected in On-Site and Off-Site Subsurface Gas Samples Collected for the Midway Landfill Remedial Investigation

accepted term for chemical structures formerly termed -"ethylene", eg., trichloroethene = trichloroethylene.)

Other USEPA HSL VOC target compounds present in both on- and off-site subsurface gas samples included:

- Chlorobenzene
- Tetrachloroethene
- Methylene chloride*
- Tetrahydrofuran*
- Trichlorofluoromethane*
- Chloroethane
- Acetone*
- 2-Butanone*
- Trichlorotrifluoroethane*
- 1,1-Dichloroethene

The results for the compounds listed above should be interpreted cautiously because several (asterisked items) are known laboratory contaminants (see Section 5.1.2). In general, the compounds in this list were found less frequently and in lower concentrations than BTX-group compounds and vinyl chloride. As discussed in Section 5.5.2, maps of the geographic distributions of these contaminants show less of a clear-cut pattern than the BTX-group compounds and vinyl chloride.

5.1.1.2. Compounds reported present on-site only, off-site only; compounds reported as non-detected

The remaining compounds listed in Table 5-1 were reported as follows:

- Seven HSL VOCs were reported present on-site only.
- Three HSL VOCs were reported present off-site only.
- Twelve of the HSL VOC target compounds were undetected in any of the gas samples collected by Parametrix for the remedial investigation.

The compounds reported as present on-site only were found at fewer of the on-site gas extraction wells than the BTX-group compounds.

Interpretation of the results for the compounds found off-site only is difficult when based solely on the gas characterization data. Data on their occurrence in leachate, groundwater, or other environmental media or other information that points to potential off-site sources of subsurface gas contaminants might help in interpreting these results. Integration and interpretation of patterns of contaminant distribution in various segments of the environment are included in the Midway Landfill Remedial Investigation Summary Report (Parametrix, 1988).

5.1.2. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) CONSIDERATIONS

5.1.2.1. Evaluation of potential sources of sample contamination

Interpretation of results for some of the target compounds is quite difficult because several are known to be common laboratory contaminants. According to the Quality Assurance/Quality Control (QA/QC) Plan followed by Analytical Technologies, "Ten (10) times the amount in the blank had to be in the samples for there to be reasonable confidence that the compounds were present in the original samples," except for compounds that would be expected to be found together, such as benzene, toluene, and the xylenes. Data were rejected if the QA/QC criteria were not met, and the symbol "R" is substituted for the rejected lab result in data summary tables (see Tables 5-2 and 5-3).

Results for the following compounds should be interpreted particularly cautiously because of the high frequency of non-reportable data (see Tables 5-2 and 5-3) resulting from the presence of these compounds in laboratory blanks:

- Chloroform
- Methylene chloride
- 1,1,1-Trichloroethane
- Acetone
- 2-Butanone
- Carbon disulfide
- Tetrahydrofuran
- Trichlorofluoromethane
- Trichlorotrifluoroethane

Laboratory data from Parametrix' sampling activities for the remedial investigation have undergone extensive Quality Assurance/Quality Control (QA/QC) review. The detailed QA/QC reviews evaluated whether observed concentrations of these compounds in a given sample were more likely to have resulted from laboratory contamination or from the actual presence of the compound in the sample.

Compounds other than those listed above were occasionally reported present at low concentrations in lab blanks, including benzene, toluene, total xylenes, and ethylbenzene. These occurrences are considered much less problematic, except in the rare instances where observed field sample concentrations were also very low and close to the concentrations seen in the lab blanks.

5.1.2.2. Blank-correction of raw laboratory data

It should be noted that concentrations reported in Tables 5-1, 5-2, and 5-3 have deliberately not been blank-corrected. By reporting non-blank-corrected data, the analysis examines the highest plausible concentrations present in the samples, i.e., provides a conservatively high estimate of the sample concentration. As described previously, only four target compounds (benzene, toluene, total xylenes, and ethylbenzene) were subject to blank correction. The effects of blank correction on all the affected on-site and off-site

subsurface gas samples shown in Tables 5-2 and 5-3 are shown in Tables 5-4 and 5-5.

As demonstrated in Tables 5-4 and 5-5, blank correction did not substantially affect the overall sampling results for the remedial investigation data. Although values for specific compounds in certain samples decreased by factors ranging from 0% to 90% as the result of blank-correction, average decreases in reported concentration across samples for a given compound that resulted from blank-correction were in the range of 0.01% to 14%. In general, the largest percentage decreases were observed for samples with raw lab values close to the limits of detection. Differences related to the use of non-blank-corrected versus blank-corrected data clearly do not affect the general conclusions drawn in this Technical Memorandum. It should be recognized, however, that there is a purely quantitative distinction between those compounds for which lab blank concentrations are sufficiently low that blank correction is methodologically acceptable and those compounds for which lab blank values are sufficiently high as to lead to the conclusion that the data for them for specific samples should be rejected as highly suspect.

5.1.2.3. Replicate sample results

Evaluation of the agreement between replicate samples indicated that for certain analyses, results varied by as much as 200%. This finding highlights the fact that although analytical methods used were highly sensitive (i.e., achieved relatively low detection limits), the repeatability of field sampling results was somewhat lower than ideal. One probable source of variability is related to the fact that replicate samples (i.e., successive samples at a given probe or well completion) were collected, rather than duplicate or "split" (i.e., one thoroughly-mixed sample divided into two or more subsamples, to be analyzed independently) samples. One possible approach toward achieving true duplicate analyses would have been to collect larger field samples and then have had the laboratory analyze several aliquots from each sample. Replicate samples are generally used to evaluate the degree of variability inherent in the sample collection method (i.e., the extent to which results for two or more independent samples from one sampling point coincide). Duplicate samples are used to evaluate the degree of variability associated with laboratory analytical methods (the extent to which results for subsamples of a single, presumably homogeneous, sample coincide; the extent to which analytical results coincide for subsamples sent to different laboratories). Replicate samples are generally expected to result in a higher degree of variability than true duplicate samples due to various factors that reduce the probability of drawing identical samples in succession (e.g., effects related to purging, effects related to heterogeneity of the materials being sampled).

5.1.3. MAXIMUM AND ARITHMETIC MEAN CONCENTRATIONS IN ON-SITE SUBSURFACE GAS

The maximum detected on-site concentration for any USEPA HSL VOC was 31,215 ppb (31 ppm) for vinyl chloride (Tables 5-1 and 5-2). This result was seen in a single sample taken from an on-site gas extraction well that had a relatively low gas flow rate (well 44D-0) and probably represents an artificially high finding because of the low flow rate and greater opportunity for

Table 5-5. Effects of blank-correction on all affected off-site subsurface gas samples shown in Table 5-3.

CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)+	HSL VOC #	OFF-SITE GAS MONITORING PROBE COMPLETIONS SAMPLED — No. of Sampling Rounds = 2 (N = 12 probe completions; total of 27 samples)																											Average % Difference Between Lab & Blank Corrected Values
			2-S (#1	2-S #1R	2-S #2)	37-D (#1	37-D #2)	44-D (#1	44-D #2)	50-S (#1	50-S #2)	88-M (#1	88-M #2)	88-S (#1	88-S #2)	J-D (#1	J-D #2)	M-M (#1	M-M #2)	T-S (#1	T-S #2)	Z-S (#1	Z-S #2	Z-S #2R)	AC-S (#1	AC-S #1R	AC-S #2)	AF-D (#1	AF-D #2)	
71-43-2	Benzene	3																												
	Lab Value		43	49	58 E	166	ND	R	40	R	ND	R	ND	38	ND	185	ND	28	48	ND	ND	R	R	R	ND	ND	22	43	49	
	Blank-Corrected Value		9	15	15	132	ND	R	40	R	ND	R	ND	4	ND	185	ND	19	48	ND	ND	R	R	R	ND	ND	22	34	49	
	Percentage Change		-79%	-70%	-74%	-21%	0%	0%	0%	0%	0%	0%	0%	-90%	0%	0%	0%	-31%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-21%	0%	-14%
100-41-4	Ethylbenzene	21																												
	Lab Value		76	75	14 E	102	ND	57	8	R	ND	115	28 E	113	63	118	8 E	18	14	9	6 E	46	29 E	27 E	66	17	37	127	12	
	Blank-Corrected Value		73	72	14	99	ND	57	8	R	ND	112	28	110	63	118	8	18	14	9	6	43	29	27	66	17	37	127	12	
	Percentage Change		-4%	-4%	0%	-3%	0%	0%	0%	0%	0%	-3%	0%	-3%	0%	0%	0%	0%	0%	0%	0%	-6%	0%	0%	0%	0%	0%	0%	0%	-1%
108-88-3	Toluene	25																												
	Lab Value		47	68	ND	55	ND	13	ND	R	ND	30	ND	25	ND	16	12 E	16	25	ND	ND	16	8 E	ND	63	ND	52	27	8	
	Blank-Corrected Value		41	62	ND	49	ND	13	ND	R	ND	24	ND	16	ND	16	12	16	25	ND	ND	7	8	ND	63	ND	52	27	8	
	Percentage Change		-13%	-9%	0%	-11%	0%	0%	0%	0%	0%	-20%	0%	-37%	0%	0%	0%	0%	0%	0%	0%	-55%	0%	0%	0%	0%	0%	0%	0%	-5%
1330-20-7	Xylenes (Total)	37																												
	Lab Value		12	ND	R	106	ND	16	11	R	ND	25	61 E	18	77	24	26 E	14	48	R	R	R	R	ND	ND	9	20	17	24	
	Blank-Corrected Value		5	ND	R	99	ND	16	11	R	ND	18	59	11	77	24	24	14	48	R	R	R	R	ND	ND	9	20	17	24	
	Percentage Change		-60%	0%	0%	-7%	0%	0%	0%	0%	0%	-28%	-3%	-39%	0%	0%	-8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-5%

ND = Not Detected (detection limits vary by compound and as a function of matrix interferences).
R = Rejected data value; QA/QC review indicated sample results not sufficiently higher than lab blank to report value.
ND and R values assumed to have a numerical value equal to zero for purposes of statistical computations.
(data value) E = Estimated data value; estimate based on cryogenic system blank from date other than sample analysis date due to lab's loss of blank data file.

Table 5-4. Effects of blank-correction on all affected on-site subsurface gas samples shown in Table 5-2.

CAS #	USEPA Hazardous Substances List Volatile Organic Compound (USEPA HSL VOC)*	HSL VOC #	ON-SITE GAS EXTRACTION WELL COMPLETIONS SAMPLED — No. of Sampling Rounds = 1 (N = 14 well completions; total of 16 samples)																Average % Difference Between Lab & Blank Corrected Values
			4-0	12-0	18-0	21-0	24-0	25-0	(#1 33-0	#2 33-0	#2R) 33-0	34-0	36D-0	41D-0	44D-0	PA8D-0	PD6D-0	PD12D-0	
71-43-2	Benzene	3																	
	Lab Value		102	381 E	ND	861	77	461	707	ND	ND	1,384	400	R	640	74	ND	R	
	Blank-Corrected Value		40	338	ND	849	15	399	707	ND	ND	1,384	391	R	578	65	ND	R	
	Percentage Change		-61%	-11%	0%	-1%	-80%	-14%	0%	0%	0%	0%	-2%	0%	-10%	-12%	0%	0%	-12.0%
108-88-3	Toluene	25																	
	Lab Value		235	125 E	ND	1,043	70	704	ND	ND	ND	417	2,105	1,961	24,044	22	ND	R	
	Blank-Corrected Value		230	125 E	ND	1,043	65	691	ND	ND	ND	417	2,105	1,961	24,039	22	ND	R	
	Percentage Change		-2%	0%	0%	0%	-8%	-2%	0%	0%	0%	0%	0%	0%	-0.02%	0%	0%	0%	-0.7%
1330-20-7	Xylenes (Total)	37																	
	Lab Value		611	1,417 E	ND	2,965	104	1,743	4,323	7	ND	ND	11,090	3,168	29,195	72	ND	11	
	Blank-Corrected Value		611	1,415 E	ND	2,965	104	1,743	4,323	7	ND	ND	11,090	3,168	29,195	72	ND	11	
	Percentage Change		0%	-0.12%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-0.01%

ND = Not Detected (detection limits vary by compound and as a function of matrix interferences).
R = Rejected data value; QA/QC review indicated sample results not sufficiently higher than lab blank to report value.
ND and R values assumed to have a numerical value equal to zero for purposes of statistical computations.
(data value) E = Estimated data value; estimate based on cryogenic system blank from date other than sample analysis date due to lab's loss of blank data file.

contaminant accumulation in the relatively small volume of gas (see discussion below in Section 5.2.1). The maximum detected on-site concentrations for other compounds (Tables 5-1 and 5-2) included: total xylenes (29 ppm), toluene (24 ppm), and ethylbenzene (17 ppm). The maximum on-site concentrations for all other HSL VOCs were below 3 ppm. The maximum observed concentrations for compounds reported solely on-site (Table 5-1) were all below 1 ppm. Arithmetic mean on-site concentrations for ethylbenzene, vinyl chloride, total xylenes, and toluene were in the range of 2 to 4 ppm. Arithmetic mean concentrations for all other HSL VOCs detected on-site were below 0.4 ppm. Other studies of on-site Midway Landfill subsurface gas reported similar results.

5.1.4. MAXIMUM AND ARITHMETIC MEAN CONCENTRATIONS IN OFF-SITE SUBSURFACE GAS

The maximum detected off-site concentration of any USEPA HSL VOC was approximately 40,000 ppb (40 ppm) for acetone in a single, off-site sample (see Tables 5-1 and 5-3). A value this high is difficult to reject as due to laboratory contamination and may reflect an acetone "hot spot" at this location. However, the second sample value for acetone at probe J-D (Appendix A) was rejected as being insufficiently elevated over the lab blank to allow reporting. The second-highest concentration value for acetone was 4,716 ppb (less than 5 ppm) found in another off-site sample (probe T-S); this concentration is almost an order of magnitude lower than the peak value (however, the result from the second sampling round at probe T-S was rejected during the QA/QC review process). The maximum off-site concentrations for all other HSL VOCs were below 3 ppm (Table 5-3). With the exception of acetone (arithmetic mean off-site concentration = 1.7 ppm), the arithmetic mean concentrations for all off-site HSL VOCs were below 0.2 ppm. Other related studies conducted outside the scope of the remedial investigation found somewhat higher concentrations of contaminants present in gas samples collected from off-site gas control wells.

5.2. CHEMICAL COMPOSITION OF ON-SITE EXTRACTION WELL GAS

Detailed results of Parametrix' on-site subsurface gas sampling program are summarized in Table 5-2. These data confirmed the findings of previous studies that indicated the presence of numerous volatile organic compounds at or below the parts-per-million level in on-site subsurface gas. The USEPA HSL VOCs reported in the highest concentrations in on-site subsurface gas included:

- Vinyl chloride (31,215 ppb = 31 ppm)
- Total Xylenes (29,195 ppb = 29 ppm)
- Toluene (24,044 ppb = 24 ppm)
- Ethylbenzene (16,610 ppb = 17 ppm)

All the maximum contaminant concentrations for this group were from well 44D-0, which operated at a relatively low gas flow rate, as discussed earlier. The maximum on-site concentrations for all other HSL VOCs were below 3 ppm. Benzene was reported present at a maximum on-site subsurface gas concentration of approximately 1.4 ppm. Maximum concentrations of methylene chloride (3 ppm) and tetrahydrofuran (2 ppm) are suspect due to the high frequency

with which these compounds were reported in laboratory blanks. Arithmetic mean on-site concentrations for ethylbenzene, vinyl chloride, total xylenes, and toluene were in the range of 2 to 4 ppm. Arithmetic mean concentrations for all other HSL VOCs detected on-site were below 0.4 ppm, generally in the low parts-per-billion range near the detection limits for these compounds.

The fact that all the peak concentrations that exceeded 10 ppm were from one on-site gas extraction well (44D-0; see Figure 3-1) led to closer examination of the characteristics of gas extraction well 44D-0.

On-site gas extraction well 44D-0 was observed to have higher subsurface gas concentrations of several HSL VOCs than other on-site sampling points. Of the 23 HSL VOCs detected collectively in on-site subsurface gas, the maximum reported concentrations for 13 compounds were observed at well 44D-0 (see Table 5-2). These thirteen compounds included:

- Chlorobenzene
- 1,1-Dichloroethane
- 1,2-Dichloroethane
- 1,1-Dichloroethene
- trans-1,2-Dichloroethene
- cis-1,3-Dichoropropene
- Ethylbenzene
- Toluene
- Trichloroethene
- Vinyl chloride
- Styrene
- Vinyl acetate
- Xylenes (total)

One possible explanation for these results is that on-site gas extraction well 44D-0 had a relatively low gas flow rate, approximately 6 ft^3/min ("equilibrium flow"), at the time of sampling. Other gas extraction wells were operated at much higher flow rates at the time of the on-site subsurface gas sampling activities conducted for the remedial investigation. Therefore, the relatively higher on-site HSL VOCs concentrations at well 44D-0 may have resulted from the increased opportunity for gas contaminants to accumulate in the relatively smaller, slower-moving volume of gas.

Because the total landfill gas production at well 44D-0 was low relative to other on-site gas extraction wells, concentrations of HSL VOCs at selected on-site gas extraction wells were adjusted for gas flow rate to examine the effect of flow rate on estimated contaminant Mass Emission Rates (MERs), expressed in units of grams per day (g/day). Calculations for MERs are based on the following equation:

Mass Emission Rate (mass/time)	=	Sample Concentration (mass/volume)	x	Gas Extraction Well Flow Rate (volume/time)

Estimated MERs at selected gas extraction wells are shown in Table 5-6. As would be expected, a well with relatively higher concentrations of a given

compound in subsurface gas will be likely to have relatively higher mass emission of that compound when compared with other wells (eg., compare the results for total xylenes in Table 5-6 for wells 33-0 and 44D-0).

However, because MER is the product of sample concentration multiplied by gas extraction well flow rate, it may be seen that a well with relatively higher gas flow rate (eg., well 33-0, 28 ft^3/min) may have a higher MER than a well with relatively lower gas flow rate (eg., well 44D-0, 6 ft^3/min) despite having a relatively lower gas concentration of a given compound. For example, compare the MERs at wells 33-0 and 44D-0 for ethylbenzene and vinyl chloride, Table 5-6. In this case, the differences in gas extraction well flow rates are great enough to offset the differences in contaminant concentrations.

It should be noted that the extraction well gas flow rate is not necessarily directly related to methane concentration. Subsurface landfill gas may also contain substantial percentages of carbon dioxide, nitrogen, and oxygen. The relative proportions of these constituents in subsurface landfill gas depends largely on the operational status of the on-site gas control system, on the balance of anaerobic to aerobic biodegradation of landfilled waste, and on the magnitude of unavoidable ambient air intrusion through subsurface geologic conduits or through landfill cover materials. Therefore, MERs are most appropriately evaluated on the basis of total gas flow rate at a given gas extraction well rather than on the basis of methane production or concentration.

These preliminary comparisons suggest that both gas flow rate and contaminant concentration are important factors that must be considered in using mass emission rates to identify the location of subsurface "hot spots," that is, areas of relatively higher contaminant concentration or total contaminant mass within the landfill.

5.3. CHEMICAL COMPOSITION OF PRE-COMBUSTION FLARE GAS

Data on the chemical composition of on-site gas from the flare manifold inlets are available from several studies (see Table 4-1). TRC's results for pre-combustion flare gas composition are compared with results obtained during the other investigations listed in Table 4-1. In general, results of pre-combustion flare gas sampling closely approximated the mean contaminant concentrations observed across samples collected from individual on-site gas extraction wells. Results are discussed in more detail below.

5.3.1. TRC ENVIRONMENTAL CONSULTANTS FLARE SAMPLING RESULTS

The results of TRC's pre- and post-combustion flare sampling activities are contained in Section 4.3 and Appendix C of the Midway Landfill Air Quality Technical Report (Parametrix, 1988). Those portions of TRC's results that pertain to characterization of the pre-combustion flare gas composition are also summarized here.

Concentrations of USEPA HSL VOCs in pre-combustion flare gases sampled by TRC are shown in Table 5-7.

Table 5-6. Estimated Mass Emission Rates (MERs) for USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) from Selected Midway Landfill on-site gas extraction wells.

CAS #	USEPA Hazardous Substances List Volatile Organic Compound (HSL VOC)	(1) 4-0 3 cfm (ug/m3)	(ppb)	MER (g/day)	(2) 33-0 28 cfm (ug/m3)	(ppb)	MER (g/day)	(3) 44D-0 6 cfm (ug/m3)	(ppb)	MER (g/day)
71-43-2	benzene	330	102	0.040	2,300	707	2.626	2,080	640	0.509
75-27-4	bromodichloromethane	0	0	0.000	0	0	0.000	0	0	0.000
74-83-9	bromomethane	0	0	0.000	0	0	0.000	0	0	0.000
75-25-2	bromoform	0	0	0.000	0	0	0.000	0	0	0.000
56-23-5	carbon tetrachloride	0	0	0.000	0	0	0.000	0	0	0.000
108-90-7	chlorobenzene	240	51	0.029	0	0	0.000	1,210	258	0.296
75-00-3	chloroethane	40	15	0.005	0	0	0.000	0	0	0.000
110-75-8	2-chloroethylvinyl ether	0	0	0.000	0	0	0.000	0	0	0.000
67-66-3	chloroform	0	0	0.000	0	0	0.000	0	0	0.000
74-87-3	chloromethane	0	0	0.000	0	0	0.000	0	0	0.000
124-48-1	dibromochloromethane	0	0	0.000	0	0	0.000	0	0	0.000
75-34-3	1,1-dichloroethane	50	12	0.006	0	0	0.000	3,080	748	0.754
107-06-2	1,2-dichloroethane	0	0	0.000	0	0	0.000	520	126	0.127
75-35-4	1,1-dichloroethene	0	0	0.000	0	0	0.000	450	112	0.110
156-60-5	trans-1,2-dichloroethene	0	0	0.000	0	0	0.000	320	79	0.078
78-87-5	1,2-dichloropropane	0	0	0.000	0	0	0.000	0	0	0.000
10061-01-5	cis-1,3-dichloropropene	0	0	0.000	0	0	0.000	70	15	0.017
10061-02-6	trans-1,3-dichloropropene	0	0	0.000	0	0	0.000	0	0	0.000
100-41-4	ethylbenzene	10,900	2,467	1.333	24,500	5,544	27.972	73,400	16,610	17.958
75-09-2	methylene chloride	0	0	0.000	0	0	0.000	0	0	0.000
79-34-5	1,1,2,2-tetrachloroethane	0	0	0.000	0	0	0.000	0	0	0.000
127-18-4	tetrachloroethene (PCE)	45	7	0.006	0	0	0.000	390	57	0.095
108-88-3	toluene	900	235	0.110	0	0	0.000	92,200	24,044	22.557
71-55-6	1,1,1-trichloroethane	0	0	0.000	0	0	0.000	0	0	0.000
79-00-5	1,1,2-trichloroethane	0	0	0.000	0	0	0.000	0	0	0.000
79-01-6	trichloroethene (TCE)	0	0	0.000	0	0	0.000	530	97	0.130
75-01-4	vinyl chloride	55	21	0.007	22,000	8,457	25.118	81,200	31,215	19.866
67-64-1	acetone	0	0	0.000	0	0	0.000	0	0	0.000
78-93-3	2-butanone (MEK)	0	0	0.000	0	0	0.000	0	0	0.000
75-15-0	carbon disulfide	0	0	0.000	0	0	0.000	0	0	0.000
591-78-6	2-hexanone (MNBK)	0	0	0.000	0	0	0.000	0	0	0.000
108-10-1	4-methyl-2-pentanone (MIBK)	0	0	0.000	0	0	0.000	0	0	0.000
100-42-5	styrene	200	46	0.024	0	0	0.000	2,200	508	0.538
108-05-4	vinyl acetate	200	56	0.024	0	0	0.000	1,730	483	0.423
1330-20-7	xylenes (total)	2,700	611	0.330	19,100	4,323	21.807	129,000	29,195	31.561
109-99-9	tetrahydrofuran	0	0	0.000	0	0	0.000	0	0	0.000
75-69-4	trichlorofluoromethane	0	0	0.000	0	0	0.000	0	0	0.000
76-13-1	trichlorotrifluoroethane	0	0	0.000	0	0	0.000	0	0	0.000

Mass Emission Rate (MER, mass/time) = sample concentration (mass/sample volume) x gas extraction well flow rate (volume/time).
(1) On-site gas extraction well 4-0 considered to have "medium" HSL VOCs concentrations, "low" flow (3 cfm).
(2) On-site gas extraction well 33-0 considered to have "high" HSL VOCs concentrations, "medium" flow (28 cfm).
(3) On-site gas extraction well 44D-0 considered to have "high" HSL VOCs concentrations, "low" flow (6 cfm).

Table 5-7. Concentrations of Selected Target USEPA HSL VOCs in Pre-Combustion Flare Gas Samples Collected by TRC, June, 1987

Compounds	North Flare (ppbV)	South Flare (ppbV)
Vinyl Chloride	1056	197
Trichlorofluoromethane*	bdl	56
1,1-dichloroethane	bdl	340
1,1-dichloroethene	bdl	1004
1,1,2-Trichloro-1,2,2-Trifluoroethane*	bdl	451
1,1,1-Trichloroethane	bdl	60
Trichloroethene	bdl	683
Benzene	716	944
Toluene	6579	2508
Ethylbenzene	5749	1356
Xylenes (total)	22489	3924

Notes: bdl - below detection limits of 0.002 ug (0.008 - 1.00 ppbV).
ppbV - parts per billion by volume.

* Compound not included on USEPA Hazardous Substances List; results for this compound were routinely provided by Research Triangle Laboratory.

These results are consistent with Parametrix' sampling data for gas from on-site gas extraction wells with respect to the following:

- USEPA HSL VOCs found in the highest concentrations in pre-combustion flare gas included BTX-type compounds and vinyl chloride; maximum concentrations for these compounds were in the range of about 1 to 22.5 ppm (22.5 ppm = total xylenes).

- Other USEPA HSL VOCs, such as chlorinated ethanes and ethenes, were present at concentrations at or below 1 ppm.

Other results of TRC's sampling of pre-combustion flare gases include the following:

- Hydrogen sulfide concentrations ranged from an average of 17 ppm at the South Flare inlet to an average of 26 ppm at the North Flare inlet.

- Hydrogen cyanide concentrations for all samples were below the detection limit of 0.4 ppm by volume.

- Hydrogen chloride concentrations were below average detection limits of approximately 15 ppm by volume. (The detection limits for hydrogen chloride were somewhat higher than anticipated due to the presence of substances that interfered with the ion chromatography analysis.)

- Methane [combustible gas] concentrations ranged from 26 to 32% by volume.

- Carbon dioxide (CO_2) concentrations ranged from 26 to 29.5% by volume.

- Oxygen (O_2) concentrations ranged from 3.0 to 3.3% by volume.

- Gas moisture (H_2O) content was 4.0% at both flare inlets.

- Carbon monoxide (CO) concentrations were less than 2 ppm by volume.

5.3.2. COMPARISON WITH OTHER STUDIES

5.3.2.1. Parametrix pre-combustion flare gas sampling results during studies outside the scope of the RI

Prior to the start of remedial investigation activities, Parametrix had collected Tedlar bag samples of pre-combustion flare gas from the two temporary flares. Samples were collected on 06/18/86 and shipped to Analytical Technologies for analysis for USEPA HSL VOCs by gas chromatography/mass spectrometry. The results of these analyses (available for review at the Midway Landfill Data Repositories as Gas Analysis Data, 8 volumes) were

similar to TRC's flare sampling results for the remedial investigation in the following respects:

- USEPA HSL VOCs were present at or below the low parts-per-million range. The highest concentration for any compound was approximately 15 ppm of ethylbenzene; total xylenes were present in concentrations up to 12 ppm.

- Vinyl chloride, benzene, and toluene were present in the range of roughly 1 to 4 ppm.

- Additional USEPA HSL VOCs were either present at concentrations below 1 ppm or were below the detection limits.

Sampling for hydrogen sulfide and hydrogen cyanide in pre-combustion flare gas was conducted outside the scope of the remedial investigation by Parametrix on 11/19/86 in order to determine potential health and safety hazards to on-site workers. Hydrogen sulfide concentrations ranged from 50 to 65 ppm, as measured using Sensidyne (Draeger-type) direct-reading colorimetric tubes. These results were somewhat higher than those obtained in June 1987 by TRC.

Because it was suspected that the hydrogen cyanide (HCN) concentrations that were measured using direct-reading colorimetric tubes would be subject to interferences from hydrogen sulfide, HCN was measured using two different methods: 1) the Sensidyne tube method and 2) a laboratory method in which samples were collected by bubbling the gas through a reagent in a glass impinger bottle. Results of the two methods were compared. Two midget impinger samples (replicates) were collected from the North Flare inlet and analyzed by Analytical Technologies using ion specific electrode techniques.

HCN concentrations measured by Parametrix using the impinger method were below the detection limit of 0.04 ug/m^3 (for HCN, this is equivalent to 0.04 ppm). Results for a spiked QA/QC sample demonstrated 100% sample recovery. These results are consistent with TRC's impinger sampling results that indicate the absence of hydrogen cyanide. (Note that the impinger method is not sensitive to the presence of hydrogen sulfide as an interferant.) In contrast, each of two Sensidyne tube measurements made by Parametrix appeared to indicate 15 ppm of HCN. The technical data sheet for Sensidyne tube No. 12L (hydrogen cyanide low-range tube) states that hydrogen sulfide concentrations greater than 5 ppm produce a stain similar to that produced by HCN. This observation, along with the impinger results, confirmed previous suspicions that the direct-reading tubes were in fact giving false positive readings due to the presence of interferants, presumably the known concentrations of hydrogen sulfide.

5.3.2.2. Black & Veatch pre-combustion flare gas sampling results

Results of pre-combustion flare gas sampling conducted by Black & Veatch for the Department of Ecology are presented in Appendix E-2. Pre-combustion flare sampling results obtained by Black & Veatch were generally consistent with the types of compounds and concentrations seen in the other studies of pre-combustion flare gas composition. However, these results differ from

other sampling results in that xylenes were not reported present in samples collected by Black & Veatch on 05/01/86.

5.3.2.3. Farr, Friedman & Bruya pre-combustion flare gas sampling results

Results of the flare sampling activities conducted by Farr, Friedman & Bruya (FFB) during March 1987 are presented in Appendix E-3. FFB's flare sampling results are of somewhat limited value for purposes of comparison with the previously described studies because their sampling and analytical methods resulted in higher detection limits for most of the compounds of interest.

Volatile organic compounds detected in the flare feed (inlet) gas in the FFB study (Appendix E-3) included 1,1-dichloroethene (0.05 ppm), trichloroethene (0.08 ppm), and 1,1,2,2-tetrachloroethene (0.1 ppm). Vinyl chloride was not detected in the pre-combustion flare gas; however, the detection limit of 1 ppm for vinyl chloride in the FFB sampling program was much higher than detection limits achieved for this compound in other studies. The maximum concentration for any compound detected in the pre-combustion flare gas in the FFB study was 0.1 ppm for 1,1,2,2-tetrachloroethene at both the North and South flare feed lines.

Farr, Friedman & Bruya, under subcontract to Parametrix, also conducted methane/ethane/propane analyses of pre-combustion flare gas and selected samples from off-site gas monitoring probes (Appendix E-3). These studies attempted to differentiate Midway Landfill on-site gas from utility natural gas supplied by the Washington Natural Gas Company, based on analysis of the ethane/methane and propane/methane ratios in the gas samples. Major findings of this study included:

- Data regarding the composition of Washington Natural Gas Company's gas supplies are discussed in a letter from FFB to Parametrix dated 04/20/87 (see Appendix E-3).

- Pre-combustion flare gas had ([ethane/methane] X 100) ratios on the order of 0.005 to 0.018.

- Pre-combustion flare gas had ([propane/methane] X 100) ratios of less than 0.01.

- Subsurface gas samples from several off-site gas monitoring probes and off-site gas control wells closely matched the above figures for precombustion flare gas.

- Subsurface gas samples from off-site gas monitoring probe completions 45-S, 45-M, and 45-D had ethane/methane ratios from 30 to 260 times greater than those for pre-combustion flare gas and propane/-methane ratios up to 77 times those for pre-combustion flare gas. These results were interpreted as indicating the presence of utility gas that could be attributed to a leaking natural gas main.

Overall, the results of the ethane/methane and propane/methane ratio studies indicate that measurement of these parameters may be useful in distinguishing subsurface gas from the Midway Landfill from subsurface gas originating from Washington Natural Gas Company utility lines.

5.4. CHEMICAL COMPOSITION OF SUBSURFACE GAS FROM OFF-SITE GAS MONITORING PROBES AND OFF-SITE GAS CONTROL WELLS

5.4.1. PARAMETRIX OFF-SITE SUBSURFACE GAS SAMPLING RESULTS

5.4.1.1. Parametrix off-site subsurface gas sampling results for the remedial investigation studies

The results of Parametrix' off-site subsurface gas sampling program for the remedial investigation are summarized in Table 5-3. These data confirmed the findings of previous studies indicating the presence of numerous volatile organic compounds at or below the parts-per-million level in off-site subsurface gas.

The USEPA HSL VOCs found most frequently in off-site subsurface gas are listed below; numbers in parentheses are the percentage of off-site gas monitoring probe completions in which the compound was reported:

- Ethylbenzene (92%)
- Toluene (83%)
- Total Xylenes (75%)
- Benzene (67%)
- Styrene (50%)
- 1,1,1-Trichloroethane (50%)

The compound 1,1,1-trichloroethane was reported present at 50% of the off-site gas monitoring probes sampled but was not found for any of the on-site gas extraction wells sampled by Parametrix during the remedial investigation. Other compounds listed in Table 5-3 were found in less than 50% of the off-site gas monitoring probe completions sampled.

Maximum concentrations of the HSL VOCs reported in off-site subsurface gas included:

- Acetone (40,002 ppb = 40 ppm)
- Trichlorotrifluoroethane (3,000 ppb [estimated] = 3 ppm)
- Methylene chloride (2,489 ppb [estimated] = 2.5 ppm)
- Chloroethane (1,192 ppb = 1.2 ppm)

The maximum off-site concentrations for all other HSL VOCs were below 1 ppm. The second-highest concentration value for acetone was 4,716 ppb (less than 5 ppm) found in another off-site sample; this second-highest concentration is almost an order of magnitude lower than the peak value. With the exception of acetone (arithmetic mean off-site concentration = 1.7 ppm), the arithmetic mean concentrations for all other off-site HSL VOCs were below 0.2 ppm.

It should be emphasized that of the four compounds listed above, results for the first three (acetone, trichlorotrifluoroethane and methylene chloride) are suspect due to the high frequency with which these compounds were reported present in laboratory blanks. The fourth compound, chloroethane, was reported in only one sample at off-site gas probe J-D during the first round of sampling. Chloroethane was not detected elsewhere, including at probe J-D during the second round of sampling.

5.4.1.2. Parametrix' off-site subsurface gas sampling results from studies performed outside scope of the remedial investigation

Results of Tedlar bag samples collected by Parametrix February-April 1986 from off-site gas control wells C-1 through C-5 indicated the presence of the following compounds:

- Vinyl chloride
- Chloroethane
- Methylene chloride
- Acetone
- Carbon disulfide
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon tetrachloride
- 1,1,2,2-Tetrachloroethane
- 2-Hexanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethylbenzene
- Styrene
- Total Xylenes

The maximum concentrations of these compounds were all below 1 ppm. It should be noted that the sampling and analysis program that generated these data was not subjected to the more stringent Quality Assurance/Quality Control provisions required for the Midway Landfill Remedial Investigation. However, the results appear to be generally similar to the results obtained during the remedial investigation; it is interesting to note that benzene was not detected in subsurface gas collected from off-site gas control wells during this sampling activity, whereas it was detected at off-site gas monitoring probes during remedial investigation sampling.

5.4.2. COMPARISON WITH OTHER STUDIES

5.4.2.1. Black & Veatch off-site subsurface gas sampling results

Results of off-site subsurface gas samples collected by Black & Veatch for the Department of Ecology are presented in Appendix E-2. In general, these data indicated the presence of several USEPA HSL VOCs at levels well below 1 ppm, typically in the low parts-per-billion range (near the limits of

detection for these compounds). In general, the compounds reported present were similar to those found by Parametrix during the remedial investigation sampling and analysis program.

5.4.2.2. Farr, Friedman & Bruya off-site subsurface gas sampling results

Parametrix retained Farr, Friedman & Bruya (FFB) to collect and analyze samples of gas from off-site gas monitoring probes and off-site gas control wells. Sampling results were reported in a letter to Parametrix from FFB, dated May 6, 1987 (Appendix E-3). Numerous USEPA HSL VOCs were also detected in this study, generally well below 1 ppm. The findings of these studies included the following:

- Vinyl chloride was reported at concentrations of up to 3 ppm at off-site gas control well C-15 (inlet versus outlet not specified) and at the limit of detection (1 ppm) at off-site gas control wells C-3 (inlet versus outlet not specified), C-7 (inlet only), and C-9 (inlet versus outlet not specified).

- Toluene was reported at concentrations of up to 20 ppm at the outlet of the carbon filter drum at off-site gas control well C-7; lower concentrations were reported at off-site gas control wells C-5 (0.6 ppm), C-12 (1 ppm), and E-1 (0.8 ppm).

- Other BTX-group compounds detected included p-xylene (4 ppm) and ethylbenzene (2 ppm), found at the carbon filter inlet at off-site gas control well C-13. A footnote to the data sheets mentions that data for ethylbenzene were based on instrument response for toluene.

- Chlorinated solvents, including 1,1-dichloroethene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene, 1,1,2,2-tetrachloroethane, and 1,1,2,2-tetrachloroethene, were found at levels generally well below 1 ppm at numerous off-site gas control wells (including inlet and outlet samples) and some off-site gas monitoring probes.

These data should be interpreted with caution because analysis did not include mass spectrometric (MS) confirmation of the identity of compounds detected using gas chromatography (GC) and injection of analytical standards. Studies in which analyses were performed by gas chromatography/mass spectrometry are considered more reliable and generally achieve lower detection limits.

5.5. MAPPING CONCENTRATIONS OF SELECTED SUBSURFACE GAS COMPONENTS

The comparisons of on-site and off-site subsurface gas in Table 5-1 suggest that off-site migration of at least some of the on-site subsurface gas contaminants has occurred. Concentrations of selected gas components were plotted on base maps of the site and surrounding areas to help evaluate the association between on- and off-site contaminant distribution. The mapping

results support the conclusion that off-site migration of certain on-site subsurface gas contaminants appears to have occurred. Data suggesting off-site contaminant migration are observed most consistently for the BTX compounds, notably benzene, toluene, total xylenes, ethylbenzene, and styrene. The results for these compounds further suggest that migration has potentially occurred in all directions away from the landfill; however, the possibility exists that at some sampling locations the presence of the compounds may be due to off-site sources.

Although some compounds were detected in off-site gas monitoring probes to the east, the remedial investigation data do not suggest extensive migration of gas contaminants in this direction. Several compounds were detected due east of the landfill at off-site gas probe M-M, the closest probe to the landfill in that direction. However, none of the compounds reported at probe M-M appear to have migrated as far east as probe 50-S.

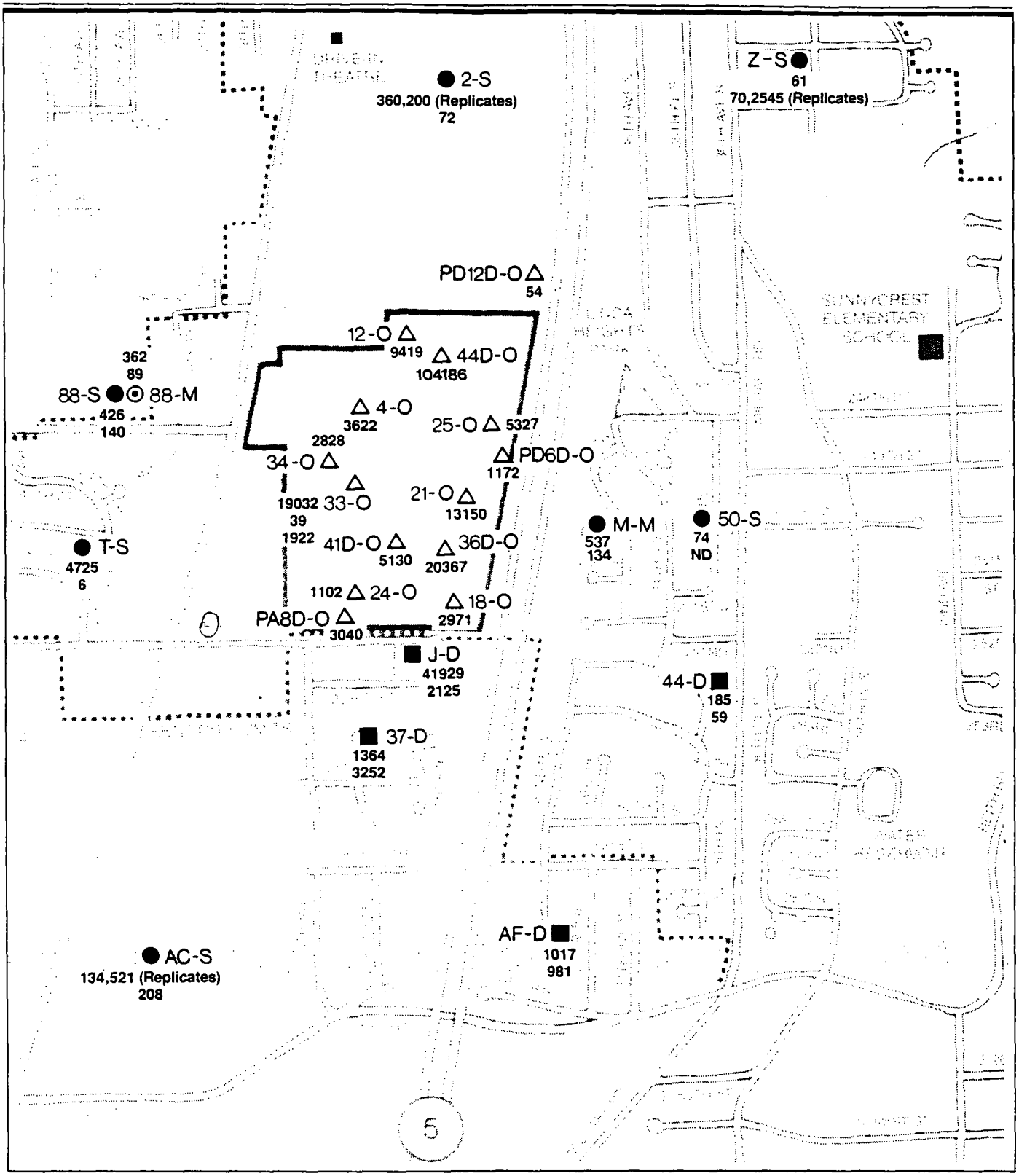
5.5.1. DISTRIBUTION OF SUMMED USEPA HAZARDOUS SUBSTANCES LIST VOLATILE ORGANIC COMPOUNDS (SUMMED HSL VOCs)

For each sample shown in Tables 5-2 and 5-3, the concentrations of each of the compounds detected were summed for that sample and the resulting sum plotted on a base map of the Midway Landfill area. The resulting geographic distribution of Summed HSL VOCs is shown in Figure 5-2. This map provides a rough first indication of the geographic distribution of "composite" concentrations of subsurface gas contaminants in the vicinity of Midway Landfill. The concentration values presented in Figure 5-2 must be interpreted cautiously due to Quality Assurance/Quality Control considerations described in greater detail below.

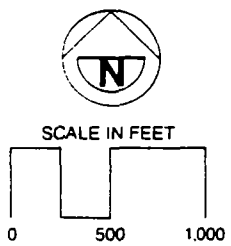
It may be seen that there are several relatively high values on-site (interpreted as "total HSL VOCs, in parts per billion [volume] in gas"), particularly at the locations of on-site gas extraction wells 44D-0, 36D-0, 33-0, and 21-0. It may also be seen that, in general, values decrease with increasing off-site distance from the landfill. Some of the off-site numbers must be interpreted with caution because of the presence at high concentrations of specific compounds suspected as potential laboratory contaminants. Values for concentrations of specific on-site and off-site contaminants contributing to the Summed HSL VOCs values are taken from Tables 5-2 and 5-3, respectively. The following general trends are seen:

- o There appears to be a gradient toward the south from off-site probe J-D to probe 37-D, which then possibly continues south-southwest to probe AC-S and/or south-southeast to probe AF-D. This gradient is somewhat less clear-cut when the Summed HSL VOCs at each location are further broken down into the major constituents; however, BTX compounds and vinyl chloride appear to decrease with increasing southerly distance from the landfill.

    - At probe J-D, about 40,000 ppb of the 41,929 ppb sum are attributable to acetone, which may reflect an acetone "hot spot" at this location as discussed previously. However, the second sample value for acetone at probe J-D was rejected as



Note: **ND** = Not Detected
These data are not blank-corrected.



- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Figure 5-2.
Summed USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCS)

being insufficiently elevated over the lab blank to allow reporting. The contribution of BTX-group compounds to the two samples amounted to 447 ppb of the 41,929 ppb sample and 46ppb of the 2,125 ppb sample. The absence of vinyl chloride at probe J-D is difficult to explain relative to the presence of vinyl chloride further south at probes 37-D and AF-D.

- At probe 37-D, there was generally very poor correlation between compounds found during each of the two sampling rounds (see Table 5-3 and related discussion in Section 5.1.2.3). The exception was vinyl chloride, detected at 269 ppb and an estimated 252 ppb during the first and second sampling rounds, respectively.

- At probe AC-S, more than 90% of the total HSL VOCs present in two of the three samples (#1 and #2) were attributable to BTX-group compounds. The replicate samples (#1 and #1R) correlated poorly (see Table 5-3 and related discussion in Section 5.1.2.3). In addition, 486 ppb of the 521 ppb sum for this sample were attributable to 2-butanone, a contaminant found in the laboratory blank.

- At probe AF-D, BTX-group compounds and vinyl chloride were found during both rounds of sampling; however, the sums for both samples were elevated largely due to carbon disulfide and trichlorotrifluoroethane in round 1 and tetrahydrofuran in round 2, all of which are suspected lab contaminants. Carbon disulfide and trichlorotrifluoroethane were contaminants in the lab blank for round 1; tetrahydrofuran was found in the lab blank for round 2.

o To the west, probes 88-S and 88-M show a consistent presence of low levels of HSL VOCs; Table 5-3 indicates this is due in part to the low-level presence of the BTX-group compounds ethylbenzene, total xylenes, and toluene. Roughly half of the 426 ppb value at probe 88-S is due to 2-butanone, a lab contaminant present in the laboratory blank. The 4,725 ppb value at probe T-S is most likely spurious; 4,716 ppb of this value is attributable to acetone, another lab contaminant found in the laboratory blank.

o To the north, the low-level values at probe 2-S are consistently attributable to the BTX-group compounds benzene, ethylbenzene, and toluene (and in one sample, styrene).

o To the northeast, 2,489 ppb of the 2,545 ppb value at probe Z-S is attributable to methylene chloride, a lab contaminant found in the lab blank. However, the consistent 56 to 70 ppb residual is attributable to the BTX-group compounds ethylbenzene, styrene, and toluene at levels just above the detection limits.

o To the east, samples from probe M-M consistently contained low parts-per-billion concentrations of the BTX-group compounds

benzene, ethylbenzene, toluene, and total xylenes; slightly more than 100 ppb in each of the two samples are attributable to the sum of the BTX-group compounds. About 207 ppb of the 537 ppb value are attributable to 2-butanone and carbon disulfide (contaminants found in the lab blank); another 223 ppb are attributable to trichlorofluoromethane. Farther east at probe 50-S, the 66 ppb of the 74 ppb sum is attributable to acetone, and the remaining 8 ppb is attributable to 1,1,1-trichloroethane. Acetone and trichloroethane were not found in the lab blank specific to this set of analyses. However, their presence in several other lab blanks and their inclusion on a list of common laboratory contaminants compiled by AGI would suggest that their presence in the two samples is questionable and may be a result of laboratory contamination.

- To the southeast, the values shown for probe 44-D are all attributable to BTX-group compounds.

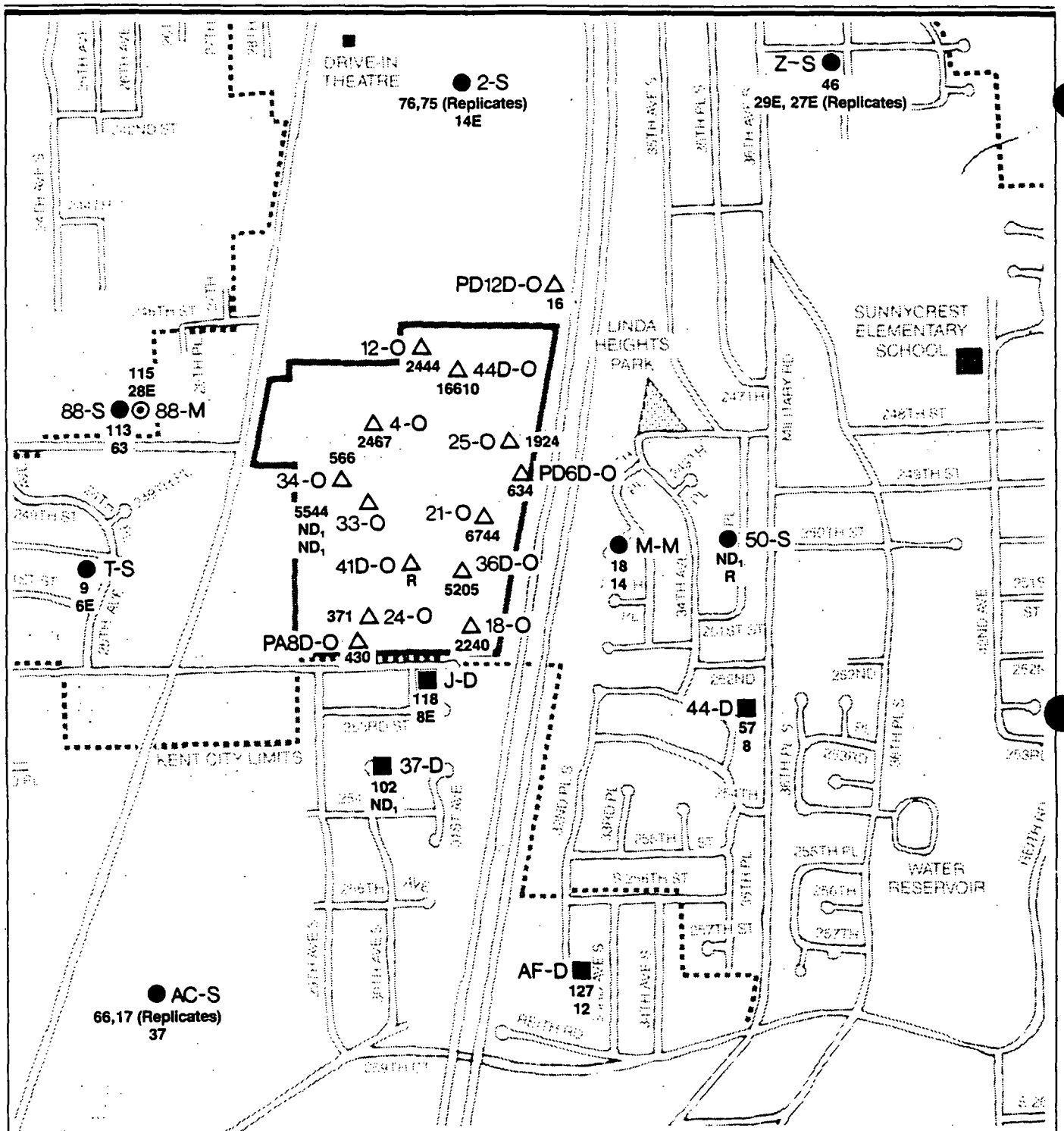
Overall, these mapping results should be interpreted cautiously, because it is clear that many of the high values seen for the Summed HSL VOCs appear to be a result of the inconsistent and highly variable intrusion of laboratory contaminants, most notably acetone, methylene chloride, trichlorotrifluoroethane, 2-butanone, and tetrahydrofuran, in roughly decreasing order of importance. However, consistent underlying patterns related to the distribution of BTX-group compounds may be seen after adjusting for background "noise" that is due to lab contaminants.

5.5.2. DISTRIBUTION OF SPECIFIC USEPA HAZARDOUS SUBSTANCES LIST VOLATILE ORGANIC COMPOUNDS

For each sample shown in Tables 5-2 and 5-3, each compound that was detected was plotted on a separate base map of the Midway Landfill area (see example in Figure 5-3). The resulting geographic distributions for each of the USEPA HSL VOCs are shown in Appendix E-1. The maps are discussed in groups, in the same manner as the compounds were presented in Table 5-1:

- Compounds reported both on-site and off-site
- Compounds reported on-site only
- Compounds reported off-site only

Discussions regarding the geographic distributions of compounds found at or near their respective detection limits are necessarily limited. This is true because the natural statistical variation that is due to the sampling and analysis methods used may be expected to strongly influence the relative probability that such a compound will be reported "present" versus "absent" in any given sample and, therefore, at any given sampling location.



Example of figure from Appendix A:
Distribution of individual USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) by sampling location

Notes: ND_1 = Below Detection Limit of 1.1 PPB
E = Estimated Data Value
R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

These data are not blank-corrected.

● Shallow Probes
⊙ Medium Probes
■ Deep Probes
△ On-Site Control Wells

Figure 5-3.
Distribution of Subsurface Gas Contaminants (ppb)
Ethylbenzene

5.5.2.1. Compounds reported both on-site and off-site

The compounds included in this section have all been detected at greater or lesser concentrations in on-site subsurface gas. The following discussion therefore focuses on the off-site geographic distribution of these compounds.

The BTX-group compounds ethylbenzene, total xylenes, toluene, and benzene share a common pattern of distribution (see maps presented in Appendix E-1), which includes the following general attributes:

- South: positive results in off-site probes J-D, 37-D, AC-S, and AF-D. There is weak evidence of a concentration gradient that decreases in value with increasing distance from the southern boundary of the landfill property.
- West: positive results in off-site probes 88-S and/or 88-M.
- North: positive results in off-site probe 2-S.
- Northeast: positive results in off-site probe Z-S for ethylbenzene and toluene; results for benzene and total xylenes were not reportable due to insufficient elevation above lab blank values.
- East: positive results at probe M-M; results at probe 50-S either not detected or not reportable.
- Southeast: positive results at probe 44-D.

Styrene also generally followed the above pattern:

- South: positive results at J-D and AC-S (however, in contrast to the above compounds, negative results at 37-D)
- North: positive results at 2-S
- Northeast: positive results at Z-S
- East: positive results at M-M and negative results at 50-S
- Southeast: positive results at 44-D

Comparison of the on-site and off-site concentrations of ethylbenzene, total xylenes, toluene, benzene, and styrene (see Table 5-1) suggests that these five compounds constitute the best available "fingerprint" of HSL VOCs common to both on-site and off-site subsurface gas in the vicinity of the Midway Landfill. As described in Section 5.1.1.1 and shown in Table 5-1, ethylbenzene, total xylenes, toluene, and benzene were found in greater than 50% of both the on-site gas extraction well and off-site gas monitoring probe completions sampled. Styrene was found in 36% of the on-site gas extraction well completions sampled and 50% of the off-site gas monitoring probe completions sampled. Furthermore, the similar off-site geographic distribu-

tions of these compounds (see maps presented in Appendix E-1) suggest that they share a common set of transport mechanisms and geologic migration pathways.

Vinyl chloride and trichlorotrifluoroethane followed only the southward trend, with positive results at probes 37-D and AF-D. For both rounds of samples collected at probe J-D, vinyl chloride was not detected and trichlorotrifluoroethane was non-reportable. This would appear to be an unexplained physical gap in any hypothesized on-site to off-site gradient for these compounds. Results for trichlorotrifluoroethane should be interpreted cautiously because of the high percentage of data values that were non-reportable throughout the entire subsurface gas sampling program; see Tables 5-2 and 5-3 and related discussion in Section 5.1.2.1.

Trichlorofluoromethane was reported at probe M-M to the east and probe 88-M to the west; 2-butanone was reported at probes M-M and 88-S. Tetrachloroethene was reported off-site only at probe M-M. Acetone was reported at off-site probes J-D to the south, T-S to the west, and 50-S to the east; these data should be interpreted cautiously because other results for acetone were not reportable. As previously mentioned in Section 5.5.1, the 40,002 ppb of acetone detected at probe J-D is difficult to dismiss as due to laboratory contamination and may reflect an acetone "hot spot" at this location. Methylene chloride was reported at probe J-D to the south and probe Z-S to the northeast; as with acetone, these results should be interpreted with caution because of the high percentage of non-reportable results. Chloroethane and chlorobenzene were reported off-site only at probe J-D to the immediate south of the landfill.

Positive results for tetrahydrofuran were reportable only at probe AF-D to the extreme south and probe 2-S to the north; tetrahydrofuran is a suspected laboratory contaminant. A positive result for 1,1-dichloroethene of 7 ppb was reported at probe AF-D; this value is only slightly above the detection limit (1.2 ppb) for this compound.

<u>Attenuation During Subsurface Migration</u>

The five BTX-group compounds identified as comprising the best available "fingerprint" of compounds common to both on-site and off-site subsurface landfill gas, appear to be attenuated with increasing distance from the landfill. Off-site concentrations were consistently lower than on-site concentrations (see Table 5-8):

- Comparison of <u>maximum</u> on-site and off-site concentrations of the five BTX compounds showed estimated attenuation of these compounds to be in the range of 73.6 to 99.7%.

- Comparison of <u>mean</u> on-site and off-site concentrations of the five BTX compounds showed estimated attenuation of these compounds to be in the range of 56.1 to 99.4%.

Table 5-8. Estimated On-Site/Off-Site Attenuation of Primary HSL VOCs Detected in Subsurface Gas Samples

CAS #	Target Compound	MAXIMUM CONCENTRATIONS On-Site (ppb)	Off-Site (ppb)	Attenuation (%)	MEAN CONCENTRATIONS On-Site (ppb)	Off-Site (ppb)	Attenuation (%)
100-41-4	Ethylbenzene	16,610	127	99.2	2,825	44	98.4
1330-20-7	Xylenes (Total)	29,195	106	99.6	3,419	19	99.4
108-88-3	Toluene	24,044	68	99.7	1,920	18	99.1
71-43-2	Benzene	1,384	185	86.6	318	28	91.2
100-42-5	Styrene	508	134	73.6	41	18	56.1
75-01-4	Vinyl chloride	31,215	275	99.1	2,807	35	98.8

$$\text{Attenuation (\%)} = \frac{\text{On-Site Concentration (ppb)} - \text{Off-Site Concentration (ppb)}}{\text{On-Site Concentration (ppb)}} \times 100$$

Source: Parametrix, 1987.

As shown in Table 5-1, vinyl chloride was not found off-site at as many locations as the BTX compounds, but its off-site concentrations were also substantially lower than its on-site concentrations:

- Comparison of maximum on-site and off-site concentrations of vinyl chloride showed an approximate attenuation of 99.1%.

- Comparison of mean on-site and off-site concentrations of vinyl chloride showed an approximate attenuation of 98.8%.

The studies conducted for the Midway Landfill Remedial Investigation were not designed to identify the specific mechanisms by which attenuation might be occurring or to quantify the rate of attenuation attributable to any specific mechanism. Therefore, no statement may be made solely from the gas characterization data regarding the role of any hypothesized mechanism that would explain the observed attenuation. Examples of mechanisms that might be hypothesized as explanations of the attenuation include:

- Biodegradation resulting from microbial breakdown of the compounds in the solid waste, soil, or saturated zones.

- Chemical interactions between the compounds and water or soil components.

- Physical adsorption of the compounds onto organic matter present in the solid waste, soil, or saturated zones.

- Physical extraction of volatile organic compound vapors from solid waste, subsurface soils, leachate, groundwater, or other potentially contaminated media.

  - The vacuum maintained by the gas extraction system would tend to result in increased volatilization, ie., conversion of volatile liquids to more mobile organic vapors. Volatile organic compounds would therefore have a greater tendency to be extracted from contaminated solid waste, subsurface soils, leachate, or groundwater into subsurface gas.

  - The action of the on-site gas extraction system's motor blowers is intended to draw subsurface gas and vapors back toward the landfill to be destroyed by combustion in the on-site temporary gas flares. This action would tend to stop off-site migration of any volatile organic vapors present in subsurface gas.

5.5.2.2. Compounds reported on-site only

Of the seven compounds reported on-site only, six were reported present at on-site gas extraction well 44D-0. As discussed previously, results at this well may be somewhat atypical due to its relatively low gas flow rate and increased potential for contaminant accumulation (see discussion in Section 5.2.1). Three (vinyl acetate, trichloroethene, and trans-1,2-dichloroethene)

were reported present at well 25-0. Two compounds were reported at each of two wells: vinyl acetate and 1,1-dichloroethane at well 4-0 and 4-methyl-2-pentanone and trichloroethene at well PA8D-0.

5.5.2.3. Compounds reported off-site only

No obvious pattern is seen for the three compounds reported off-site only (1,1,1-trichloroethane, chloromethane, and carbon disulfide). All were reported present in samples from at least two of the four sampled probe locations to the south of the landfill; 1,1,1-trichloroethane was reported present at all four locations. All were reported at either probe 88-S or 88-M; 1,1,1-trichloroethane was reported at both. Results for carbon disulfide may be spurious due to its presence in lab blanks.

6.0 CONCLUSIONS

The combined results of the studies described in this technical memorandum suggest that certain gas contaminants consistently identified in on-site subsurface Midway Landfill gas have migrated off-site through subsurface pathways. This conclusion is based on the following:

- Comparison of the types of compounds found in on-site and off-site subsurface gas samples.
- Mapping of the geographic distribution of the concentrations of specific compounds in relation to the landfill site.
- The likelihood of these compounds occurring in association because of their similar chemical structures and properties and their frequent occurrence together in commercial solvent and fuel mixtures.

It is further concluded that the five BTX-group compounds identified in this report (benzene, toluene, total xylenes, ethylbenzene, and styrene) comprise the best available "fingerprint" of the USEPA HSL VOCs that are consistently present in both on-site and the off-site subsurface gas within a limited distance from the landfill. However, BTX-group compounds are also present in gas from other sources. Therefore, their presence in a particular sample of off-site gas is not conclusive evidence that the gas originated from the landfill, only that it may have originated there. Results of a study conducted outside the scope of the remedial investigation (Farr, Friedman & Bruya, 1987; see Appendix E-3) indicate that evaluation of ethane/methane and propane/methane ratios may also be useful in distinguishing natural gas supplied by local utilities, such as the Washington Natural Gas Company, from Midway Landfill subsurface gas.

In summary, a comparison of on-site and off-site subsurface gas constituents shows the following:

- Several USEPA HSL VOCs are present in a high percentage of both on-site and off-site subsurface gas samples. These compounds, listed in decreasing frequency of on-site occurrence, include:
  - Ethylbenzene
  - Total Xylenes
  - Toluene
  - Benzene
- Mean concentrations of these compounds in on-site subsurface gas are in the range of 2 to 4 parts-per-million (ppm); mean concentrations of these compounds in off-site gas are less than 50 parts-per-billion (ppb).

- Styrene is frequently found associated with the compounds listed above, although generally at much lower concentrations.

- Mapping of the geographic distribution of these compounds suggests that off-site migration has occurred and that these compounds share similar off-site distributions.

- The five BTX-group compounds (ethylbenzene, total xylenes, toluene, benzene, and styrene) together comprise the best available "fingerprint" of the USEPA HSL VOCs that are consistently present in both on-site and the off-site subsurface gas within a limited distance from the landfill.

- Vinyl chloride is frequently associated with the BTX-group compounds listed above in on-site subsurface gas but is found much less frequently than the BTX compounds in off-site subsurface gas; factors affecting the distribution of vinyl chloride appear to be different than for the BTX-group compounds. Further discussions regarding potential sources of vinyl chloride and possible explanations for the observed distribution of this compound in various environmental media are given in the Midway Landfill Remedial Investigation Summary Report (Parametrix, 1988).

- Evaluation of ethane/methane and propane/methane ratios may be useful in distinguishing Midway Landfill gas from natural gas supplied by the local utilities.

- Because several USEPA HSL VOCs were identified as probable laboratory contaminants, results for these compounds are difficult to interpret.

- Because agreement between replicate samples was generally poor, conclusions regarding the absolute presence or absence of compounds generally found at the lower limits of detection in this study (low parts-per-billion range) can only be made with great caution. Similarly, conclusions regarding potential off-site migration of these compounds can only be made with great caution.

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Parametrix, Inc. 1986. Midway Landfill Scope of Work Memo. Prepared for City of Seattle Engineering Department, Solid Waste Utility.

TRC Environmental Consultants, Inc. 1987 (August). Draft Emission Test Report for the Midway Landfill Flare Systems. Prepared for Parametrix, Inc. TRC Project No. 4157-K83.

U.S. Environmental Protection Agency. 1984 (March). Protocol for the Collection and Analysis of Volatile POHCs Using VOST. EPA-600/8-84-007.

APPENDIX E-1

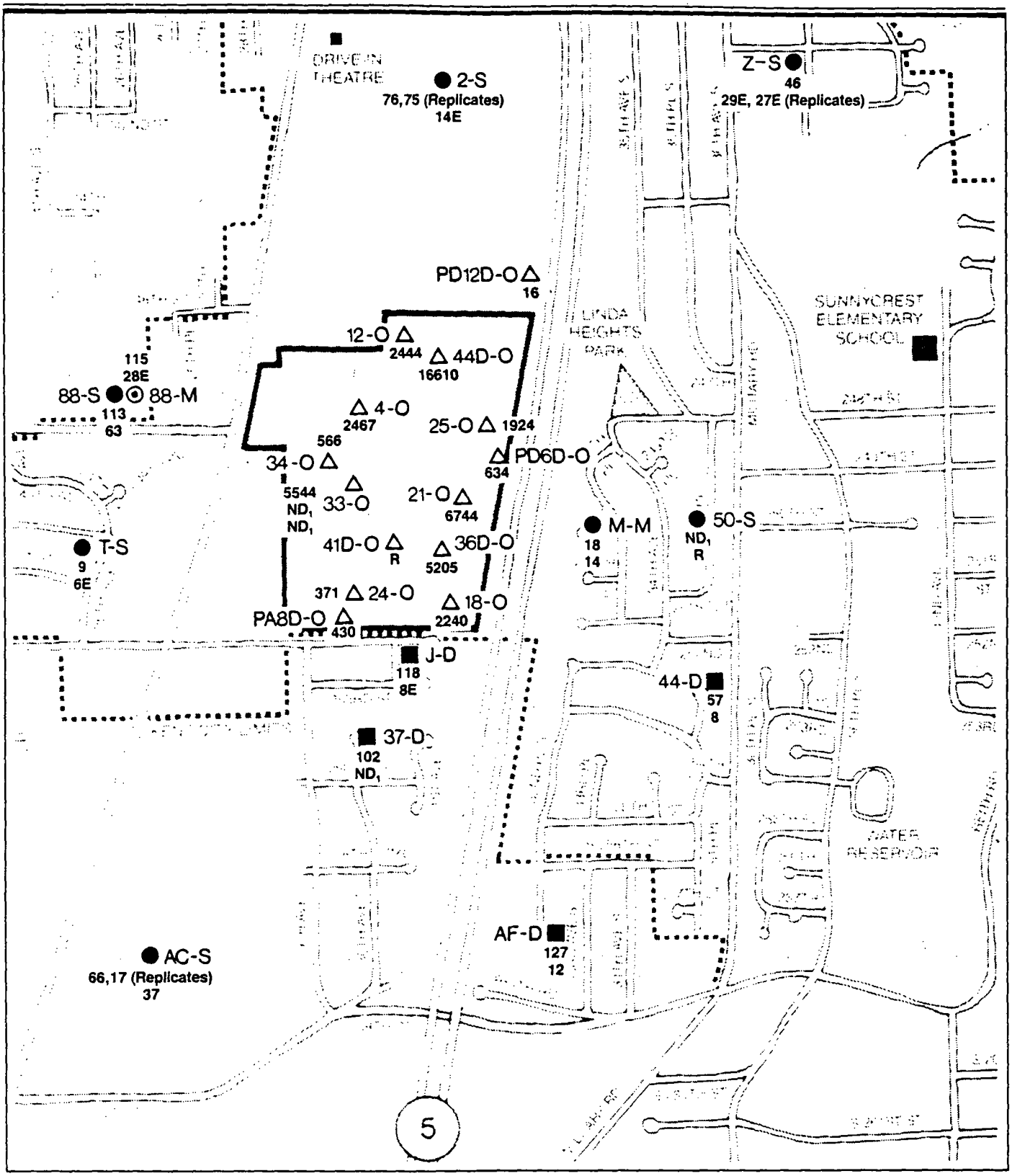
Distribution of Individual USEPA Hazardous Substances List Volatile Organic Compounds (HSL VOCs) by Sampling Location

NOTE: Maps are organized as follows:

- Compounds reported present both on-site and off-site
- Compounds reported present on-site only
- Compounds reported present off-site only

All data presented in this Appendix have been fully quality assured but have not been blank-corrected; therefore, these data represent conservatively high estimates of true HSL VOC concentrations in subsurface gas. Blank-correction would affect the results only for benzene, ethylbenzene, toluene, and total xylenes; see Tables 5-4 and 5-5 and accompanying text in Section 5.1.2.2 for further details.

COMPOUNDS REPORTED BOTH ON-SITE AND OFF-SITE



Notes: ND_1 = Below Detection Limit of 1.1 PPB
E = Estimated Data Value
R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

These data are not blank-corrected.

N

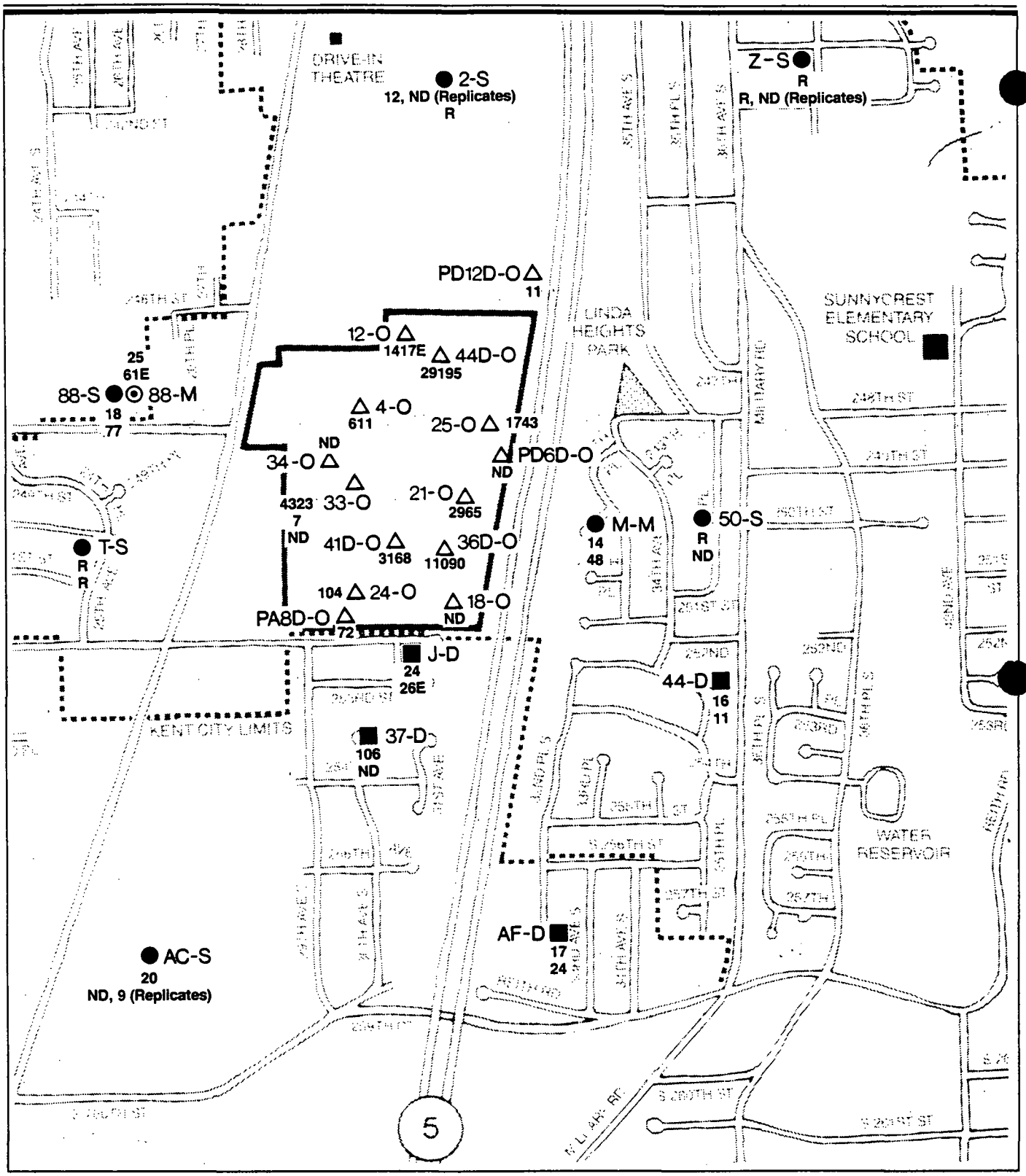
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Ethylbenzene



Notes: R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks
ND = Below Detection Limit of 113 PPB
E = Estimated Data Value

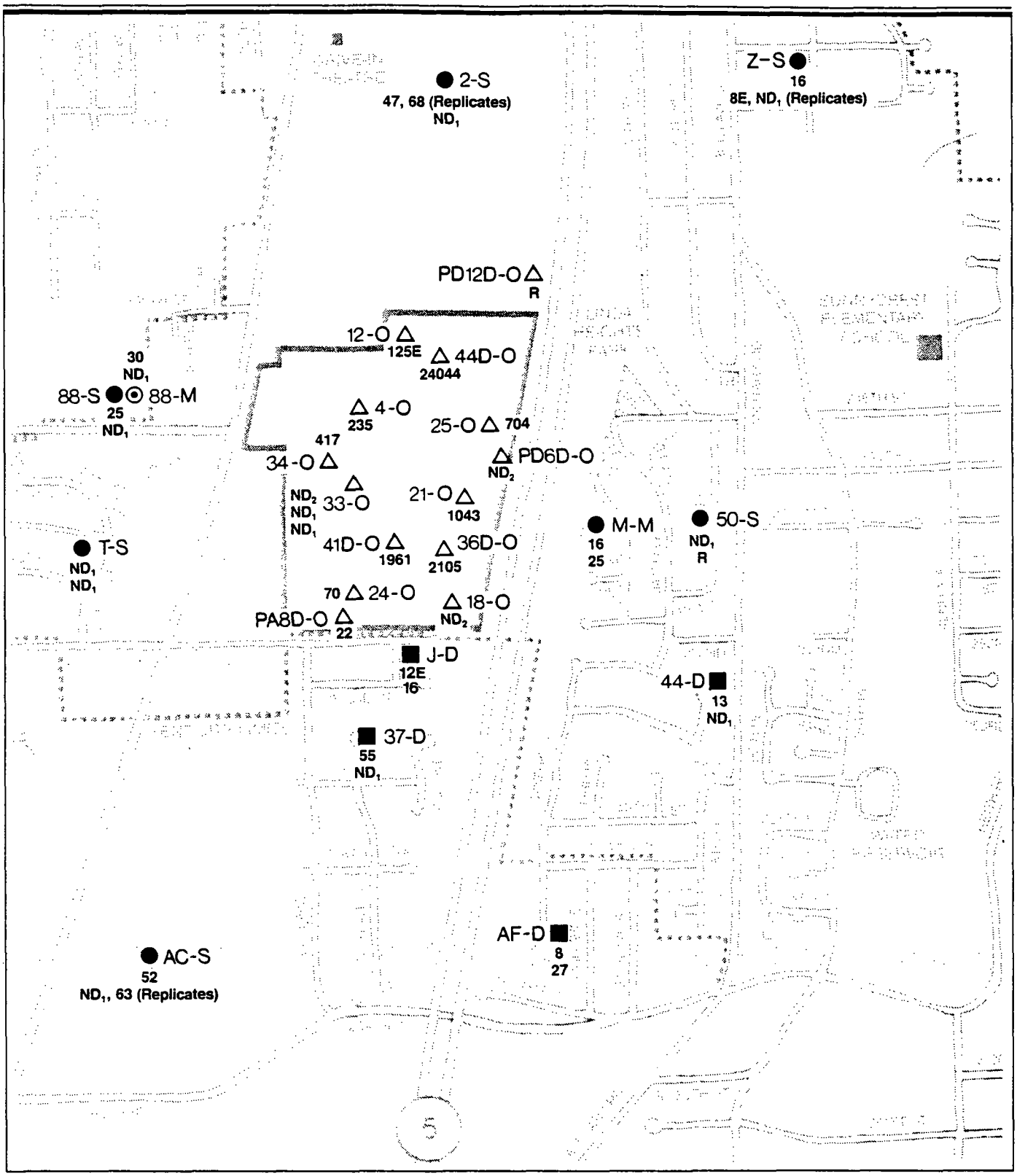
These data are not blank-corrected.

N

SCALE IN FEET
0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)
Total xylenes



Notes: ND_1 = Below Detection Limit of 1.3 PPB
ND_2 = Below Detection Limit of 130 PPB
E = Estimated Data Value
R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

These data are not blank-corrected.

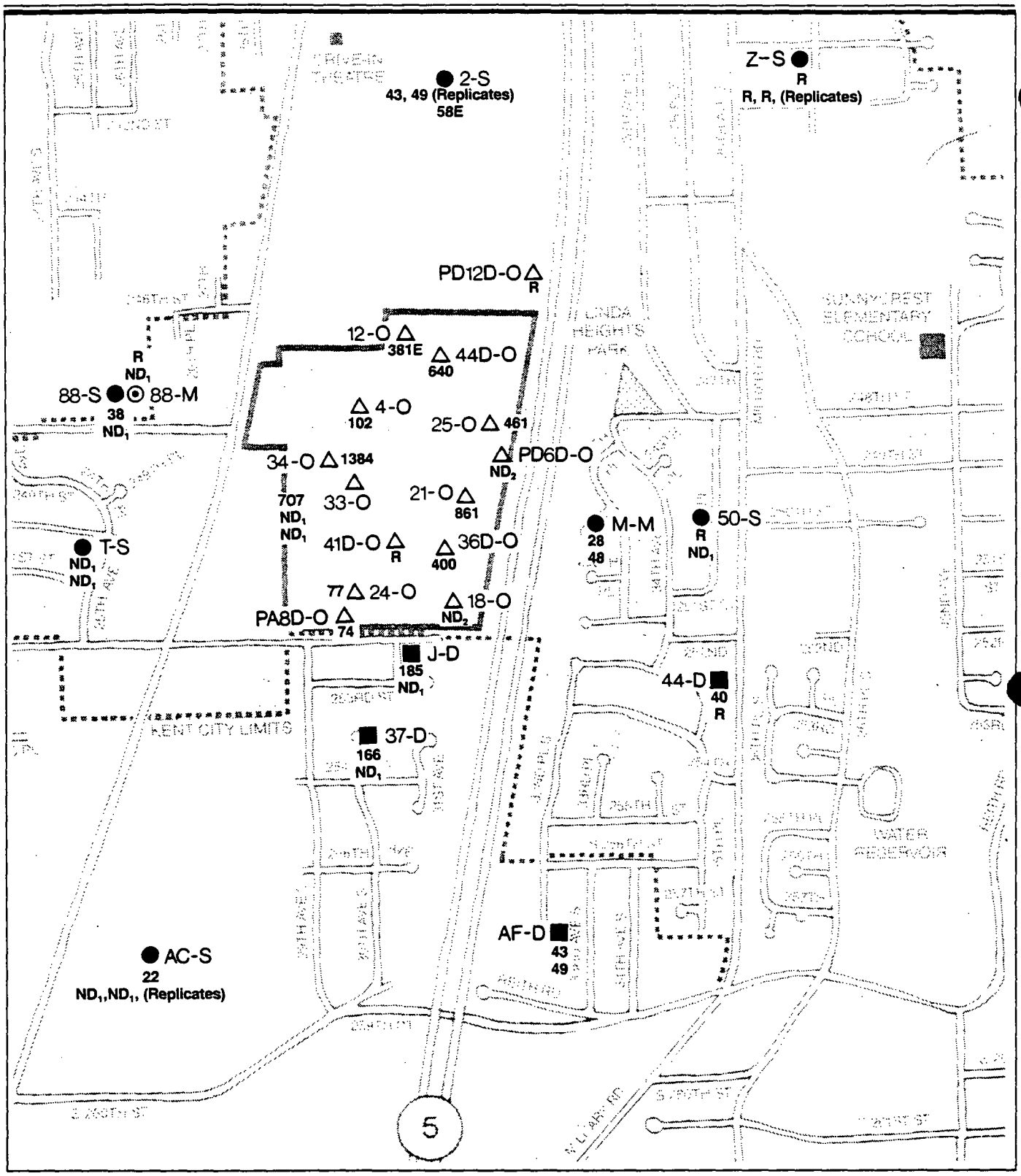
N

SCALE IN FEET
0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Toluene



Notes: R = Not Reported Present Due to Insufficient Elevation Above Lab Blank
ND_1 = Below Detection Limit of 1.5 PPB
ND_2 = Below Detection Limit of 154 PPB
E = Estimated Data Value

These data are not blank-corrected.

N

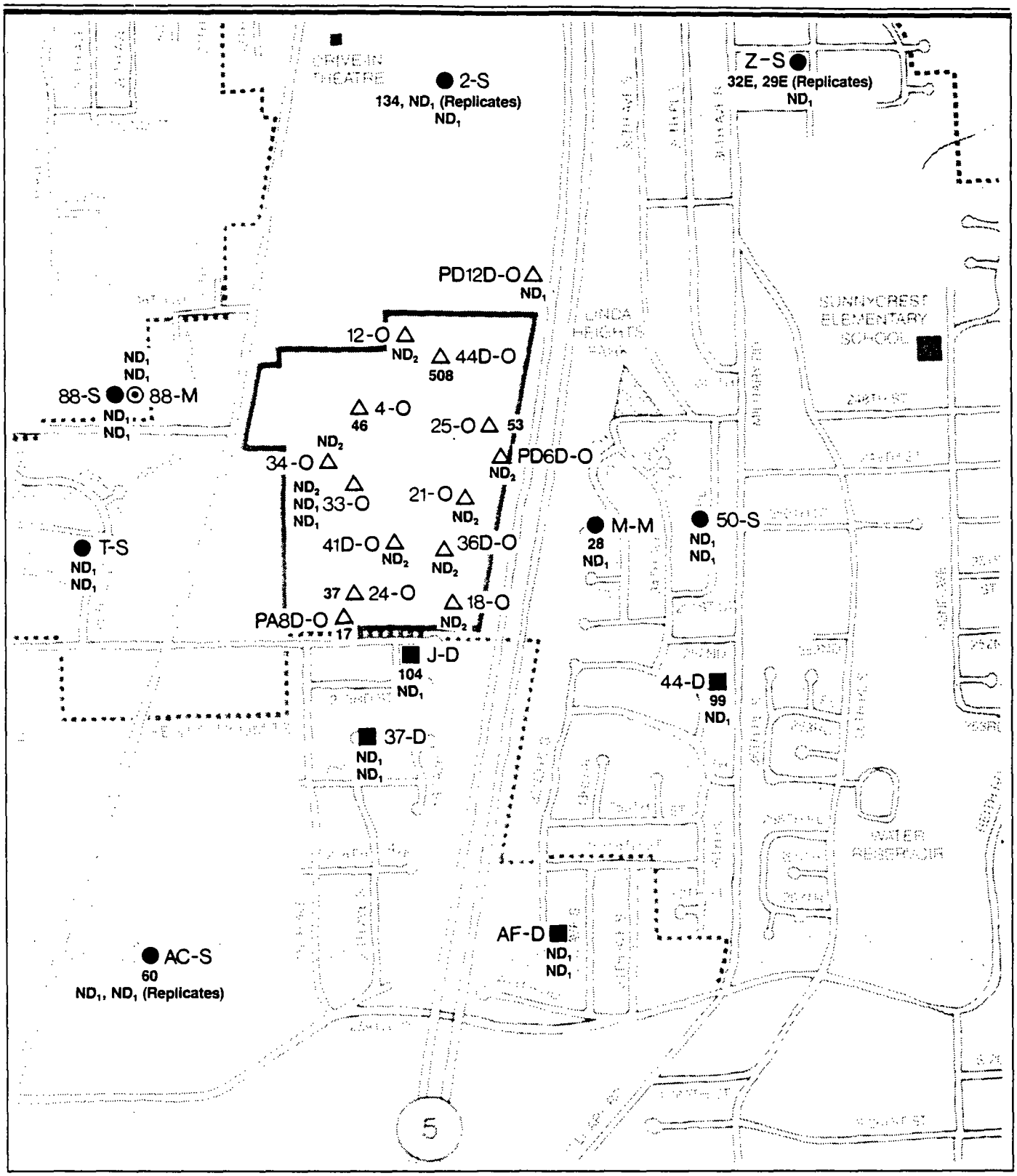
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Benzene



Notes: ND_1 = Below Detection Limit of 1.2 PPB

ND_2 = Below Detection Limit of 115 PPB

N

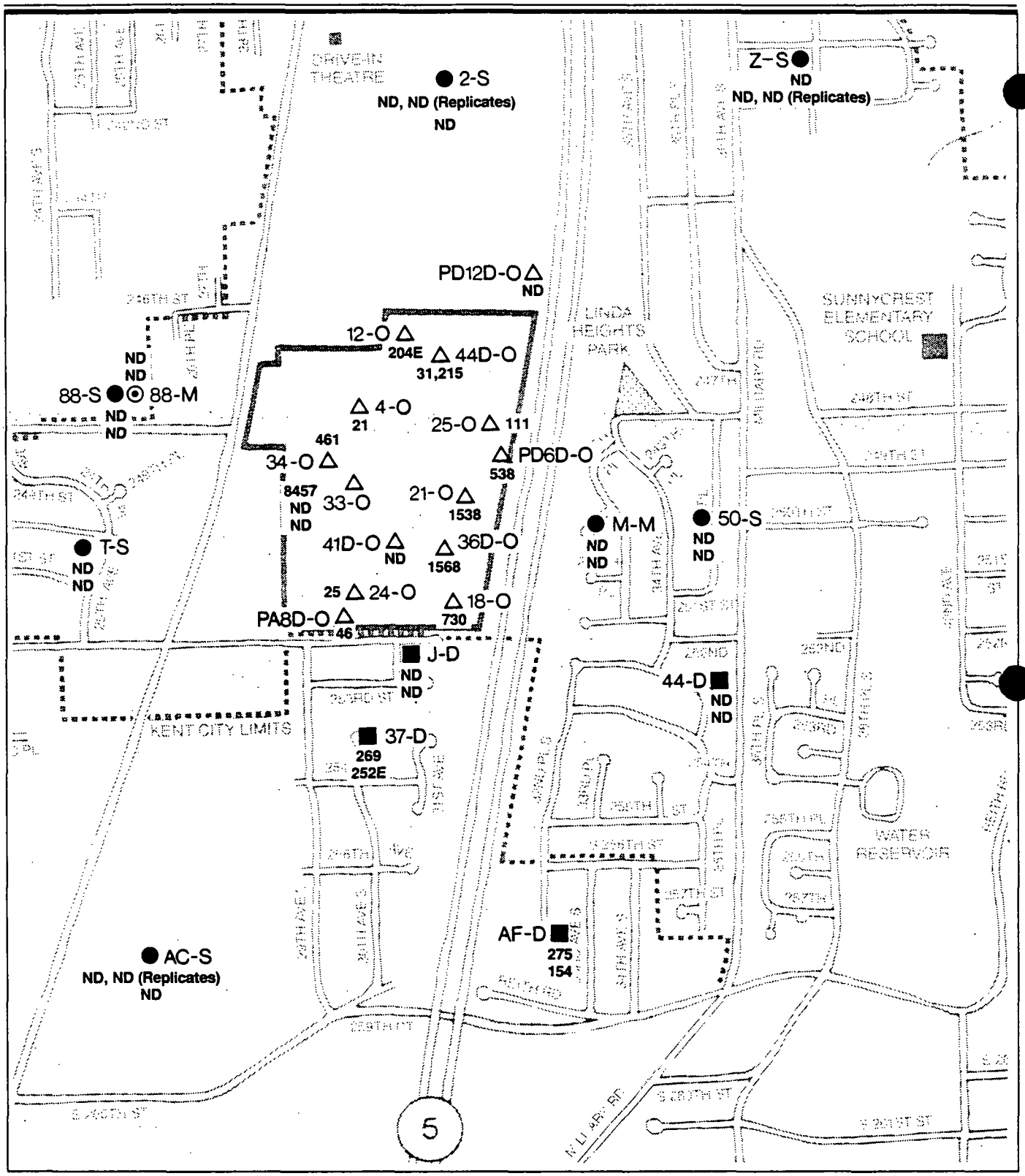
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Styrene



Notes: ND = Below Detection Limit of 3.8 PPB

E = Estimated Data Value

N

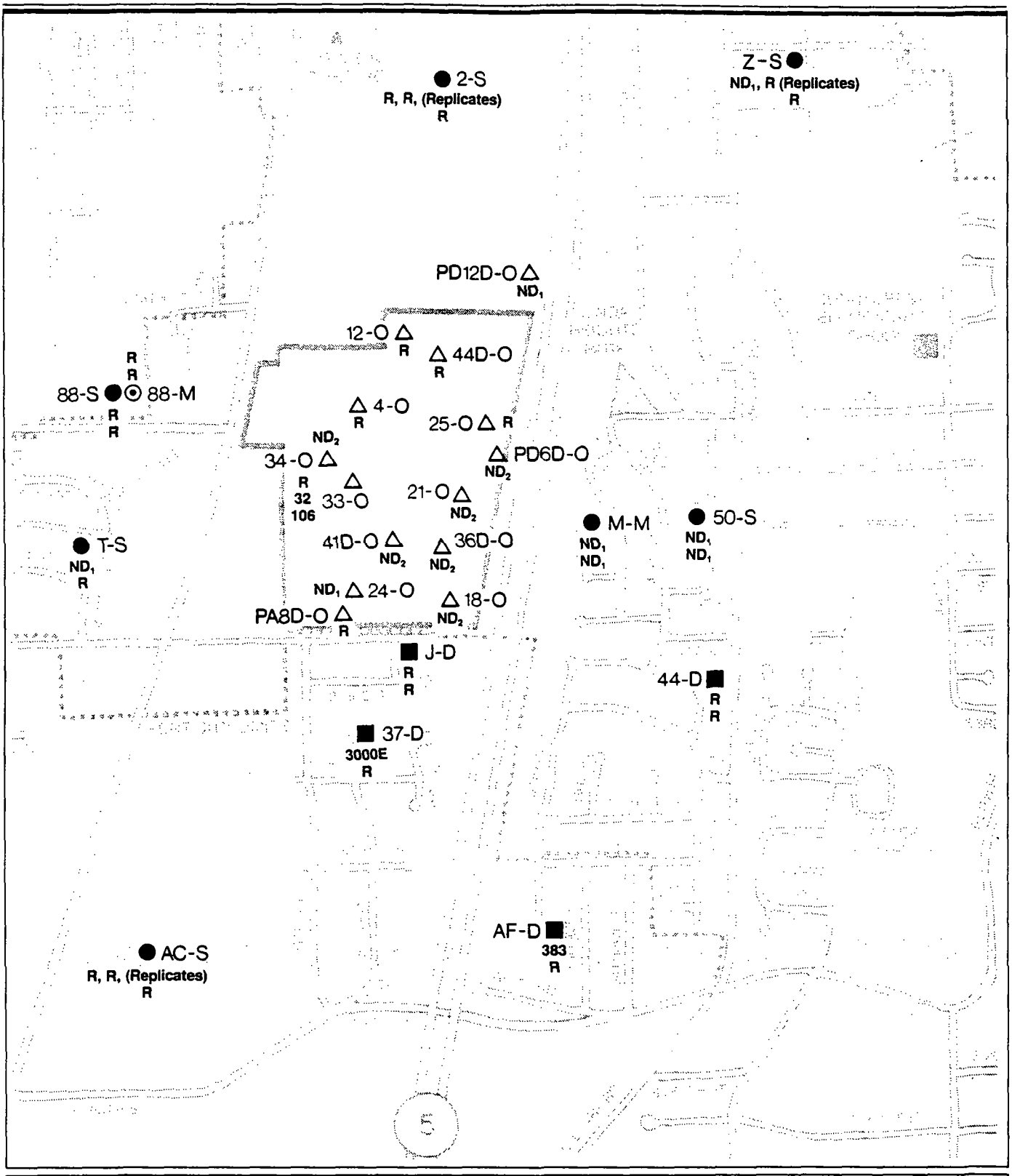
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Vinyl chloride



Notes: ND_1 = Below Detection Limit of 0.6 PPB
ND_2 = Below Detection Limit of 64 PPB
E = Estimated Data Value
R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

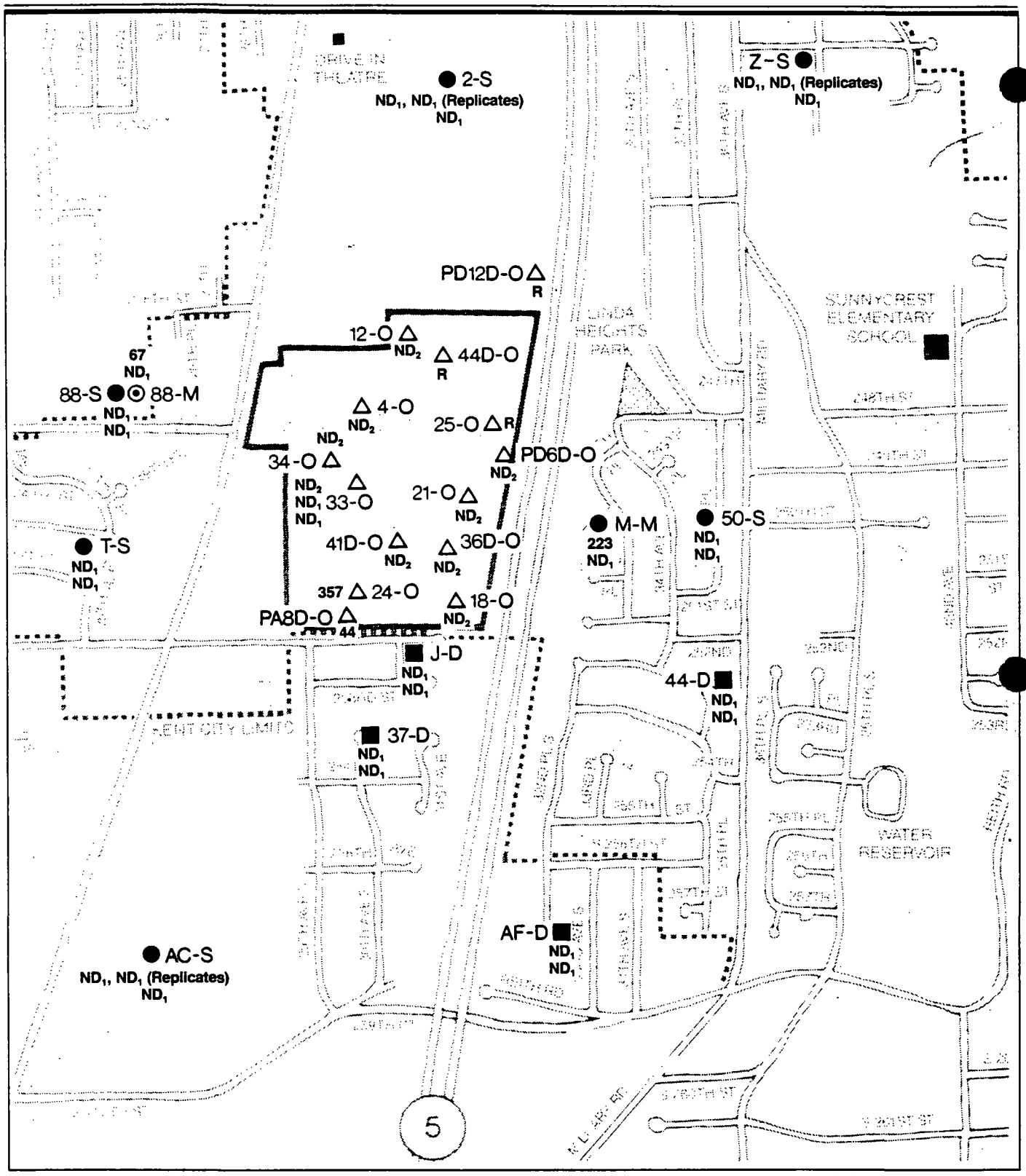
N

SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)
Trichlorotrifluoroethane



Notes: ND_1 = Below Detection Limit of 2.3 PPB

ND_2 = Below Detection Limit of 230 PPB

R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

N

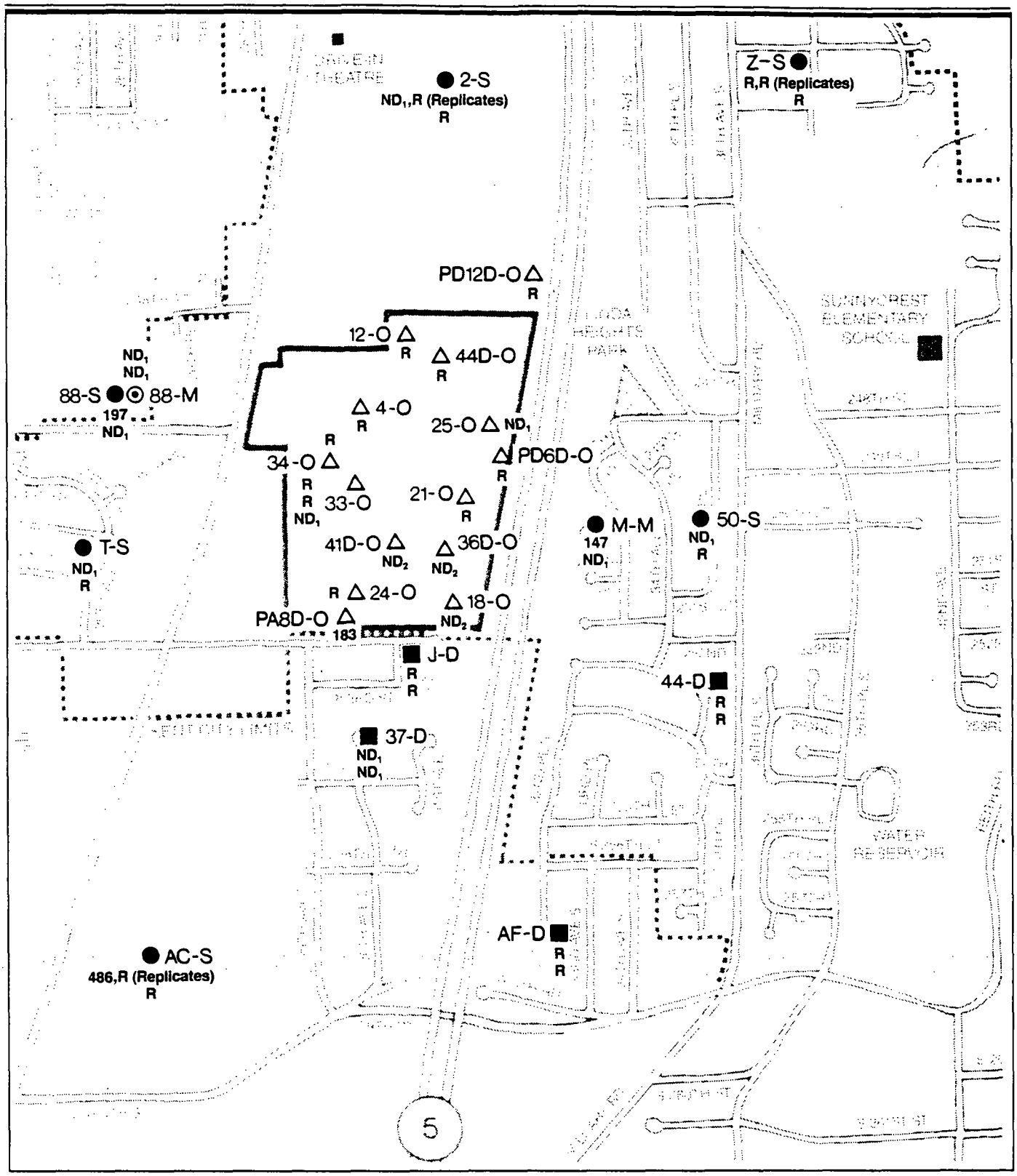
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Trichlorofluoromethane



Notes: ND_1 = Below Detection Limit of 3.3 PPB

ND_2 = Below Detection Limit of 333 PPB

R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

N

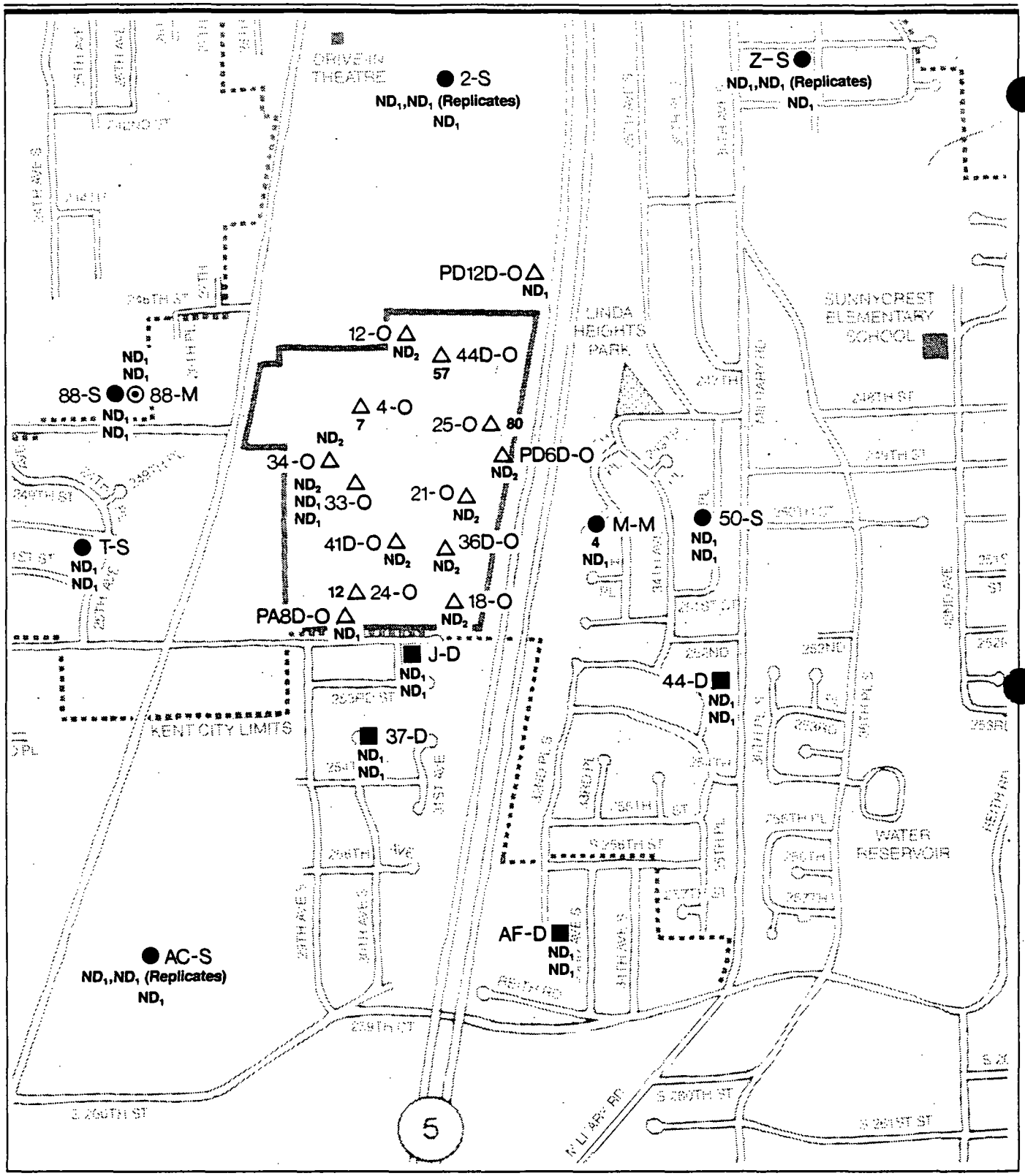
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

2-butanone



Notes: ND_1 = Below Detection Limit of 0.7 PPB

ND_2 = Below Detection Limit of 72 PPB

N

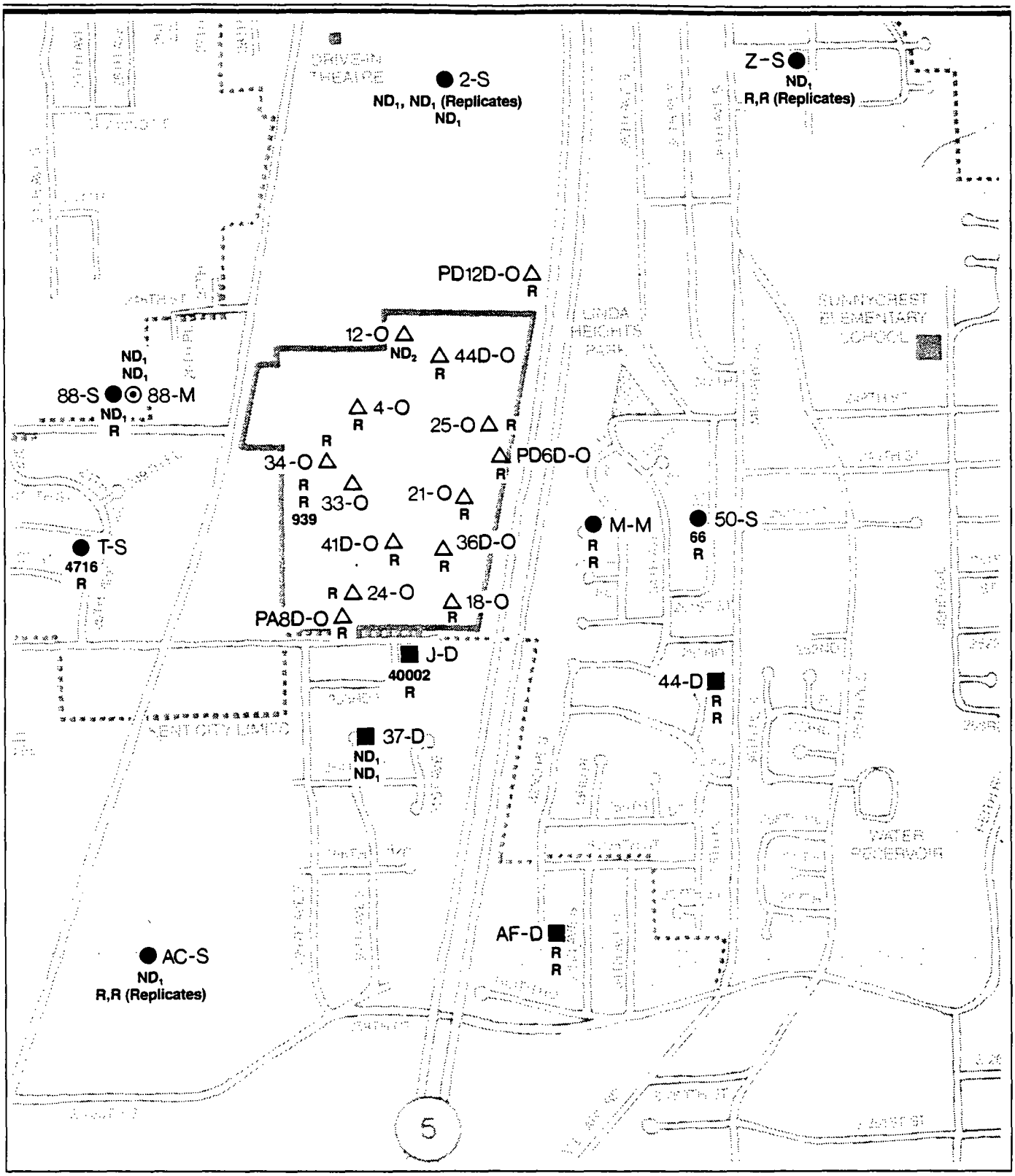
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Tetrachloroethene



Notes: ND_1 = Below Detection Limit of 4.1 PPB
ND_2 = Below Detection Limit of 414 PPB
R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

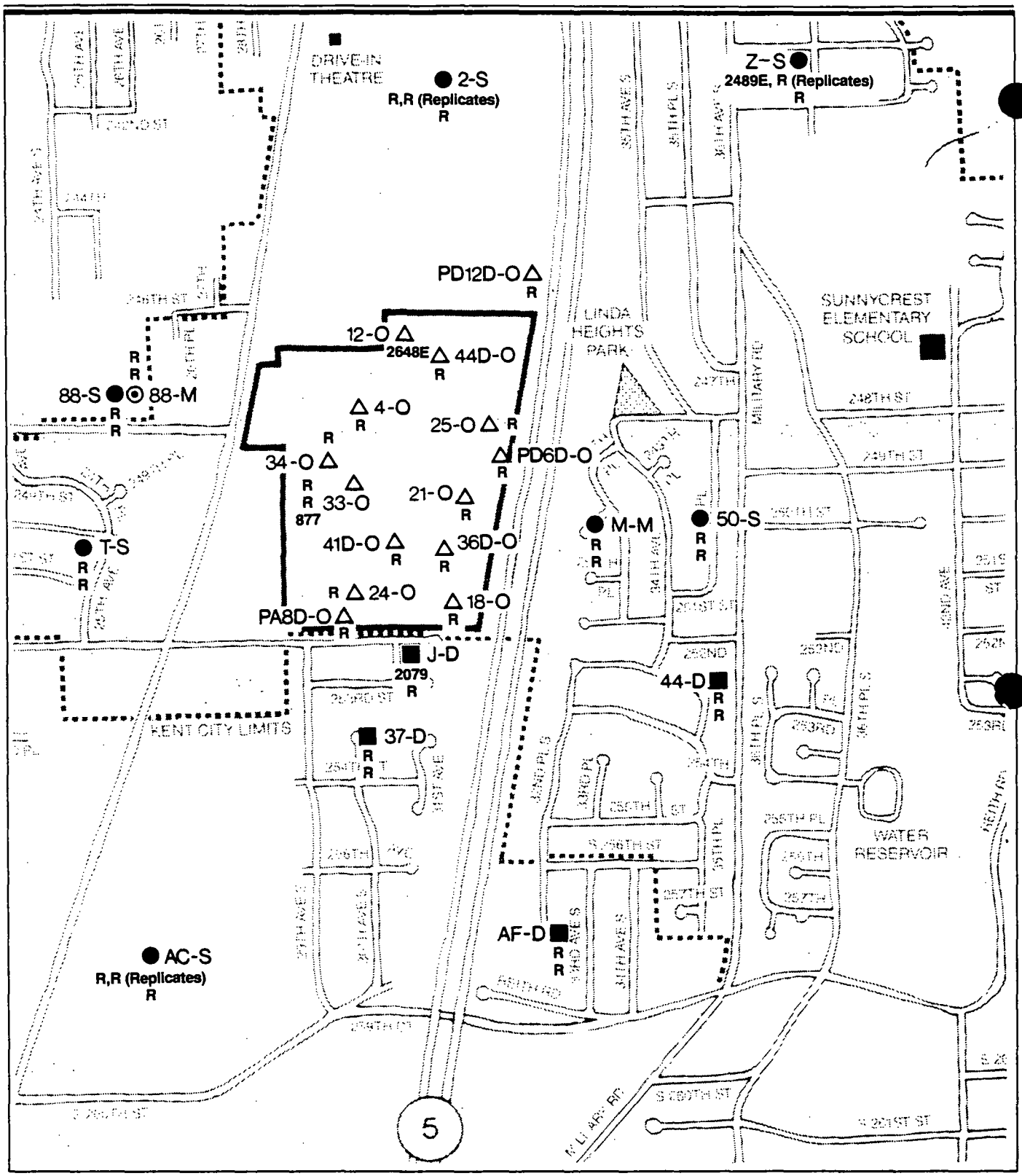
N

SCALE IN FEET
0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Acetone



Notes: E = Estimated Data Value

R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

N

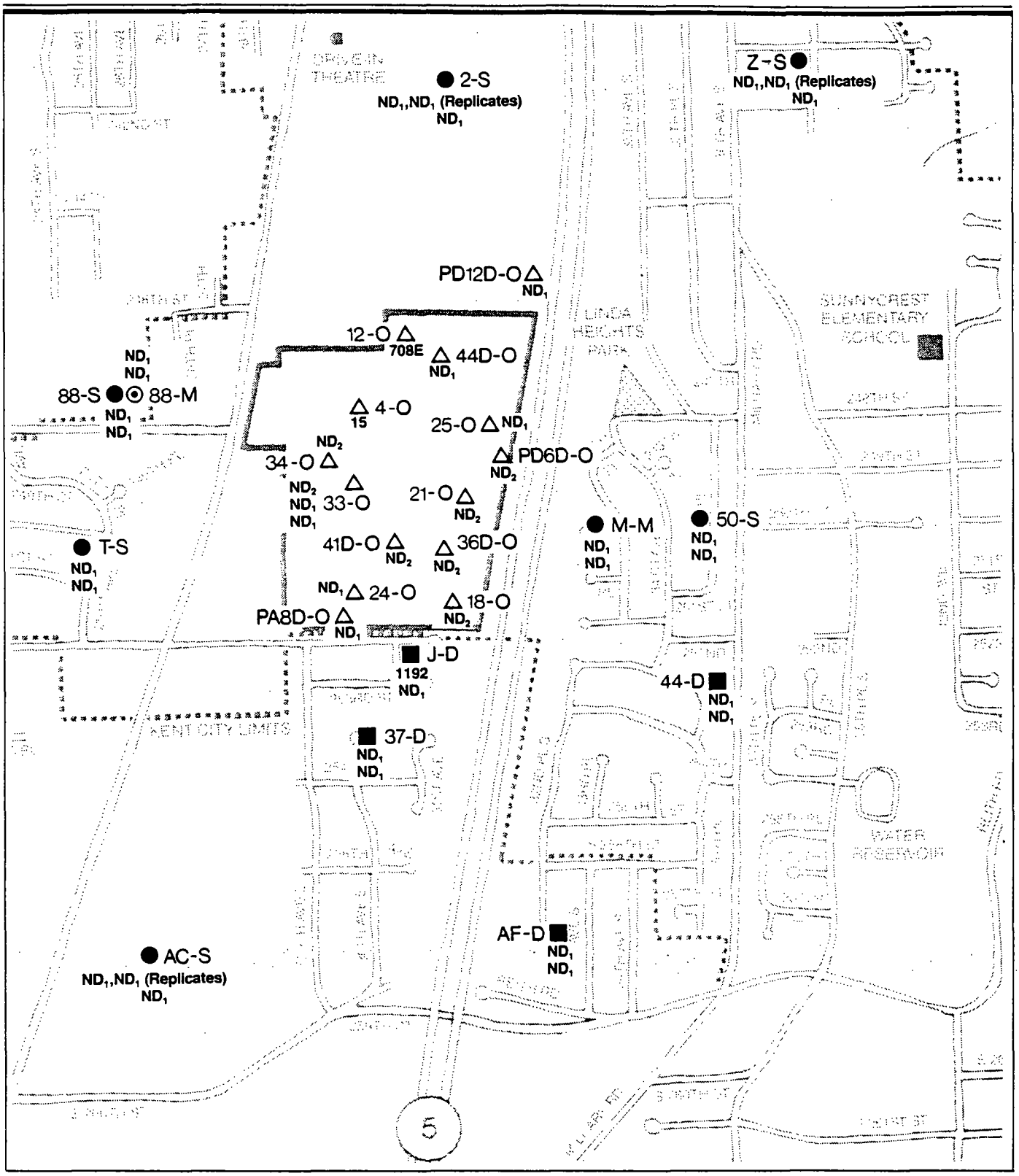
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells.

Distribution of Subsurface Gas Contaminants (ppb)

Methylene chloride



Notes: ND_1 = Below Detection Limit of 3.7 PPB

ND_2 = Below Detection Limit of 372 PPB

E = Estimated Data Value

N

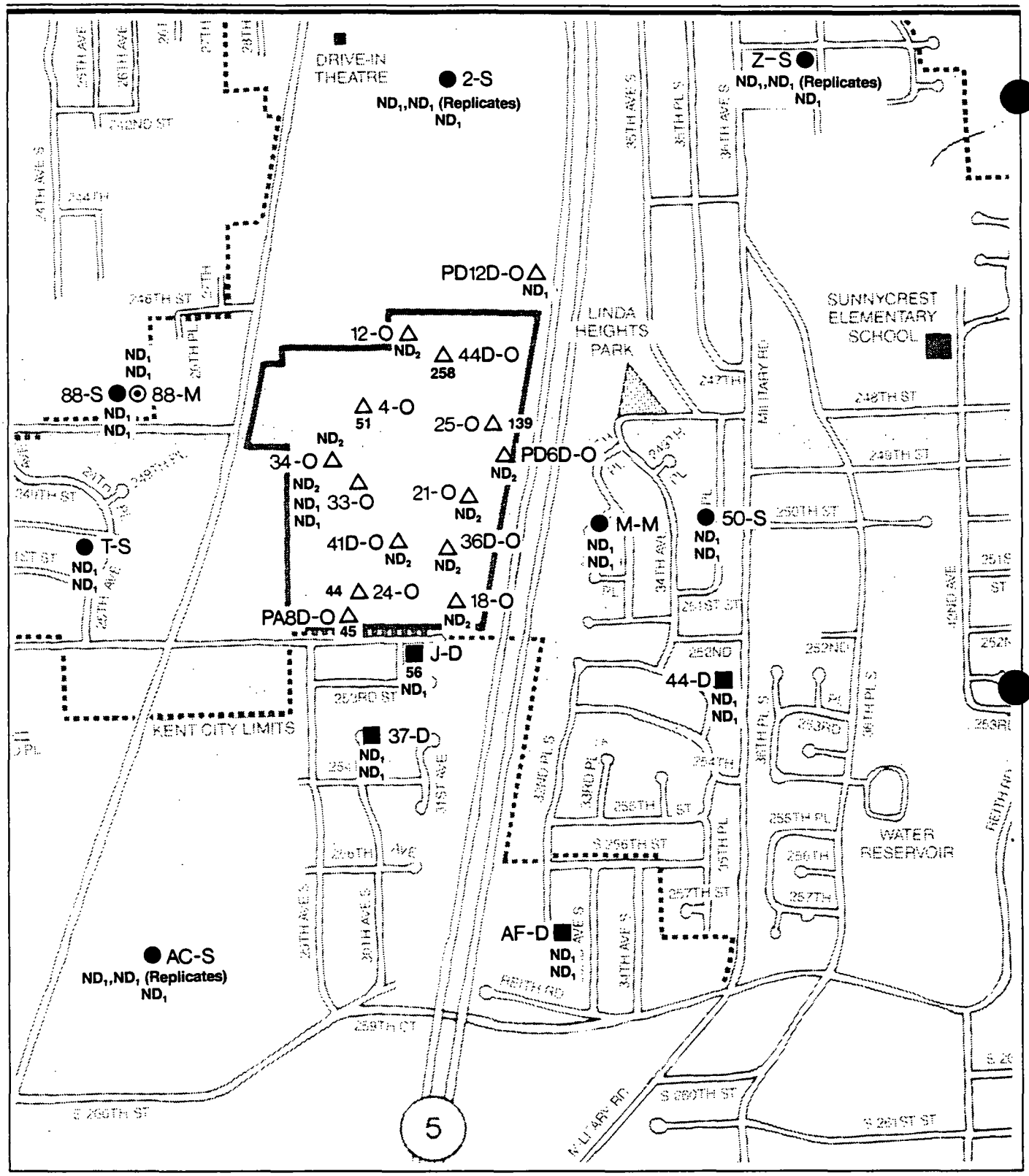
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

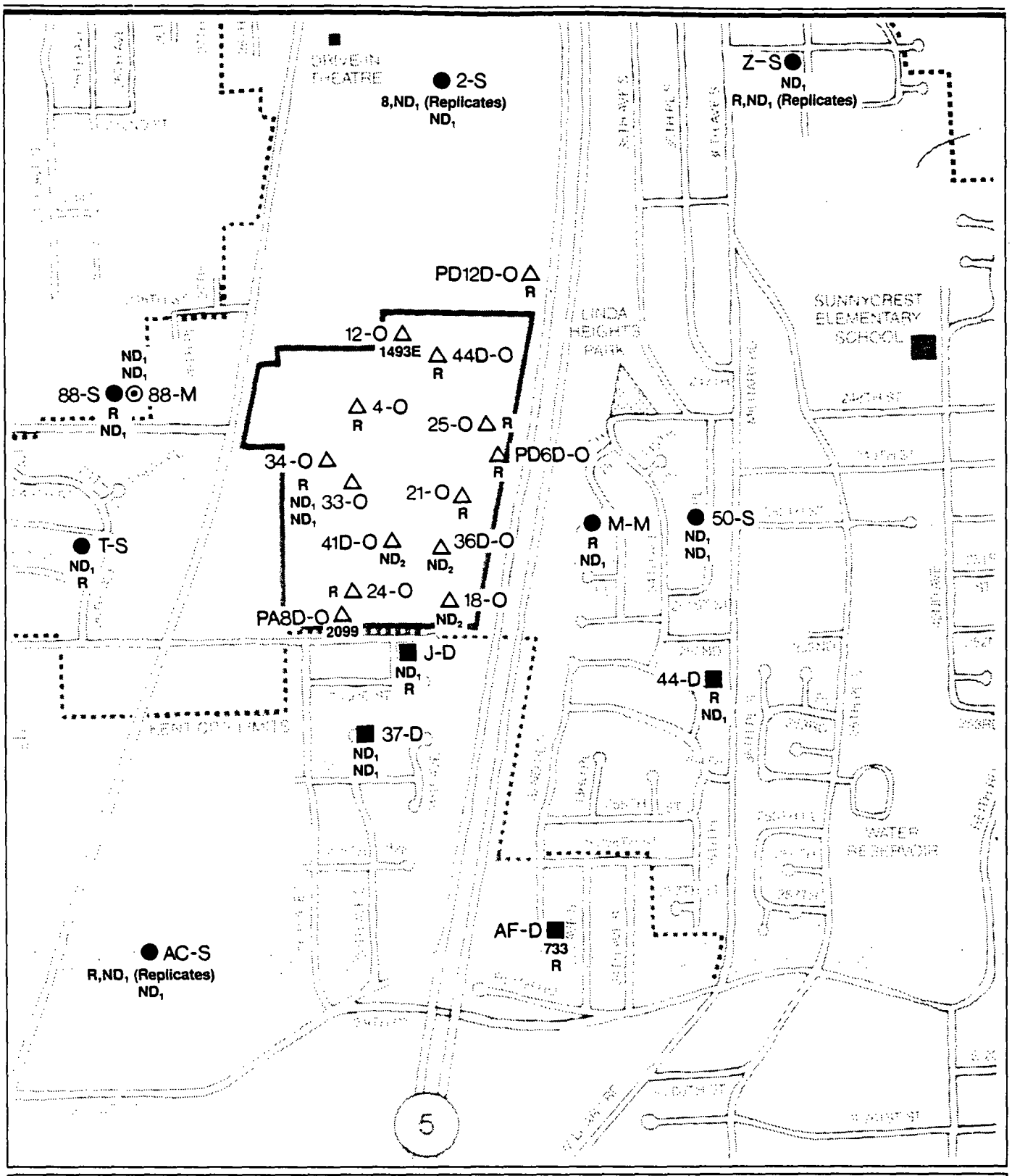
Distribution of Subsurface Gas Contaminants (ppb)

Chloroethane



Distribution of Subsurface Gas Contaminants (ppb)

Chlorobenzene



Notes: R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks
ND_1 = Below Detection Limit of 1.7 PPB
ND_2 = Below Detection Limit of 167 PPB
E = Estimated Data Value

N

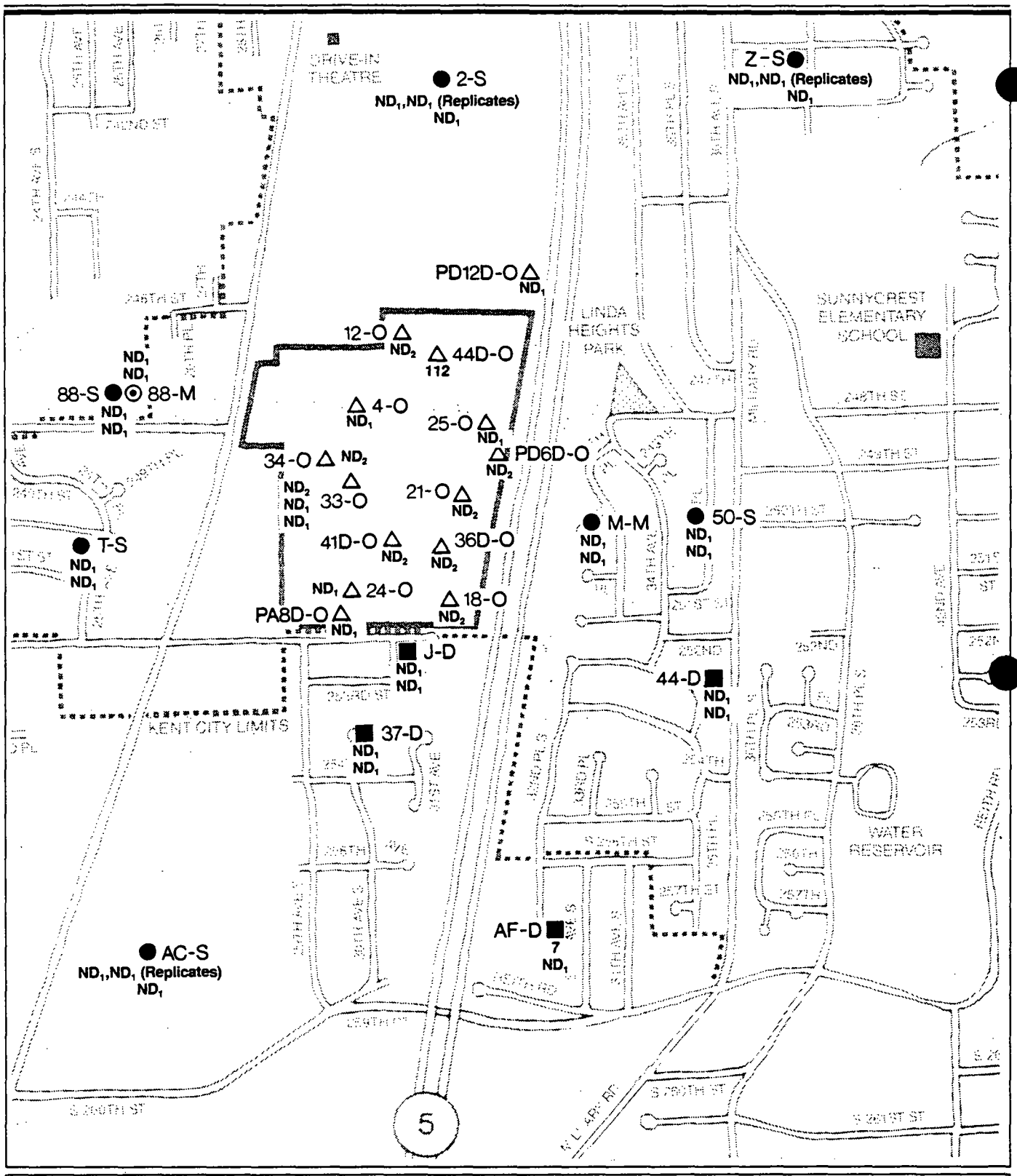
SCALE IN FEET

0 500 1,000

● Shallow Probes
⊙ Medium Probes
■ Deep Probes
△ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Tetrahydrofuran



Notes:

ND_1 = Below Limit of Detection of 1.2 PPB

ND_2 = Below Limit of Detection of 124 PPB

N

SCALE IN FEET

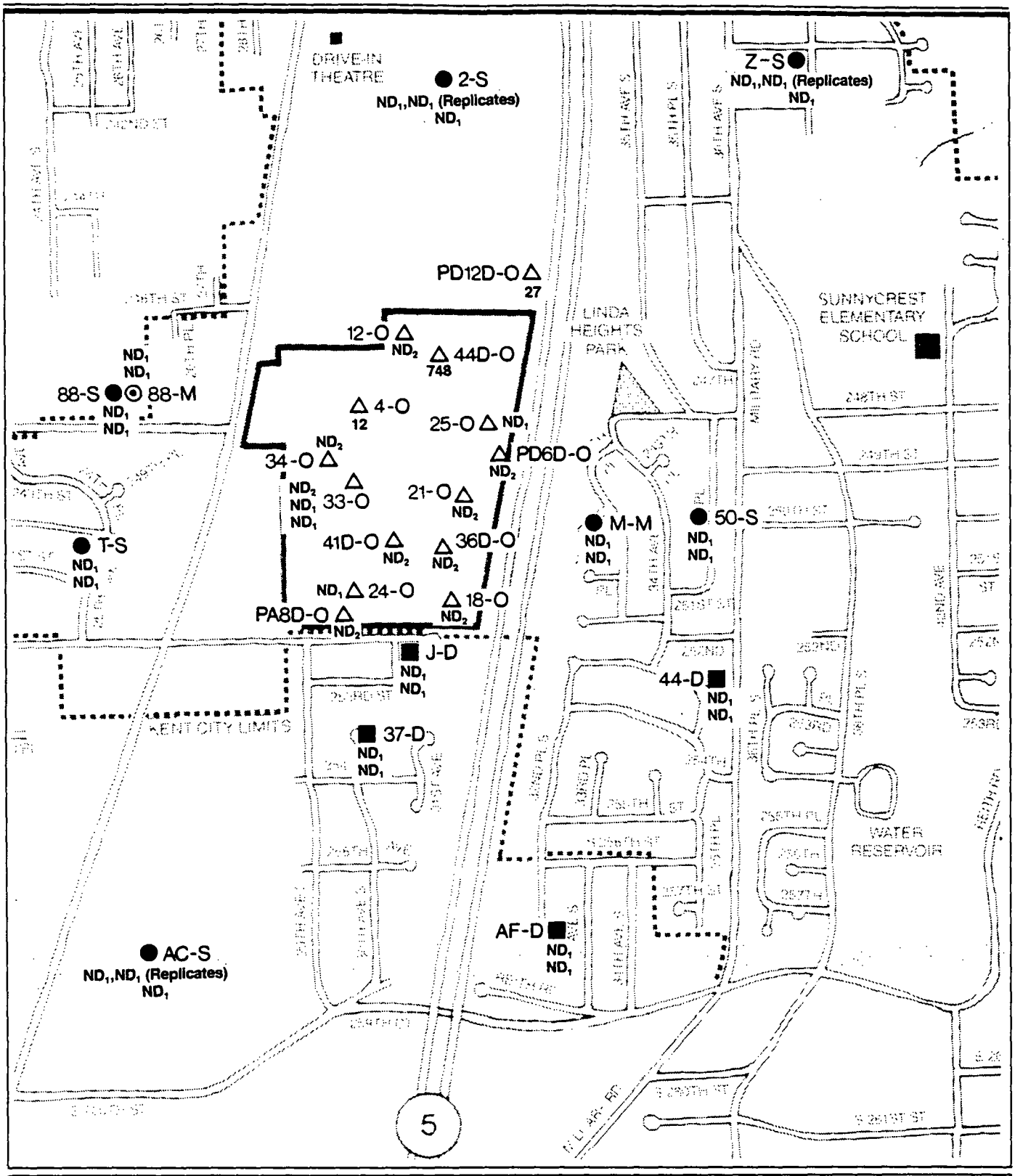
0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

1,1-dichloroethene

COMPOUNDS REPORTED ON-SITE ONLY



Notes:

ND_1 = Below Detection Limit of 1.2 PPB

ND_2 = Below Detection Limit of 121 PPB

N

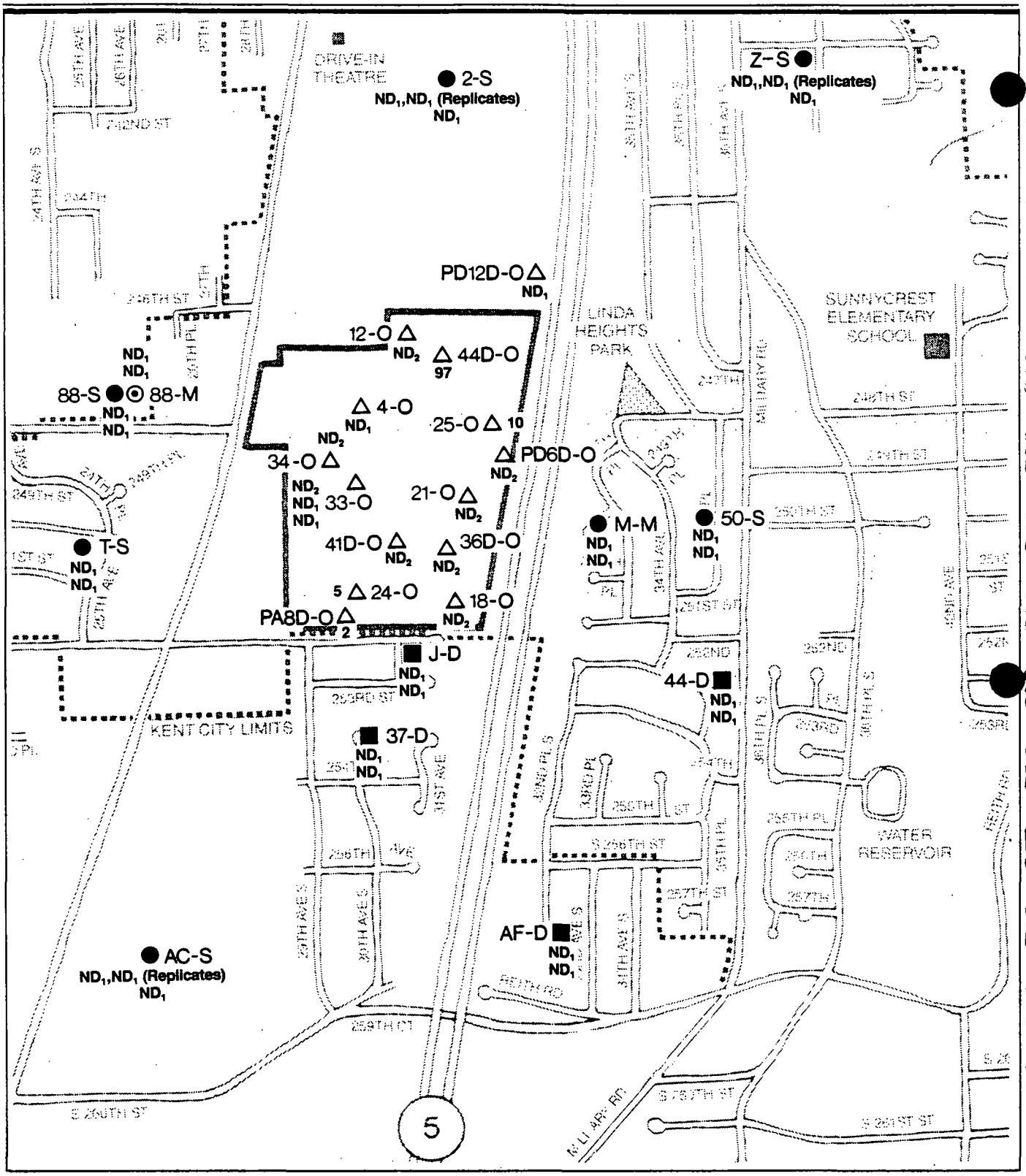
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

1,1-dichloroethane



Notes: ND_1 = Below Detection Limit of 0.9 PPB

ND_2 = Below Detection Limit of 91 PPB

N

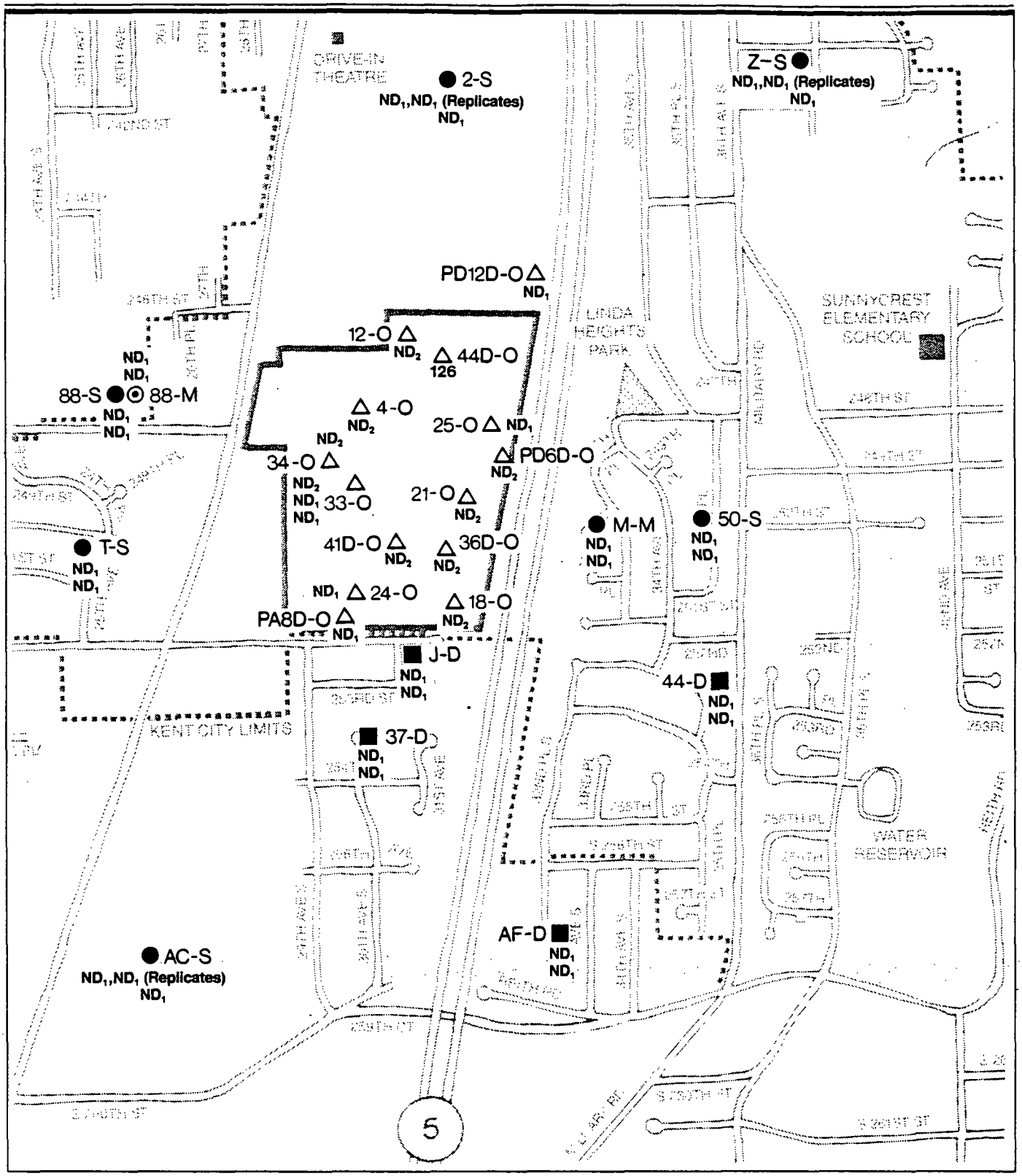
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Trichloroethene



Notes: ND_1 = Below Detection Limit of 1.2 PPB

ND_2 = Below Detection Limit of 121 PPB

N

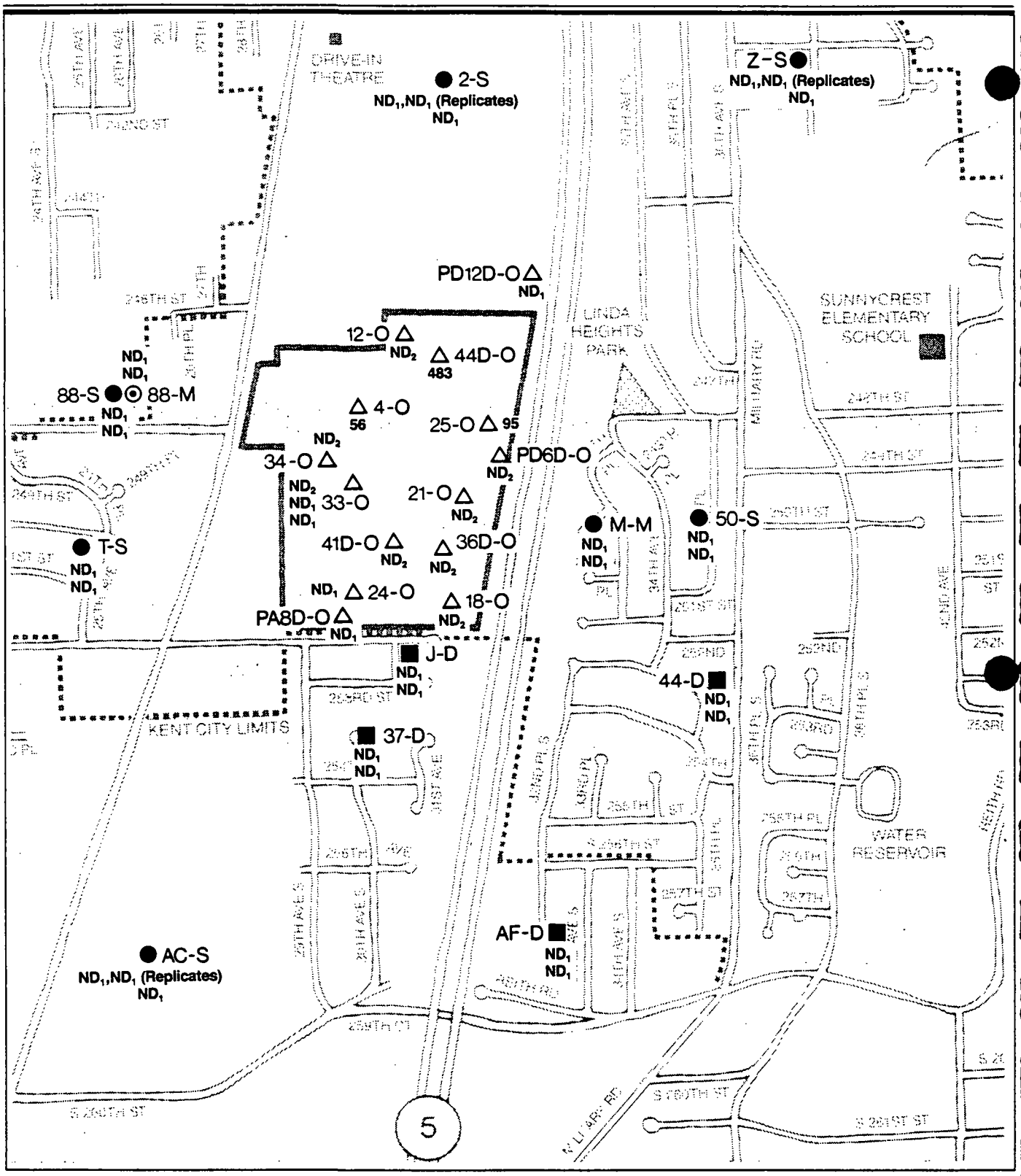
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

1,2-dichloroethane



Notes: ND_1 = Below Detection Limit of 2.8 PPB

ND_2 = Below Detection Limit of 279 PPB

N

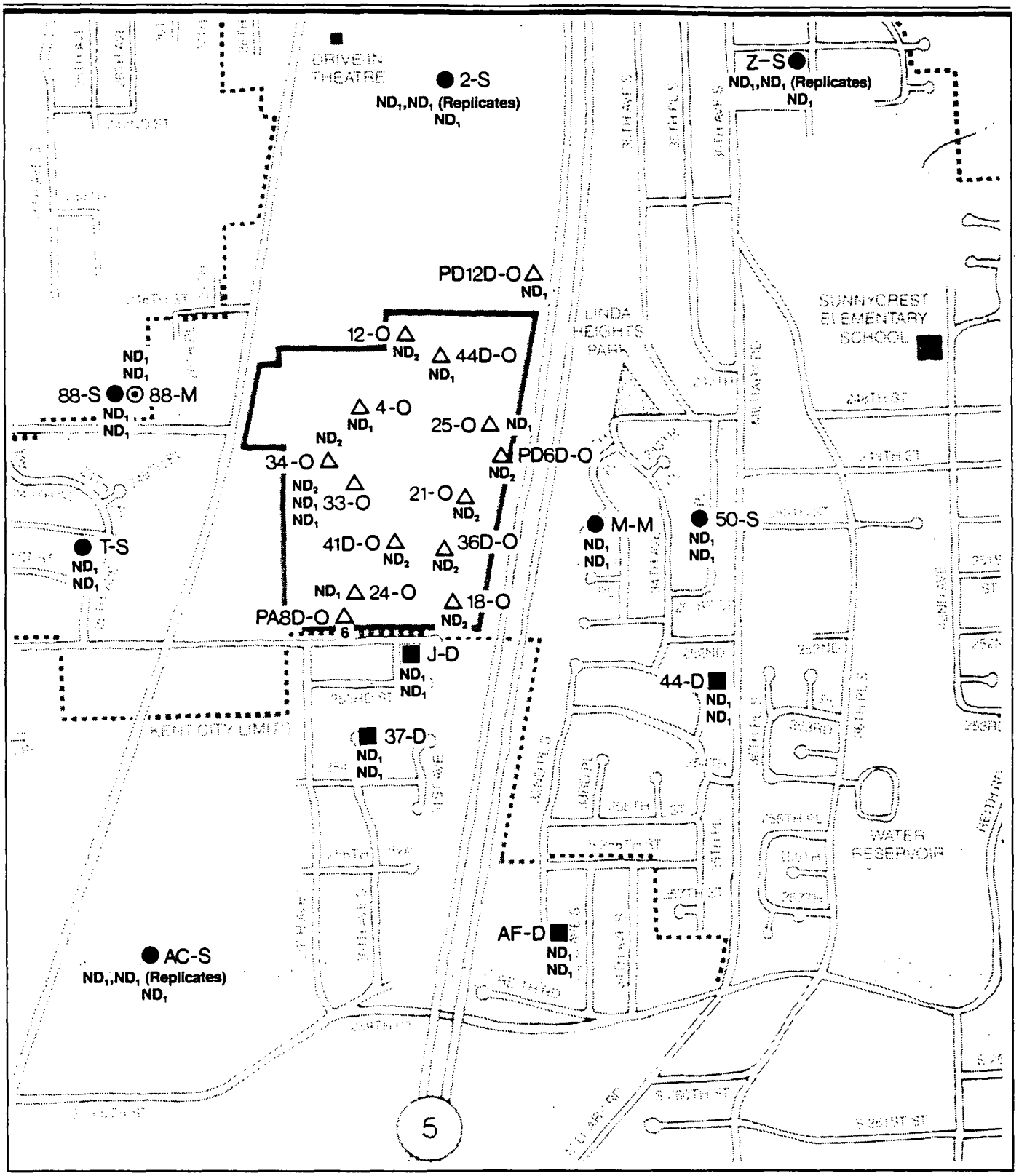
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

vinyl acetate



Notes: ND_1 = Below Detection Limit of 2.4 PPB

ND_2 = Below Detection Limit of 240 PPB

N

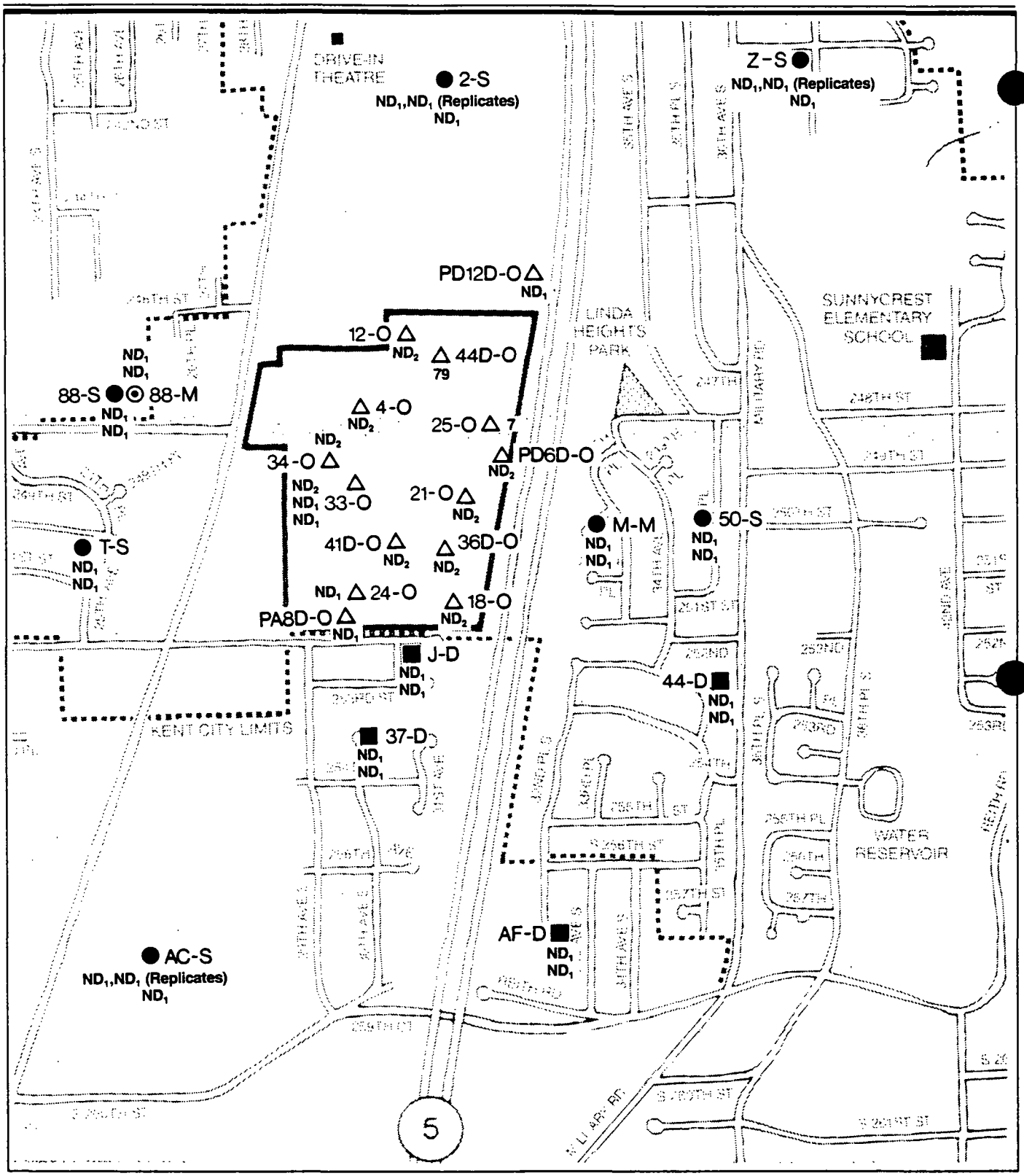
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

4-methyl-2-pentanone



Notes: ND_1 = Below Detection Limit of 1.2 PPB

ND_2 = Below Detection Limit of 124 PPB

N

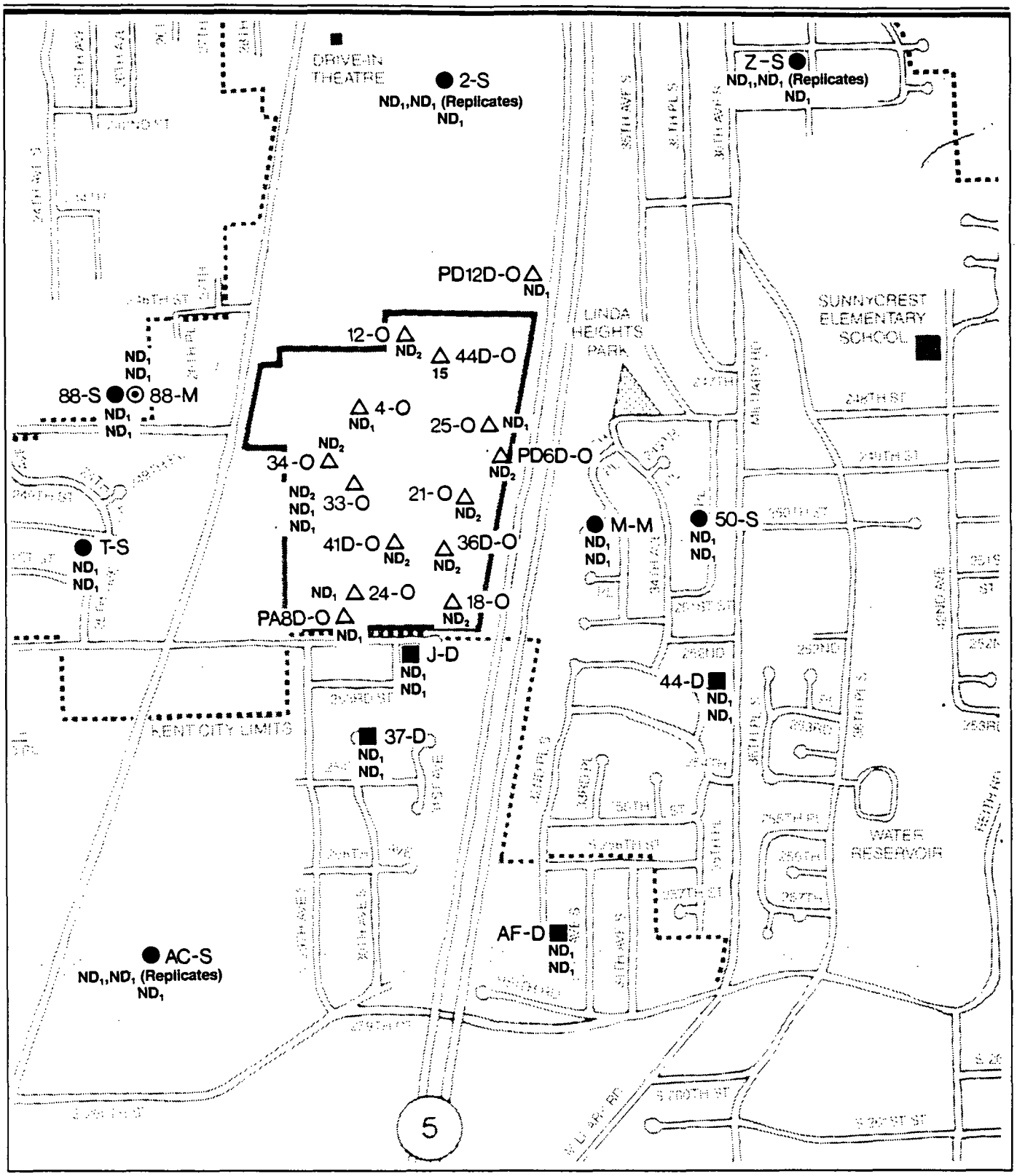
SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells.

Distribution of Subsurface Gas Contaminants (ppb)

trans-1,2-dichloroethene



Notes:

ND_1 = Below Detection Limit of 1.1 PPB

ND_2 = Below Detection Limit of 121 PPB

N

SCALE IN FEET

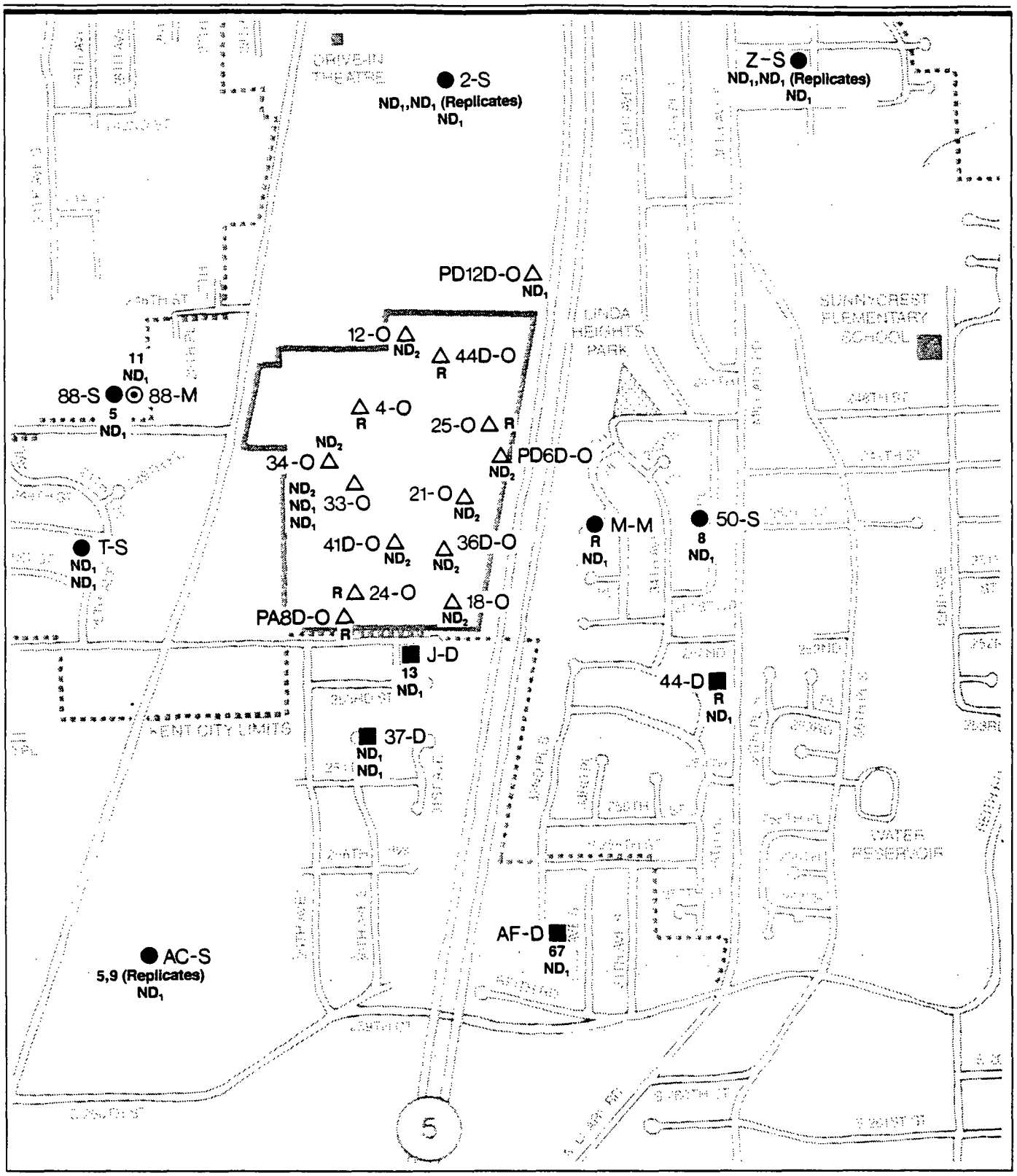
0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

cis-1,3-dichloropropene

COMPOUNDS REPORTED OFF-SITE ONLY



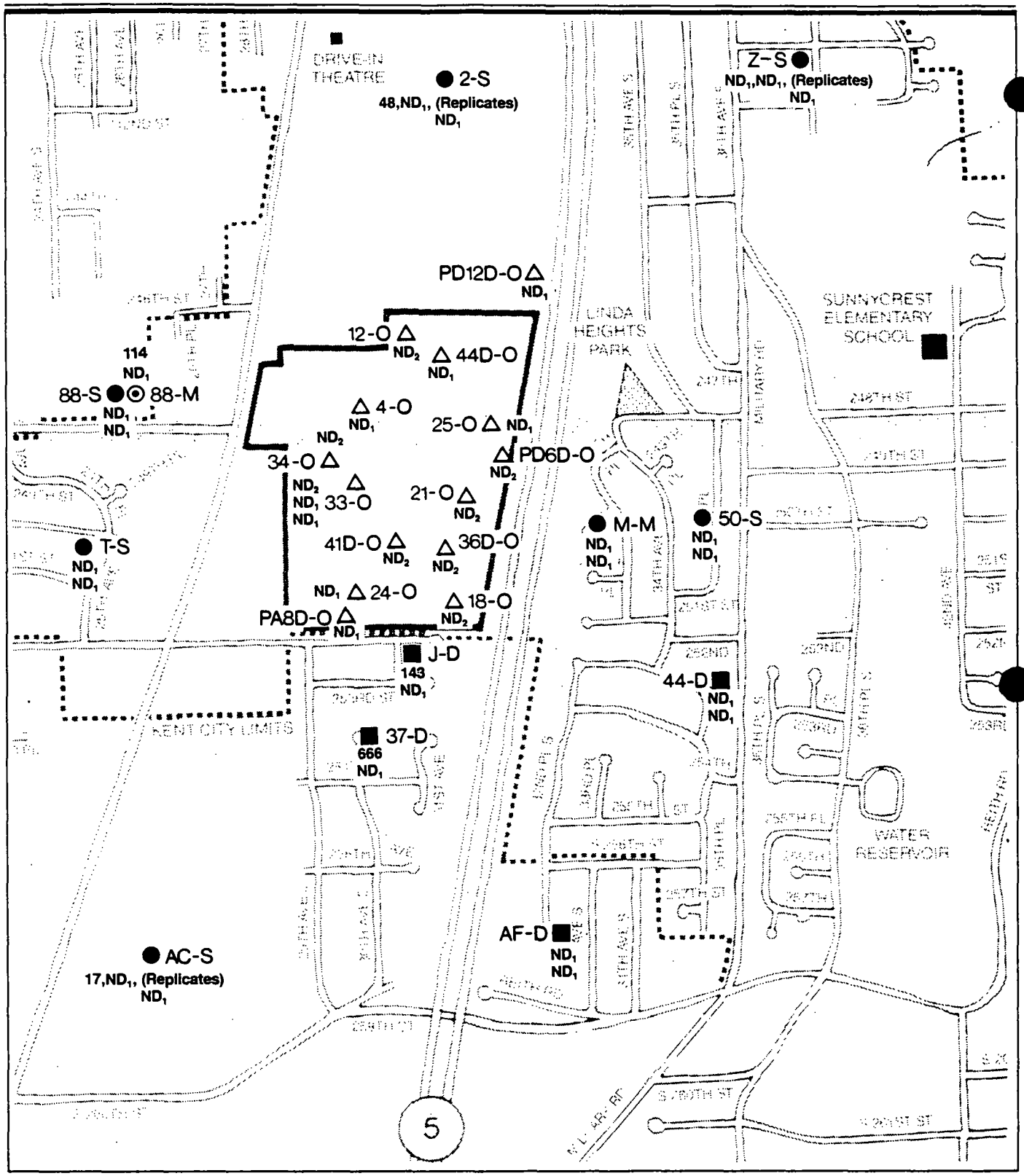
Notes: R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks
ND_1 = Below Detection Limit of 0.9 PPB
ND_2 = Below Detection Limit of 90 PPB

N

SCALE IN FEET
0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)
1,1,1-trichloroethane



Notes: ND_1 = Below Detection Limit of 4.8 PPB

ND_2 = Below Detection Limit of 476 PPB

N

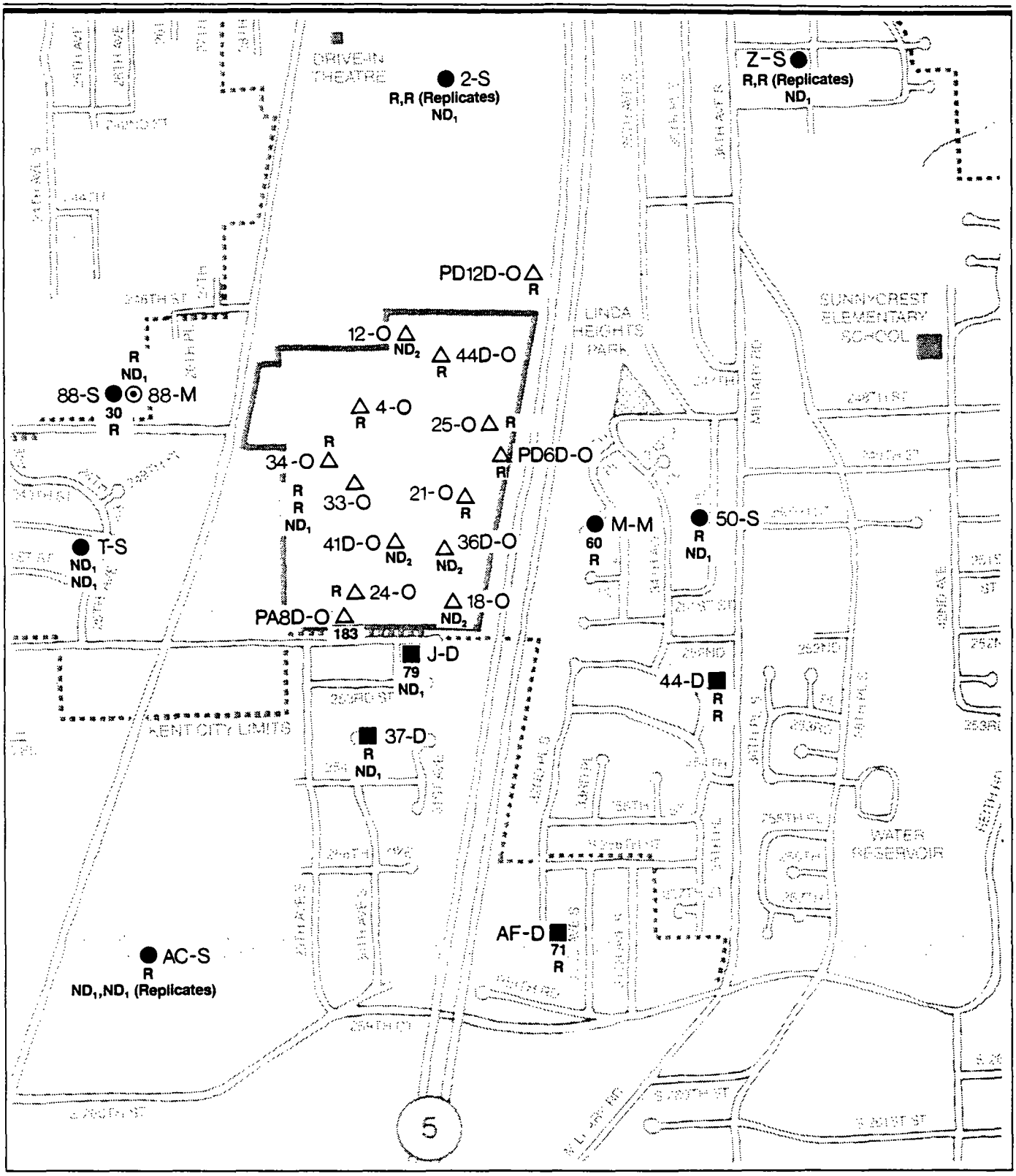
SCALE IN FEET

0 500 1,000

- Shallow Probes
- Medium Probes
- Deep Probes
- On-Site Control Wells.

Distribution of Subsurface Gas Contaminants (ppb)

Chloromethane



Notes: R = Not Reported Present Due to Insufficient Elevation Above Lab Blanks

ND_1 = Below Detection Limit of 1.6 PPB

ND_2 = Below Detection Limit of 158 PPB

N

SCALE IN FEET

0 500 1,000

- ● Shallow Probes
- ⊙ Medium Probes
- ■ Deep Probes
- △ On-Site Control Wells

Distribution of Subsurface Gas Contaminants (ppb)

Carbon disulfide

APPENDIX E-2

Summaries of Gas Characterization Data Collected by Black & Veatch for the Washington State Department of Ecology

RECEIVED DEC 1 1987

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
[redacted]

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	QA	REV	TYPE	SAMPLE	LAB	LAB I.D.	ANALYSIS	UNITS	SAMPLE VOLUME	ACROLEIN	ACRYLONITR	BENZENE	BROMODICHL	BROMOMETHA	BROMOFORM	CARBONTETR	CHLOROBENZ	CHLOROETHA	CHLOROETHZ
ML101	SWI-01	1	02/28/86	03/03/86			AIR	TEDLAR	[redacted]	06001	8240	ug/M3 (wt/v)		N/A	N/A	ND	100U	200U	100U	100U	38J	29J	200U
ML101-011	SWI-01	1	03/13/86	03/14/86			AIR	TEDLAR	ATI	07302-01	8240	ug/M3 (wt/v)		N/A	N/A	100J	125U	250U	125U	125U	30J	26J	250U
ML101-013	SWI-01	1	03/13/86	03/14/86			AIR	TEDLAR	ATI	07302-02	8240	ug/M3 (wt/v)		N/A	N/A	12J	50U	100U	50U	50U	32J	24J	100U
ML101-015	SWI-01	1	03/13/86	03/14/86			AIR	TEDLAR	ATI	07302-03	8240	ug/M3 (wt/v)		N/A	N/A	11J	83U	167U	83U	83U	30J	26J	167U
ML101-02	SWI-01	1	03/07/86	03/10/86			AIR	TEDLAR	ATI	06901-01	8240	ug/M3 (wt/v)		N/A	N/A	15J	100U	200U	100U	100U	13J	11J	200U
ML102-01	SWI-02	1	03/07/86	03/10/86			AIR	TEDLAR	ATI	06901-02	8240	ug/M3 (wt/v)		N/A	N/A	ND	100U	200U	100U	100U	100U	16J	200U
ML102-011	SWI-02	1	03/13/86	03/14/86			AIR	TEDLAR	ATI	07302-04	8240	ug/M3 (wt/v)		N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
ML102-012	SWO-02	1	03/13/86	03/14/86			AIR	TEDLAR	ATI	07302-05	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	90J	100U
ML103-01	SWI-02	1	03/07/86	03/10/86			AIR	TEDLAR	ATI	06901-03	8240	ug/M3 (wt/v)		N/A	N/A	ND	125U	250U	125U	125U	125U	18J	250U
ML104	SWI-01	1	02/28/86	03/03/86			AIR	TEDLAR	ATI	06001	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	74J	51J	100U
ML105	TBLANK	1	02/28/86	03/03/86			AIR	TEDLAR	ATI	06001	8240	ug/M3 (wt/v)		N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
ML105-02	TBLANK	1	03/07/86	03/10/86			AIR	TEDLAR	ATI	06901-05	8240	ug/M3 (wt/v)		N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
ML106-01	CWI-03	1	03/07/86	03/10/86			AIR	TEDLAR	ATI	06901-04	8240	ug/M3 (wt/v)		N/A	N/A	ND	125U	250U	125U	125U	125U	91J	250U
ML200-01	TBLANK	1	03/13/86	03/14/86			AIR	TEDLAR	ATI	07302-06	8240	ug/M3 (wt/v)		N/A	N/A	ND	83U	167U	83U	83U	83U	167U	167U
ML401-01	EWO-01	1	03/21/86	03/24/86			AIR	TEDLAR	ATI	08304-01	8240	ug/M3 (wt/v)		N/A	N/A	12J	50U	100U	50U	50U	50U	28J	100U
ML401-02	EWO-01	1	03/21/86	03/24/86			AIR	TEDLAR	ATI	08304-02	8240	ug/M3 (wt/v)		N/A	N/A	15J	50U	100U	50U	50U	50U	34J	100U
ML401-03	EWI-01	1	03/21/86	03/24/87			AIR	TEDLAR	ATI	08304-03	8240	ug/M3 (wt/v)		N/A	N/A	10J	50U	100U	50U	50U	51U	21J	100U
ML401-04	EWI-02	1	03/21/86	03/24/86			AIR	TEDLAR	ATI	08304-04	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	6J	100U
ML401-05	EWO-02	1	03/21/86	03/24/86			AIR	TEDLAR	ATI	08304	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	83J	100U
ML501-01	EWI-01	1	04/17/86	04/18/86			AIR	TEDLAR	ATI	10802-01	8240	ug/M3 (wt/v)		N/A	N/A	16J	125U	250U	125U	125U	125U	25J	250U
ML501-02	EWO-01	1	04/17/86	04/22/86			AIR	TEDLAR	ATI	10802-02	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	65J	100U
ML501-03	EWO-01	1	04/17/86	04/21/86			AIR	TEDLAR	ATI	10802-03	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	28J	100U
ML501-04	EWI-02	1	04/17/86	04/21/86			AIR	TEDLAR	ATI	10802-04	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	4J	100U
ML501-05	EWO-02	1	04/17/86	05/02/86			AIR	TEDLAR	ATI	10802-05	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
ML501-06	CWI-03	1	04/17/86	04/21/86			AIR	TEDLAR	ATI	10802-06	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
ML501-07	CWI-02	1	04/17/86	04/22/86			AIR	TEDLAR	ATI	10802-07	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
ML601-01	EWO-01	1	04/23/86	04/25/86			AIR	TEDLAR	ATI	11405-01	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	30J	100U
ML601-02	EWO-02	1	04/23/86	04/25/86			AIR	TEDLAR	ATI	1140502	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
ML601-03	CWI-03	1	04/23/86	04/25/86			AIR	TEDLAR	ATI	11405-03	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
ML601-04	CWI-02	1	04/23/86	04/24/86			AIR	TEDLAR	ATI	11405-04	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
ML601-05	CWI-05	1	04/23/86	04/28/86			AIR	TEDLAR	ATI	1140505	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
ML701-01	FLARE(N)	1	05/01/86	05/07/86			AIR	TEDLAR	ATI	12206001	8240	ug/M3 (wt/v)		N/A	N/A	220J	150U	300U	150U	N/D	180J	30J	300U
ML701-02	FLARE(S)	1	05/01/86	05/07/86			AIR	TEDLAR	ATI	12206002	8240	ug/M3 (wt/v)		N/A	N/A	175J	150U	300U	150U	150U	170J	30J	300U
ML701-03	FLARE(S)	1	05/01/86	05/07/86			AIR	TEDLAR	ATI	12206003	8240	ug/M3 (wt/v)		N/A	N/A	230J	150U	300U	150U	150U	260J	30J	300U
ML701-04	CWI-04	1	05/01/86	05/07/86			AIR	TEDLAR	ATI	12206004	8240	ug/M3 (wt/v)		N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
ML701-05	CWI-01	1	05/01/86	05/07/86			AIR	TEDLAR	ATI	12206005	8240	ug/M3 (wt/v)		N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
ML87M-001	GP-87M	1	08/26/86	09/17/86			AIR	TEDLAR	ATI	23307009	8240	ug/M3 (wt/v)		N/A	N/A	ND	25U	50U	25U	25U	25U	50U	50U
MLAA-001	CWAA-10	1	09/22/86	10/10/86			AIR	TEMAT	ATI	26606002	8240	ug/M3 (wt/v)		N/A	N/A	1J	1U	3U	1U	1U	1U	3U	3U
MLAA-002	CWAA-10	1	10/15/86	10/20/86			AIR	TEMAT	ATI	28910001	8240	ug/M3 (wt/v)		N/A	N/A	1J	.14U	1.4U	.7U	.14U	.3	.14U	1.4U
MLAA-003	CWAA-10	1	10/22/86	11/07/86			AIR	TEMAT	ATI	29603011	8240	ug/M3 (wt/v)		N/A	N/A	12J	1.10U	2.20U	1.10U	1.10U	1.10U	2.20U	2.20U
MLCWV-501	CWI-05	1	06/05/86	06/11/86			AIR	TEDLAR	ATI	15703-05	8240	ug/M3 (wt/v)		N/A	N/A	TR	50U	100U	50U	50U	50U	100U	100U
MLCW-01-05	CWO-01	1	11/11/86	12/02/86			AIR	TEDLAR	ATI	31713005	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-01-06	CWI-01	1	01/13/87	01/26/87			AIR	TEDLAR	ATI	01509005	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-01-07	CWO-01	1	04/29/87	05/06/87	MO		AIR	TEDLAR	ATI	70500421	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	50U	100U
MLCW-01-08	CWI-01		06/02/87	06/05/87	MO		AIR	TEDLAR	ATI	9804-13	8240	ug/M3 (wt/v)				48B	5U	10U	5U	5U	5U	10U	10U
MLCW-02-05	CWO-02	1	11/06/86	11/17/86			AIR	TEDLAR	ATI	31502009	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U

Data submitted to Ecology by Black & Veatch
September 14, 1987
File name : VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 1 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	QA REV	TYPE	SAMPLE	LAB	LAB I.D.	ANALYSIS	UNITS	SAMPLE VOLUME	ACROLEIN	ACRYLONITR	BENZENE	BROMODICHL	BROMOMETHA	BROMOFORM	CARBONTETR	CHLOROBENZ	CHLOROETHA	CHLOROETHZ
MLCW-02-06	CWI-02	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509012	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-02-07	CWO-02	1	04/27/87	05/07/87	NO	AIR	TEDLAR	ATI	70500416	8240	ug/M3 (wt/v)		N/A	N/A	140	50U	100U	50U	50U	100	210	100U
MLCW-02-08	CWI-02		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-7	8240	ug/M3 (wt/v)				32.0B	5U	10U	5U	5U	5U	10U	10U
MLCW-03-05	CWO-03	1	11/06/86	11/18/86		AIR	TEDLAR	ATI	31502003	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-03-06	CWI-03	1	01/13/87	01/27/87		AIR	TEDLAR	ATI	01509014	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-03-07	CWO-03	1	04/27/87	05/06/87	NO	AIR	TEDLAR	ATI	70500403	8240	ug/M3 (wt/v)		N/A	N/A	20J	50U	100U	50U	50U	50U	50U	100U
MLCW-03-08	CWI-03		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-6	8240	ug/M3 (wt/v)				100B	5U	10U	5U	5U	5U	10U	10U
MLCW-03-08-LDUP	CWI-03		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-5	8240	ug/M3 (wt/v)				96.0B	5U	10U	5U	5U	18.0	10U	10U
MLCW-04-04	CWO-04	1	11/11/86	12/02/86		AIR	TEDLAR	ATI	31713006	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-04-05	CWI-04	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509004	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-04-06	CWO-04	1	04/27/87	05/08/87	NO	AIR	TEDLAR	ATI	70500401	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	50U	100U
MLCW-04-07	CWI-04		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-12	8240	ug/M3 (wt/v)				25B	5U	10U	5U	5U	13.0	10	10U
MLCW-05-06	CWO-05	1	11/06/86	11/17/86		AIR	TEDLAR	ATI	31502011	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-05-07	CWI-05	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509007	8240	ug/M3 (wt/v)		N/A	N/A	ND	70U	140U	70U	70U	70U	140U	140U
MLCW-05-08	CWO-05	1	04/28/87	05/08/87	NO	AIR	TEDLAR	ATI	70500402	8240	ug/M3 (wt/v)		N/A	N/A	10J	50U	100U	50U	50U	50U	50U	100U
MLCW-05-08,LDUP	CWO-05	1	04/28/87	05/11/87	NO	AIR	TEDLAR	ATI	70500402	8240	ug/M3 (wt/v)		N/A	N/A	30J	50U	100U	50U	50U	50U	50U	100U
MLCW-05-09	CWI-05		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-1	8240	ug/M3 (wt/v)				84B	5U	29.5	5U	5U	5U	10U	10U
MLCW-05-09-LDUP	CWI-05		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-3	8240	ug/M3 (wt/v)				153B	5U	61.0	5U	8.0B	14.0	10U	10U
MLCW-06-08	CWO-06	1	11/11/86	12/02/86		AIR	TEDLAR	ATI	31713007	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	90J	100U
MLCW-06-09	CWI-06	1	01/13/87	01/27/87		AIR	TEDLAR	ATI	01509018	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	60U	60	100U
MLCW-06-10	CWO-06	1	04/29/87	05/08/87	NO	AIR	TEDLAR	ATI	70500407	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	50U	100U
MLCW-07-08	CWO-07	1	11/06/86	11/17/86		AIR	TEDLAR	ATI	31502007	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-07-09	CWI-07	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509010	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-07-10	CWO-07	1	04/27/87	05/01/87	NO	AIR	TEDLAR	ATI	70500419	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	50U	100U
MLCW-07-11	CWI-07		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-4	8240	ug/M3 (wt/v)				98.0B	10.0	86.0	5U	22.0B	5U	10U	10U
MLCW-08-08	CWO-08	1	11/11/86	12/02/86		AIR	TEDLAR	ATI	31713008	8240	ug/M3 (wt/v)		N/A	N/A	20J	50U	100U	50U	50U	50U	100U	100U
MLCW-08-09	CWI-08	1	01/13/87	01/27/87		AIR	TEDLAR	ATI	01509019	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-08-10	CWO-08	1	04/27/87	05/08/87	NO	AIR	TEDLAR	ATI	70500406	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	50U	100U
MLCW-08-11	CWI-08		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-2	8240	ug/M3 (wt/v)				61.0B	5U	10U	5U	5U	5U	10U	10U
MLCW-09-07	CWO-09	1	11/11/86	12/03/86		AIR	TEDLAR	ATI	31713009	8240	ug/M3 (wt/v)		N/A	N/A	20J	50U	100U	50U	50U	50U	100U	100U
MLCW-09-08	CWI-09	1	01/13/87	01/27/87		AIR	TEDLAR	ATI	01509013	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-09-09	CWO-09	1	04/28/87	05/08/87	NO	AIR	TEDLAR	ATI	70500410	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	50U	100U
MLCW-09-10	CWI-09		06/03/87	06/11/87	NO	AIR	TEDLAR	ATI	9804-10	8240	ug/M3 (wt/v)				240B	5U	10U	5U	5U	5U	10U	10U
MLCW-1002	CWO-01	1	08/26/86	09/17/86		AIR	TEDLAR	ATI	23907006	8240	ug/M3 (wt/v)		N/A	N/A	10J	25U	50U	25U	25U	25U	210	50U
MLCW-1003	CWO-01	1	09/30/86	10/16/86		AIR	TEDLAR	ATI	27614005	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	60U	120	100U
MLCW-1004	CWO-01	1	10/22/86	10/29/86		AIR	TEDLAR	ATI	29603006	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100	100U
MLCW-101	CWI-10	1	06/05/86	06/06/86		AIR	TEDLAR	ATI	15703-01	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-102	CWO-10	1	07/25/86	08/06/86		AIR	TEDLAR	ATI	20903005	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-103	CWI-10	1	07/25/86	08/05/86		AIR	TEDLAR	ATI	20903006	8240	ug/M3 (wt/v)		N/A	N/A	125U	125U	250U	125U	125U	125U	250U	250U
MLCW-104	CWO-10	1	08/26/86	09/16/86		AIR	TEDLAR	ATI	23907004	8240	ug/M3 (wt/v)		N/A	N/A	ND	25U	50U	25U	25U	25U	50U	50U
MLCW-105	CWO-10	1	09/15/86	10/02/86		AIR	TEDLAR	ATI	26006006	8240	ug/M3 (wt/v)		N/A	N/A	10J	50U	100U	50U	50U	30J	100U	100U
MLCW-106	CWO-10	1	10/15/86	10/23/86		AIR	TEDLAR	ATI	28911004	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-10-07	CWO-10	1	11/06/86	11/17/86		AIR	TEDLAR	ATI	31502010	8240	ug/M3 (wt/v)		N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-10-08	CWI-10	1	01/13/87	01/27/87		AIR	TEDLAR	ATI	01509015	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-10-09	CWO-10	1	04/27/87	05/08/87	NO	AIR	TEDLAR	ATI	70500404	8240	ug/M3 (wt/v)		N/A	N/A	ND	50U	100U	50U	50U	50U	50U	100U
MLCW-10-10	CWI-10		06/03/87	06/08/87	NO	AIR	TEDLAR	ATI	9804-19	8240	ug/M3 (wt/v)				32B	5U	10U	5U	5U	25.0	10U	10U

Data submitted to Ecology by Black & Veatch
September 1[illegible]
File name = [illegible]

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 1 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	QA	REV	TYPE	SAMPLE	LAB	LAB I.D.	ANALYSIS	UNITS	SAMPLE VOLUME	ACROLEIN	ACRYLONITR	BENZENE	BROMODICHL	BROMOMETHA	BROMOFORM	CARBONTETR	CHLOROBENZ	CHLOROETHA	CHLOROETHZ
MLCW-111	CWI-11	1	06/05/86	06/11/86			AIR	TEDLAR	ATI	15703-04	8240	ug/M3 (wt/v)	N/A	N/A	59	50U	100U	50U	50U	90	130	100U
MLCW-112	CWO-11	1	07/25/86	08/05/86			AIR	TEDLAR	ATI	20903012	8240	ug/M3 (wt/v)	N/A	N/A	ND	N/D50U	100U	50U	50U	50U	100U	100U
MLCW-113	CWI-11	1	07/25/86	08/05/86			AIR	TEDLAR	ATI	20903013	8240	ug/M3 (wt/v)	N/A	N/A	ND	125U	250U	125U	125U	TR	250U	250U
MLCW-114	CWO-11	1	08/26/86	09/15/86			AIR	TEDLAR	ATI	23907008	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-115	CWO-11	1	09/15/86	10/02/86			AIR	TEDLAR	ATI	26006008	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	820	100U
MLCW-116	CWO-11	1	10/15/86	10/23/86			AIR	TEDLAR	ATI	28911003	8240	ug/M3 (wt/v)	N/A	N/A	170	85U	170U	85U	85U	85U	260	170U
MLCW-11-07	CWO-11	1	11/06/86	11/17/86			AIR	TEDLAR	ATI	31502008	8240	ug/M3 (wt/v)	N/A	N/A	30J	50U	100U	50U	50U	130	370	100U
MLCW-121	CWI-12	1	06/05/86	06/11/86			AIR	TEDLAR	ATI	15703-03	8240	ug/M3 (wt/v)	N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
MLCW-122	CWO-12	1	07/25/86	08/05/86			AIR	TEDLAR	ATI	20903010	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-123	CWI-12	1	07/25/86	08/05/86			AIR	TEDLAR	ATI	20903011	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-124	CWO-12	1	09/05/86	09/23/86			AIR	TEDLAR	ATI	25106010	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-125	CWO-12	1	09/30/86	10/17/86			AIR	TEDLAR	ATI	27614007	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-126	CWO-12	1	10/22/86	10/30/86			AIR	TEDLAR	ATI	29603002	8240	ug/M3 (wt/v)	N/A	N/A	85U	85U	170U	85U	85U	85U	170U	170U
MLCW-12-07	CWO-12	1	11/11/86	12/03/86			AIR	TEDLAR	ATI	31713010	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-12-08	CWI-12	1	01/13/87	01/23/87			AIR	TEDLAR	ATI	01509001	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-12-09	CWO-12	4	04/27/87	05/08/87	NO		AIR	TEDLAR	ATI	70500405	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	20J	50U	100U
MLCW-12-10	CWI-12		06/02/87	06/05/87	NO		AIR	TEDLAR	ATI	9804-5	8240	ug/M3 (wt/v)			31B	5U	10U	5U	5U	5U	20U	20U
MLCW-131	CWO-13	1	10/15/86	10/23/86			AIR	TEDLAR	ATI	28911005	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-13-02	CWO-13	1	11/08/86	11/17/86			AIR	TEDLAR	ATI	31502006	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-13-03	CWI-13	1	01/13/87	01/23/87			AIR	TEDLAR	ATI	01509002	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-13-04	CWO-13	1	04/27/87	05/08/87	NO		AIR	TEDLAR	ATI	70500418	8240	ug/M3 (wt/v)	N/A	N/A	ND	125U	250U	125U	125U	125U	125U	250U
MLCW-13-05	CWI-13		06/03/87	06/10/87	NO		AIR	TEDLAR	ATI	9804-17	8240	ug/M3 (wt/v)			210B	5U	10U	5U	5U	43.0	10U	10U
MLCW-141	CWO-14	1	10/15/86	10/23/86			AIR	TEDLAR	ATI	28911006	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-14-02	CWO-14	1	11/06/86	12/03/86			AIR	TEDLAR	ATI	31713011	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-14-03	CWI-14	1	01/13/87	01/27/87			AIR	TEDLAR	ATI	01509016	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-151	CWO-15	1	10/15/86	10/23/86			AIR	TEDLAR	ATI	28911007	8240	ug/M3 (wt/v)	N/A	N/A	20J	50U	100U	50U	50U	50U	100U	100U
MLCW-15-02	CWO-15	1	11/06/86	11/26/86			AIR	TEDLAR	ATI	31502001	8240	ug/M3 (wt/v)	N/A	N/A	10J	50U	100U	50U	50U	50U	100U	100U
MLCW-15-03	CWI-15	1	01/13/87	01/23/87			AIR	TEDLAR	ATI	01509003	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-202	CWO-02	1	09/05/86	09/24/86			AIR	TEDLAR	ATI	25106005	8240	ug/M3 (wt/v)	N/A	N/A	62.5U	62.5U	125U	62.5U	62.5U	62.5U	125U	125U
MLCW-203	CWO-02	1	09/15/86	10/03/86			AIR	TEDLAR	ATI	26006010	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-204	CWO-02	1	10/15/86	10/23/86			AIR	TEDLAR	ATI	28911004	8240	ug/M3 (wt/v)	N/A	N/A	125U	125U	250U	125U	125U	125U	250U	250U
MLCW-302	CWO-03	1	09/05/86	09/24/86			AIR	TEDLAR	ATI	25106006	8240	ug/M3 (wt/v)	N/A	N/A	ND	25U	50U	25U	25U	25U	TR	50U
MLCW-303	CWO-03	1	09/15/86	10/02/86			AIR	TEDLAR	ATI	26006007	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-304	CWO-03	1	10/15/86	10/24/86			AIR	TEDLAR	ATI	28912005	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	10U	100U
MLCW-402	CWO-04	1	09/30/86	10/17/86			AIR	TEDLAR	ATI	27614009	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-403	CWO-04	1	10/22/86	10/29/86			AIR	TEDLAR	ATI	29603003	8240	ug/M3 (wt/v)	N/A	N/A	30J	50U	100U	50U	50U	50U	100U	100U
MLCW-502	CWO-05	1	08/26/86	09/17/86			AIR	TEDLAR	ATI	23907002	8240	ug/M3 (wt/v)	N/A	N/A	ND	25U	50U	25U	25U	25U	TR	50U
MLCW-503	CWO-05	1	08/26/86	09/16/86			AIR	TEDLAR	ATI	23907005	8240	ug/M3 (wt/v)	N/A	N/A	ND	25U	50U	25U	25U	25U	50U	50U
MLCW-504	CWO-05	1	09/15/86	10/02/86			AIR	TEDLAR	ATI	26006	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLCW-505	CWO-05	1	10/15/86	10/23/86			AIR	TEDLAR	ATI	28911001	8240	ug/M3 (wt/v)	N/A	N/A	85U	85U	170U	85U	85U	85U	170U	170U
MLCW-601	CWI-06	1	06/04/86	06/10/86			AIR	TEDLAR	ATI	15603001	8240	ug/M3 (wt/v)	N/A	N/A	ND	25U	50U	25U	25U	25U	50U	50U
MLCW-602	CWO-06	1	06/04/86	06/10/86			AIR	TEDLAR	ATI	15603002	8240	ug/M3 (wt/v)	N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
MLCW-603	CWO-06	1	07/01/86	07/03/86			AIR	TEDLAR	ATI	18305001	8240	ug/M3 (wt/v)	N/A	N/A	ND	125U	250U	125U	125U	125U	250U	250U
MLCW-604	CWI-06	1	07/01/86	07/03/86			AIR	TEDLAR	ATI	18305003	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLCW-605	CWO-06	1	09/05/86	09/24/86			AIR	TEDLAR	ATI	25106007	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	150	100U
MLCW-606	CWO-06	1	09/30/86	10/17/86			AIR	TEDLAR	ATI	27614006	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	40J	100U

Data submitted to Ecology by Black & Veatch
September 14, 1987
File name = VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 1 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	QA REV	TYPE	SAMPLE	LAB	LAB I.D.	ANALYSIS	UNITS	SAMPLE VOLUME	ACROLEIN	ACRYLONITR	BENZENE	BROMODICHL	BROMOMETHA	BROMOFORM	CARBONTETR	CHLOROBENZ	CHLOROETHA	CHLOROETHZ
MLCW-607	CWO-06	1	10/22/86	10/30/86		AIR	TEDLAR	ATI	25603001	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	50J	100U
MLCW-701	CWI-07	1	06/04/86	06/10/86		AIR	TEDLAR	ATI	15603003	8240	ug/M3 (wt/v)	N/A	N/A		TR	50U	100U	50U	50U	50U	100U	100U
MLCW-702	CWO-07	1	07/25/86	08/05/86		AIR	TEDLAR	ATI	20903008	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-703	CWI-07	1	07/25/86	08/05/86		AIR	TEDLAR	ATI	20903009	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-704	CWO-07	1	08/26/86	09/15/86		AIR	TEDLAR	ATI	23907010	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-705	CWI-07	1	08/26/86	09/16/86		AIR	TEDLAR	ATI	23907007	8240	ug/M3 (wt/v)	N/A	N/A		TR	25U	50U	25U	25U	25U	50U	50U
MLCW-706	CWO-07	1	09/15/86	10/03/86		AIR	TEDLAR	ATI	26006009	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLCW-707	CWO-07	1	10/16/86	10/23/86		AIR	TEDLAR	ATI	28911002	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLCW-801	CWI-08	1	06/04/86	06/10/86		AIR	TEDLAR	ATI	15603004	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-802	CWO-08	1	07/01/86	07/03/86		AIR	TEDLAR	ATI	18305003	8240	ug/M3 (wt/v)	N/A	N/A		ND	125U	250U	125U	125U	125U	250U	250U
MLCW-802	CWO-08	1	07/25/86	08/06/86		AIR	TEDLAR	ATI	20903001	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-803	CWI-08	1	07/25/86	08/06/86		AIR	TEDLAR	ATI	20903002	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-804	CWO-08	1	08/26/86	09/16/86		AIR	TEDLAR	ATI	23907001	8240	ug/M3 (wt/v)	N/A	N/A		ND	25U	50U	25U	25U	25U	50U	50U
MLCW-805	CWO-08	1	09/05/86	09/23/86		AIR	TEDLAR	ATI	25106008	8240	ug/M3 (wt/v)	N/A	N/A		ND	25U	50U	25U	25U	25U	50U	50U
MLCW-806	CWO-08	1	09/30/86	10/17/86		AIR	TEDLAR	ATI	27614008	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLCW-807	CWO-08	1	10/22/86	10/29/86		AIR	TEDLAR	ATI	29603004	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLCW-807 (DUP)			10/22/86	10/30/86		AIR	8240	ATI	29603004		ug/m3				50U	50U	100U	50U	50U	50U	100U	100U
MLCW-901	CWI-09	1	06/05/86	06/11/86		AIR	TEDLAR	ATI	15703-02	8240	ug/M3 (wt/v)	N/A	N/A		ND	125U	250U	125U	125U	125U	250U	250U
MLCW-902	CWO-09	1	07/25/86	08/06/86		AIR	TEDLAR	ATI	20903003	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-903	CWI-09	1	07/25/86	08/06/86		AIR	TEDLAR	ATI	20903004	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLCW-904	CWO-09	1	09/05/86	09/23/86		AIR	TEDLAR	ATI	25106009	8240	ug/M3 (wt/v)	N/A	N/A		ND	25U	50U	25U	25U	25U	TR	50U
MLCW-905	CWO-09	1	09/30/86	10/17/86		AIR	TEDLAR	ATI	27614001	8240	ug/M3 (wt/v)	N/A	N/A		125U	125U	250U	125U	125U	125U	250U	250U
MLCW-906	CWO-09	1	10/22/86	11/05/86		AIR	TEDLAR	ATI	29603005	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLRVV-01-33	RWI-01	1	04/28/87	05/08/87	NO	AIR	TEDLAR	ATI	70500409	8240	ug/M3 (wt/v)	N/A	N/A		10J	50U	100U	50U	50U	50U	50U	100U
MLRVV-116	RWI-01	1	09/30/86	10/16/86		AIR	TEDLAR	ATI	27614004	8240	ug/M3 (wt/v)	N/A	N/A		20J	50U	100U	50U	50U	50U	20J	100U
MLRVV-118	RWI-01	1	10/15/86	10/24/86		AIR	TEDLAR	ATI	28912002	8240	ug/M3 (wt/v)	N/A	N/A		30	10U	100U	TR	10U	10U	40	100U
MLRV-01-22	RWI-01	1	11/06/86	11/18/86		AIR	TEDLAR	ATI	31502004	8240	ug/M3 (wt/v)	N/A	N/A		20	10U	100U	50U	10U	10U	20	100U
MLRV-01-23	RWO-01	1	11/06/86	11/18/86		AIR	TEDLAR	ATI	31502005	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	10J	30J	100U
MLRV-01-24	RWI-01	1	11/11/86	12/02/86		AIR	TEDLAR	ATI	31713001	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLRV-01-25	RWO-01	1	11/11/86	12/02/86		AIR	TEDLAR	ATI	31713002	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLRV-01-26	RWI-01	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509009	8240	ug/M3 (wt/v)	N/A	N/A		50B	50U	100U	50U	50U	50U	50J	100U
MLRV-01-27	RWO-01	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509008	8240	ug/M3 (wt/v)	N/A	N/A		80	50U	100U	50U	50U	50U	100U	100U
MLRV-01-27(DUP)	RWO-01	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509008	8240	ug/M3 (wt/v)	N/A	N/A		100	50U	100U	50U	50U	50U	100U	100U
MLRV-01-28	RWI-01	1	03/12/87	03/24/87		AIR	TEDLAR	ATI	70311401	8240	ug/M3 (wt/v)	NA	NA		23	10U	100U	50U	10U	25	10U	100U
MLRV-01-29	RWI-01	1	03/12/87	03/25/87		AIR	TEDLAR	ATI	70311402	8240	ug/M3 (wt/v)	NA	NA		19	10U	100U	50U	10U	10U	10U	100U
MLRV-01-30	RWO-01	1	03/12/87	03/25/87		AIR	TEDLAR	ATI	70311403	8240	ug/M3 (wt/v)	NA	NA		21	10U	100U	50U	10U	10U	10U	100U
MLRV-01-31	RWI-01	1	04/28/87	05/08/87	NO	AIR	TEDLAR	ATI	70500415	8240	ug/M3 (wt/v)	N/A	N/A		10J	50U	100U	50U	50U	50U	50U	100U
MLRV-01-32	RWO-01	1	04/28/87	05/08/87	NO	AIR	TEDLAR	ATI	70500408	8240	ug/M3 (wt/v)	N/A	N/A		ND	250U	500U	250U	250U	250U	250U	500U
MLRV-01-34	RWI-01		06/02/87	06/08/87	NO	AIR	TEDLAR	ATI	9804-10	8240	ug/M3 (wt/v)				5U	5U	10U	5U	5U	20.0	10U	10U
MLRV-01-35	RWO-01		06/02/87	06/05/87	NO	AIR	TEDLAR	ATI	9804-11	8240	ug/M3 (wt/v)				468	5U	10U	5U	5U	5U	10U	10U
MLRV-02-22	RWI-02	1	11/12/86	12/04/86		AIR	TEDLAR	ATI	31713012	8240	ug/M3 (wt/v)	N/A	N/A		30J	50U	100U	50U	50U	50U	100U	100U
MLRV-02-23	RWO-02	1	11/12/86			AIR	TEDLAR	ATI	31713013	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLRV-02-24	RWI-02	1	11/11/86	12/02/86		AIR	TEDLAR	ATI	31713003	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLRV-02-25	RWO-02	1	11/11/86	12/02/86		AIR	TEDLAR	ATI	31713004	8240	ug/M3 (wt/v)	N/A	N/A		50U	50U	100U	50U	50U	50U	100U	100U
MLRV-02-26	RWI-02	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509006	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLRV-02-27	RWO-02	1	01/13/87	01/27/87		AIR	TEDLAR	ATI	01509017	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U

Data submitted to Ecology by Black & Veatch
September 18
File [illegible] - VOC

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	QA	REV	TYPE	SAMPLE	LAB	LAB I.D.	ANALYSIS	UNITS	SAMPLE VOLUME	ACROLEIN	ACRYLONITR	BENZENE	BROMODICHL	BROMOMETHA	BROMOFORM	CARBONTETR	CHLOROBENZ	CHLOROETHA	CHLOROETHZ
MLRW-02-28	RWI-02		03/12/87	03/25/87			AIR	TEDLAR	ATI	70311404	8240	ug/M3 (wt/v)	NA	NA	ND	10U	100U	50U	10U	10U	10U	100U
MLRW-02-28,LDUP	RWI-02	1	03/12/87	03/25/87			AIR	TEDLAR	ATI	70311404	8240	ug/M3 (wt/v)			ND	10U	100U	50U	10U	10U	10U	100U
MLRW-02-29	RWO-02		03/12/87	03/24/87			AIR	TEDLAR	ATI	70311405	8240	ug/M3 (wt/v)	NA	NA	ND	10U	100U	50U	10U	10U	10U	100U
MLRW-02-30	RWI-02	1	04/28/87	05/11/87	NO		AIR	TEDLAR	ATI	70500411	8240	ug/M3 (wt/v)	N/A	N/A	20J	50U	100U	50U	50U	10J	50U	100U
MLRW-02-31	RWO-02	1	04/28/87	05/08/87	NO		AIR	TEDLAR	ATI	70500420	8240	ug/M3 (wt/v)	N/A	N/A	ND	250U	500U	250U	250U	250U	250U	500U
MLRW-02-31	RWI-02		06/02/87	06/05/87	NO		AIR	TEDLAR	ATI	9804-8	8240	ug/M3 (wt/v)			40B	5U	10U	5U	5U	5U	10U	10U
MLRW-02-32	RWO-02		06/02/87	06/05/87	NO		AIR	TEDLAR	ATI	9804-9	8240	ug/M3 (wt/v)			5U	5U	10U	5U	5U	5U	10U	10U
MLRW-109	RWI-01	1	05/23/86	05/27/86			AIR	TEDLAR	ATI	14702-01	8240	ug/M3 (wt/v)	N/A	N/A	30B	100U	200U	100U	100U	100U	35B	200U
MLRW-110	RWI-01	1	06/18/86	06/23/86			AIR	TEDLAR	ATI	17002001	8240	ug/M3 (wt/v)	N/A	N/A	13B	125U	250U	125U	125U	125U	15B	250U
MLRW-111	RWI-01	1	08/07/86	08/22/86			AIR	TEDLAR	ATI	22302002	8240	ug/M3 (wt/v)	N/A	N/A	86B	50U	100U	50U	50U	50U	TR	100U
MLRW-112	RWI-01	1	09/05/86	09/24/86			AIR	TEDLAR	ATI	25106001	8240	ug/M3 (wt/v)	N/A	N/A	40J	50U	100U	50U	50U	50U	60J	100U
MLRW-113	RWO-01	1	09/05/86	09/24/86			AIR	TEDLAR	ATI	25106002	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	10B	100U
MLRW-114	RWI-01	1	09/15/86	10/14/86			AIR	TEDLAR	ATI	26006001	8240	ug/M3 (wt/v)	N/A	N/A	TR	84U	167U	84U	84U	84U	TR	167U
MLRW-115	RWO-01	1	09/15/86	10/16/86			AIR	TEDLAR	ATI	26006002	8240	ug/M3 (wt/v)	N/A	N/A	125U	125U	250U	125U	125U	125U	50J	250U
MLRW-116	RWI-01	1	09/30/86	10/16/86			AIR	TEDLAR	ATI	27614002	8240	ug/M3 (wt/v)	N/A	N/A	83.5U	83.5U	167U	83.5U	83.5U	83.5U	167U	167U
MLRW-117	RWO-01	1	09/30/86	10/17/86			AIR	TEDLAR	ATI	27614003	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	20J	100U
MLRW-118	RWI-01	1	10/15/86	10/24/86			AIR	TEDLAR	ATI	28912001	8240	ug/M3 (wt/v)	N/A	N/A	40J	125U	250U	125U	125U	125U	25U	250U
MLRW-119	RWO-01	1	10/15/86	10/24/86			AIR	TEDLAR	ATI	28912006	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	30J	100U
MLRW-120	RWI-01	1	10/22/86	11/05/86			AIR	TEDLAR	ATI	29603010	8240	ug/M3 (wt/v)	N/A	N/A	20J	50U	100U	50U	50U	50U	100U	100U
MLRW-121	RWO-01	1	10/22/86	11/05/86			AIR	TEDLAR	ATI	29603008	8240	ug/M3 (wt/v)	N/A	N/A	25J	125U	250U	125U	125U	125U	250U	250U
MLRW-12-02			11/06/86	11/18/86	NO		AIR	TEDLAR	ATI	31502004	8240	ug/M3 (wt/v)			20J	50U	100U	50U	50U	50U	20J	100U
MLRW-209	RWI-02	1	05/23/86	05/27/86			AIR	TEDLAR	ATI	14702-02	8240	ug/M3 (wt/v)	N/A	N/A	ND	100U	200U	100U	100U	100U	200U	200U
MLRW-210	RWI-02	1	06/18/86	06/30/86			AIR	TEDLAR	ATI	17002002	8240	ug/M3 (wt/v)	N/A	N/A	ND	125U	250U	125U	125U	TR	250U	250U
MLRW-211	RWI-02	1	08/07/86	08/22/86			AIR	TEDLAR	ATI	22302001	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLRW-212	RWI-02	1	09/05/86	09/23/86			AIR	TEDLAR	ATI	25106003	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLRW-213	RWO-02	1	09/05/86	09/24/86			AIR	TEDLAR	ATI	25106004	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLRW-214	RWI-02	1	09/15/86	10/02/86			AIR	TEDLAR	ATI	26006003	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLRW-215	RWO-02	1	09/15/86	10/02/86			AIR	TEDLAR	ATI	26006004	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLRW-216	RWI-02	1	10/01/86	10/17/86			AIR	TEDLAR	ATI	27614010	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLRW-217	RWO-02	1	10/01/86	10/16/86			AIR	TEDLAR	ATI	27614011	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLRW-218	RWI-02	1	10/15/86	10/24/86			AIR	TEDLAR	ATI	28912003	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLRW-219	RWO-02	1	10/15/86	10/24/86			AIR	TEDLAR	ATI	28912007	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLRW-220	RWI-02	1	10/22/86	10/29/86			AIR	TEDLAR	ATI	29603007	8240	ug/M3 (wt/v)	N/A	N/A	50U	50U	100U	50U	50U	50U	100U	100U
MLRW-221	RWO-02	1	10/22/86	10/30/86			AIR	TEDLAR	ATI	29603009	8240	ug/M3 (wt/v)	N/A	N/A	10J	50U	100U	50U	50U	50U	100U	100U
MLRW-V118			10/15/86	10/24/86	NO		AIR	TEDLAR	ATI	28912002	8240	ug/M3 (wt/v)			30J	50U	100U	50U	50U	50U	40J	100U
MLFB-001	TBLANK	1	07/25/86	07/26/86			AIR	TEDLAR	ATI	20903007	8240	ug/M3 (wt/v)	N/A	N/A	ND	50U	100U	50U	50U	50U	100U	100U
MLFV-S-03	FLARE(S)	1	04/28/87	05/11/87	NO		AIR	TEDLAR	ATI	70500414	8240	ug/M3 (wt/v)	N/A	N/A	160B	250U	500U	250U	250U	140B	250B	500U
MLFV-S-05	FLARE(S)		06/02/87	06/09/87	NO		AIR	TEDLAR	ATI	9804-15	8240	ug/M3 (wt/v)			5U	5U	5U	10U	18.6	5U	38B	10U
MLF-M-02	FLARE(M)	1	04/28/87	05/07/87	NO		AIR	TEDLAR	ATI	70500417	8240	ug/M3 (wt/v)	N/A	N/A	180B	250U	500U	250U	250U	230B	130B	500U
MLF-M-03	FLARE(M)		06/02/87	06/10/87	NO		AIR	TEDLAR	ATI	9804-16	8240	ug/M3 (wt/v)			430OB	5U	10U	5U	5U	5U	10U	10U
MLF-S-02	FLARE(S)	1	04/28/87	05/11/87	NO		AIR	TEDLAR	ATI	70500412	8240	ug/M3 (wt/v)	N/A	N/A	250OB	250U	500U	250U	250U	200B	400B	500U
MLF-S-04	FLARE(S)		06/02/87	06/09/87	NO		AIR	TEDLAR	ATI	9804-14	8240	ug/M3 (wt/v)			290OB	5U	10U	5U	5U	5U	10U	10U
MLF-S-04-LDUP	FLARE(S)		06/02/87	06/09/87			AIR	TEDLAR	ATI	9804-14	8240	ug/M3 (wt/v)			170OB	5U	10U	5U	5U	140B	660B	10U
MLLF-102	FLARE(M)	1	06/18/86	06/23/86			AIR	TEDLAR	ATI	17002003	8240	ug/M3 (wt/v)	N/A	N/A	110B	500U	1000U	500U	500U	100B	TR	1000U
MLLF-202	FLARE(S)	1	06/18/86	06/23/86			AIR	TEDLAR	ATI	17002004	8240	ug/M3 (wt/v)	N/A	N/A	520B	500U	1000U	500U	500U	300B	90B	1000U
MLTB-001	TBLANK	1	08/26/86	09/16/86			AIR	TEDLAR	ATI	23907003	8240	ug/M3 (wt/v)	N/A	N/A	ND	25U	50U	25U	25U	25U	50U	50U

Data submitted to Ecology by Black & Veatch
September 14, 1987
File name : VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 1 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	QA REV	TYPE	SAMPLE	LAB	LAB I.D.	ANALYSIS	UNITS	SAMPLE VOLUME	ACROLEIN	ACRYLONITR	BENZENE	BROMODICHL	BROMOMETHA	BROMOFORM	CARBONTETR	CHLOROBENZ	CHLOROETHA	CHLOROETHZ
MLTB-002	TBLANK	1	09/05/86	09/23/86		AIR	TEDLAR	ATI	25106011	8240	ug/M3 (wt/v)	N/A	N/A		25U	25U	50U	25U	25U	25U	50U	50U
MLTB-003	TBLANK	1	09/22/86	10/13/86		AIR	TENAX	ATI	26606001	8240	ug/M3 (wt/v)	N/A	N/A		ND	1U	3U	1U	1U	1U	3U	3U
MLTB-005	TBLANK	1	01/13/87	01/26/87		AIR	TEDLAR	ATI	01509011	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	100U	100U
MLTB-006	TBLANK	1	04/28/87	05/08/87	NO	AIR	TEDLAR	ATI	70500413	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	50U	100U
MLTB-007	TB-007		06/03/87	06/11/87	NO	AIR	TEDLAR	ATI	9804-20	8240	ug/M3 (wt/v)				TOB	5U	10U	5U	5U	5U	10U	10U
ML-02001	GP-02S	1	05/08/86	05/12/86		AIR	TEDLAR	ATI	12903-01	8240	ug/M3 (wt/v)	N/A	N/A		ND	166U	333U	166U	166U	166U	333U	333U
ML-10001	GP-10S	1	05/08/86	05/12/86		AIR	TEDLAR	ATI	12903-02	8240	ug/M3 (wt/v)	N/A	N/A		60B	125U	250U	125U	125U	125U	225J	250U
ML-17001	GP-17S	1	05/08/86	05/12/86		AIR	TEDLAR	ATI	12903-03	8240	ug/M3 (wt/v)	N/A	N/A		ND	125U	250U	125U	125U	125U	250U	250U
ML-37001	GP-37D	1	05/08/86	05/12/86		AIR	TEDLAR	ATI	12903-04	8240	ug/M3 (wt/v)	N/A	N/A		34J	50U	100U	50U	50U	50U	65J	100U
ML-44D02	GP-44D	1	05/13/86	05/14/86		AIR	TEDLAR	ATI	13403-03	8240	ug/M3 (wt/v)	N/A	N/A		ND	100U	200U	100U	100U	100U	160J	200U
ML-44D03	GP-44D	1	05/13/86	05/14/86		AIR	TEDLAR	ATI	13403-04	8240	ug/M3 (wt/v)	N/A	N/A		ND	100U	200U	100U	100U	100U	240	200U
ML-45D01	GP-45D	1	05/13/86	05/14/86		AIR	TEDLAR	ATI	13403-02	8240	ug/M3 (wt/v)	N/A	N/A		ND	100U	200U	100U	100U	100U	200U	200U
ML-63001	GP-63S	1	05/08/86	05/12/86		AIR	TEDLAR	ATI	12903-05	8240	ug/M3 (wt/v)	N/A	N/A		ND	125U	250U	125U	125U	125U	250U	250U
ML-79D01	GP-79D	1	05/13/86	05/14/86		AIR	TEDLAR	ATI	13403-05	8240	ug/M3 (wt/v)	N/A	N/A		ND	100U	200U	100U	100U	100U	200U	200U
ML-81001	GP-81D	1	05/13/86	05/14/86		AIR	TEDLAR	ATI	13403-01	8240	ug/M3 (wt/v)	N/A	N/A		ND	100U	200U	100U	100U	100U	200U	200U
REAGENT BLANK	RBLANK			11/17/86				ATI	31502-RB	8240	ug/M3 (wt/v)				5J	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK			11/26/86				ATI	31502-RB	8240	ug/M3 (wt/v)				50U	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK			10/14/86				ATI	26006RB6	8240	ug/M3 (wt/v)				50U	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK			10/16/86				ATI	26006RB3	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK			12/02/86				ATI	31713-RB	8240	ug/M3 (wt/v)				50U	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK		1		10/23/86		AIR		ATI	28912-RB	8240	ug/m3				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK		1		12/05/86		AIR		ATI	31713-RB	8240	ug/m3				50U	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK			11/10/86				ATI	31502-RB	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK			10/23/86				ATI	28911-RB	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK			10/17/86				ATI	27614-RB	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK				12/03/86		AIR	1	ATI	31713-RB	8240	ug/m3				50U	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK			10/03/86				ATI	26006RB2	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK				12/04/86		AIR		ATI	31713-RB	8240	ug/m3				50U	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK			10/29/86				ATI	29603-RB	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK			11/05/86				ATI	29603-RB	8240	ug/M3 (wt/v)				25U	50U	50U	25U	25U	25U	5U	50U
REAGENT BLANK	RBLANK			11/07/86			TENAX	ATI	29603	8240	ug/M3 (wt/v)				3B	25U	50U	50U	25U	25U	50U	25U
REAGENT BLANK	RBLANK			10/02/86				ATI	26006RB1	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK		05/27/86	05/27/86				ATI	14702-RB	8240	ug/M3 (wt/v)				ND	5U	10U	5U	5U	5U	10U	10U
REAGENT BLANK	RBLANK		06/10/86	06/10/86				ATI		8240	ug/M3 (wt/v)				ND	5U	10U	5U	5U	5U	10U	10U
REAGENT BLANK	RBLANK		06/11/86	06/11/86				ATI	15703-RB	8240	ug/M3 (wt/v)				ND	5U	10U	5U	5U	5U	10U	10U5U
REAGENT BLANK	RBLANK		06/23/86	06/23/86				ATI	17002-RB	8240	ug/M3 (wt/v)				ND	5U	10U	5U	5U	5U	10U	10U
REAGENT BLANK	RBLANK		07/03/86	07/03/86				ATI	18305-RB	8240	ug/M3 (wt/v)				ND	5U	10U	5U	5U	5U	10U	10U
REAGENT BLANK	RBLANK		08/22/86	08/22/86				ATI	22302-RB	8240	ug/M3 (wt/v)				50TB	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK		09/24/86	09/24/86				ATI	25106-RB	8240	ug/M3 (wt/v)				ND	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK		10/10/86	10/10/86				ATI	26606-RB	8240	ug/M3 (wt/v)				ND	5U	10U	5U	TR	5U	10U	10U
REAGENT BLANK	RBLANK		10/13/86	10/13/86				ATI	26606-RB	8240	ug/M3 (wt/v)				ND	5U	10U	5U	5U	TR	10U	10U
REAGENT BLANK	RBLANK		10/16/86	10/16/86				ATI	27614-RB	8240	ug/M3 (wt/v)				ND	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK		10/24/86	10/24/86				ATI	28912-RB	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK		10/28/86	10/28/86				ATI	28910-RB	8240	ug/M3 (wt/v)				ND	1U	10U	5U	1U	1U	1U	10U
REAGENT BLANK	RBLANK		10/30/86	10/30/86				ATI	29603-RB	8240	ug/M3 (wt/v)				25U	25U	50U	25U	25U	25U	50U	50U
REAGENT BLANK	RBLANK		01/23/87	01/23/87				ATI	01509-RB	8240	ug/M3 (wt/v)				ND	50U	100U	50U	50U	50U	100U	100U

Data submitt[illegible] by Black & Veatch
September 1[illegible]
File name : VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 1 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	QA	REV	TYPE	SAMPLE	LAB	LAB I.D.	ANALYSIS	UNITS	SAMPLE VOLUME	ACROLEIN	ACRYLONITR	BENZENE	BROMODICHL	BROMOMETHA	BROMOFORM	CARBONTETR	CHLOROBENZ	CHLOROETHA	CHLOROETHZ
REAGENT BLANK	RBLANK		01/26/87	01/26/87					ATI	01509-RB	8240	ug/M3 (wt/v)				20J	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK		01/26/87	01/26/87					ATI	01509-RB	8240	ug/M3 (wt/v)				ND	50U	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK		01/27/87	01/27/87					ATI	01509-RB	8240	ug/M3 (wt/v)				ND	110	100U	50U	50U	50U	100U	100U
REAGENT BLANK	RBLANK		03/24/87	03/24/87					ATI	703114RB	8240	ug/M3 (wt/v)				ND	10U	100U	50U	10U	10U	10U	100U
REAGENT BLANK	RBLANK		03/24/87	03/24/87					ATI	703114RB	8240	ug/M3 (wt/v)				ND	10U	100U	50U	10U	10U	10U	100U
REAGENT BLANK	RBLANK	1	05/01/87	05/01/87	NO	AIR	TEDLAR		ATI	705004RB	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	50U	100U
REAGENT BLANK	RBLANK	1	05/07/87	05/07/87	NO	AIR	TEDLAR		ATI	705004RB	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	50U	100U
REAGENT BLANK	RBLANK	1	05/08/87	05/08/87	NO	AIR	TEDLAR		ATI	705004RB	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	50U	100U
REAGENT BLANK	RBLANK	1	05/08/87	05/08/87	NO	AIR	TEDLAR		ATI	705004RB	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	50U	100U
REAGENT BLANK	RBLANK	1	05/11/87	05/11/87	NO	AIR	TEDLAR		ATI	705004RB	8240	ug/M3 (wt/v)	N/A	N/A		ND	50U	100U	50U	50U	50U	50U	100U
SYSTEM BLANK			06/05/87	06/05/87	NO	AIR	TEDLAR		ATI		8240	ug/M3 (wt/v)				11.7	5U	10U	5U	1.3J	5U	10U	10U
SYSTEM BLANK			06/08/87	06/08/87	NO	AIR	TEDLAR		ATI		8240	ug/M3 (wt/v)				5U	5U	10U	5U	5U	5U	10	10U
SYSTEM BLANK			06/10/87	06/10/87	NO	AIR	TEDLAR		ATI		8240	ug/M3 (wt/v)				5U	5U	10U	5U	5U	5U	10U	10U

Data submitted to Ecology by Black & Veatch
September 14, 1987

MIDWAY LANDFILL RI/FS INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY

RECEIVED DEC 1 1987

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	CHLOROETHZ	CHLOROFORM	CHLOROMETH	DIBROMOCHL	DCHLBENZ11	DCHLBENZ12	DCHLBENZ11	TRAN12DICH	DCHLPROP12	DCHLPROP12	CIS13DICHP	TRAN13DICH	ETHYLBENZE	METHYLCHLO	TETRACL122	TETRACHLOR
ML101	EWI-01	1	02/28/86	03/03/86	200U	100U	62J	100U	38J	100U	25J	332	100U	100U	100U	100U	314	1864	504	184J
ML101-011	EWI-01	1	03/13/86	03/14/86	250U	125U	250U	125U	125U	125U	125U	330	125U	125U	125U	125U	330	650	125U	275
ML101-013	EWI-01	1	03/13/86	03/14/86	100U	50U	100U	50U	30	50U	20	350	50U	50U	50U	50U	350	410	50U	260
ML101-015	EWI-01	1	03/13/86	03/14/86	167U	83U	167U	83U	17J	83U	17J	317	83U	83U	83U	83U	317	517	100	250
ML101-02	EWI-01	1	03/07/86	03/10/86	200U	100U	520	100U	48J	100U	44J	310	100U	100U	100U	100U	340	980	90J	290
ML102-01	EWI-02	1	03/07/86	03/10/86	200U	100U	200	100U	100U	100U	100U	100U	100U	100U	100U	100U	110	2200	60J	100U
ML102-011	EWI-02	1	03/13/86	03/14/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	26J	675	125U	125U
ML102-012	EWO-02	1	03/13/86	03/14/86	100U	50U	100U	50U	50U	50U	50U	60U	50U	50U	60U	50U		470	40J	30J
ML103-01	EWI-02	1	03/07/86	03/10/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	125U	2500	125U	125U
ML104	EWI-01	1	02/28/86	03/03/86	100U	50U	86J	50U	60	50U	39J	610	50U	50U	50U	50U	570	1370	50U	360
ML105	TBLANK	1	02/28/86	03/03/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	36J	3850	125U	125U
ML105-02	TBLANK	1	03/07/86	03/10/86	250U	125U	110J	125U	125U	125U	125U	125U	125U	125U	125U	125U	140	1750	125U	125U
ML106-01	CWI-03	1	03/07/86	03/10/86	250U	125U	210J	125U	125U	125U	125U	125U	125U	125U	125U	125U	125U	2280	125U	125U
ML200-01	TBLANK	1	03/13/86	03/14/86	167U	83U	167U	83U	83U	83U	83U	83U	83U	83U	83U	83U	83U	400	83U	83U
ML401-01	EWO-01	1	03/21/86	03/24/86	100U	50U	100U	50U	31J	50U	29J	344	50U	50U	50U	50U	268	288	50U	238
ML401-02	EWO-01	1	03/21/86	03/24/86	100U	50U	100U	50U	38J	50U	39J	470	50U	50U	50U	50U	338	360	50U	290
ML401-03	EWI-01	1	03/21/86	03/24/87	100U	50U	100U	50U	34J	50U	25J	300	50U	50U	50U	50U	72	310	601	185
ML401-04	EWI-02	1	03/21/86	03/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	72	415	50U	50U
ML401-05	EWO-02	1	03/21/86	03/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	360	50U	50U
ML501-01	EWI-01	1	04/17/86	04/18/86	250U	125U	250U	125U	125U	125U	125U	520	125U	125U	125U	125U	360	690	140	360
ML501-02	EWO-01	1	04/17/86	04/22/86	100U	50U	100U	50U	50U	50U	50U	120	50U	50U	50U	50U	150	27J	50U	130
ML501-03	EWO-01	1	04/17/86	04/21/86	100U	50U	100U	50U	50U	50U	50U	510	50U	50U	50U	50U	370	140	50U	310
ML501-04	EWI-02	1	04/17/86	04/21/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	38	200	50U	50U
ML501-05	EWO-02	1	04/17/86	05/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	86	310B	50U	50U
ML501-06	CWI-03	1	04/17/86	04/21/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	60	52	26J	28J
ML501-07	CWI-02	1	04/17/86	04/22/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	44J	71	50U	50U
ML601-01	EWO-01	1	04/23/86	04/25/86	100U	50U	160	50U	21J	50U	30J	450	50U	50U	50U	50U	260	270B	50U	310
ML601-02	EWO-02	1	04/23/86	04/25/86	100U	89	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	200	240B	50U	1100
ML601-03	CWI-03	1	04/23/86	04/25/86	100U	39J	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	140	50U	50U	570
ML601-04	CWI-02	1	04/23/86	04/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	390	280B	50U	190
ML601-05	CWI-05	1	04/23/86	04/28/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	92	285B	50U	50U
ML701-01	FLARE(N)	1	05/01/86	05/07/86	300U	150U	300U	150U	100J	150U	63J	3900	150U	150U	150U	150U	28000	150U	150U	180
ML701-02	FLARE(S)	1	05/01/86	05/07/86	300U	150U	300U	150U	150U	150U	39J	1800	150U	150U	150U	150U	27000	150U	150U	210
ML701-03	FLARE(E)	1	05/01/86	05/07/86	300U	150U	300U	150U	150U	150U	52J	2400	150U	150U	150U	150U	35000	150U	150U	260
ML701-04	CWI-04	1	05/01/86	05/07/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	1250	680B	26J	125U
ML701-05	CWI-01	1	05/01/86	05/07/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	1080	550B	125U	125U
ML87W-001	GP-87W	1	08/26/86	09/17/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	257B	100B	25U	25U
MLAA-001	CWAA-10	1	09/22/86	10/10/86	3U	1U	3U	1U	1U	1U	1U	1U	1U	1U	1U	1U	6B	3B	1U	3
MLAA-002	CWAA-10	1	10/15/86	10/20/86	1.4U	.5	1.4U	.14U	.14U	.14U	.14U	.14U	.14U	.14U	.14U	.14U	11	3	.14U	11
MLAA-003	CWAA-10	1	10/22/86	11/07/86	2.20U	0.7J	2.20U	1.10U	1.10U	1.10U	1.10U	1.10U	1.10U	1.10U	1.10U	1.10U	12	4B	1.10U	9
MLCW-901	CWI-05	1	06/05/86	06/11/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	53	580B	50U	50U
MLCW-01-05	CWO-01	1	11/11/86	12/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	10J	320B	50U	50U
MLCW-01-06	CWI-01	1	01/13/87	01/26/87	100U	10J	100U	50U	50U	50U	20J	50U	50U	50U	50U	50U	60B	120B	50U	50U
MLCW-01-07	CWO-01	1	04/29/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40BJ	470B	50U	50U
MLCW-01-08	CWI-01		06/02/87	06/05/87	10U	140B	88.0	5U	5U	5U	5U	5U	5U	5U	5U	5U	28.0	6500B	5U	48.0
MLCW-02-05	CWO-02	1	11/06/86	11/17/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	80B	50U	50U

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MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 2 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	CHLOROETHE	CHLOROFORM	CHLOROMETH	DIBROMOCHL	DCHLBENZII	DCHLBRANZI2	DCHLBRANZI1	TRANS2DICH	DCHLPROPI2	DCHLPROPI2	CIS13DICHP	TRANS3DICH	ETHYLBENZE	METHYLCHLO	TETRACL122	TETRACHLOR
MLCW-02-06	CWI-02	1	01/13/87	01/26/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	60B	440B	50U	50U
MLCW-02-07	CWO-02	1	04/27/87	05/07/87	100U	60U	48J	50U	12J	50U	13	130	50U	50U	50U	50U	1200	800B	50U	19J
MLCW-02-08	CWI-02		06/02/87	06/05/87	10U	160B	20.0	5U	5U	5U	5U	5U	5U	5U	5U	5U	10.0	2600B	5U	5U
MLCW-03-05	CWO-03	1	11/06/86	11/18/86	100U	50U	100U	50U	50U	50U	50U	20J	50U	50U	50U	50U	50U	120B	50U	50U
MLCW-03-06	CWI-03	1	01/13/87	01/27/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	130B	50U	50U
MLCW-03-07	CWO-03	1	04/27/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	60	670B	50U	50U
MLCW-03-08	CWI-03		06/02/87	06/05/87	10U	320B	24.6	5U	5U	5U	5U	5U	5U	5U	5U	5U	52	15000B	5U	30
MLCW-03-08-LDUP	CWI-03		06/02/87	06/05/87	10U	280B	16.4	5U	5U	5U	5U	5U	5U	5U	5U	5U	32.0	4400B	5U	34.0
MLCW-04-04	CWO-04	1	11/11/86	12/02/86	100U	10J	100U	50U	50U	50U	140	50U	50U	50U	50U	50U	50U	140B	50U	50U
MLCW-04-05	CWI-04	1	01/13/87	01/26/87	100U	10J	100U	50U	50U	50U	70	50U	50U	50U	50U	50U	50U	90B	50U	50U
MLCW-04-06	CWO-04	1	04/27/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50J	690B	50U	50U
MLCW-04-07	CWI-04		06/02/87	06/08/87	10U	32B	10U	5U	5U	5U	160	5U	5U	5U	5U	5U	25.0	1020B	5U	12.0
MLCW-05-06	CWO-05	1	11/06/86	11/17/86	100U	50U	100U	50U	50U	50U	60U	50U	50U	50U	50U	50U	30JB	80B	50U	50U
MLCW-05-07	CWI-05	1	01/13/87	01/26/87	140U	70U	140U	70U	70U	70U	10U	70U	70U	70U	70U	70U	84B	340B	70U	70U
MLCW-05-08	CWO-05	1	04/28/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40BJ	220B	50U	50U
MLCW-05-08,LDUP	CWO-05	1	04/28/87	05/11/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	180B	870B	50U	20J
MLCW-05-09	CWI-05		06/02/87	06/05/87	10U	116B	32.0	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	1120B	5U	17.0
MLCW-05-09-LDUP	CWI-05		06/02/87	06/05/87	10U	480B	10U	5U	34.0	5U	5U	5U	5U	5U	5U	5U	22.0	3150B	5U	5U
MLCW-06-08	CWO-06	1	11/11/86	12/02/86	100U	50U	100U	50U	50U	50U	50U	10J	50U	50U	50U	50U	30J	150B	50U	50U
MLCW-06-09	CWI-06	1	01/13/87	01/27/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	160B	50U	50U
MLCW-06-10	CWO-06	1	04/29/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	610B	50U	50U
MLCW-07-08	CWO-07	1	11/06/86	11/17/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	110B50U	50U	50U
MLCW-07-09	CWI-07	1	01/13/87	01/26/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	120B	50U	50U
MLCW-07-10	CWO-07	1	04/27/87	05/01/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	18BJ	730B	50U	50U
MLCW-07-11	CWI-07		06/02/87	06/05/87	10U	600B	73.0	5U	18.6	5U	5U	5U	5U	5U	5U	5U	32	4300B	5U	20.0
MLCW-08-08	CWO-08	1	11/11/86	12/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	20J	130B	50U	20J
MLCW-08-09	CWI-08	1	01/13/87	01/27/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	290B	50U	50U
MLCW-08-10	CWO-08	1	04/27/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30J	390B	50U	50U
MLCW-08-11	CWI-08		06/02/87	06/05/87	10U	154B	10U	5U	5U	5UD	5U	5U	5U	5U	5U	5U	12.0	990B	5U	5U
MLCW-09-07	CWO-09	1	11/11/86	12/03/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	60U	50U	50U
MLCW-09-08	CWI-09	1	01/13/87	01/27/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	190B	50U	50U
MLCW-09-09	CWO-09	1	04/28/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40J	190B	50U	50U
MLCW-09-10	CWI-09		06/03/87	06/11/87	10U	110B	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	1560B	5U	5U
MLCW-1002	CWO-01	1	08/26/86	09/17/86	50U	25U	50U	25U	25U	25U	50	25U	25U	25U	25U	25U	22B	240B	25U	20J
MLCW-1003	CWO-01	1	09/30/86	10/16/86	100U	50U	100U	50U	50U	50U	40J	50U	50U	50U	50U	50U	210B	140B	50U	20J
MLCW-1004	CWO-01	1	10/22/86	10/28/86	100U	50U	100U	50U	50U	50U	60B	50U	50U	50U	50U	50U	120B	90B	50U	20J
MLCW-101	CWI-10	1	06/05/86	06/06/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	9J	460B	50U	50U
MLCW-102	CWO-10	1	07/25/86	08/06/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	97B	2300B	50U	50U
MLCW-103	CWI-10	1	07/25/86	08/05/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	75JB	125U	125U	125U
MLCW-104	CWO-10	1	08/26/86	09/16/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25TB	170B	25U	25U
MLCW-105	CWO-10	1	09/15/86	10/02/86	100U	24B	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40J	900B	50U	20J
MLCW-106	CWO-10	1	10/15/86	10/23/86	100U	50U	20J	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	20J
MLCW-10-07	CWO-10	1	11/06/86	11/17/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30JB	100B	50U	50U
MLCW-10-08	CWI-10	1	01/13/87	01/27/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	100B	200B	50U	50U
MLCW-10-09	CWO-10	1	04/27/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50	520B	50U	50U
MLCW-10-10	CWI-10		06/03/87	06/08/87	10U	32B	80	5U	5U	5U	5U	5U	5U	5U	5U	5U	26.0	1300B	5U	16.0

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September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	CHLOROETHZ	CHLOROFORM	CHLOROMETH	DIBROMOCHL	DCHLBENZ11	DCHLBENZ12	DCHLBENZ13	TRAN12DICH	DCHLPROP12	DCHLPROP12	CIS13DICHP	TRAN13DICH	ETHYLBENZE	METHYLCHLO	TETRACL122	TETRACHLOR
MLCW-111	CWI-11	1	05/05/86	06/11/86	100U	50U	100U	N/D	TR	TR	7J	50U	50U	50U	50U	50U	91J	270B	50U	50U
MLCW-112	CWO-11	1	07/25/86	08/05/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	80B	50U	50U	50U
MLCW-113	CWI-11	1	07/25/86	08/05/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	250B	125U	125U	125U
MLCW-114	CWO-11	1	08/26/86	09/15/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50TR	75B	50U	50U
MLCW-115	CWO-11	1	09/15/86	10/02/86	100U	50U	100U	50U	50U	40J	60J	9J	50U	50U	50U	50U	30J	220B	50U	50U
MLCW-116	CWO-11	1	10/15/86	10/23/86	170U	85U	170U	85U	18J	20J	44J	50J	85U	85U	85U	85U	85U	220B	85U	85U
MLCW-11-07	CWO-11	1	11/06/86	11/17/86	100U	50U	100U	50U	20J	6J	41J	11J	50U	50U	50U	50U	40JB	180B	24J	20JB
MLCW-121	CWI-12	1	06/05/86	06/11/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	18J	560B	125U	125U
MLCW-122	CWO-12	1	07/25/86	08/05/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	100B	50U	50U	50U
MLCW-123	CWI-12	1	07/25/86	08/05/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	80B	50U	50U	50U
MLCW-124	CWO-12	1	09/05/86	09/23/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	10J	170B	50U	50U
MLCW-125	CWO-12	1	09/30/86	10/17/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	7J	230B	50U	50U
MLCW-126	CWO-12	1	10/22/86	10/30/86	170U	85U	170U	85U	85U	85U	85U	85U	85U	85U	85U	85U	60J	460B	85U	85U
MLCW-12-07	CWO-12	1	11/11/86	12/03/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	490B	50U	50U
MLCW-12-08	CWI-12	1	01/13/87	01/23/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	170B	170B	50U	50U
MLCW-12-09	CWO-12	1	04/27/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40J	510B	50U	50U
MLCW-12-10	CWI-12		06/02/87	06/05/87	10U	200B	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	19.0	1920B	5U	18.0
MLCW-131	CWO-13	1	10/15/86	10/23/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	80	130B	50U	10J
MLCW-13-02	CWO-13	1	11/06/86	11/17/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40BJ	130B	50U	50U
MLCW-13-03	CWI-13	1	01/13/87	01/23/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	100B	210B	50U	50U
MLCW-13-04	CWO-13	1	04/27/87	05/08/87	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	125U	2200B	125U	125U
MLCW-13-05	CWI-13		06/02/87	06/10/87	20U	200B	20U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	42B	5U	5U
MLCW-141	CWO-14	1	10/15/86	10/23/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40J	110B	50U	10J
MLCW-14-02	CWO-14	1	11/06/86	12/03/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	210B	50U	10J
MLCW-14-03	CWI-14	1	01/13/87	01/23/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	140B	50U	50U
MLCW-151	CWO-15	1	10/15/86	10/23/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	33J	590B	50U	20J
MLCW-15-02	CWO-15	1	11/06/86	11/26/86	100U	130J	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	130B	170B	50U	20J
MLCW-15-03	CWI-15	1	01/13/87	01/23/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	110B	220B	50U	50U
MLCW-202	CWO-02	1	09/05/86	09/23/86	125U	62.5U	125U	62.5U	62.5U	62.5U	62.5U	62.5U	62.5U	62.5U	62.5U	62.5U	100B	250B	62.5U	62.5U
MLCW-203	CWO-02	1	09/15/86	10/03/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	20J	310B	50U	50U
MLCW-204	CWO-02	1	10/15/86	10/29/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	50JB	280B	125U	25J
MLCW-302	CWO-03	1	09/05/86	09/24/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	50B	55B	25U	TR
MLCW-303	CWO-03	1	09/15/86	10/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	20J	230B	50U	10J
MLCW-304	CWO-03	1	10/15/86	10/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	90B	50U	50U
MLCW-402	CWO-04	1	09/30/86	10/17/86	100U	50U	100U	50U	50U	50U	11J	50U	50U	50U	50U	50U	7J	240B	50U	10J
MLCW-403	CWO-04	1	10/22/86	10/29/86	100U	50U	100U	50U	50U	50U	8J	50U	50U	50U	50U	50U	30JB	320B	50U	20J
MLCW-502	CWO-05	1	08/26/86	09/17/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	5J	140B	25U	TR
MLCW-503	CWO-05	1	08/26/86	09/16/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	140B	25U	25U
MLCW-504	CWO-05	1	09/15/86	10/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30J	180B	50U	20J
MLCW-505	CWO-05	1	10/15/86	10/23/86	170U	85U	170U	85U	85U	85U	85U	85U	85U	85U	85U	85U	55J	200B	85U	85U
MLCW-601	CWI-06	1	06/04/86	06/10/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	4J	135B	25U	25U
MLCW-602	CWO-06	1	06/04/86	06/10/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	125TR	780B	125U	125U
MLCW-603	CWO-06	1	07/01/86	07/03/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	5B	150B	125U	125U
MLCW-604	CWI-06	1	07/01/86	07/03/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	5B	58B	50U	50U
MLCW-605	CWO-06	1	09/05/86	09/24/86	100U	50U	100U	50U	TR	50U	50U	50U	50U	50U	50U	50U	90B	110B	50U	TR
MLCW-606	CWO-06	1	09/30/86	10/17/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40J	120B	50U	50U

Data submitte[redacted]cology by Black & Veatch
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MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
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September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	CHLOROETHE	CHLOROFORM	CHLOROMETH	DIBROMOCHL	DCHLBENZ11	DCHLBENZ12	DCHLBENZ13	TRANS12DICH	DCHLPROP12	DCHLPROP13	CIS13DICHP	TRANS13DICH	ETHYLBENZE	METHYLCHLO	TETRACL122	TETRACHLOR
MLCW-607	CWO-06	1	10/22/86	10/30/86	100U	50U	100U	50U	50U	50U	50U	20J	50U	50U	50U	50U	20J	230B	50U	40JB
MLCW-701	CWI-07	1	06/04/86	06/10/86	100U	50U	100U	50U	TR	50U	50U	50U	50U	50U	50U	50U	19J	340B	50U	50U
MLCW-702	CWO-07	1	07/25/86	08/05/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	80B	50U	50U	50U
MLCW-703	CWI-07	1	07/25/86	08/05/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	65B	50U	50U	50U
MLCW-704	CWO-07	1	08/26/86	09/15/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50TB	59B	50U	50U
MLCW-705	CWI-07	1	08/26/86	09/16/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	45B	330B	25U	TR
MLCW-706	CWO-07	1	09/15/86	10/03/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30J	180B	50U	50U
MLCW-707	CWO-07	1	10/15/86	10/23/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	5B	110B	50U	10J
MLCW-801	CWI-08	1	06/04/86	06/10/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	9B	270B	50U	50U
MLCW-802	CWO-08	1	07/01/86	07/03/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	125TB	7BB	125U	125U
MLCW-802	CWO-08	1	07/25/86	08/06/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	9BB	50U	50U	50U
MLCW-803	CWI-08	1	07/25/86	08/06/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	170B	50U	50U	50U
MLCW-804	CWO-08	1	08/26/86	09/16/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	2J	8BB	25U	TR
MLCW-805	CWO-08	1	09/05/86	09/23/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	9J	75B	25U	TR
MLCW-806	CWO-08	1	09/30/86	10/17/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	6J	210B	50U	10J
MLCW-807	CWO-08	1	10/22/86	10/29/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	80B	50U	50U
MLCW-807 (DUP)			10/22/86	10/30/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	10J	370B	50U	50U
MLCW-901	CWI-09	1	06/05/86	06/11/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	50U	570B	125U	125U
MLCW-902	CWO-09	1	07/25/86	08/06/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	160B	50U	50U	50U
MLCW-903	CWI-09	1	07/25/86	08/06/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	180B	500B	50U	50U
MLCW-904	CWO-09	1	09/05/86	09/23/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	7J	170B	25U	TR
MLCW-905	CWO-09	1	09/30/86	10/17/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	75J	160B	125U	125U
MLCW-906	CWO-09	1	10/22/86	11/05/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	140B	50U	50U
MLBWV-01-33	BWI-01	1	04/28/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40BJ	60B	50U	40J
MLBWV-116	BWI-01	1	09/30/86	10/16/86	100U	50U	100U	50U	50U	50U	50U	10U	50U	50U	50U	50U	110B	100B	50U	8U
MLBWV-118	BWI-01	1	10/15/86	10/24/86	100U	17U	100U	10U	10U	10U	10U	2U	10U	10U	10U	10U	100B	50U	10U	100B
MLBW-01-22	BWI-01	1	11/06/86	11/18/86	100U	10U	100U	10U	10U	10U	1U	13U	10U	10U	10U	10U	10U	50U	10U	10U
MLBW-01-23	BWO-01	1	11/06/86	11/18/86	100U	50U	100U	50U	10J	50U	20J	16U	50U	50U	50U	50U	40B	670B	50U	50U
MLBW-01-24	BWI-01	1	11/11/86	12/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	270B	50U	10J
MLBW-01-25	BWO-01	1	11/11/86	12/02/86	100U	50U	100U	50U	50U	50U	50U	10J	50U	50U	50U	50U	10J	320B	50U	50U
MLBW-01-26	BWI-01	1	01/13/87	01/26/87	100U	50U	100U	50U	50U	50U	30J	26U	50U	50U	50U	50U	140B	150B	50U	20U
MLBW-01-27	BWO-01	1	01/13/87	01/26/87	100U	50U	100U	50U	50U	50U	50U	20U	50U	50U	50U	50U	110B	120B	50U	26U
MLBW-01-27(DUP)	BWO-01	1	01/13/87	01/26/87	100U	50U	100U	50U	50U	50U	30J	27U	50U	50U	50U	50U	140B	140B	50U	33U
MLBW-01-28	BWI-01	1	03/12/87	03/24/87	100U	10U	100U	10U	10U	10U	4J	10U	10U	10U	10U	10U	7J	170B	10U	25U
MLBW-01-29	BWI-01	1	03/12/87	03/25/87	100U	10U	100U	10U	10U	10U	2J	6J	10U	10U	10U	10U	4J	240B	10U	16U
MLBW-01-30	BWO-01	1	03/12/87	03/25/87	100U	10U	100U	10U	10U	10U	1J	3J	10U	10U	10U	10U	10U	290B	10U	18U
MLBW-01-31	BWI-01	1	04/28/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	60B	460B	50U	7U
MLBW-01-32	BWO-01	1	04/28/87	05/08/87	500U	250U	500U	250U	250U	250U	250U	250U	250U	250U	250U	250U	250U	1200B	250U	130J
MLBW-01-34	BWI-01		06/02/87	06/08/87	10U	7.6B	35.0	5U	5U	5U	20.0	5U	5U	5U	5U	5U	20.0	6700B	5U	14U
MLBW-01-35	BWO-01		06/02/87	06/05/87	10U	98.0	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	2700B	5U	33U
MLBW-02-22	BWI-02	1	11/12/86	12/04/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	310B	50U	50U
MLBW-02-23	BWO-02	1	11/12/86		100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	150B	50U	50U
MLBW-02-24	BWI-02	1	11/11/86	12/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	20J	110B	50U	50U
MLBW-02-25	BWO-02	1	11/11/86	12/02/86	100U	8U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	9U	1100B	50U	50U
MLBW-02-26	BWI-02	1	01/13/87	01/26/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	60B	210B	50U	50U
MLBW-02-27	BWO-02	1	01/13/87	01/27/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	160B	50U	50U

Data submitted to Ecology by Black & Veatch
September 14, 1987
File name = VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 2 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	CHLOROETHE	CHLOROFORM	CHLOROMETH	DIBROMOCHL	DCHLBENZ1	DCHLBENZ2	DCHLBENZ1	TRANS1DICH	DCHLPROP1	DCHLPROP1	CIS1DICHP	TRANS1DICH	ETHYLBENZE	METHYLCHLO	TETRACL1E2	TETRACHLOR
MLEW-02-28	EWI-02		03/12/87	03/25/87	100U	10U	100U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	150B	10U	10U
MLEW-02-28,LDUP	EWI-02	I	03/12/87	03/25/87	100U	10U	100U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	200B	10U	10
MLEW-02-29	EWO-02		03/12/87	03/24/87	100U	10U	100U	10U	10U	10U	10U	10U	10U	10U	10U	10U	23	140B	10U	10
MLEW-02-30	EWI-02	I	04/20/87	05/11/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	60B	370B	80U	10J
MLEW-02-31	EWO-02	I	04/20/87	05/08/87	500U	250U	500U	250U	250U	250U	250U	250U	250U	250U	250U	250U	250U	2000B	250U	250U
MLEW-02-31	EWI-02		06/02/87	06/05/87	10U	110B	41.0	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	20.0	6000B	5U	5U
MLEW-02-32	EWO-02		06/02/87	06/05/87	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	6500B	5U	5U
MLEW-109	EWI-01	I	05/23/86	05/27/86	200U	100U	200U	100U	100U	100U	100U	400	100U	100U	100U	100U	400	820B	100U	220
MLEW-110	EWI-01	I	06/10/86	06/23/86	250U	125U	250U	125U	125U	125U	125U	430	125U	125U	125U	125U	210	1100B	125U	2200
MLEW-111	EWI-01	I	08/07/86	08/22/86	100U	50U	100U	50U	50U	50U	TR	370	50U	60U	50U	50U	80	200B	50U	120
MLEW-112	EWI-01	I	09/05/86	09/24/86	100U	50U	100U	50U	50U	50U	20J	190	50U	50U	50U	50U	120B	190B	50U	100
MLEW-113	EWO-01	I	09/05/86	09/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	110B	140B	50U	TR
MLEW-114	EWI-01	I	09/15/86	10/14/86	167U	84U	167U	84U	84U	84U	84U	100	84U	84U	84U	84U	80	250B	84U	TR
MLEW-115	EWO-01	I	09/15/86	10/16/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	75J	350B	125U	125U
MLEW-116	EWI-01	I	09/30/86	10/16/86	167U	83.5U	167U	83.5U	83.5U	83.5U	83.5U	17J	83.5U	83.5U	83.5U	83.5U	220B	400B	83.5U	33J
MLEW-117	EWO-01	I	09/30/86	10/17/86	100U	50U	100U	50U	50U	50U	50U	17JU	50U	50U	50U	50U	80	200B	50U	50U
MLEW-118	EWI-01	I	10/15/86	10/24/86	250U	125U	250U	125U	125U	125U	125U	85J	125U	125U	125U	125U	100BJ	700B	125U	80BJ
MLEW-119	EWO-01	I	10/15/86	10/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	20JB	260B	50U	50U
MLEW-120	EWI-01	I	10/22/86	11/05/86	100U	50U	100U	50U	50U	50U	16J	130	50U	50U	50U	50U	30JB	90B	10J	90
MLEW-121	EWO-01	I	10/22/86	11/05/86	250U	125U	50J	125U	125U	125U	125U	125U	125U	125U	125U	125U	25JB	500B	125U	125U
MLEW-12-02			11/06/86	11/18/86	100U	50U	100U	50U	50U	50U	10J	130	50U	50U	50U	50U	50U	170B	50U	100
MLEW-209	EWI-02	I	05/23/86	05/27/86	200U	100U	200U	100U	100U	100U	100U	100U	100U	100U	100U	100U	220	520B	100U	TR
MLEW-210	EWI-02	I	06/10/86	06/30/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	125TR	530	125U	TR
MLEW-211	EWI-02	I	08/07/86	08/22/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50TR	120B	50U	50U
MLEW-212	EWI-02	I	09/05/86	09/23/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	10	160B	50U	50U
MLEW-213	EWO-02	I	09/05/86	09/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	90B	50U	50U
MLEW-214	EWI-02	I	09/15/86	10/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40J	240B	50U	50U
MLEW-215	EWO-02	I	09/15/86	10/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	20J	110B	50U	50U
MLEW-216	EWI-02	I	10/01/86	10/17/86	100U	50U	100U	50U	50U	60U	50U	50U	50U	50U	50U	50U	60	220B	50U	10J
MLEW-217	EWO-02	I	10/01/86	10/16/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30JB	110B	50U	50U
MLEW-218	EWI-02	I	10/15/86	10/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30JB	160B	50U	50U
MLEW-219	EWO-02	I	10/15/86	10/24/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	10JB	140B	50U	50U
MLEW-220	EWI-02	I	10/22/86	10/29/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	10JB	100B	50U	10J
MLEW-221	EWO-02	I	10/22/86	10/30/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	10U	30J	290B	50U	10U
MLEW-V110			10/15/86	10/24/86	100U	170	100U	50U	50U	50U	50U	20J	50U	60U	60U	50U	100B	220B	50U	100B
MLFB-001	TBLANK	I	07/25/86	07/28/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U		50U	50U	50U
MLFV-S-03	FLARE(S)	I	04/20/87	05/11/87	500U	250U	500U	250U	250U	250U	890	2000	250U	250U	250U	250U	19000B	2600B	250U	136J
MLFV-S-05	FLARE(S)		06/02/87	06/09/87	10U	78B	940	5U	82.0	5U	5U	98.0	5U	5U	5U	5U	300	620B	5U	300
MLF-N-02	FLARE(N)	I	04/20/87	05/01/87	500U	250U	500U	250U	97J	250U	700	3600	250U	250U	250U	250U	42000	1900B	250U	170J
MLF-N-03	FLARE(N)		06/02/87	06/10/87	10U	3800B	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	26000	22300B	5U	5U
MLF-S-02	FLARE(S)	I	04/20/87	05/11/87	500U	250U	500U	250U	110J	250U	1400	2700	250U	250U	250U	250U	28000B	10000B	250U	150J
MLF-S-04	FLARE(S)		06/02/87	06/09/87	10U	3400B	4400	5U	5U	5U	5U	5U	5U	5U	5U	5U	14000	21000	5U	5U
MLF-S-04-LDUP	FLARE(S)		06/02/87	06/09/87	10U	680B	880	5U	5U	5U	720	5U	5U	5U	5U	5U	18000	5600B	5U	5U
MLLF-102	FLARE(N)	I	06/18/86	06/23/86	1000U	500U	1000U	500U	500U	500U	TR	2500	500U	500U	500U	500U	18000	3300B	500U	TR
MLLF-202	FLARE(S)	I	06/18/86	06/23/86	1000U	500U	1000U	500U	500U	500U	530	2600	500U	500U	500U	500U	56000	5100	500U	TR
MLTB-001	TBLANK	I	08/26/86	09/16/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25TR	140B	25U	25U

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September 14, 1[illegible]
File name: [illegible]

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 2 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	CHLOROBENZ	CHLOROFORM	CHLOROMETH	DIBROMOCHL	DCHLBENZEN	DCHLBENZEN	DCHLBENZEN	TRANSDICH	DCHLPROPAN	DCHLPROPEN	CISDICHP	TRANSDICH	ETHYLBENZE	METHYLCHLO	TETRACLEEE	TETRACHLOR
MLTB-002	TBLANK	1	09/05/86	09/23/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	7B	85B	25U	10J
MLTB-003	TBLANK	1	09/22/86	10/13/86	3U	1U	3U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	2B	1U	1U
MLTB-005	TBLANK	1	01/13/87	01/26/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	120B	50U	50U
MLTB-006	TBLANK	1	04/20/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50J	410B	50U	50U
MLTB-007	TB-001		06/03/87	06/11/87	10U	16B	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	400B	5U	5U
ML-02001	GP-02B	1	05/08/86	05/12/86	333U	166U	333U	166U	166U	166U	166U	166U	166U	166U	166U	166U	53B	1200B	166U	166U
ML-10001	GP-10B	1	05/08/86	05/12/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	77B	900B	125U	125U
ML-17001	GP-17B	1	05/08/86	05/12/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	65B	575B	125U	125U
ML-37001	GP-37B	1	05/08/86	05/12/86	100U	50U	200	50U	50U	50U	50U	50U	50U	50U	50U	50U	92B	630B	50U	50U
ML-44002	GP-44D	1	05/13/86	05/14/86	200U	100U	200U	100U	100U	100U	100U	100U	100U	100U	100U	100U	18B	320B	100U	100U
ML-44D03	GP-44D	1	05/13/86	05/14/86	200U	100U	80J	100U	100U	100U	100U	100U	100U	100U	100U	100U	20B	560B	100U	100U
ML-45D01	GP-45D	1	05/13/86	05/14/86	200U	100U	40J	100U	100U	100U	100U	100U	100U	100U	100U	100U	28B	240B	100U	100U
ML-63001	GP-63B	1	05/08/86	05/12/86	250U	125U	250U	125U	125U	125U	125U	125U	125U	125U	125U	125U	48B	825B	125U	125U
ML-79001	GP-79D	1	05/13/86	05/14/86	200U	100U	200U	100U	100U	100U	100U	100U	100U	100U	100U	100U	60J	780B	100U	100U
ML-81001	GP-81D	1	05/13/86	05/14/86	200U	100U	74J	100U	100U	100U	100U	100U	100U	100U	100U	100U	14B	100U	100U	100U
REAGENT BLANK	RBLANK			11/17/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	5J	12B	25U	15J
REAGENT BLANK	RBLANK			11/26/86	100U	12B	100U	50U	50U	50U	50U	50U	50U	50U	50U	28J	50U	13B	60U	50U	10U
REAGENT BLANK	RBLANK			10/14/86	100U	58U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	17B	50U	50U
REAGENT BLANK	RBLANK			10/16/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	5J	7B	25U	25U
REAGENT BLANK	RBLANK			12/02/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	7B	50U	50U
REAGENT BLANK		1		10/29/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	10J	7B	25U	25U
REAGENT BLANK		1		12/05/86	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	38J	95B	50U	50U
REAGENT BLANK	RBLANK			11/18/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	5J	7B	25U	25U
REAGENT BLANK	RBLANK			10/23/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	1B	25U	11B	25U	5U
REAGENT BLANK	RBLANK			10/17/86	50U	25U	5B	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	6B	25U	25U
REAGENT BLANK				12/03/86	100U	50U	100U	50U	5B	50U	50U	50U	50U	50U	50U	50U	50U	5B	50U	50U	50U
REAGENT BLANK	RBLANK			10/03/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	4B	25U	25U	25U
REAGENT BLANK				12/04/86	100U	5B	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	4B	35J	50U	50U	50U
REAGENT BLANK	RBLANK			10/29/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	10J	7B	25U	25U	25U
REAGENT BLANK	RBLANK			11/05/86	50U	25U	50U	25U	4B	25U	25U	25U	25U	25U	25U	25U	5J	50B	25U	25U	25U
REAGENT BLANK	RBLANK			11/07/86	25U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	3B	25U	25U	25U	50U
REAGENT BLANK	RBLANK			10/02/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	14B	25U	25U	25U
REAGENT BLANK	RBLANK		05/27/86	05/27/86	10U	5U	10U	5U	6	5U	5U	5U	5U	5U	5U	5U	5U	5TR	5U	5U	5U
REAGENT BLANK	RBLANK		06/10/86	06/10/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	6	5U	5U	5U
REAGENT BLANK	RBLANK		06/11/86	06/11/86	10U5U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5TR	5U	5U	5U
REAGENT BLANK	RBLANK		06/23/86	06/23/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5TR	5U	5U	5U
REAGENT BLANK	RBLANK		07/03/86	07/03/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	2TR	5U	5U	5U
REAGENT BLANK	RBLANK		08/22/86	08/22/86	100U	50U	100TR	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	14B	50U	50U	50U
REAGENT BLANK	RBLANK		09/24/86	09/24/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	4B	14B	25U	25U
REAGENT BLANK	RBLANK		10/10/86	10/10/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	TR	TR	5U	5U
REAGENT BLANK	RBLANK		10/13/86	10/13/86	10U	5U	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	TR	TR	5U	TR
REAGENT BLANK	RBLANK		10/16/86	10/16/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	TR	7B	25U	25U
REAGENT BLANK	RBLANK		10/24/86	10/24/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	25U	5J	12B	25U	5J
REAGENT BLANK	RBLANK		10/28/86	10/28/86	10U	1U	10U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	TR	1U	1U	1U
REAGENT BLANK	RBLANK		10/30/86	10/30/86	50U	25U	50U	25U	25U	25U	25U	25U	25U	25U	25U	25U	10J	25U	6B	25U	4B
REAGENT BLANK	RBLANK		01/23/87	01/23/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	40J	13B	50U	50U	50U

Data submitted to Ecology by Black & Veatch
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File name = VOC

VOLATILE ORGANIC COMPOUNDS SUMMARY

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	CHLOROETHZ	CHLOROFORM	CHLOROMETH	DIBROMOCHL	DCHLBENZ11	DCHLBENZ12	DCHLBENZ11	TRAN12DICH	DCHLPROP12	DCHLPROP12	CIS13DICHP	TRAN13DICH	ETHYLBENZE	METHYLCHLO	TETRAC1122	TETRACHLOR
REAGENT BLANK	RBLANK		01/26/87	01/26/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30J	110	50U	50U
REAGENT BLANK	RBLANK		01/26/87	01/26/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	30J	110	50U	50U
REAGENT BLANK	RBLANK		01/27/87	01/27/87	100U	260	100U	50	50U	50U	50U	50U	50U	50U	50U	50U	36J	200	60U	50U
REAGENT BLANK	RBLANK		03/24/87	03/24/87	100U	10U	100U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	120	10U	10U
REAGENT BLANK	RBLANK		03/26/87	03/26/87	100U	10U	100U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	170	10U	10U
REAGENT BLANK	RBLANK	1	05/01/87	05/01/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	14J	320	50U	50U
REAGENT BLANK	RBLANK	1	05/07/87	05/07/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	350	50U	50U
REAGENT BLANK	RBLANK	1	05/08/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	50U	340	50U	50U
REAGENT BLANK	RBLANK	1	05/08/87	05/08/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	18J	130	50U	50U
REAGENT BLANK	RBLANK	1	05/11/87	05/11/87	100U	50U	100U	50U	50U	50U	50U	50U	50U	50U	50U	50U	31J	220	50U	50U
SYSTEM BLANK			06/05/87	06/05/87	10U	27.3	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	195	5U	5U
SYSTEM BLANK			06/08/87	06/08/87	10U	46.0	10	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	900	5U	5U
SYSTEM BLANK			06/10/87	06/10/87	10U	5	10U	5U	5U	5U	5U	5U	5U	5U	5U	5U	5U	4.6	5	5U

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September 1[illegible], 1987
F[illegible] : VOC[illegible]

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MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	TOLUENE	TRICHLOIII	TRICHLOII2	TRICHLOROE	VINYLCHLOR	ACETONE	BUTANONE2	CARBONDISU	METHANONE2	METHYLPENE2	STYRENE	VINYLACETA	XYLENE_TOT	DCBLIZ_D4	BFB	TOLUENE_D6	OWNER
ML101	EWI-01	1	02/28/86	03/03/86	100U	100U	202	220	2300	5380	276	100	200U	200U	100U	200U	1488	68	80	57	
ML101-011	EWI-01	1	03/13/86	03/14/86	275	125U	125U	280	1950	4600	250U	150	250U	250U	125U	250U	1800	77	112	73	
ML101-013	EWI-01	1	03/13/86	03/14/86	310	50U	50U	270	1690	80J	70	80	100U	100U	50U	100U	2020	104	189	98	
ML101-015	EWI-01	1	03/13/86	03/14/86	283	83U	83U	267	2150	100J	117J	183	100	167U	83U	167U	1800	87	81	144	
ML101-02	EWI-01	1	03/07/86	03/10/86	390	100U	100U	320	5100	190B	230B	250	200U	200U	100U	200U	390	85	117	92	
ML102-01	EWI-02	1	03/07/86	03/10/86	290	100U	100U	100U	1340	230B	250B	430	200U	200U	100U	200U	58J	86	108	89	
ML102-011	EWI-02	1	03/13/86	03/14/86	75J	125U	125U	125U	550	2850	250U	200	250U	250U	125U	250U	125J	99	112	90	
ML102-012	EWO-02	1	03/13/86	03/14/86	190	70	50U	20J	540	2300	100U	150	100U	100U	50U	100U	130	117	142	108	
ML103-01	EWI-02	1	03/07/86	03/10/86	160	125U	125U	125U	1600	340B	540B	580	250U	250U	125U	250U	125U	67	79	67	
ML104	EWI-01	1	02/28/86	03/03/86	500	15J	50U	400	4760	6180	150	240	100U	100U	50U	100U	3140	79	230	93	
ML105	TBLANK	1	02/28/86	03/03/86	125U	125U	125U	125U	250U	355	245J	380	250U	250U	125U	250U	280	125	127	132	
ML105-02	TBLANK	1	03/07/86	03/10/86	250	125U	125U	125U	250U	210JB	350B	340	250U	250U	125U	250U	125U	88	99	84	
ML106-01	CWI-03	1	03/07/86	03/10/86	230	125U	125U	125U	1030	270B	425B	510	250U	250U	125U	250U	125U	77	90	76	
ML200-01	TBLANK	1	03/13/86	03/14/86	50J	83U	83U	83U	167U	117J	100J	117	167U	167U	83U	167U	83U	76	79	65	
ML401-01	EWO-01	1	03/21/86	03/24/86	300	50U	50U	276	1940	72B	137B	87	100U	100U	50U	100U	140B	76	133	77	
ML401-02	EWO-01	1	03/21/86	03/24/86	340	50U	50U	330	2300	76B	86B	73	100U	100U	50U	100U	180B	98	166	91	
ML401-03	EWI-01	1	03/21/86	03/24/87	353	30J	50U	219	1450	100U	10B	85	61J	100U	69	100U	263	95	118	90	
ML401-04	EWI-02	1	03/21/86	03/24/86	234	50U	50U	50U	616	97B	100B	115	100U	100U	50U	100U	180	95	116	90	
ML401-05	EWO-02	1	03/21/86	03/24/86	90	50U	50U	50U	560	100B	280B	56	100U	100U	50U	100U	50U	92	121	84	
ML501-01	EWI-01	1	04/17/86	04/18/86	125U	125U	125U	430	730	350	600	220	250U	250U	125U	250U	1200	122	173	130	
ML501-02	EWO-01	1	04/17/86	04/22/86	50U	50U	50U	110	430	110	170	50U	100U	100U	50U	100U	200	99	164	110	
ML501-03	EWO-01	1	04/17/86	04/21/86	50U	50U	50U	350	1450	100U	660	70	100U	100U	50U	100U	410	98	231	105	
ML501-04	EWI-02	1	04/17/86	04/21/86	130	50U	50U	50U	190	100U	140	120	100U	100U	50U	100U	50U	71	39	85	
ML501-05	EWO-02	1	04/17/86	05/02/86	270	50U	50U	50U	280	140	270B	220	100U	100U	50U	100U	50U	87	111	88	
ML501-06	CWI-03	1	04/17/86	04/21/86	290	50U	50U	50U	260	100U	80	86	100U	100U	50U	100U	50U	98	155	99	
ML501-07	CWI-02	1	04/17/86	04/22/86	280	50U	50U	50U	97J	130	150	110	100U	100U	45J	100U	52	100	103	101	
ML601-01	EWO-01	1	04/23/86	04/25/86	50U	39J	50U	350	1700	81B	31JB	130B	100U	100U	50U	100U	410	71	145	89	
ML601-02	EWO-02	1	04/23/86	04/25/86	72	50U	50U	50U	100U	140B	100JB	50U	100U	100U	50U	100U	310	86	94	89	
ML601-03	CWI-03	1	04/23/86	04/25/86	50U	50U	50U	50U	100U	2600B	100U	160B	100U	100U	50U	100U	210	98	131	98	
ML601-04	CWI-02	1	04/23/86	04/24/86	270	50U	50U	50U	100U	67JB	70JB	50U	100U	100U	70	100U	130	78	96	85	
ML601-05	CWI-05	1	04/23/86	04/28/86	50U	50U	50U	50U	430	130B	170B	93	100U	100U	50U	100U	50U	128	141	121	
ML701-01	FLARE(N)	1	05/01/86	05/07/86	10300	150U	150U	210	8100	5300	160JB	150U	300U	300U	150U	300U	150U	91	126	93	
ML701-02	FLARE(S)	1	05/01/86	05/07/86	8300	150U	150U	240	5900	3100	380B	150U	300U	300U	150U	300U	150U	93	108	94	
ML701-03	FLARE(S)	1	05/01/86	05/07/86	10700B	270	150U	310	8900	1800	520B	150U	300U	300U	150U	300U	150U	93	136	89	
ML701-04	CWI-04	1	05/01/86	05/07/86	200	125U	125U	125U	250U	250B	175JB	125	250U	250U	100J	250U	310	83	110	85	
ML701-05	CWI-01	1	05/01/86	05/07/86	275	2880	125U	125U	63J	200B	250B	125	250U	250U	125U	250U	750	82	117	79	
ML87M-001	GP-87M	1	08/26/86	09/17/86	35B	TR	25U	25U	50U	120B	50U	80B	50U	50U	TR	50U	25U	53	74	66	
MLAA-001	CWAA-10	1	09/22/85	10/10/86	30	5	1U	1U	3U	20	9	1U	30B	20B	1U	3U	30B				
MLAA-002	CWAA-10	1	10/15/86	10/28/86	51	4	.14U	14	.14U	1.4U	33	.14U	13	5	1	1.4U	55	51	94	86	
MLAA-003	CWAA-10	1	10/22/86	11/07/86	86	6	1.10U	10	2.20U	23B	46	1.10U	15	28	6	2.20U	50	146	113	114	
MLCWV-901	CWI-09	1	06/05/86	06/11/86	55	50U	50U	50U	100U	100B	140B	160	100U	100U	50U	100U	53	84	87	82	
MLCW-01-05	CWO-01	1	11/11/86	12/02/86	70B	50	50U	50U	100U	110B	100U	50U	100U	100U	50U	100U	60	75	82	73	
MLCW-01-06	CWI-01	1	01/13/87	01/26/87	100B	70	50U	20J	100U	430B	100U	60B	100U	100U	50U	100U	210B	83	109	91	
MLCW-01-07	CWO-01	1	04/29/87	05/08/87	70B	70	50U	50U	50U	100B	100U	160B	100U	100U	80	100U	140B	94	101	91	
MLCW-01-08	CWI-01		06/02/87	06/05/87	65B	140B	5U	5U	10U	1100B	400B	200B	5U	10U	34.0	10.0B	112	63	84	84	
MLCW-02-05	CWO-02	1	11/06/86	11/17/86	70B	50U	50U	50U	100U	100B	100U	50U	100U	10J	20J	100U	50U	89	87	77	

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VOLATILE ORGANIC COMPOUNDS SUMMARY
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September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	TOLUENE	TRICHLOIII	TRICHLOIII2	TRICHLOROE	VINYLCHLOR	ACETONE	BUTANONE2	CARBONDISU	HEXANONE2	METHYLPENE2	STYRENE	VINYLACETA	XYLENE_TOT	DCHLIE_D4	BFB	TOLUENE_D6	OTHER
NLCW-02-06	CWI-02	1	01/13/87	01/26/87	110B	60B	50U	50U	100U	120B	100U	60B	100U	100U	70	100U	160B	92	91	93	
NLCW-02-07	CWO-02	1	04/27/87	05/07/87	12000B	35J	50U	50U	490	1900B	100U	210B	100U	100U	50U	100U	1400	101	106	104	
NLCW-02-08	CWI-02		06/02/87	06/05/87	42B	5U	5U	6.0J	10U	1120B	320B	114B	5U	10U	22.0	10U	32B	56	87	71	
NLCW-03-05	CWO-03	1	11/06/86	11/18/86	80B	50U	50U	50U	100U	160B	100U	60B	100U	70J	50U	100U	60U	92	85	104	
NLCW-03-06	CWI-03	1	01/13/87	01/27/87	90B	50U	50U	50U	100U	150B	100U	60B	100U	100U	50U	100U	160B	97	113	109	
NLCW-03-07	CWO-03	1	04/27/87	05/08/87	100B	50U	50U	50U	50U	100U	100U	50U	100U	100U	170	100U	310	99	113	110	
NLCW-03-08	CWI-03		06/02/87	06/05/87	72B	44B	5U	5U	10U	1640B	220B	200B	5U	10U	70	10U	160B	63%	77%	75%	
NLCW-03-08-LDUP	CWI-03		06/02/87	06/05/87	92B	36B	5U	18.0	10U	780B	220B	136B	5U	10U	68.0	38.0	62B	67	71	80	
NLCW-04-04	CWO-04	1	11/11/86	12/02/86	120B	60	50U	50U	100U	140B	30J	110B	100U	100U	50U	100U	50	85	78	77	
NLCW-04-05	CWI-04	1	01/13/87	01/26/87	120B	50	50U	10J	100U	120B	100U	60B	100U	100U	50U	100U	200B	70	101	96	
NLCW-04-06	CWO-04	1	04/27/87	05/08/87	90B	50U	50U	20J	50U	110	100U	107	100U	100U	130	100U	180	73	74	70	
NLCW-04-07	CWI-04		06/02/87	06/08/87	60B	60B	5U	5U	10U	22400B	840B	200B	5U	10U	48.0	10U	5U	102	83	95	
NLCW-05-06	CWO-05	1	11/06/86	11/17/86	70B	50U	50U	50U	100U	100B	100U	50U	100U	100U	30J	100U	50U	96	99	93	
NLCW-05-07	CWI-05	1	01/13/87	01/26/87	180B	60J	70U	70U	140U	140B	140U	70U	140U	140U	70	140U	350B	100	113	103	
NLCW-05-08	CWO-05	1	04/28/87	05/08/87	60B	40J	50U	10J	50U	70B	100U	140B	100U	100U	90	100U	160B	90	93	90	
NLCW-05-08,LDUP	CWO-05	1	04/28/87	05/11/87	90B	20J	50U	30J	50U	130B	100U	480B	100U	100U	120	100U	280B	128	131	133	
NLCW-05-09	CWI-05		06/02/87	06/05/87	52.0	59.0	5U	9.0J	10U	625B	300B	78.0B	5U	10U	38.5	10U	33.0B	77	76	185	
NLCW-05-09-LDUP	CWI-05		06/02/87	06/05/87	57.0B	88.0B	5U	8.5J	10U	263B	320B	121B	5U	10U	37.0	28.5B	44.0B	79	76	78	
NLCW-06-08	CWO-06	1	11/11/86	12/02/86	140B	50	50U	50U	450	100U	100U	200B	100U	100U	10J	100U	50U	87	117	101	
NLCW-06-09	CWI-06	1	01/13/87	01/27/87	80B	50U	50U	50U	100U	1200B	100U	50U	100U	100U	50U	100U	50U	74	133	77	
NLCW-06-10	CWO-06	1	04/29/87	05/08/87	110B	50U	50U	50U	50U	230	100U	150	100U	100U	110	100U	260	112	110	105	
NLCW-07-08	CWO-07	1	11/06/86	11/17/86	90B	50U	50U	50U	100U	100U	100U	50U	100U	100U	50U	100U	90B	85	103	88	
NLCW-07-09	CWI-07	1	01/13/87	01/26/87	100B	50U	50U	50U	100U	110B	100U	50B	100U	100U	50U	100U	240B	93	102	91	
NLCW-07-10	CWO-07	1	04/27/87	05/01/87	83B	340	50U	40J	50U	6000B	100U	120B	100U	100U	110	100U	150	109	52	100	
NLCW-07-11	CWI-07		06/02/87	06/05/87	118B	232B	5U	14J	10U	780B	150B	124B	5U	10U	87.0	2800B	655B	66	81	73	
NLCW-08-08	CWO-08	1	11/11/86	12/02/86	130B	60J	50U	10J	100U	100U	100U	90B	100U	100U	50U	100U	60U	88	67	69	
NLCW-08-09	CWI-08	1	01/13/87	01/27/87	70B	50U	50U	50U	100U	160B	100U	50U	100U	100U	50U	100U	50U	85	94	84	
NLCW-08-10	CWO-08	1	04/27/87	05/08/87	50B	50U	50U	10J	50U	70B	100U	120B	100U	100U	90	100U	150	73	80	67	
NLCW-08-11	CWI-08		06/02/87	06/05/87	49.0B	87.0	5U	28.0	10U	660B	310B	92B	5U	10U	44.5	13.5B	29.0B	69	76	80	
NLCW-09-07	CWO-09	1	11/11/86	12/03/86	90B	50B	50U	30J	100U	140B	190	100B	100U	100U	50U	100U	50U	101	89	79	
NLCW-09-08	CWI-09	1	01/13/87	01/27/87	80B	50U	50U	50U	100U	110B	100U	80B	100U	100U	50U	100U	120B	96	106	101	
NLCW-09-09	CWO-09	1	04/28/87	05/08/87	50B	50U	50U	10J	50U	80BJ	100U	50U	100U	100U	100	100U	110	78	83	69	
NLCW-09-10	CWI-09		06/03/87	06/11/87	5U	50B	55U	5U	10U	13000B	10U	265B	5U	10U	5U	10U	5U	105	99	96	
NLCW-1002	CWO-01	1	08/26/86	09/17/86	50B	60B	25U	25U	40J	200B	95	110B	50U	50U	25U	50U	25U	72	92	137	
NLCW-1003	CWO-01	1	09/30/86	10/16/86	140B	130	50U	10J	100U	90JB	100U	60B	100U	50J	80	100U	250B	99	134	99	
NLCW-1004	CWO-01	1	10/22/86	10/29/86	70B	90	50U	20J	10U	100B	100U	50B	100U	100U	50U	500U	210	80	104	76	
NLCW-101	CWI-10	1	06/05/86	06/06/86	7B	50U	50U	50U	450	7BB	160B	110	100U	100U	50U	100U	7B	84	96	83	
NLCW-102	CWO-10	1	07/28/86	08/05/86	50U	50U	50U	50U	100U	100U	100U	50U	100U	100U	7B	100U	50U				
NLCW-103	CWI-10	1	07/25/86	08/05/86	125U	125U	125U	125U	250U	250U	250U	125U	250U	250U	125U	250U	125U				
NLCW-104	CWO-10	1	08/26/86	09/16/86	28B	25U	25U	25U	50U	70	50U	56	50U	50U	25U	50U	25U	56	76	62	
NLCW-105	CWO-10	1	09/15/86	10/02/86	180B	50U	50U	50U	100U	4000B	100U	50U	100U	20J	20J	100U	50U				
NLCW-106	CWO-10	1	10/15/86	10/23/86	300B	20J	50U	50U	120	190B	100U	50U	100U	210	50U	100U	50U	105	112	106	
NLCW-10-07	CWO-10	1	11/06/86	11/17/86	80B	50U	50U	10J	40J	140B	100U	50B	100U	160	30J	100U	50U	103	108	109	
NLCW-10-08	CWI-10	1	01/13/87	01/27/87	70B	50U	50U	50U	100U	180B	100U	50U	100U	100U	110	100U	150B	82	97	84	
NLCW-10-09	CWO-10	1	04/27/87	05/08/87	90B	50U	50U	10J	50U	100U	100U	50U	100U	100U	130	100U	210	108	118	105	
NLCW-10-10	CWI-10		06/03/87	06/08/87	60B	30B	5U	5U	10U	10U	820B	200B	5U	10U	5U	140B	80.0	99	103	96	

Data submitted to Ecology by Black & Veatch
September 14, 1987
File name : VOC

MIDWAY LANDFILL RE[illegible] INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 3 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	TOLUENE	TRICHLO111	TRICHLO112	TRICHLOROE	VINYLCHLOR	ACETONE	BUTANONE2	CARBONDISU	HEXANONE2	METHYLPENT2	STYRENE	VINYLACETA	XYLENE_TOT	DCHL12_D4	BFB	TOLUENE_D6	OWNER
MLCW-111	CWI-11	1	06/05/86	06/11/86	120	50U	50U	TR	100U	TRB	120B	97	100U	100U	92	100U	69	105	127	111	
MLCW-112	CWO-11	1	07/25/86	08/05/86	50U	50U	50U	50U	100U	100U	200U	50U	100U	100U	TR	100U	50U				
MLCW-113	CWI-11	1	07/25/86	08/05/86	125U	125U	125U	125U	250U	1500B	250U	125U	250U	250U	TR	250U	125U				
MLCW-114	CWO-11	1	08/26/86	09/15/86	100B	50U	50U	50U	100U	200B	100U	100	100U	100U	TR	100U	50U	55	80	72	
MLCW-115	CWO-11	1	09/15/86	10/02/86	140B	50U	50U	70	100U	760B	100U	30J	100U	130U	20J	100U	50U				
MLCW-116	CWO-11	1	10/15/86	10/23/86	170B	85U	85U	85B	17U	1580B	40J	85U	470B	400	40J	170U	85U	72	94	66	
MLCW-11-07	CWO-11	1	11/06/86	11/17/86	100	50B	50U	110	80J	1400B	100U	50U	100U	1600	80	100U	140B	79	130	84	
MLCW-121	CWI-12	1	06/05/86	06/11/86	125U	125U	125U	125U	250U	TRB	310B	125U	250U	250U	125U	250U	125U	89	114	97	
MLCW-122	CWO-12	1	07/25/86	08/05/86	50U	50U	50U	50U	100U	100U	100U	50U	100U	100U	50U	100U	50U				
MLCW-123	CWI-12	1	07/25/86	08/05/86	50U	50U	50U	50U	100U	4200	400	50U	100U	100U	50U	100U	50U				
MLCW-124	CWO-12	1	09/05/86	09/23/86	60B	50U	50U	50U	100U	130B	100U	190B	100U	100U	20J	100U	70	89	90	95	
MLCW-125	CWO-12	1	09/30/86	10/17/86	70B	30J	50U	50U	100U	100B	100U	70B	100U	100U	18J	100U	10J	101	67	89	
MLCW-126	CWO-12	1	10/22/86	10/30/86	80JB	20J	85U	85U	170U	270B	170U	100B	170U	170U	80J	170U	80B	78	96	77	
MLCW-12-07	CWO-12	1	11/11/86	12/03/86	80B	80B	50U	50U	100U	270B	100U	210B	100U	100U	50U	100U	50U	67	88	75	
MLCW-12-08	CWI-12	1	01/13/87	01/23/87	290B	50U	50U	50U	100U	100U	100U	50U	100U	100U	50U	100U	680B	65	75	65	
MLCW-12-09	CWO-12	1	04/27/87	05/08/87	70B	50U	50U	50U	50U	160	100U	120	100U	100U	90	100U	130	74	72	63	
MLCW-12-10	CWI-12		06/02/87	06/05/87	46B	22B	5U	5U	10U	710B	288B	100B	5U	10U	25.2	20.0	16B	64	88	70	
MLCW-131	CWO-13	1	10/15/86	10/23/86	110B	50U	50U	30JB	100U	100U	100U	50U	100U	100U	60	100U	60	66	95	59	
MLCW-13-02	CWO-13	1	11/06/86	11/17/86	80B	50U	50U	10J	100U	900J	100U	50U	100U	50J	50U	100U	90B	88	98	88	
MLCW-13-03	CWI-13	1	01/13/87	01/23/87	230B	50U	50U	50U	100U	1100B	100U	50U	100U	100U	60	100U	520B	62	66	78	
MLCW-13-04	CWO-13	1	04/27/87	05/08/87	125U	630	125U	125U	3100	75000B	250U	125U	250U	250U	148	250U	350	92	112	99	
MLCW-13-05	CWI-13		06/03/87	06/10/87	5U	160B	5U	17.0	730	10U	10U	240B	5U	10U	5U	1800B	5U	99	70	114	
MLCW-141	CWO-14	1	10/15/86	10/23/86	300B	50U	50U	50U	100U	240B	160	120B	100U	100U	40J	100U	80	123	135	108	
MLCW-14-02	CWO-14	1	11/06/86	12/03/86	140B	50U	50U	20J	100U	260B	100U	120B	100U	100U	50U	100U	40J	91	91	92	
MLCW-14-03	CWI-14	1	01/13/87	01/27/87	90B	50U	50U	50U	100U	130B	100U	70B	100U	100U	50U	100U	130B	94	107	102	
MLCW-151	CWO-15	1	10/15/86	10/23/86	180B	40J	50U	100B	100U	240B	70J	110U	100U	20J	140	100U	120	120	140	115	
MLCW-15-02	CWO-15	1	11/06/86	11/26/86	130B	20J	50U	20J	100U	100U	180J	50U	100U	100U	40J	100U	220B	109	111	100	
MLCW-15-03	CWI-15	1	01/13/87	01/23/87	280B	50B	50U	50U	100U	110B	100U	50U	100U	100U	80	100U	60B	72	80	76	
MLCW-202	CWO-02	1	09/05/86	09/24/86	TRB	62.5U	62.5U	62.5U	125U	125U	125U	75B	125U	125U	TR	125U	TR	83	91	86	
MLCW-203	CWO-02	1	09/16/86	10/03/86	190B	30JB	50U	60U	100U	210B	200B	60B	100U	100U	50U	100U	40J				
MLCW-204	CWO-02	1	10/15/86	10/29/86	180B	100J	125U	1100	250U	250U	250U	250B	250U	250U	75J	250U	140	79	84	75	
MLCW-302	CWO-03	1	09/05/86	09/24/86	36B	25U	25U	25U	55	95B	50U	80B	50U	50U	TR	50U	45	85	96	90	
MLCW-303	CWO-03	1	09/15/86	10/02/86	170B	50U	50U	50U	100U	200B	100U	70B	100U	100U	50U	100U	50U				
MLCW-304	CWO-03	1	10/15/86	10/24/86	60B	50U	50U	190	20	110B	100U	50U	100U	100U	20JB	100U	50U	89	76	88	
MLCW-402	CWO-04	1	09/30/86	10/17/86	70B	60	50U	50U	100U	90JB	100U	90B	100U	80J	20J	100U	50U	102	107	92	
MLCW-403	CWO-04	1	10/22/86	10/29/86	80B	150	50U	20J	100U	100B	100U	50U	100U	100U	40J	100U	72	66	55	56	
MLCW-502	CWO-05	1	08/26/86	09/17/86	60B	TR	25U	TR	50U	200B	50U	170B	50U	50U	40	50U	25U	72	108	108	
MLCW-503	CWO-05	1	08/26/86	09/16/86	110B	25U	25U	25U	340	320	50U	450	50U	50U	25U	50U	25U	66	98	128	
MLCW-504	CWO-05	1	09/15/86	10/02/86	200B	20J	50U	50U	100U	570B	100U	50U	100U	30J	20J	100U	10J				
MLCW-505	CWO-05	1	10/15/86	10/23/86	200B	17J	85U	85U	170U	170U	170U	85U	170U	68J	40J	170U	85U	92	101	86	
MLCW-601	CWI-06	1	06/04/86	06/10/86	46	25U	25U	TR	50U	60B	160B	35	50U	50U	TR	50U	140	82	95	84	
MLCW-602	CWO-06	1	06/04/86	06/10/86	TR	125U	125U	125U	TR	250B	1200B	125U	250U	250U	125U	250U	120	95	103	96	
MLCW-603	CWO-06	1	07/01/86	07/03/86	160B	125U	125U	125U	250U	250U	250U	125U	250U	250U	125U	250U	160				
MLCW-604	CWI-06	1	07/01/86	07/03/86	60B	50U	50U	50U	220	640B	100U	22	100U	100U	50U	100U	TR				
MLCW-605	CWO-06	1	09/05/86	09/24/86	50U	50U	50U	50U	1400	100U	100U	180	1400	100U	50U	100U	65	87	96	103	
MLCW-606	CWO-06	1	09/30/86	10/17/86	70B	50U	50U	50U	270	30JB	100U	60B	100U	530	20J	100U	40J	92	105	81	

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MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
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September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	TOLUENE	TRICHLOIII	TRICHLOIII2	TRICHLOROE	VINYLCHLOR	ACETONE	BUTANONE2	CARBONDISU	HEXANONE2	ETHYLPRN2	STYRENE	VINYLACETA	XYLENE_TOT	DCHLIE_D4	BFB	TOLUENE_D6	OWNER
MLCW-S07	CWO-06	1	10/22/86	10/30/86	60B	20J	50U	20JB	270	100U	100U	50U	100	160B	50U	100U	50B	73	109	69	
MLCW-T01	CWI-07	1	06/04/86	06/10/86	96	237	50U	TR	TR	1800B	3870B	97	100U	100U	50U	100U	185	108	124	113	
MLCW-T02	CWO-07	1	07/25/86	08/05/86	50U	50U	50U	50U	100U	80B	100U	50U	100U	100U	50U	100U	50U				
MLCW-T03	CWI-07	1	07/25/86	08/05/86	50U	80	50U	50U	100U	200B	100U	50U	100U	100U	50U	100U	50U				
MLCW-T04	CWO-07	1	08/26/86	09/15/86	100B	50U	50U	50U	100U	TRB	100U	110	100U	100U	TR	100U	50U	53	68	62	
MLCW-T05	CWI-07	1	08/26/86	09/16/86	65B	TR	25U	25U	50U	95	50U	140	50U	50U	200	50U	35	68	90	101	
MLCW-T06	CWO-07	1	09/15/86	10/03/86	50B	50U	50U	50U	100U	1100B	450	50U	100U	100U	50U	100U	50U				
MLCW-T07	CWO-07	1	10/15/86	10/23/86	236B	50U	50U	50U	100U	1600B	100U	70B	100U	100U	40J	100U	60	113	115	118	
MLCW-B01	CWI-08	1	06/04/86	06/10/86	52	50U	50U	TR	100U	100U	371B	58	100U	100U	50U	100U	96	91	111	97	
MLCW-B02	CWO-08	1	07/01/86	07/03/86	TRB	125U	125U	125U	250U	250U	250U	TR	250U	250U	125U	250U	TR				
MLCW-B02	CWO-08	1	07/25/86	08/06/86	50U	50U	50U	50U	100U	100U	100U	50U	100U	100U	25	100U	50U				
MLCW-B03	CWI-08	1	07/25/86	08/05/86	50U	50U	50U	50U	100U	100U	100U	50U	100U	100U	35	100U	50U				
MLCW-B04	CWO-08	1	08/26/86	09/16/86	42B	25U	25U	25U	50U	88	50U	110	50U	50U	25U	50U	TR	54	72	60	
MLCW-B05	CWO-08	1	09/05/86	09/23/86	40B	25U	25U	25U	50U	75B	TR	115B	50U	50U	25TR	50U	65	85	85	86	
MLCW-B06	CWO-08	1	09/30/86	10/17/86	60B	20J	50U	50U	100U	50JB	100U	80B	100U	100U	20J	100U	40J	119	93	89	
MLCW-B07	CWO-08	1	10/22/86	10/29/86	20JB	50U	50U	10J	100U	100U	100U	50U	100U	100U	10J	100U	40J	67	78	54	
MLCW-B07 (DUP)			10/22/86	10/30/86	50B	50U	50U	50U	100U	100U	100U	50U	100U	100U	20J	100U	40JB	73	101	83	
MLCW-S01	CWI-09	1	06/05/86	06/11/86	125U	125U	125U	125U	250U	TRB	TRB	TR	250U	250U	125U	250U	125U	86	90	84	
MLCW-S02	CWO-09	1	07/25/86	08/06/86	50U	50U	50U	50U	100U	100U	100U	50U	100U	100U	32	100U	50U				
MLCW-S03	CWI-09	1	07/26/86	08/06/86	50U	50U	50U	50U	100U	100U	100U	50U	100U	100U	TR	100U	50U				
MLCW-S04	CWO-09	1	09/05/86	09/23/86	50B	25U	25U	25U	50U	100B	50U	220B	50U	50U	TR	50U	30	104	100	111	
MLCW-S05	CWO-09	1	09/30/86	10/17/86	190JB	50J	125U	125U	250U	80JB	250U	40JB	250U	250U	125U	250U	25J	108	82	76	
MLCW-S06	CWO-09	1	10/22/86	11/05/86	60B	50U	50U	50U	100U	150B	40J	50U	100U	40JU	50U	100U	70	67	88	66	
MLRWV-01-33	RWI-01	1	04/28/87	05/08/87	30BJ	40J	50U	50U	50U	60BJ	100U	120B	100U	100U	120	100U	980B	92	109	41	
MLRWV-116	RWI-01	1	09/30/86	10/16/86	80B	10J	50U	80	50J	90JB	90J	40JB	100U	90J	50U	100U	470B	88	120	81	
MLRWV-118	RWI-01	1	10/15/86	10/24/86	190B	70B	10U	1200	70	100U	100U	10U	TR	100U	10U	100U	450B	106	112	86	
MLRW-01-22	RWI-01	1	11/06/86	11/18/86	70	10U	10U	90	10U	130B	100U	40	100U	TR	10U	100U	550	92	104	85	
MLRW-01-23	RWO-01	1	11/06/86	11/18/86	80B	50U	50U	20J	60J	610B	100U	70B	100U	50J	40J	100U	500	84	97	82	
MLRW-01-24	RWI-01	1	11/11/86	12/02/86	70B	60	50U	50U	100U	110B	100U	120B	100U	100U	50U	100U	160	75	75	66	
MLRW-01-25	RWO-01	1	11/11/86	12/02/86	70B	30J	50U	50U	100U	100U	100U	50U	100U	100U	50U	100U	50U	82	95	93	
MLRW-01-26	RWI-01	1	01/13/87	01/26/87	120B	50U	50U	200	70J	100U	100U	60B	100U	100U	50U	100U	900B	87	110	89	
MLRW-01-27	RWO-01	1	01/13/87	01/26/87	120B	30J	50U	260	100U	630B	100U	90B	100U	130	50U	100U	220B	64	155	90	
MLRW-01-27(DUP)	RWO-01	1	01/13/87	01/26/87	160B	40J	50U	340	100U	1700B	100U	200B	100U	180	50U	100U	290B	78	199	111	
MLRW-01-28	RWI-01	1	03/12/87	03/24/87	99B	38	10U	190	10U	240B	100U	10U	100U	100U	10U	100U	200B	102	130	124	
MLRW-01-29	RWI-01	1	03/12/87	03/25/87	73B	29	10U	130	10U	120B	100U	10U	100U	100U	10U	100U	430B	96	125	89	
MLRW-01-30	RWO-01	1	03/12/87	03/25/87	58B	33	10U	110	10U	150B	100U	10U	100U	100U	10U	100U	230B	63	106	63	
MLRW-01-31	RWI-01	1	04/28/87	05/08/87	60B	40	50U	60	50U	100U	100U	83B	100U	100U	150	100U	300B	98	101	91	
MLRW-01-32	RWO-01	1	04/28/87	05/08/87	580B	250U	250U	250U	250U	600B	500U	250B	500U	500U	250U	500U	450B	85	83	79	
MLRW-01-34	RWI-01		06/02/87	06/08/87	70B	27B	5U	90.0	10U	630B	380B	180B	5U	10U	70.0	34.0B	60B	107	106	93	
MLRW-01-35	RWO-01		06/02/87	06/05/87	63.0B	60B	5U	180	10U	970B	400B	90B	5U	50U	5U	32.0B	170B	59	91	76	
MLRW-02-22	RWI-02	1	11/12/86	12/04/86	90B	110	10U	50U	100U	130B	100U	110B	100U	100U	20J	100U	50U	111	106	73	
MLRW-02-23	RWO-02	1	11/12/86		130B	50U	50U	20J	100U	130B	100U	200B	100U	100U	50U	100U	50U	125	113	80	
MLRW-02-24	RWI-02	1	11/11/86	12/02/86	70B	20J	50U	10J	100U	100U	100U	50U	100U	100U	50U	100U	50U	50	75	66	
MLRW-02-25	RWO-02	1	11/11/86	12/02/86	100B	20J	50U	10J	100U	250B	110	50U	100U	100U	50U	100U	50U	83	97	97	
MLRW-02-26	RWI-02	1	01/13/87	01/26/87	100B	200	50U	50U	100U	1900B	100U	50U	100U	70J	50U	100U	150B	60	96	85	
MLRW-02-27	RWO-02	1	01/13/87	01/27/87	60B	50U	50U	50U	100U	260B	100U	50B	100U	100U	50U	100U	110B	85	91	82	

Data submitted to Ecology by Black & Veatch
September 1[illegible]
File name = [illegible]

MIDWAY LANDFILL REM[illegible] VESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
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September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	TOLUENE	TRICHLOEE	TRICHLOEE	TRICHLOROE	VINYLCHLOR	ACETONE	BUTANONE2	CARBONDISU	HEXANONE2	METHLPENE	STYRENE	VINYLACETA	ETLENE_TOT	DCHLE_D4	BFB	TOLUENE_D6	OWNER
MLEW-02-28	EWI-02		03/12/87	03/25/87	44B	20	10U	10U	10U	110B	100U	10U	100U	100U	25B	100U	28B	81	92	76	
MLEW-02-28,LDUP	EWI-02	1	03/12/87	03/25/87	68B	30	10U	10	10U	104B	100U	10U	100U	100U	29	100U	28BJ	87	86	78	
MLEW-02-29	EWO-02		03/12/87	03/24/87	79B	15	10U	14	10U	130B	100U	10U	100U	100U	64B	100U	42B	79	87	78	
MLEW-02-30	EWI-02	1	04/28/87	05/11/87	60B	40J	50U	20J	50U	90BJ	80J	490B	100U	100U	100	100U	100B	95	99	95	
MLEW-02-31	EWO-02	1	04/28/87	05/08/87	130BJ	250U	250U	250U	250U	500U	500U	250U	500U	500U	160J	500U	400B	81	85	75	
MLEW-02-31	EWI-02		06/02/87	06/05/87	54B	44B	5U	5U	10U	1100B	114B	150B	5U	10U	50.0	10U	33B	98	98	94	
MLEW-02-32	EWO-02		06/02/87	06/05/87	5U	36.5B	5U	5U	10U	10U	10U	6U	5U	10U	5U	220B	19B	61	73	63	
MLEW-109	EWI-01	1	05/23/86	05/27/86	220	100U	100U	240	3500	TRB	TRB	280	200U	200U	100U	200U	1200	100	135	100	
MLEW-110	EWI-01	1	06/18/86	06/23/86	160	TR	125U	320	900	140B	180	290	250U	250U	125U	250U	1300				
MLEW-111	EWI-01	1	08/07/86	08/22/86	130B	50U	50U	280	400	100U	180	320B	100U	100U	50U	100U	610				
MLEW-112	EWI-01	1	05/05/86	05/24/86	50B	50U	50U	120	240	100U	100	190B	100U	100U	30J	100U	506	85	105	95	
MLEW-113	EWO-01	1	05/05/86	05/24/86	70B	50U	50U	50U	100U	120B	TRB	220B	100U	100U	60U	100U	70	81	96	96	
MLEW-114	EWI-01	1	08/18/86	10/14/86	100B	TRB	84U	TR	TR	420B	180B	170B	TR	167U	TR	167U	270				
MLEW-115	EWO-01	1	09/18/86	10/16/86	150B	125U	125U	125U	60J	150J	250U	230B	250U	250U	125U	250U	78J				
MLEW-116	EWI-01	1	09/30/86	10/16/86	220B	67J	83.5U	33J	167	130JB	50J	84JB	167U	170	67J	167U	320B	101	97	122	
MLEW-117	EWO-01	1	09/30/86	10/17/86	60B	60	50U	50U	100U	120B	100U	110B	100U	100U	20J	100U	20J	110	99	93	
MLEW-118	EWI-01	1	10/15/86	10/24/86	200B	450B	125U	6600	25U	250B	250U	125U	250U	50J	150B	250U	270B	106	114	82	
MLEW-119	EWO-01	1	10/15/86	10/24/86	50U	10JB	50U	300	60J	100B	100U	50U	100U	100U	60B	100U	50B	87	108	78	
MLEW-120	EWI-01	1	10/22/86	11/05/86	90B	50U	50U	90	40J	100U	100U	50U	100U	90J	50U	100U	500	68	92	66	
MLEW-121	EWO-01	1	10/22/86	11/05/86	95JB	125U	125U	125U	250U	250U	250U	200B	250U	250U	125U	250U	110J	79	86	77	
MLEW-12-02			11/06/86	11/18/86	90B	50U	50U	90	100U	200B	100U	60B	100U	60J	50U	100U	550	92	85	106	
MLEW-209	EWI-02	1	05/23/86	05/27/86	120	100U	100U	100U	220	200B	200B	180	200U	200U	100U	200U	320	82	102	81	
MLEW-210	EWI-02	1	06/18/86	06/30/86	TR	125U	125U	TR	TR	380	250U	200	250U	250U	TR	250U	125U				
MLEW-211	EWI-02	1	08/07/86	08/22/86	TRB	50U	50U	50U	100U	100U	100U	290B	100U	100U	50U	100U	TR				
MLEW-212	EWI-02	1	09/05/86	09/23/86	50B	50U	50U	50U	100U	100U	100U	130B	100U	100U	TR	100U	60	91	96	98	
MLEW-213	EWO-02	1	09/05/86	09/26/86	50B	50U	50U	50U	100U	100B	100U	120B	100U	100U	TR	100U	60	88	99	94	
MLEW-214	EWI-02	1	09/15/86	10/02/86	60B	30J	50U	50U	100U	120B	100U	80B	100U	100U	50U	100U	50U				
MLEW-215	EWO-02	1	09/15/86	10/02/86	30J	50U	50U	50U	100U	100B	100U	70B	100U	100U	50U	100U	20J				
MLEW-216	EWI-02	1	10/01/86	10/17/86	70B	50U	50U	50U	100U	110B	100U	100B	100U	70J	20J	100U	50U	106	112	95	
MLEW-217	EWO-02	1	10/01/86	10/16/86	110B	50U	50U	50U	100U	100B	40J	40JB	100U	50J	20J	100U	40JB	96	102	100	
MLEW-218	EWI-02	1	10/15/86	10/24/86	20BJ	30JB	50U	500	100U	100U	100U	50U	100U	100U	20JB	100U	60JB	96	121	86	
MLEW-219	EWO-02	1	10/15/86	10/24/86	50U	50U	50U	280	100U	100U	100U	50U	100U	100U	20JB	100U	20JB	71	95	68	
MLEW-220	EWI-02	1	10/22/86	10/29/86	40B	30J	50U	30J	100U	100U	100U	50U	100U	100U	20J	100U	50	63	72	56	
MLEW-221	EWO-02	1	10/22/86	10/30/86	80B	25J	50U	30JB	100U	200B	100U	80B	100U	100U	40J	100U	60B	86	117	86	
MLEW-V118			10/15/86	10/24/86	190B	70B	50U	1200	70J	160B	100U	80B	80J	100U	50U	100U	460B	106	112	86	
MLPB-001	TBLANK	1	07/25/86	07/28/86	50U	50U	50U	50U	100U	100U	100U	50U	100U	100U	TR	100U	50U				
MLFV-S-03	FLARE(S)	1	04/28/87	05/11/87	4500B	200J	250U	200J	5700	500U	500U	370B	500U	500U	250U	500U	20000B	89	102	82	
MLFV-S-05	FLARE(S)		06/02/87	06/09/87	66000B	130B	5U	5U	4200	360B	88B	220B	5U	10U	5U	840B	12500	80	88	112	
MLF-M-02	FLARE(M)	1	04/28/87	05/07/87	30000B	250U	250U	250U	15000	17000B	500U	1100B	500U	500U	250U	500U	46000	82	117	80	
MLF-M-03	FLARE(M)		06/02/87	06/10/87	13000B	1600B	5U	5U	17000	262000B	1900B	1200B	5U	10U	5U	10U	12000	108	85	96	
MLF-S-02	FLARE(S)	1	04/28/87	05/11/87	6800B	240J	250U	300	10000	16000B	500U	860B	500U	500U	250U	500U	25000B	102	119	99	
MLF-S-04	FLARE(S)		06/02/87	06/09/87	4600B	5U	5U	5U	4200	15000B	7600B	5U	5U	10U	5U	24000B	48000B	85	93	96	
MLF-S-04-LDUP	FLARE(S)		06/02/87	06/09/87	3700B	260B	5U	320	3800	12000B	1440B	5U	5U	10U	220	10U	19000	84%	99%	64%	
MLLF-102	FLARE(M)	1	06/18/86	06/23/86	4600	500U	500U	TR	1800	TRB	TR	500U	1000U	1000U	500U	1000U	16000				
MLLF-202	FLARE(S)	1	06/18/86	06/23/86	12000	TR	500U	TR	4600	5500	1600	500U	900	1000U	500U	1000U	51000				
MLTB-001	TBLANK	1	08/26/86	09/16/86	69B	25U	25U	25U	50U	94	50U	140	50U	50U	TR	50U	25U	85	91	75	

Data submitted to Ecology by Black & Veatch
September 14, 1987
File name : VOC

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	TOLUENE	TRICHLOIII	TRICHLOIII2	TRICHLOROE	VINYLCHLOR	ACETONE	BUTANONE2	CARBONDISU	BRMANONE2	MTHYL4PENT2	STYRENE	VINYLACETA	XYLENE_TOT	DCHLE2_D4	BFB	TOLUENE_D6	OWNER
MLTB-002	TBLANK	1	09/05/86	09/23/86	30B	25U	25U	25U	50U	55B	50U	90B	50U	50U	20J	50U	50	88	91	93	
MLTB-003	TBLANK	1	09/22/86	10/13/86	2B	1U	1U	1U	3U	5B	8	1U	3B	TRB	1U	3U	2B				
MLTB-005	TBLANK	1	01/13/87	01/26/87	90B	90	50U	50U	100U	150B	100U	50U	100U	100U	40J	100U	170B	88	93	89	
MLTB-006	TBLANK	1	04/28/87	05/08/87	80B	50U	50U	10J	50U	220	100U	50U	100U	100U	110	100U	200	106	95	100	
MLTB-007	TB-007		06/03/87	06/11/87	5U	5U	5U	5U	10U	6700B	10U	160B	5U	10U	5U	10U	5U	97	98	99	
ML-02001	GP-02D	1	05/08/86	05/12/86	600	166U	166U	166U	333U	400B	500B	167J	333U	333U	166U	333U	260	74	88	78	
ML-10001	GP-10D	1	05/08/86	05/12/86	450	125U	125U	125U	250U	325B	425B	175	250U	250U	125U	250U	2200	74	86	72	
ML-17001	GP-17D	1	05/08/86	05/12/86	450	125U	125U	125U	250U	250U	200JB	125	250U	250U	125U	250U	220	87	106	82	
ML-37001	GP-37D	1	05/08/86	05/12/86	770	110	50U	50U	2400	100U	115B	40J	100U	100U	50U	100U	115	107	125	97	
ML-44002	GP-44D	1	05/13/86	05/14/86	110	100U	100U	100U	14700	680B	420B	40J	200U	200U	100U	200U	120	78	98	91	
ML-44003	GP-44D	1	05/13/86	05/14/86	100	100U	100U	100U	22500	640B	700B	60J	200U	200U	100U	200U	100	87	87	85	
ML-45001	GP-45D	1	05/13/86	05/14/86	140	100U	100U	100U	240	180B	300B	100	200U	200U	100U	200U	220	69	71	64	
ML-63001	GP-63D	1	05/08/86	05/12/86	200	125U	125U	125U	250U	300B	450B	150	250U	250U	125U	250U	530	68	86	61	
ML-79001	GP-79D	1	05/13/86	05/14/86	200	80J	100U	100U	200U	220B	210B	100U	200U	200U	100U	200U	100U	93	106	97	
ML-81001	GP-81D	1	05/13/86	05/14/86	260	100U	100U	100U	200U	200U	320B	160	160J	200U	100U	200U	100	119	88	86	
REAGENT BLANK	RBLANK			11/17/86	25	20J	25U	25U	50U	40J	30J	15J	10J	50U	25U	50U	15J	97	90	91	
REAGENT BLANK	RBLANK			11/26/86	50	50U	50U	50U	100U	160B	120	50U	100U	100U	50U	100U	90	88	102	101	
REAGENT BLANK	RBLANK			10/14/86	90	50U	50U	50U	100U	170	80J	60	100U	100U	50U	100U	50U				
REAGENT BLANK	RBLANK			10/16/86	15J	25U	25U	25U	50U	25J	50U	10J	50U	50U	25U	50U	10J	90	106	80	
REAGENT BLANK	RBLANK			12/02/86	26J	50U	50U	50U	100U	70J	100U	54	100U	100U	50U	100U	50U	97	104	98	
REAGENT BLANK		1		10/29/86	15J	25U	25U	25U	50U	40J	20J	25J	50U	10J	25U	50U	25U	74	80	67	
REAGENT BLANK		1		12/05/86	64	50U	50U	50U	100U	130	100U	120	100U	100U	50J	100U	50U	84	82	83	
REAGENT BLANK	RBLANK			11/18/86	10J	25U	25U	25U	50U	35J	5J	10J	60U	50U	25U	50U	25U	82	95	95	
REAGENT BLANK	RBLANK			10/23/86	20J	25U	25U	25U	50U	90	50U	160	10J	50U	25U	50U	25U	106	109	111	
REAGENT BLANK	RBLANK			10/17/86	15J	25U	25U	25U	50U	25J	50U	15J	50U	50U	25U	50U	25U	112	74	82	
REAGENT BLANK				12/03/86	50	20J	50U	50U	100U	260	100U	90	100U	100U	50U	100U	50U	83	88	93	
REAGENT BLANK	RBLANK			10/03/86	25	10J	25U	25U	50U	35J	50U	75U	50U	50U	25U	50U	25U				
REAGENT BLANK				12/04/86	40J	20J	50U	50U	100U	180	130	60	100U	100U	50U	100U	180	91	65	64	
REAGENT BLANK	RBLANK			10/29/86	15J	25U	25U	25U	50U	40J	20J	25	50U	10J	25U	50U	25U	74	80	67	
REAGENT BLANK	RBLANK			11/05/86	15J	5J	25U	25U	50U	55	50U	30J	50U	50U	25U	25U	25U	86	93	83	
REAGENT BLANK	RBLANK			11/07/86	25U	25U	25U	25U	50U	120	50U	25U	25U	50U	25U	50U	25U	98	131	92	
REAGENT BLANK	RBLANK			10/02/86	20J	25U	25U	25U	50U	100	50U	40	50U	50U	25U	50U	25U				
REAGENT BLANK	RBLANK		05/27/86	05/27/86	5U	5U	5U	5U	10U	10TR	10TR	5U	10U	10U	5U	10U	5	103	103	100	
REAGENT BLANK	RBLANK		06/10/86	06/10/86	5U	5U	5U	5U	10U	10TR	10TR	5U	10U	10U	5U	10TR	5U	93	102	101	
REAGENT BLANK	RBLANK		06/11/86	06/11/86	5U	5U	5U	5U	10U	10TR	11	5U	10U	10U	5U	10U	5U	88	100	101	
REAGENT BLANK	RBLANK		06/23/86	06/23/86	5U	5U	5U	5U	10U	10TR	10U	5U	10U	10U	5U	10U	5U				
REAGENT BLANK	RBLANK		07/03/86	07/03/86	1TR	6U	5U	5U	10U	3TR	10U	5U	10U	10U	5U	10U	5U				
REAGENT BLANK	RBLANK		08/22/86	08/22/86	70	50U	50U	50U	100U	100U	100U	70U	100U	100U	50U	100U	50U				
REAGENT BLANK	RBLANK		09/24/86	09/24/86	25TR	25	25U	25U	50U	50TR	50TR	25TR	50U	50U	25U	50U	25U	88	98	97	
REAGENT BLANK	RBLANK		10/10/86	10/10/86	5U	5U	5U	5U	10U	10U	10U	5U	TR	TR	TR	5U	TR				
REAGENT BLANK	RBLANK		10/13/86	10/13/86	TR	5U	TR	5U	10U	TR	10U	5U	TR	TR	TR	10U	TR				
REAGENT BLANK	RBLANK		10/16/86	10/16/86	TR	25U	25U	25U	50U	TR	50U	TR	50U	50U	25U	50U	TR	90	106	80	
REAGENT BLANK	RBLANK		10/24/86	10/24/86	20J	5J	25U	25U	50U	65	50U	50	50U	50U	5J	50U	10J	113	93	102	
REAGENT BLANK	RBLANK		10/28/86	10/28/86	3	1U	1U	1U	1U	TR	TR	1U	TR	TR	1	10U	1	83	101	108	
REAGENT BLANK	RBLANK		10/30/86	10/30/86	15J	25U	25U	25U	50U	35J	10J	15J	50U	10J	25U	50U	5J	84	112	113	
REAGENT BLANK	RBLANK		01/23/87	01/23/87	100	30J	50U	50U	100U	90J	100U	150	100U	100U	50U	100U	300	96	95	97	

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September 18, 1987
File name : VO

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 3 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	TOLUENE	TRICHLOIII	TRICHLOIII	TRICHLOROE	VINYLCHLOR	ACETONE	BUTANONE2	CARBONDISU	HEXANONE2	METHYL4PEN2	STYRENE	VINYLACETA	XYLENE_TOT	DCHL12_D4	BFB	TOLUENE_D6	OWNER
REAGENT BLANK	RBLANK		01/26/87	01/26/87	90	50U	50U	50U	100U	90J	100U	50	100U	100U	50U	100U	180	85	101	89	
REAGENT BLANK	RBLANK		01/26/87	01/26/87	80	50U	50U	50U	100U	130	100U	70	100U	100U	50U	100U	180	68	77	89	
REAGENT BLANK	RBLANK		01/27/87	01/27/87	80	60	50U	50U	100U	250	100U	60	100U	100U	50U	100U	130	119	117	130	
REAGENT BLANK	RBLANK		03/24/87	03/24/87	26J	10U	10U	10U	10U	270	100U	10U	100U	100U	22J	100U	64	94	108	94	
REAGENT BLANK	RBLANK		03/24/87	03/24/87	14J	10U	10U	10U	10U	250	100U	10U	100U	100U	22J	100U	34J	83	88	84	
REAGENT BLANK	RBLANK	I	05/01/87	05/01/87	16J	50U	50U	50U	50U	130	100U	40J	100U	100U	50U	100U	50U	127	107	112	
REAGENT BLANK	RBLANK	I	05/07/87	05/07/87	130	50U	50U	50U	50U	180	100U	65	100U	100U	50U	100U	50U	83	96	81	
REAGENT BLANK	RBLANK	I	05/08/87	05/08/87	80	50U	50U	50U	50U	100U	100U	50U	100U	100U	50U	100U	50U	93	92	108	
REAGENT BLANK	RBLANK	I	05/08/87	05/08/87	46J	50U	50U	50U	50U	62J	100U	66	100U	100U	50U	100U	72	85	101	99	
REAGENT BLANK	RBLANK	I	05/11/87	05/11/87	29J	50U	50U	50U	50U	78J	100U	65	100U	100U	50U	100U	59	103	98	100	
SYSTEM BLANK			06/05/87	06/05/87	2.7	13.0	5U	5U	10U	64.0	1.72	7.3	5U	10U	5U	10U	1.7	86	76	89	
SYSTEM BLANK			06/08/87	06/08/87	5U	30.0	5U	5U	10U	30000	450	5U	5U	10U	5U	10U	5U	102	77	95	
SYSTEM BLANK			06/10/87	06/10/87	5U	5U	5U	5U	10U	11.3	16.6	5U	5U	10U	5U	1.6	5U	93	86	99	

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MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	DCHLZENE12	DCHLZENE13	DCHLZENE14	DCHLFLMETH	TRICHLFLUO	MP_XYLENE	O_XYLENE	HEPTANE	ISOPROBENZ	PERFLBENZ	PERFLETOLU	D_ETHYLBEN	HEXANE	TEMP
ML101	BWI-01	1	02/28/86	03/03/86														0.0
ML101-011	BWI-01	1	03/13/86	03/14/86														0.0
ML101-013	BWI-01	1	03/13/86	03/14/86														0.0
ML101-015	BWI-01	1	03/13/86	03/14/86														0.0
ML101-02	BWI-01	1	03/07/86	03/10/86														0.0
ML102-01	BWI-02	1	03/07/86	03/10/86														0.0
ML102-011	BWI-02	1	03/13/86	03/14/86														0.0
ML102-012	BWO-02	1	03/13/86	03/14/86														0.0
ML103-01	BWI-02	1	03/07/86	03/10/86														0.0
ML104	BWI-01	1	02/28/86	03/03/86														0.0
ML105	TBLANK	1	02/28/86	03/03/86														0.0
ML105-02	TBLANK	1	03/07/86	03/10/86														0.0
ML106-01	CWI-03	1	03/07/86	03/10/86														0.0
ML200-01	TBLANK	1	03/13/86	03/14/86														0.0
ML401-01	BWO-01	1	03/21/86	03/24/86														0.0
ML401-02	BWO-01	1	03/21/86	03/24/86														0.0
ML401-03	BWI-01	1	03/21/86	03/24/87														0.0
ML401-04	BWI-02	1	03/21/86	03/24/86														0.0
ML401-05	BWO-02	1	03/21/86	03/24/86														0.0
ML501-01	BWI-01	1	04/17/86	04/18/86														0.0
ML501-02	BWO-01	1	04/17/86	04/22/86														0.0
ML501-03	BWO-01	1	04/17/86	04/21/86														0.0
ML501-04	BWI-02	1	04/17/86	04/21/86														0.0
ML501-05	BWO-02	1	04/17/86	05/02/86														0.0
ML501-06	CWI-03	1	04/17/86	04/21/86														0.0
ML501-07	CWI-02	1	04/17/86	04/22/86														0.0
ML601-01	BWO-01	1	04/23/86	04/26/86														0.0
ML601-02	BWO-02	1	04/23/86	04/26/86														0.0
ML601-03	CWI-03	1	04/23/86	04/26/86														0.0
ML601-04	CWI-02	1	04/23/86	04/24/86														0.0
ML601-05	CWI-05	1	04/23/86	04/28/86														0.0
ML701-01	FLARE(N)	1	05/01/86	05/07/86														0.0
ML701-02	FLARE(S)	1	05/01/86	05/07/86														0.0
ML701-03	FLARE(S)	1	05/01/86	05/07/86														0.0
ML701-04	CWI-04	1	05/01/86	05/07/86														0.0
ML701-05	CWI-01	1	05/01/86	05/07/86														0.0
ML87M-001	GP-87M	1	08/26/86	09/17/86														0.0
MLAA-001	CWAA-10	1	09/22/86	10/10/86														0.0
MLAA-002	CWAA-10	1	10/15/86	10/28/86														0.0
MLAA-003	CWAA-10	1	10/22/86	11/07/86														0.0
MLCWV-901	CWI-09	1	06/05/86	06/11/86														0.0
MLCW-01-05	CWO-01	1	11/11/86	12/02/86														0.0
MLCW-01-06	CWI-01	1	01/13/87	01/26/87														0.0
MLCW-01-07	CWO-01	1	04/29/87	05/08/87														0.0
MLCW-01-08	CWI-01		06/02/87	06/05/87														0.0
MLCW-02-05	CWO-02	1	11/06/86	11/17/86														0.0

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September 18, [illegible]
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MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 4 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	DCHLZENE12	DCHLZENE13	DCHLZENE14	DCHLPLNETH	TRICHLPLUO	MP_XYLENE	O_XYLENE	HEPTANE	ISOPROBENZ	PERPLEBENZ	PERPLETOLU	O_ETHYLBEN	NONANE	TEMP
MLCW-02-06	CWI-02	1	01/13/87	01/26/87														0.0
MLCW-02-07	CWO-02	1	04/27/87	05/01/87														0.0
MLCW-02-08	CWI-02		06/02/87	06/05/87														0.0
MLCW-03-05	CWO-03	1	11/06/86	11/10/86														0.0
MLCW-03-06	CWI-03	1	01/13/87	01/27/87														0.0
MLCW-03-07	CWO-03	1	04/27/87	05/08/87														0.0
MLCW-03-08	CWI-03		06/02/87	06/05/87														0.0
MLCW-03-08-LDUP	CWI-03		06/02/87	06/05/87														0.0
MLCW-04-04	CWO-04	1	11/11/86	12/02/86														0.0
MLCW-04-05	CWI-04	1	01/13/87	01/26/87														0.0
MLCW-04-06	CWO-04	1	04/27/87	05/08/87														0.0
MLCW-04-07	CWI-04		06/02/87	06/08/87														0.0
MLCW-05-06	CWO-05	1	11/06/86	11/17/86														0.0
MLCW-05-07	CWI-05	1	01/13/87	01/26/87														0.0
MLCW-05-08	CWO-05	1	04/28/87	05/08/87														0.0
MLCW-05-08,LDUP	CWO-05	1	04/28/87	05/11/87														0.0
MLCW-05-09	CWI-05		06/02/87	06/05/87														0.0
MLCW-05-09-LDUP	CWI-05		06/02/87	06/05/87					4000B									0.0
MLCW-06-08	CWO-06	1	11/11/86	12/02/86														0.0
MLCW-06-09	CWI-06	1	01/13/87	01/27/87														0.0
MLCW-06-10	CWO-06	1	04/29/87	05/08/87														0.0
MLCW-07-08	CWO-07	1	11/06/86	11/17/86														0.0
MLCW-07-09	CWI-07	1	01/13/87	01/26/87														0.0
MLCW-07-10	CWO-07	1	04/27/87	05/01/87														0.0
MLCW-07-11	CWI-07		06/02/87	06/05/87					8200B									0.0
MLCW-08-08	CWO-08	1	11/11/86	12/02/86														0.0
MLCW-08-09	CWI-08	1	01/13/87	01/27/87														0.0
MLCW-08-10	CWO-08	1	04/27/87	05/08/87														0.0
MLCW-08-11	CWI-08		06/02/87	06/05/87					440B									0.0
MLCW-09-07	CWO-09	1	11/11/86	12/03/86														0.0
MLCW-09-08	CWI-09	1	01/13/87	01/27/87														0.0
MLCW-09-09	CWO-09	1	04/28/87	05/08/87														0.0
MLCW-09-10	CWI-09		06/03/87	06/11/87														0.0
MLCW-1002	CWO-01	1	08/26/86	09/17/86														0.0
MLCW-1003	CWO-01	1	09/30/86	10/16/86														0.0
MLCW-1004	CWO-01	1	10/22/86	10/29/86														0.0
MLCW-101	CWI-10	1	06/05/86	06/06/86														0.0
MLCW-102	CWO-10	1	07/25/86	08/06/86														0.0
MLCW-103	CWI-10	1	07/25/86	08/05/86														0.0
MLCW-104	CWO-10	1	08/26/86	09/16/86														0.0
MLCW-105	CWO-10	1	09/15/86	10/02/86														0.0
MLCW-106	CWO-10	1	10/15/86	10/23/86														0.0
MLCW-10-07	CWO-10	1	11/06/86	11/17/86														0.0
MLCW-10-08	CWI-10	1	01/13/87	01/27/87														0.0
MLCW-10-09	CWO-10	1	04/27/87	05/08/87														0.0
MLCW-10-10	CWI-10		06/03/87	06/08/87														0.0

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MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 4 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	DCHLZENE12	DCHLZENE13	DCHLZENE14	DCHLFLNETH	TRICHLFLUO	MP_XYLENE	O_XYLENE	HEPTANE	ISOPROBENZ	PERFLBENZ	PERFLBTOLU	P_ETHYLBEN	HEXANE	TEMP
MLCW-111	CWI-11	1	06/05/86	06/11/86														0.0
MLCW-112	CWO-11	1	07/25/86	08/05/86														0.0
MLCW-113	CWI-11	1	07/25/86	08/05/86														0.0
MLCW-114	CWO-11	1	08/26/86	09/15/86														0.0
MLCW-115	CWO-11	1	09/15/86	10/02/86														0.0
MLCW-116	CWO-11	1	10/15/86	10/23/86														0.0
MLCW-11-07	CWO-11	1	11/06/86	11/17/86														0.0
MLCW-121	CWI-12	1	06/05/86	06/11/86														0.0
MLCW-122	CWO-12	1	07/25/86	08/05/86														0.0
MLCW-123	CWI-12	1	07/25/86	08/05/86														0.0
MLCW-124	CWO-12	1	09/08/86	09/23/86														0.0
MLCW-125	CWO-12	1	09/30/86	10/17/86														0.0
MLCW-126	CWO-12	1	10/22/86	10/30/86														0.0
MLCW-12-07	CWO-12	1	11/11/86	12/03/86														0.0
MLCW-12-08	CWI-12	1	01/13/87	01/23/87														0.0
MLCW-12-09	CWO-12	1	04/27/87	05/08/87														0.0
MLCW-12-10	CWI-12		06/02/87	06/05/87					TSOB									0.0
MLCW-131	CWO-13	1	10/15/86	10/23/86														0.0
MLCW-13-02	CWO-13	1	11/06/86	11/17/86														0.0
MLCW-13-03	CWI-13	1	01/13/87	01/23/87														0.0
MLCW-13-04	CWO-13	1	04/27/87	05/08/87														0.0
MLCW-13-05	CWI-13		06/03/87	06/10/87														0.0
MLCW-141	CWO-14	1	10/15/86	10/23/86														0.0
MLCW-14-02	CWO-14	1	11/06/86	12/03/86														0.0
MLCW-14-03	CWI-14	1	01/13/87	01/27/87														0.0
MLCW-151	CWO-15	1	10/15/86	10/23/86														0.0
MLCW-15-02	CWO-15	1	11/06/86	11/26/86														0.0
MLCW-15-03	CWI-15	1	01/13/87	01/23/87														0.0
MLCW-202	CWO-02	1	09/05/86	09/24/86														0.0
MLCW-203	CWO-02	1	09/15/86	10/03/86														0.0
MLCW-204	CWO-02	1	10/16/86	10/29/86														0.0
MLCW-302	CWO-03	1	09/05/86	09/24/86														0.0
MLCW-303	CWO-03	1	09/15/86	10/02/86														0.0
MLCW-304	CWO-03	1	10/15/86	10/24/86														0.0
MLCW-402	CWO-04	1	09/30/86	10/17/86														0.0
MLCW-403	CWO-04	1	10/22/86	10/29/86														0.0
MLCW-502	CWO-05	1	08/26/86	09/17/86														0.0
MLCW-503	CWO-05	1	08/26/86	09/16/86														0.0
MLCW-504	CWO-05	1	09/15/86	10/02/86														0.0
MLCW-505	CWO-05	1	10/15/86	10/23/86														0.0
MLCW-601	CWI-06	1	06/04/86	06/10/86														0.0
MLCW-602	CWO-06	1	06/04/86	06/10/86														0.0
MLCW-603	CWO-06	1	07/01/86	07/03/86														0.0
MLCW-604	CWI-06	1	07/01/86	07/03/86														0.0
MLCW-605	CWO-06	1	09/05/86	09/24/86														0.0
MLCW-606	CWO-06	1	09/30/86	10/17/86														0.0

Data submitted to Ecology by Black & Veatch
September 18,
File name : VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 4 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	DCBLZENE12	DCBLZENE13	DCBLZENE14	DCBLFLMETH	TRICHLFLUO	MP_XYLENE	O_XYLENE	HEPTANE	ISOPROBENZ	PERFLBENZ	PERFLETOLU	0_ETHYLBEN	HEXANE	TEMP
MLCW-807	CWO-06	1	10/22/86	10/30/86														0.0
MLCW-101	CWI-07	1	06/04/86	06/10/86														0.0
MLCW-102	CWO-07	1	07/25/86	08/06/86														0.0
MLCW-103	CWI-07	1	07/25/86	08/06/86														0.0
MLCW-104	CWO-07	1	08/26/86	09/15/86														0.0
MLCW-105	CWI-07	1	08/26/86	09/15/86														0.0
MLCW-106	CWO-07	1	09/15/86	10/03/86														0.0
MLCW-107	CWO-07	1	10/15/86	10/23/86														0.0
MLCW-801	CWI-08	1	06/04/86	06/10/86														0.0
MLCW-802	CWO-08	1	07/01/86	07/03/86														0.0
MLCW-802	CWO-08	1	07/25/86	08/06/86														0.0
MLCW-803	CWI-08	1	07/25/86	08/06/86														0.0
MLCW-804	CWO-08	1	08/26/86	09/15/86														0.0
MLCW-805	CWO-08	1	09/05/86	09/23/86														0.0
MLCW-806	CWO-08	1	09/30/86	10/17/86														0.0
MLCW-807	CWO-08	1	10/22/86	10/29/86														0.0
MLCW-807 (DUP)			10/22/86	10/30/86														0.0
MLCW-901	CWI-09	1	06/05/86	06/11/86														0.0
MLCW-902	CWO-09	1	07/25/86	08/06/86														0.0
MLCW-903	CWI-09	1	07/25/86	08/06/86														0.0
MLCW-904	CWO-09	1	09/05/86	09/23/86														0.0
MLCW-905	CWO-09	1	09/30/86	10/17/86														0.0
MLCW-906	CWO-09	1	10/22/86	11/05/86														0.0
MLRWV-01-33	RWI-01	1	04/28/87	05/08/87														0.0
MLRWV-116	RWI-01	1	09/30/86	10/16/86														0.0
MLRWV-118	RWI-01	1	10/15/86	10/24/86														0.0
MLRW-01-22	RWI-01	1	11/06/86	11/18/86														0.0
MLRW-01-23	RWO-01	1	11/06/86	11/18/86														0.0
MLRW-01-24	RWI-01	1	11/11/86	12/02/86														0.0
MLRW-01-25	RWO-01	1	11/11/86	12/02/86														0.0
MLRW-01-26	RWI-01	1	01/13/87	01/26/87														0.0
MLRW-01-27	RWO-01	1	01/13/87	01/26/87														0.0
MLRW-01-27(DUP)	RWO-01	1	01/13/87	01/26/87														0.0
MLRW-01-28	RWI-01	1	03/12/87	03/24/87														0.0
MLRW-01-29	RWI-01	1	03/12/87	03/25/87														0.0
MLRW-01-30	RWO-01	1	03/12/87	03/25/87														0.0
MLRW-01-31	RWI-01	1	04/28/87	05/08/87														0.0
MLRW-01-32	RWO-01	1	04/28/87	05/08/87														0.0
MLRW-01-34	RWI-01		06/02/87	06/08/87														0.0
MLRW-01-35	RWO-01		06/02/87	06/05/87														0.0
MLRW-02-22	RWI-02	1	11/12/86	12/04/86														0.0
MLRW-02-23	RWO-02	1	11/12/86															0.0
MLRW-02-24	RWI-02	1	11/11/86	12/02/86														0.0
MLRW-02-25	RWO-02	1	11/11/86	12/02/86														0.0
MLRW-02-26	RWI-02	1	01/13/87	01/26/87														0.0
MLRW-02-27	RWO-02	1	01/13/87	01/27/87														0.0

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September 14, 1987
File name : VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 4 of File

September 16, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	DCHLZENE12	DCHLZENE13	DCHLZENE14	DCHLFLMETH	TRICHLFLUO	MP_XYLENE	O_XYLENE	HEPTANE	ISOPROBENZ	PERFLBENZ	PERFLETOLU	D_ETHYLBEN	HEXANE	TEMP
MLEW-02-28	EWI-02		03/12/87	03/26/87														0.0
MLEW-02-28,LDUP	EWI-02	1	03/12/87	03/25/87														0.0
MLEW-02-29	EWO-02		03/12/87	03/24/87														0.0
MLEW-02-30	EWI-02	1	04/28/87	05/11/87														0.0
MLEW-02-31	EWO-02	1	04/28/87	05/08/87														0.0
MLEW-02-31	EWI-02		06/02/87	06/05/87														0.0
MLEW-02-32	EWO-02		06/02/87	06/05/87														0.0
MLEW-109	EWI-01	1	05/23/86	05/27/86														0.0
MLEW-110	EWI-01	1	06/18/86	06/23/86														0.0
MLEW-111	EWI-01	1	08/07/86	08/22/86														0.0
MLEW-112	EWI-01	1	09/05/86	09/24/86														0.0
MLEW-113	EWO-01	1	09/05/86	09/24/86														0.0
MLEW-114	EWI-01	1	09/15/86	10/14/86														0.0
MLEW-115	EWO-01	1	09/15/86	10/16/86														0.0
MLEW-116	EWI-01	1	09/30/86	10/16/86														0.0
MLEW-117	EWO-01	1	09/30/86	10/17/86														0.0
MLEW-118	EWI-01	1	10/15/86	10/24/86														0.0
MLEW-119	EWO-01	1	10/15/86	10/24/86														0.0
MLEW-120	EWI-01	1	10/22/86	11/05/86														0.0
MLEW-121	EWO-01	1	10/22/86	11/05/86														0.0
MLEW-12-02			11/06/86	11/18/86														0.0
MLEW-209	EWI-02	1	05/23/86	05/27/86														0.0
MLEW-210	EWI-02	1	06/18/86	06/30/86														0.0
MLEW-211	EWI-02	1	08/07/86	08/22/86														0.0
MLEW-212	EWI-02	1	09/05/86	09/23/86														0.0
MLEW-213	EWO-02	1	09/05/86	09/24/86														0.0
MLEW-214	EWI-02	1	09/15/86	10/02/86														0.0
MLEW-215	EWO-02	1	09/15/86	10/02/86														0.0
MLEW-216	EWI-02	1	10/01/86	10/17/86														0.0
MLEW-217	EWO-02	1	10/01/86	10/16/86														0.0
MLEW-218	EWI-02	1	10/15/86	10/24/86														0.0
MLEW-219	EWO-02	1	10/15/86	10/24/86														0.0
MLEW-220	EWI-02	1	10/22/86	10/29/86														0.0
MLEW-221	EWO-02	1	10/22/86	10/30/86														0.0
MLEW-V118			10/15/86	10/24/86														0.0
MLFB-001	TBLANK	1	07/25/86	07/28/86														0.0
MLFV-S-03	FLARE(S)	1	04/28/87	05/11/87														0.0
MLFV-S-05	FLARE(S)		06/02/87	06/05/87														0.0
MLF-N-02	FLARE(N)	1	04/28/87	05/07/87														0.0
MLF-N-03	FLARE(N)		06/02/87	06/10/87														0.0
MLF-S-02	FLARE(S)	1	04/28/87	05/11/87														0.0
MLF-S-04	FLARE(S)		06/02/87	06/09/87														0.0
MLF-S-04-LDUP	FLARE(S)		06/02/87	06/09/87														0.0
MLLF-102	FLARE(N)	1	06/16/86	06/23/86														0.0
MLLF-202	FLARE(S)	1	06/16/86	06/23/86														0.0
MLTB-001	TBLANK	1	08/26/86	09/16/86														0.0

Data submitted to Ecology by Black & Veatch
September 16, 19[illegible]
File name - VOC

MIDWAY LANDFILL REMEDIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 4 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	DCHLZENE12	DCHLZENE13	DCHLZENE14	DCHLPLMETH	TRICHLFLUO	MP_XYLENE	O_XYLENE	HEPTANE	ISOPROBENZ	PROPLBENZ	PROPLBTOLU	D_BYBYLBEN	HEXANE	TEMP
MLTB-002	TBLANK	1	09/05/86	09/23/86														0.0
MLTB-003	TBLANK	1	09/22/86	10/13/86														0.0
MLTB-005	TBLANK	1	01/13/87	01/26/87														0.0
MLTB-006	TBLANK	1	04/20/87	05/08/87														0.0
MLTB-007	TB-007		06/03/87	06/11/87														0.0
ML-02001	GP-02B	1	05/08/86	05/12/86														0.0
ML-10001	GP-10B	1	05/08/86	05/12/86														0.0
ML-17001	GP-17B	1	05/08/86	05/12/86														0.0
ML-37001	GP-37D	1	05/08/86	05/12/86														0.0
ML-44D02	GP-44D	1	05/13/86	05/14/86														0.0
ML-44D03	GP-44D	1	05/13/86	05/14/86														0.0
ML-45D01	GP-45D	1	05/13/86	05/14/86														0.0
ML-63001	GP-63B	1	05/08/86	05/12/86														0.0
ML-79D01	GP-79D	1	05/13/86	05/14/86														0.0
ML-81D01	GP-81D	1	05/13/86	05/14/86														0.0
REAGENT BLANK	RBLANK			11/17/86														0.0
REAGENT BLANK	RBLANK			11/26/86														0.0
REAGENT BLANK	RBLANK			10/14/86														0.0
REAGENT BLANK	RBLANK			10/16/86														0.0
REAGENT BLANK	RBLANK			12/02/86														0.0
REAGENT BLANK		1		10/29/86														0.0
REAGENT BLANK		1		12/05/86														0.0
REAGENT BLANK	RBLANK			11/18/86														0.0
REAGENT BLANK	RBLANK			10/23/86														0.0
REAGENT BLANK	RBLANK			10/17/86														0.0
REAGENT BLANK				12/03/86														0.0
REAGENT BLANK	RBLANK			10/03/86														0.0
REAGENT BLANK				12/04/86														0.0
REAGENT BLANK	RBLANK			10/29/86														0.0
REAGENT BLANK	RBLANK			11/05/86														0.0
REAGENT BLANK	RBLANK			11/07/86														0.0
REAGENT BLANK	RBLANK			10/02/86														0.0
REAGENT BLANK	RBLANK		05/27/86	05/27/86														0.0
REAGENT BLANK	RBLANK		06/10/86	06/10/86														0.0
REAGENT BLANK	RBLANK		06/11/86	06/11/86														0.0
REAGENT BLANK	RBLANK		06/23/86	06/23/86														0.0
REAGENT BLANK	RBLANK		07/03/86	07/03/86														0.0
REAGENT BLANK	RBLANK		08/22/86	08/22/86														0.0
REAGENT BLANK	RBLANK		09/24/86	09/24/86														0.0
REAGENT BLANK	RBLANK		10/10/86	10/10/86														0.0
REAGENT BLANK	RBLANK		10/13/86	10/13/86														0.0
REAGENT BLANK	RBLANK		10/16/86	10/16/86														0.0
REAGENT BLANK	RBLANK		10/24/86	10/24/86														0.0
REAGENT BLANK	RBLANK		10/28/86	10/28/86														0.0
REAGENT BLANK	RBLANK		10/30/86	10/30/86														0.0
REAGENT BLANK	RBLANK		01/23/87	01/23/87														0.0

Data submitted to Ecology by Black & Veatch
September 14, 1987
File name : VOC

MIDWAY LANDFILL [redacted]DIAL INVESTIGATION
VOLATILE ORGANIC COMPOUNDS SUMMARY
Section 4 of File

September 18, 1987

STATION	I.D.	SURVEY	SAMPLE DATE	ANALYSIS DATE	DCHLBENZ12	DCHLBENZ13	DCHLBENZ14	DCHLPLMETH	TRICHLFLUO	MP_XYLENE	O_XYLENE	HEPTANE	ISOPROBENZ	PERFLBENZ	PERFLBTOLU	D_ETHYLBEN	HEXANE	TEMP
REAGENT BLANK	RBLANK		01/26/87	01/26/87														0.0
REAGENT BLANK	RBLANK		01/26/87	01/26/87														0.0
REAGENT BLANK	RBLANK		01/27/87	01/27/87														0.0
REAGENT BLANK	RBLANK		03/24/87	03/24/87														0.0
REAGENT BLANK	RBLANK		03/24/87	03/24/87														0.0
REAGENT BLANK	RBLANK	1	05/01/87	05/01/87														0.0
REAGENT BLANK	RBLANK	1	05/07/87	05/07/87														0.0
REAGENT BLANK	RBLANK	1	05/08/87	05/08/87														0.0
REAGENT BLANK	RBLANK	1	05/08/87	05/08/87														0.0
REAGENT BLANK	RBLANK	1	05/11/87	05/11/87														0.0
SYSTEM BLANK			06/05/87	06/05/87														0.0
SYSTEM BLANK			06/08/87	06/08/87														0.0
SYSTEM BLANK			06/10/87	06/10/87														0.0

Data su[redacted]d to Ecology by Black & Veatch
Septemb[redacted], 1987
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MIDWAY LANDFILL REMEDIAL INVESTIGATION
WEYERHAEUSER ANALYTICAL RESULTS
Concentration in ppm

September 18, 1987

SAMPLE NO	STATION	DEPTH	TYPE	SAMPLE	SAMPLE DATE	LAB	LAB I.D.	ANALYSIS	UNITS	CO2	CH4	O2	N2	ETHANE	PROPANE	BUTANE
MLCW-C07	CW-07	D	AIR	TEDLAR	06/03/87	WEYCO	15648	GC/COULITITRI	PPM	34000	18000	NA	NA	1	1	NA
MLCW-C12	CW-12	D	AIR	TEDLAR	06/03/87	WEYCO	15648	GC/COULITITRI	PPM	39000	8900	NA	NA	1	1	NA
MLCW-C13	CW-13	D	AIR	TEDLAR	06/03/87	WEYCO	15648	GC/COULITITRI	PPM	65000	38000	NA	NA	TR	10U	NA
	FLARE		AIR	TEDLAR	01/29/86	WEYCO	13414	GC/COULITITRI.	PPM	NA	630000	NA	NA	1	NA	NA
MLEP-02-M	GP-02	M	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	160000	1000	NA	NA	10U	10U	NA
ML-02001		S	AIR	TEDLAR	05/08/86	WEYCO	13821	GC/COULITITRI.	PPM	NA	NA	NA	NA	10U	10U	10U
MLEP-02-S		S	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	340000	400000	NA	NA	10U	10U	NA
ML-10001	GP-10	S	AIR	TEDLAR	05/08/86	WEYCO	13821	GC/COULITITRI.	PPM	NA	NA	NA	NA	10U	10U	10U
MLEP-10-S		S	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	130000	65000	NA	NA	10U	10U	NA
ML-17001	GP-17	S	AIR	TEDLAR	05/08/86	WEYCO	13821	GC/COULITITRI.	PPM	NA	NA	NA	NA	10U	10U	10U
17-S 03/04/87		S	AIR	TEDLAR	03/04/87	WEYCO	15238	GC/COULITITRI.	uL/L (v/v)	57000	82000	NA	NA	2U	NA	NA
MLEP-17-S		S	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	150000	10000	NA	NA	10U	10U	NA
MLEP-34-1	GP-34	S	AIR	TEDLAR	11/18/86	WEYCO	14741	GC/COULITITRI.	PPM	106000	20	34000	850000	NA	NA	NA
ML-37001	GP-37	D	AIR	TEDLAR	05/08/86	WEYCO	13821	GC/COULITITRI.	PPM	NA	760000	NA	NA	10U	10U	10U
MLEP-37-D		D	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	28000	420000	NA	NA	590000	10U	NA

Data submitted to Ecology by Black & Veatch
September 14, 1987
(File name = MCMON)

MIDWAY LANDFILL REMEDIAL INVESTIGATION
WEYERHAEUSER ANALYTICAL RESULTS
Concentration in ppm

September 18, 1987

SAMPLE NO	STATION	DEPTH	TYPE	SAMPLE	SAMPLE DATE	LAB	LAB I.D.	ANALYSIS	UNITS	CO2	CH4	O2	N2	ETHANE	PROPANE	BUTANE
	GP-39	S	AIR	TEDLAR	01/29/86	WEYCO	13414	GC/COULITITRI.	PPM	NA	780000	NA	NA	10	NA	NA
ML-44D01	GP-44	D	AIR	TEDLAR	05/13/86	WEYCO	13843	GC/COULITITRI.	PPM	NA	400000	NA	NA	10U	10U	10U
MLEP-45-D	GP-45	D	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	84000	5200	NA	NA	23000	10U	NA
MLEP-45-M		M	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	64000	2800	NA	NA	TR	10U	NA
ML-45S01		S	AIR	TEDLAR	05/13/86	WEYCO	13843	GC/COULITITRI.	PPM	NA	150000	NA	NA	2700	10U	10U
MLEP-45-S		S	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	82000	350	NA	NA	10U	10U	NA
ML-45S02	GP-45(DUP)	S	AIR	TEDLAR	05/13/86	WEYCO	13843	GC/COULITITRI.	PPM	NA	150000	NA	NA	2700	10U	10U
MLEP-48-1	GP-48	S	AIR	TEDLAR	11/18/86	WEYCO	14741	GC/COULITITRI.	PPM	127000	20	63000	786000	NA	NA	NA
	GP-50	S	AIR	TEDLAR	01/29/86	WEYCO	13414	GC/COULITITRI.	PPM	NA	730000	NA	NA	1	NA	NA
ML-59M01	GP-59	M	AIR	TEDLAR	05/13/86	WEYCO	13843	GC/COULITITRI.	PPM	NA	180000	NA	NA	10U	10U	10U
MLEP-61-1	GP-61	S	AIR	TEDLAR	11/18/86	WEYCO	14741	GC/COULITITRI.	PPM	117000	540	18000	853000	NA	NA	NA
61-S 2/26/87		S	AIR	TEDLAR	02/26/87	WEYCO	15209	GC/COULITITRI.	uL/L (v/v)	80500	7000	NA	NA	0170	NA	NA
MLEP-61S		S	AIR	TEDLAR	06/01/87	WEYCO	15648	GC/COULITITRI	PPM	1000	<1000	NA	NA	*NA	*NA	NA
ML-63001	GP-63	S	AIR	TEDLAR	05/08/86	WEYCO	13821	GC/COULITITRI.	PPM	NA	NA	NA	NA	10U	10U	10U

Data submitted to Ecology by Black & Veatch
September 14, 1987
(File name = MCH[illegible]

MIDWAY LANDFILL REMEDIAL INVESTIGATION
WEYERHAEUSER ANALYTICAL RESULTS
Concentration in ppm

September 18, 1987

SAMPLE NO	STATION	DEPTH	TYPE	SAMPLE	SAMPLE DATE	LAB	LAB I.D.	ANALYSIS	UNITS	CO2	CH4	O2	N2	ETHANE	PROPANE	BUTANE
MLEP-64-1	GP-64	S	AIR	TEDLAR	11/18/86	WEYCO	14741	GC/COULITITRI.	PPM	76000	25	21000	791000	NA	NA	NA
MLEP-69-1	GP-69	S	AIR	TEDLAR	11/18/86	WEYCO	14741	GC/COULITITRI.	PPM	167000	25	21000	796000	NA	NA	NA
MLEP-78-1	GP-78	S	AIR	TEDLAR	11/18/86	WEYCO	14741	GC/COULITITRI.	PPM	185000	5300	22000	763000	NA	NA	NA
MLEP-78-S		S	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	150000	38000	NA	NA	10U	10U	NA
MLEP-78-1	GP-78(DUP)	S	AIR	TEDLAR	11/18/86	WEYCO	14741	GC/COULITITRI.	PPM	183000	NA	22000	768000	NA	NA	NA
MLEP-79-M	GP-79	M	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	32000	50000	NA	NA	10U	10U	NA
MDLF-81D	GP-81	D	AIR	TEDLAR	03/07/86	WEYCO	13588	GC/COULITITRI.	PPM	NA	78000	NA	NA	34	14	NA
ML-81002		D	AIR	TEDLAR	05/13/86	WEYCO	13843	GC/COULITITRI.	PPM	NA	330000	NA	NA	10U	10U	10U
MLEP-81-D		D	AIR	TEDLAR	06/03/87	WEYCO	15648	GC/COULITITRI	PPM	9000	37000	NA	NA	10U	10U	NA
MLEP-85-D-2	GP-85	D	AIR	TEDLAR	11/10/86	WEYCO	14700	GC/COULITITRI.	PPM	30000	523000	11000	445000	NA	NA	NA
85-D 03/04/87		D	AIR	TEDLAR	03/04/87	WEYCO	15238	GC/COULITITRI.	uL/L (v/v)	23000	200000	NA	NA	7	NA	NA
MLEP-85-D		D	AIR	TEDLAR	06/03/87	WEYCO	15648	GC/COULITITRI	PPM	22000	170000	NA	NA	TR	10U	NA
MLEP-85-M-2		M	AIR	TEDLAR	11/10/86	WEYCO	14700	GC/COULITITRI.	PPM	46000	10U	107000	847000	NA	NA	NA
MLEP-85-M		M	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	43000	10U	NA	NA	10U	10U	NA
MLEP-87-D-2	GP-87	D	AIR	TEDLAR	11/10/86	WEYCO	14700	GC/COULITITRI.	PPM	31000	85000	50000	865000	NA	NA	NA
87-D 03/04/87		D	AIR	TEDLAR	03/04/87	WEYCO	15238	GC/COULITITRI.	uL/L (v/v)	21000	24000	NA	NA	2U	NA	NA
MLEP-87-D		D	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	25000	140000	NA	NA	TR	10U	NA

Data submitted to Ecology by Black & Veatch
September 14, 1987
(File name = MCMON)

MIDWAY LANDFILL REMEDIAL INVESTIGATION
WEYERHAUSER ANALYTICAL RESULTS
Concentration in ppm

September 18, 1987

MPLE NO	STATION	DEPTH	TYPE	SAMPLE	SAMPLE DATE	LAB	LAB I.D.	ANALYSIS	UNITS	CO2	CH4	O2	N2	ETHANE	PROPANE	BUTANE
87-M-2	GP-87	M	AIR	TEDLAR	11/10/86	WEYCO	14700	GC/COULITITRI.	PPM	26000	10U	190000	805000	NA	NA	NA
87-S-2		S	AIR	TEDLAR	11/10/86	WEYCO	14700	GC/COULITITRI.	PPM	14000	10U	185000	809000	NA	NA	NA
88-D	GP-88	D	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	1000	<1000	NA	NA	*	*	NA
88-M		M	AIR	TEDLAR	06/02/87	WEYCO	15648	GC/COULITITRI	PPM	46000	10U	NA	NA	10U	10U	NA

submitted to Ecology by Black & Veatch
ber 14, 1987
name = MCHO

APPENDIX E-3

Summaries of Gas Characterization Data Collected by Farr, Friedman & Bruya, Inc., for Parametrix, Inc.

BARR FRIEDMAN & BRUYA INC. / ENVIRONMENTAL CHEMISTS / 751 AURORA AVE. N. SEATTLE, WA 98103 / 206 783 3304

55-1550-09 (E)

RECEIVED APR 21 1987

April 20, 1987

Clyde Moore, Project Leader
PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

Dear Clyde:

Enclosed please find the data tables for the methane concentrations and ethane/methane ratios.

In comparing our value of the ethane to methane ratio to values calculated from Mol % data, one must keep in mind the units of the final result. The ratio we provided was obtained by dividing the ethane gas chromatograph/flame ionization detector (gc/fid) response by the methane gc/fid response and multiplying the result by 100. Using this procedure we calculated an ethane/methane ratio of 6.7 for a gas sample collected from the Washington Natural Gas (WNG) system.

When comparing this value with the ethane/methane ratio calculated from the Mol % data supplied by WNG (2.2) one must take into account two factors. First, the gc/fid response for ethane is 1.6 times that for methane. And secondly, the gc/fid response for methane and ethane drops off by a factor of two with a 100-fold increase in the hydrocarbon concentration even with calibration curve r squared values of greater than .995. Taking these two factors into account, the (ethane response)/(methane response)X100 value that was found experimentally agrees fairly well with that calculated from WGN Mol % data. Based on these results the correction factor for comparing these sets of numbers is 0.33.

If you should have any more questions, please feel free to call.

Sincerely,

James E. Bruya, Chemist

JEB/cag

RESULTS FROM THE ANALYSIS OF SAMPLES FOR METHANE, ETHANE AND PROPANE.

Sample	(Ethane/methane)x100#	(Ethane/methane)x100@
C6	<.010	<.003
C13	.024	.008
P2	<.010	<.003
17S	<.010	<.003
17S Duplicate	<.010	<.003
45S	.54	.18
45M	2.8	.92
45D	3.9	1.3
45D Replicate	3.9	1.3
AES	<.010	<.003
AED	.077	.025
Flare Feed 1 South	.015	.005
Flare Feed 2 North	.018	.006

Sample	Methane(ppm)		(Propane/methane)x100#
C6	10,000		<.01
C13	*	190,000+	<.01
P2	*		<.01
17S	100,000		<.01
17S Duplicate	100,000		<.01
45S	*	60,000+	<.01
45M	*	32,000+	.49
45D	30,000		.77
45D Replicate	30,000		.28
AES	2,000		<.01
AED	9,000		<.01
Flare Feed 1 South	*	300,000^	<.01
Flare Feed 2 North	*	260,000^	<.01

Value reported as hydrocarbon response on gc/fid.

@ Value was converted to Mol % ratio using expected the conversion factor as per the letter to Parametrix dated April 20, 1987.

* Indicates that the result was above the range of calibration that was established during these analyses.

+ Indicates that the value was supplied by the City of Seattle Engineering Department.

^ Indicates that the value was supplied by Parametrix.

55-1550-09 (8)

FARR FRIEDMAN & BRUYA INC. / ENVIRONMENTAL CHEMISTS / 7819 AURORA AVE. N. SEATTLE, WA 98103 / 206/783/3304

CLYDE

RECEIVED MAY - 7 1987

May 6, 1987

Clyde Moore, Project Leader
PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

Dear Clyde:

We have reviewed our report containing the screening data from soil-gas samples collected at and around the Midway and Kent Highlands Landfills. We have revised the data for benzene to reflect the fact that the chromatograms were sufficiently clean to determine that no possible benzene contamination was detected in any off-landfill sample except for C13A. With sample C13A, a contaminant was present which might have been benzene; however, no benzene was present at or above the quantitation limit. We have included a revised report.

With regards to the qualifying descriptors associated with the sampling locations, we would like to clarify a few points. An A following a sampling location is used to identify the sample as having been collected from the gas stream before it passed through the filter. A B following a sampling location is used to identify the sample as having been collected from the gas stream after it passed through the filter. A (Rep) following a sample number identifies the results as coming from a replicate injection of a sample analyzed at least one day following sample collection. A (Dup) indicates that the results are from a duplicate sample collected and analyzed at least one day following the collection and analysis of the initial sample.

Standards were run daily. Blanks were also analyzed daily and no contamination was found above the limits listed in the data tables. The r squared values that are associated with the calibration curves used throughout the project are presented in a separate table.

Sincerely,

Jim Bruya

James E. Bruya, Chemist

Enclosures

JEB/cag

RECEIVED MAY - 7 1987

FARR FRIEDMAN & BRUYA INC. / ENVIRONMENTAL CHEMISTS / 7819 AURORA AVE. N. SEATTLE, WA 98103 / 206/783/3304

55-1550-09 (8)

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	C1	C2A	C2B	C2B(Rep)	1C3
Vinyl chloride	<1.	<1.	<1.	--a	1.
Chloroethane	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.	<1.	<1.	--	<1.
1,1-Dichloroethylene	.04	<0.005	<0.005	<0.005	<0.005
Methylene chloride	<0.005	0.2	0.02	<0.005	0.05
trans-1,2-Dichloroethylene	<0.005	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	0.04	<0.01	<0.01	<0.01	<0.01
Carbon tetrachloride	<0.01	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethylene	0.04	0.04	<0.01	0.02	0.02
Acetone	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	<0.5	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene/styrene	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5	<0.5

[a] - Indicates that sample was not analyzed for this compound.
* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	C4	C5	C6A	C6B
Vinyl chloride	<1.	<1.	<1.	<1.
Chloroethane	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.	<1.	<1.	<1.
1,1-Dichloroethylene	<0.005	<0.005	<0.005	<0.005
Methylene chloride	<0.005	0.02	0.05	0.05
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	0.04	0.04	<0.01	<0.01
Carbon tetrachloride	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloro-ethane	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloro-ethylene	<0.01	0.04	0.04	0.02
Acetone	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	0.6	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5
o-Xylene/styrene	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	C7A	C7B	C8A	C8A(Rep)	C8B
Vinyl chloride	1.	<1.	<1.	--	<1.
Chloroethane	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.	<1.	<1.	--	<1.
1,1-Dichloroethylene	<0.005	<0.005	<0.005	<0.005	<0.005
Methylene chloride	0.01	<0.005	<0.005	0.03	<0.005
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	0.06	0.08	<0.01	<0.01	<0.01
Carbon tetrachloride	<0.01	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	0.06	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloro-ethane	<0.01	<0.01	0.02	0.02	<0.01
1,1,2,2-tetrachloro-ethylene	<0.01	<0.01	0.04	<0.01	0.02
Acetone	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	20	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene/styrene	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	C9	C10A	C10B	C12A	C12B
Vinyl chloride	1.	<1.	<1.	<1.	<1.
Chloroethane	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.	<1.	<1.	<1.	<1.
1,1-Dichloroethylene	<0.005	<0.005	<0.005	<0.005	<0.005
Methylene chloride	0.2	0.1	0.05	<0.005	<0.005
trans-1,2-Dichloroethylene	<0.005	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Carbon tetrachloride	0.01	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethane	<0.01	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethylene	<0.01	0.04	0.02	<0.01	<0.01
Acetone	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	<0.5	<0.5	<0.5	1.	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene/styrene	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	C13A	C13A(Dup)	C13B	C15
Vinyl chloride	<1.	--	<1.	3.
Chloroethane	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.	--	<1.	<1.
1,1-Dichloroethylene	0.02	0.08	0.1	<0.005
Methylene chloride	<0.005	<0.005	<0.005	<0.005
trans-1,2-Dichloroethylene	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	0.04	0.1	0.1	0.1
Carbon tetrachloride	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	0.04	0.04	0.04	<0.01
1,1,2,2-tetrachloroethane	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethylene	0.02	0.02	<0.01	<0.01
Acetone	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5
Benzene	<0.5	<0.5	<0.2	<0.2
Toluene	<0.5	<0.5	<0.5	<0.5
p-Xylene	4.	4	<0.5	<0.5
o-Xylene/styrene	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	2.	2	<0.5	<0.5

* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	CW2S	CW2M	CW3M
Vinyl chloride	<1.	<1.	<1.
Chloroethane	<0.5	<0.5	<0.5
Chloromethane	<1.	<1.	<1.
1,1-Dichloroethylene	<0.005	0.03	0.05
Methylene chloride	<0.005	<0.005	<0.005
trans-1,2-Dichloroethylene	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	<0.01	<0.01
Carbon tetrachloride	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01
Trichloroethylene	0.04	0.02	0.1
1,1,2,2-tetrachloroethane	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethylene	0.2	0.1	0.2
Acetone	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.5
Toluene	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	4.
o-Xylene/styrene	<0.5	<0.5	1.
Ethylbenzene*	<0.5	<0.5	2.

* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	P2S	P20D	P20ML	P34M
Vinyl chloride	<1.	<1.	<1.	<1.
Chloroethane	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.	<1.	<1.	<1.
1,1-Dichloroethylene	<0.005	<0.005	<0.005	<0.005
Methylene chloride	<0.005	<0.005	<0.005	<0.005
trans-1,2-Dichloroethylene	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	<0.01	<0.01	<0.01
Carbon tetrachloride	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethane	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethylene	<0.01	0.06	0.06	0.02
Acetone	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.5	<0.2
Toluene	<0.5	<0.5	<0.5	<0.5
p-Xylene	<0.5	2.	4.	<0.5
o-Xylene/styrene	<0.5	<0.5	1.	<0.5
Ethylbenzene*	<0.5	2.	4.	<0.5

* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	E1A	E1B	E1B(Rep)	E2
Vinyl chloride	--	--	--	--
Chloroethane	<0.5	<0.5	<0.5	<0.5
Chloromethane	--	--	--	--
1,1-Dichloroethylene	<0.005	<0.005	<0.005	<0.005
Methylene chloride	0.01	0.01	0.05	<0.005
trans-1,2-Dichloro-ethylene	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	0.04	0.04	<0.01	<0.01
Carbon tetrachloride	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	0.1	0.2	0.04	<0.01
1,1,2,2-tetrachloro-ethane	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloro-ethylene	0.2	0.3	0.2	<0.01
Acetone	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.2
Toluene	0.8	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5
o-Xylene/styrene	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene.

CONCENTRATION OF SELECTED ORGANIC COMPOUNDS COLLECTED FROM SITES AROUND MIDWAY AND KENT HIGHLANDS LAND FILLS. ALL RESULTS REPORTED AS uL/L (ppm).

	Flare		Flare Feed	
	1 South	2 North	1 South	2 North
Vinyl chloride	<1.	--	<1.	<1.
Chloroethane	<0.5	<0.5	<0.5	<0.5
Chloromethane	<1.	--	<1.	<1.
1,1-Dichloroethylene	<0.005	<0.005	0.05	<0.005
Methylene chloride	<0.005	<0.005	<0.005	<0.005
trans-1,2-Dichloroethylene	<0.005	<0.005	<0.005	<0.005
1,1-Dichloroethane	<0.005	<0.005	<0.005	<0.005
Chloroform	<0.01	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	<0.01	<0.01	<0.01	<0.01
Carbon tetrachloride	<0.01	<0.01	<0.01	<0.01
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	0.08	0.06
1,1,2,2-tetrachloroethane	<0.01	<0.01	<0.01	<0.01
1,1,2,2-tetrachloroethylene	<0.01	0.02	0.1	0.1
Acetone	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	<0.5	<0.5	<0.5	<0.5
Benzene	<0.2	<0.2	<0.2	<0.5
Toluene	<0.5	<0.5	<0.5	<0.5
p-Xylene	<0.5	<0.5	<0.5	<0.5
o-Xylene/styrene	<0.5	<0.5	<0.5	<0.5
Ethylbenzene*	<0.5	<0.5	<0.5	<0.5

* - Based on response for toluene.

RESULTS FROM THE ANALYSIS OF SAMPLES FOR METHANE, ETHANE AND PROPANE.

Sample	(Ethane/methane)x100#	(Ethane/methane)x100@
C6	<.010	<.003
C13	.024	.008
P2	<.010	<.003
17S	<.010	<.003
17S Duplicate	<.010	<.003
45S	.54	.18
45M	2.8	.92
45D	3.9	1.3
45D Replicate	3.9	1.3
AES	<.010	<.003
AED	.077	.025
Flare Feed 1 South	.015	.005
Flare Feed 2 North	.018	.006

Sample	Methane(ppm)		(Propane/methane)x100#
C6	10,000		<.01
C13	*	190,000+	<.01
P2	*		<.01
17S	100,000		<.01
17S Duplicate	100,000		<.01
45S	*	60,000+	<.01
45M	*	32,000+	.49
45D	30,000		.77
45D Replicate	30,000		.28
AES	2,000		<.01
AED	9,000		<.01
Flare Feed 1 South	*	300,000^	<.01
Flare Feed 2 North	*	260,000^	<.01

Value reported as hydrocarbon response on gc/fid.

@ Value was converted to Mol % ratio using expected the conversion factor as per the letter to Parametrix dated April 20, 1987.

* Indicates that the result was above the range of calibration that was established during these analyses.

+ Indicates that the value was supplied by the City of Seattle Engineering Department.

^ Indicates that the value was supplied by Parametrix.

CORRELATION COEFFICIENT FOR STANDARDS.

Standard	Date	Correlation Coefficient
1,1 Dichloroethylene	March 20	.999
	March 23	.998
	March 24	.999
	March 27	.999
Trichloroethane	March 20	.999
	March 23	.995
	March 24	.999
	March 27	.996
Trichloroethylene	March 20	.999
	March 23	.999
	March 24	.999
	March 27	.986
Toluene	March 23	.990
	March 24	.976
Tetrachloroethylene	March 20	.999
	March 23	.999
	March 24	.997
	March 27	.978
Vinyl chloride	March 31	.998

RE[illegible] 03 1987 55-1550-09 (8)

FARR, FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James K. Farr
Andrew John Friedman
James E. Bruya

7819 Aurora Avenue North
Seattle, WA 98103
(206) 783-3304

May 29, 1987

Mr. Clyde N. Moore, P. E.
PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

Re: Midway Landfill Project

Dear Mr. Moore:

Below are the results of sampling for vinyl chloride and chloromethane from sites around the Midway and Kent Highlands landfills. The results are reported as uL/L (v/v) (ppm).

	E1A	E1B	E2B	Flare 2 (North)
Vinyl chloride	<1	<1	<1	<1
Chloromethane	<1	<1	<1	<1

We regret that these results were not present in the original report dated April 15, 1987; however, the keys supplied to us did not fit the well despite several requests. We were disappointed that the correct key and proper equipment for sampling the flare were not available for our re-sampling on May 27. Fortunately Ted and myself were able to find someone who did have a key and were able to eventually identify and construct the equipment for sampling the flare.

Please note our new phone number: 285-8282.

Sincerely,

Robert J. Wallace

Robert J. Wallace, Chemist

RJW/cag

APPENDIX F

UTILITY CONDUITS AS POTENTIAL PATHWAYS FOR GAS MIGRATION

TECHNICAL MEMORANDUM

FOR

THE MIDWAY LANDFILL RI

UTILITY CONDUITS AS POTENTIAL PATHWAYS FOR GAS MIGRATION

Prepared for:

SEATTLE ENGINEERING DEPARTMENT
SOLID WASTE UTILITY

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

March 23, 1988
PMX #55-1550-11 (Task 2.5.5)

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1.0 INTRODUCTION

Gas produced from the decomposition of waste in the Midway Landfill has been found migrating offsite. Also, methane from other sources offsite has been found. Methane has been detected in offsite gas probes, and has also been found in structures such as basements and underground utility vaults. Two possibilities exist. Either the offsite gas migration followed the natural geology underlying the landfill and vicinity, or the gas migrated offsite following a path or conduit created by underground utility lines or pipes, or both.

The objectives of this task were, specifically, to:

- Identify the locations of major underground utility lines.
- Compare utility locations with occurrences of gas in households and other structures.

2.0 METHODOLOGY

Information on the locations of major underground utilities was compiled from existing maps and records. Cities of Kent and Des Moines Sewer Districts, Water District #75, City of Kent water supply utility and Washington Natural Gas provided copies of their utility location maps. The information from these maps was then transferred to a common base map. Base maps were provided to Pacific Northwest Bell Telephone Company and Puget Sound Power and Light Company, and these utilities transferred their information to the base maps. Individual contacts were made by telephone call, letter, or both. The following table lists the utilities identified and the corresponding individuals contacted for information included in this study.

Utility	Individual(s) Contacted
Water District #75	Duane Huskey, Engineering/Operations Manager Jay Gibson, Supervisor of Engineering & Administration
Washington Natural Gas	Joe Jainga, Supervisor - Public Improvement, Distribution Department
Des Moines Sewer District	John R. Henry, Manager
Kent Sewer District	Dawn Anderson, Engineer
Kent Water Supply	Don Wikstrom
Puget Sound Power and Light	Dan Swan, Customer Service Assistant
Pacific Northwest Bell	Mike Michaelis

3.0 RESULTS

A map (Figure F-1 Underground Utility Lines in the Midway Landfill Vicinity) was prepared compiling all of the information obtained from the major utilities listed in Section 2.0. The map includes complete information on underground lines and pipes obtained from the utilities, but does not include hook-ups to individual households.

The shallow gas isopleths (Figure F-2 Shallow Gas Concentration Isopleth, December 1987) indicate that significant methane concentrations in the shallow soil zone remain in only four areas offsite. Those areas appear to be isolated from the landfill. A comparison of these areas with utility conduits in Figure 4.1 gives no indication that utility conduits are transmitting methane from the landfill. It is believed that the shallow gas detected in probe "AE", located southeast of the site, is from a nearby peat bog. The shallow gas detected in probe 2, north of the site, and probes 10 and 17, west of the site, appears to be from peat or other deposits buried nearby. The shallow gas in probe "AC", located southwest of the site, is from an unknown source. Additional monitoring, testing and evaluation of these areas will continue. No significant gas has been reported in structures, vaults or utilities for several months.

Note: All sets of probes and
wells may not be shown.

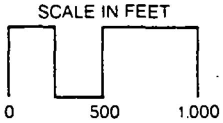

Figure F-2
Deep Gas Concentration Isopleth, December 1987

4.0 CONCLUSIONS

Methane gas was found to be migrating away from the landfill at shallow depths in 1981. It was first discovered when methane was measured in utility vaults, water meter vaults, catch basins and shallow bar holes. The offsite gas was concentrated primarily west of the landfill, on both the east and west side of Highway 99 (Pacific Highway South). It was believed at this time that gas was migrating along shallow conduits just under the ground surface. In 1985-86, the onsite gas extraction system was installed at the Midway Landfill, and in 1986-87 offsite extraction wells were installed. These extraction systems are believed to have stopped the migration of gas away from the landfill at shallow depths. Essentially all of the shallow offsite gas probes near the site exhibit a slight negative pressure. At this time it is believed that very little, if any, shallow landfill gas is migrating offsite. However, this observation will need to be confirmed by continued monitoring for gas in probes around the site. It appears that at this time underground utility lines are not serving as shallow underground conduits for landfill gas migration.

It is recommended that periodic monitoring of utility conduits and vaults be performed within the four areas offsite where probes indicate shallow gas concentrations above the lower explosive limit.

APPENDIX G

GEOLOGIC PATHWAYS FOR GAS MIGRATION

MIDWAY LANDFILL REMEDIAL INVESTIGATION

TECHNICAL MEMORANDUM

GEOLOGIC PATHWAYS FOR GAS MIGRATION

Prepared for:

CITY OF SEATTLE
Department of Engineering
Solid Waste Utility

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

March 1988

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1.0 INTRODUCTION

This technical memorandum reviews and interprets hydrogeologic and other data and constructs a picture of the potential geologic pathways for gas migration in the Midway Landfill vicinity.

This study is based upon work accomplished under the geological evaluation subtask (2.5.1) of the Final Work Plan for the Midway Landfill Remedial Investigation (Black and Veatch, 1986). To develop this report, lithologic data from wells that existed prior to the Remedial Investigation were interpreted. Also used were data from Task 2.2, which includes the following subtasks: Groundwater Well Installation (2.2.1), Leachate Well Installation (2.2.5), and Aquifer Testing (2.2.2).

When combustible gas was discovered in structures within 1000 feet of the Midway Landfill, it was assumed that gas generated by decomposition in the landfill had migrated off-site. The City of Seattle and the Washington Department of Ecology drilled exploratory gas probes and installed gas extraction wells to address the immediate problem of withdrawing subsurface gas from the affected structures.

However, both for the Remedial Investigation and for the longterm operation of the gas migration control system installed as part of the landfill closure, it was necessary to determine with greater certainty the source of the off-site gas. The Gas Characterization Technical Memorandum (Appendix E of the Landfill Gas Technical Report) and this technical memorandum provide complementary evidence of the relationship between landfill gas and off-site gas. Both studies also indicate the possibility that sources other than the landfill have contributed or can contribute to subsurface gases in the Midway area.

2.0 OBJECTIVES

The primary objective of this study was to identify subsurface geologic pathways in the area surrounding the landfill through which landfill gas might potentially migrate off-site, and to compare these potential pathways with known concentrations of off-site gas to construct a hypothesis of how the gas reached the areas in which it was found.

In addition, the following questions were of importance to the continuing operation of the gas migration control system:

- Are there geological conditions below the depth of the existing (prior to the Remedial Investigation) gas probe borings that may affect the functioning of the gas migration control system?
- Will geological conditions prevent the removal of gas from the remaining off-site areas?
- Do geological conditions indicate that additional migration control wells may be needed?
- Are there off-site sources of subsurface gas in the area that also may potentially migrate beyond their immediate area?

3.0 EXISTING CONDITIONS

Residential neighborhoods surround the Midway Landfill. Some homes are as close as 120 feet from the southern boundary. On the east the homes are separated from the landfill by the I-5 corridor, on the west by the Highway 99 corridor and its business strip, and on the north by a small stand of mixed hardwood-conifer trees.

When, in 1985, combustible gas was detected in the businesses west of the landfill, the landfill was suspected as a source. Exploratory borings down to 100 feet below ground surface provided some information about the location of the gas and the underlying soil strata; however, in the initial phases of expedited response actions (ERAs) to remove the gas from off-site structures, no comprehensive evaluation was made of the surrounding area as a whole. Efforts to evaluate the extent of landfill gas off-site began soon after initiation of the ERAs.

A gas migration control system was installed on the landfill perimeter to draw any gas migrating from the landfill back toward the landfill, and prevent further migration. Gas extraction wells were installed in the affected neighborhoods to eliminate gas from the soils below. This system has been highly successful in removing gas from some off-site areas and moderately successful in others.

For the longterm operation of the gas migration control system, more information was needed about subsurface stratigraphy and the geologic pathways through which the gas had probably travelled and might potentially travel.

During the remedial investigation, a comprehensive evaluation of the stratigraphy underlying the landfill and its vicinity was made by Parametrix, Inc., and its subcontractor, Applied Geotechnology, Inc. The Hydrogeology Technical Memorandum, Appendix A of the Groundwater Technical Report (AGI, 1988), reports the findings of the hydrogeological investigation. The data used for the hydrogeological analysis included drilling logs for gas monitoring probes, gas extraction wells, and groundwater monitoring wells. Figure G-1 shows the locations of wells used in this analysis.

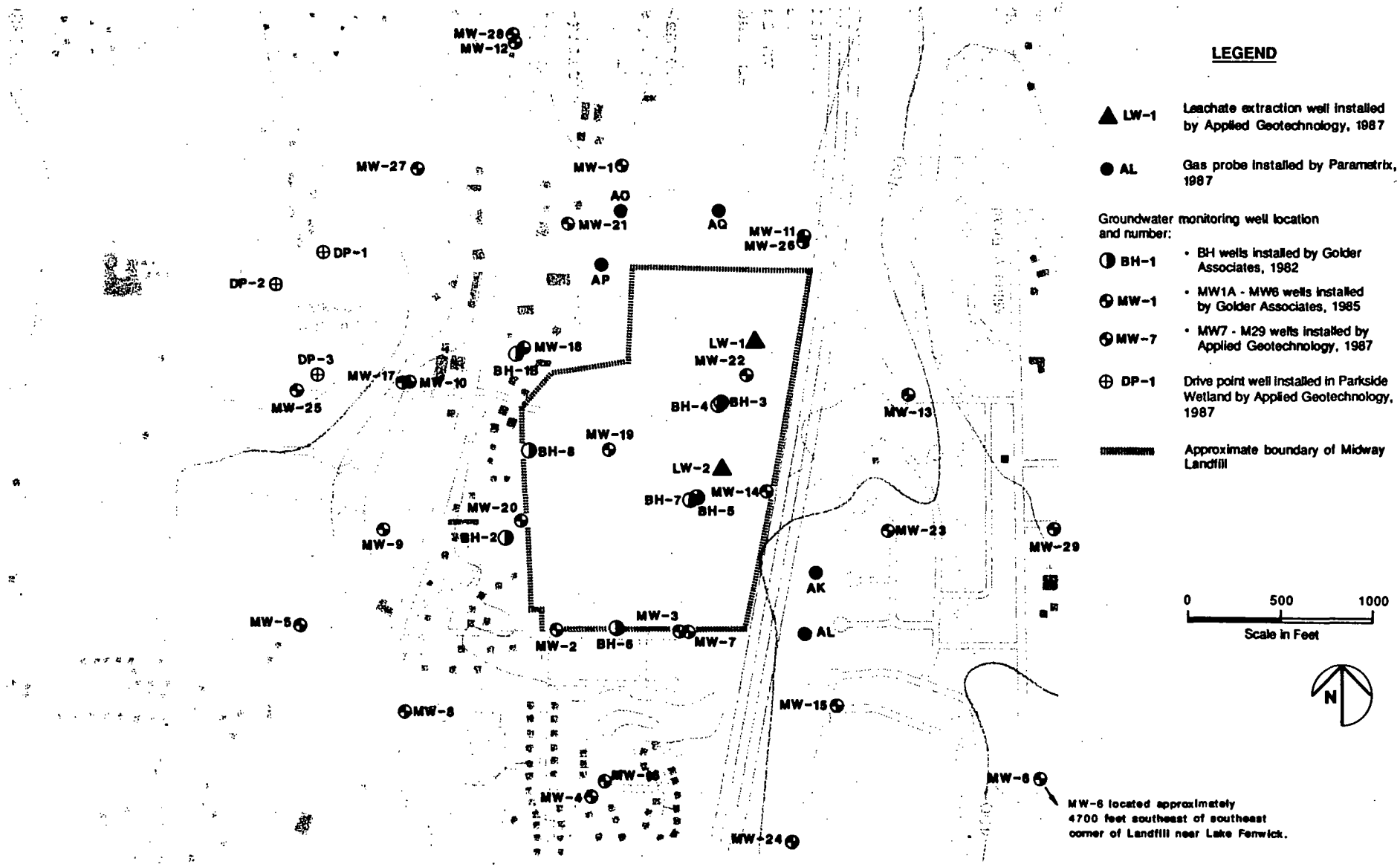


Figure G-1
Groundwater Monitoring Locations

4.0 METHODOLOGY

To identify potential geologic pathways for gas migration, aquifers underlying the study area and identified in the hydrogeology report (AGI 1988) were examined for evidence of undersaturated zones. Undersaturated zones are located where the potentiometric surface of the groundwater (i.e., the level to which the water would rise if it were unconfined) is below the roof of the aquifer, leaving a portion of the aquifer through which air and other gases can travel. These zones usually contain some water and should not be referred to as unsaturated.

The undersaturated zones of the aquifers identified in the hydrogeology report were mapped, using hydrogeologic cross sections and potentiometric surface data. It should be noted that potentiometric surface data were collected on September 21, 1987, a time at which the potentiometric surface was at the lower end of its yearly range.

The relationship of the potentiometric surface to the base and roof of an aquifer was interpreted in the following manner for this report:

Potentiometric Surface Measured	Potential for Gas Migration
Below base of aquifer	High in undersaturated aquifer.
Between base and roof of aquifer	Variable, depending on thickness of aquifer remaining undersaturated.
At roof of aquifer	Very low--aquifer considered saturated.
Above roof of aquifer	Almost none--aquifer saturated and under pressure.

The potential gas migration pathways were then defined by correlating hydrogeologic cross-sections and noting connections between the landfill, the undersaturated zones, and locations off-site where the ground surface intercepts the undersaturated zones. At these locations gas potentially could escape to the atmosphere. Potential sources and receptors were reviewed in relation to the potential pathways. Potential sources of subsurface gas include the landfill, surface peat bogs, buried peat bogs, lake beds, and other buried wetland areas, small undocumented landfills, and natural gas pipeline leaks. The possible receptors are homes and business structures where the migration routes reach the ground surface.

The next phase of the analysis involved comparing the potential gas migration pathways with known gas concentrations off-site. This was done using computer-generated gas concentration isopleths that illustrate the distribu-

tion of subsurface gases by plotting data points from gas extraction wells and monitoring probes.

Finally, the variables that can affect the migration of gases within the geologic pathways were evaluated. Some of these variables originate in the landfill; others originate away from the landfill; and others are physical conditions or forces.

Variables associated with the landfill include:

- Gas generation within the landfill
- Perched water tables and moisture content within the landfill material
- Characteristics of the landfill cover material, including soil types, thickness, compaction, and water content. Ice content may also have an effect, although ice content was not measured.
- Characteristics of the contact between the upper gravel aquifer and the landfill

Variables in the vicinity of the landfill include:

- Undersaturated zones within the aquifers
- Contacts between the upper gravel aquifer and the sand aquifer
- Aquitards and heterogeneities within the aquitards that may allow vertical migration
- Thin sedimentary layers close to ground surface
- Other potential sources of methane, including surface and buried peat bog deposits, lake beds, and small undocumented landfills
- Interception of the ground surface by the main migration pathways
- Man-made underground conduits for utility lines or sewers (see Appendix F of the Landfill Gas Technical Report)

Varying physical conditions or forces that affect gas movement include:

- Hydraulic conductivity and permeability
- Barometric pressure
- Fluctuations in water tables
- Gas concentrations and mass flux

5.0 RESULTS

Undersaturated zones in the aquifer underlying the Midway Landfill vicinity were mapped, using hydrogeologic cross sections and potentiometric surface data. The next phase of the analysis involved comparing the potential gas migration pathways with known gas concentrations off-site, then evaluating the variables that might affect gas movement. The goal was to construct a hypothesis well-supported by the available data to explain how off-site gas had collected and to answer the other questions listed in the Objectives section concerning future operation of the gas migration control system and sources of gas other than the landfill.

5.1 HYDROGEOLOGICAL DESCRIPTION

The geologic deposits in the study area consist of a variety of sediments with varying hydraulic properties. Figure G-2 illustrates the geologic and hydrostratigraphic characteristics of these sediments. Despite this complexity, distinct hydrostratigraphic units can be defined within each of the geologic units on the basis of similar hydraulic properties, as follows:

Geologic Unit	Hydrostratigraphic Unit
Fill, Recent Alluvium, Vashon Recessional Outwash, Vashon Advance Outwash	Perched Aquifers
Midway Landfill	Landfill Aquifer
Outwash Gravels	Upper Gravel Aquitard Upper Gravel Aquifer
Deltaic Sediments	Upper Silt Aquitard Sand Aquifer Lower Silt Aquitard
Non-Glacial Sediments	Northern Gravel Aquifer Southern Gravel Aquifer

It is important to note that some of these geologic units contain both aquifers and aquitards. Aquifers are sediments having a large proportion of sand and gravel and relatively little silt and clay. This composition creates pore spaces through which gas, air, and water may travel. Aquitards are sediments consisting of all silt and clay or at least enough silt and clay to fill in the pore spaces between larger grains. This composition creates a tightly packed material that retards the movement of gas, air and water. However, aquitards are not totally impermeable; they are charac-

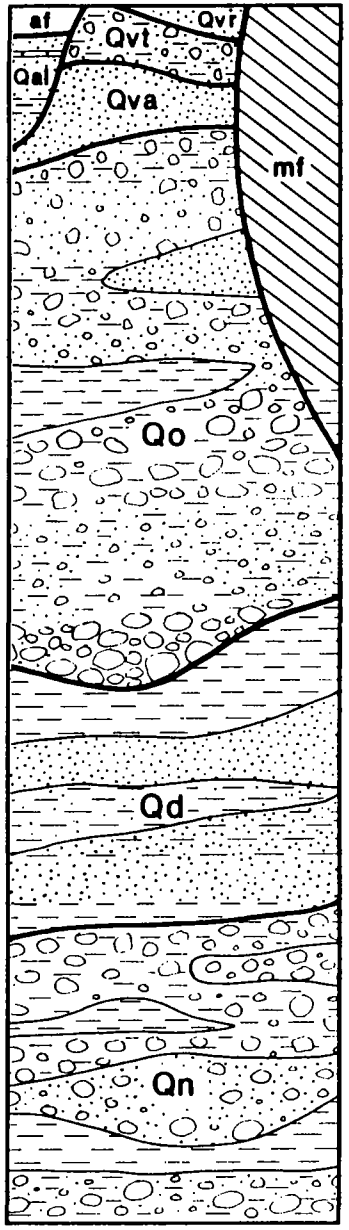
BASE ELEVATION (feet)	STRATIGRAPHIC SECTION	GEOLOGIC UNIT	HYDROSTRATIGRAPHIC UNIT
		FILL (af) Miscellaneous surficial fills. MIDWAY LANDFILL (mf) Refuse and miscellaneous fills within the landfill boundary.	PERCHED AQUIFER (see also below) Seasonally perched groundwater at base of fills. LANDFILL AQUIFER Perched leachate at base of landfill.
		RECENT ALLUVIUM (Qal) Recent fluvial and lacustrine sediments including peat. VASHON RECESSIONAL OUTWASH (Qvr) Thin scattered deposits of well sorted sand and silty sand. VASHON TILL (Qvt) Thin scattered deposits consisting of compact silt, sand, and gravel glacial till. VASHON ADVANCE OUTWASH (Qva) Well sorted sand deposits with trace gravel.	PERCHED AQUIFER Seasonally perched groundwater at base of Recessional Outwash or in weathered Vashon Till. Saturated thickness several inches to several feet. Perched groundwater in Parkside Wetland in sandy portions of Recent Alluvium and in Outwash Gravels north of Landfill.
		OUTWASH GRAVELS (Qo) Oxidized silty sandy gravel, sandy gravel, and open work gravel with subordinate silt and sand lenses. Sand and silt proportions vary; gravel ranges from pebble to cobble size. Glacial outwash deposit.	UPPER GRAVEL AQUITARD Dense till-like mixture of silt, sand and gravel. UPPER GRAVEL AQUIFER Saturated highly permeable open work gravel and sandy gravel deposits associated with a buried channel at the base of the Outwash Gravels.
190-250		DELTAIC SEDIMENTS (Qd) Interbedded fine grained sand, silty sand, sandy silt and silt. Occasional silty clay lenses, silty gravel channel deposits, and ash layers. Trace organic matter scattered throughout entire deposit. Sediments near base of deposit often have lavender cast from abundant hypersthene(?) crystals. Occasional dropstones. Possible glacio-lacustrine/deltaic deposit.	UPPER SILT AQUITARD Discontinuous layer of interbedded silt, clayey silt, and silty fine sand at the top of the Deltaic Sediments. Maximum thickness 55 feet; generally ranges between 15 and 35 feet thick. SAND AQUIFER 20 to 60 foot thick sand beds with intervening silt, clayey silt, and silty fine sand beds. LOWER SILT AQUITARD Discontinuous layer of interbedded silt, clayey silt, and silty fine sand at base of Deltaic Sediments: generally range from 1 to 5 feet thick where present.
80-150		NON-GLACIAL SEDIMENTS (Qn) Interbedded silty gravel, sandy gravel, silt, and silty sand. Silt and sand beds often have lavender cast. Wood fragments locally abundant. Tree encountered during drilling MW-29. Terrestrial non-glacial deposit.	NORTHERN GRAVEL AQUIFER Highly permeable 5 to 30 foot thick sandy gravel channel(?) deposits between elevation +30 and +80 feet. Potentiometric head greater than elevation +220. SOUTHERN GRAVEL AQUIFER Highly permeable 5 to 30 foot thick sandy gravel channel(?) deposits between elevations +50 and +110 feet. Potentiometric head less than elevation +175 feet.

Figure G-2
Generalized Hydrogeologic Section

terized by lower permeability than aquifers. The hydrostratigraphic units underlying the Midway area are further described below.

Perched Aquifers: Perched aquifers occur as near-surface seasonal groundwater bodies present around the landfill perched on unweathered Vashon till or outwash gravels.

There are also zones of perched water within the generally unsaturated upper portion of the outwash gravels. Most of the perched water bodies are limited in extent. However, one extensive body of perched groundwater is located immediately north of the landfill between wells MW-21 and MW-11.

Landfill Aquifer: Leachate forms a nearly continuous body of water at the base of the landfill, and appears as scattered perched bodies within the landfill.

Data gathered in February, 1987 from all on-site gas extraction wells and leachate wells showed leachate elevations an average of 30 to 40 feet higher in the northern half of the landfill. Leachate thicknesses also generally appear to increase from east to west in accordance with the general deepening of the original gravel pit excavation.

Upper Gravel Aquitard: The outwash gravels, particularly the upper portion, are predominantly lower permeability "silt-bound" gravels that tend to retard groundwater movement. The upper unsaturated portion of this deposit is therefore defined as the upper gravel aquitard.

The upper gravel aquitard typically occurs as 50- to 100-foot-thick beds of silty gravel interbedded with more permeable sand and sandy gravel zones. The maximum observed thickness of continuous silty gravel was nearly 180 feet at MW-15; the minimum was 40 feet at MW-21. The upper gravel aquitard extends from near land surface to the first major bodies of permeable gravel, which typically occur near the base of the outwash gravels. The base of the upper gravel aquitard therefore ranges from Elevation 240 to 330.

Upper Gravel Aquifer: The first major aquifer occurs near the base of the outwash gravels in a deep deposit of more permeable, sandy or open-work gravels that tend to be cleaner and to have less silt than the gravels of the upper gravel aquitard. The size and distribution of particles in this stratum indicate that the material was deposited in rapidly moving water, interpreted as glacial outwash close to a glacial front. The deposit is described as a buried channel extending in an arc from north to south through the middle of the landfill. The saturated thickness occurs at the north end of the buried channel, where up to 80 feet of groundwater was observed near MW-27 and MW-21. Gravels occupying the north end of the channel in this area are of relatively high permeability compared to the upper gravel aquifer in other areas.

Groundwater occurs in the upper gravel aquifer generally under water table or only slightly confined conditions. Consequently, the upper surface of the saturated thickness of this aquifer can be considered as the regional water table.

Upper Silt Aquitard: A 5- to 40-foot-thick sequence of fine-grained silt and silty fine sand designated as the upper silt aquitard underlies the upper gravel aquifer throughout much of the study area. However, the aquitard is absent in a band extending north-south through the landfill and throughout most of the study area south of the landfill. There is also a "window" or gap in the aquitard west of the landfill near MW-17.

The north-south window in the upper silt aquitard coincides to some extent with the buried channel, suggesting the upper silt aquitard was eroded from this area during deposition of the outwash gravels.

Sand Aquifer: Groundwater occurs under generally confined conditions in sand deposits within the deltaic sediments. These saturated sand deposits and intervening finer-grained sediments are called the sand aquifer. Although the sand aquifer is confined in most areas, unconfined or water table conditions prevail in the southeastern portion of the study area.

The top of the sand aquifer generally occurs between Elevations 180 and 240 feet. The base typically occurs between Elevations 90 and 100 feet, but in some areas rises to above 180 feet.

The distribution of the saturated sand deposits within the deltaic sediments varies considerably throughout the study area. In some areas there are up to 80 feet of sand, while in others there are 20- to 30-foot-thick sand beds with intervening 10- to 30-foot beds of silt or silty fine sand. However, in most areas the sand deposits occur in one or two major zones ranging from 30 to 80 feet thick. The sand and silt units are not as uniform as shown later in this report in the hydrogeologic cross sections. They actually include a variety of sediments, but have been grouped into either sand or silt to facilitate hydrogeologic interpretation.

Lower Silt Aquitard: Fine-grained silt and silty sand occur at the base of the deltaic sediments, as shown in the hydrogeologic cross sections. These fine-grained sediments, collectively called the lower silt aquitard, range from less than 10 feet to approximately 50 feet thick. The thickness and inferred areal distribution of the lower silt aquitard is shown in Figures G-4 through G-8. As illustrated, maximum thicknesses are located beneath the central portion of the landfill and east of the landfill. The aquitard appears to be absent in a band extending across the north part of the landfill and in the western part of the study area.

Northern and Southern Gravel Aquifers: Groundwater occurs under confined conditions in gravel beds within the non-glacial sediments. The gravel beds typically range from 5 to 30 feet thick and are separated by intervening lower permeability silty sandy gravel and silt beds. There are no apparent lithologic differences between these gravel beds in the northern and southern part of the study area, but they have substantially different potentiometric heads, electrical conductivities (i.e., total dissolved solids content), and groundwater flow directions. Potentiometric heads in the northern part of the study area average 90 feet higher than in the southern part, and electrical conductivities are typically ten times less. Based on these observa-

tions, the hydrogeologists defined two separate aquifers, the northern gravel aquifer and the southern gravel aquifer. The apparent boundary separating the two aquifers trends east-west across the middle of the landfill between wells MW-18 and MW-19.

The entire sequence of non-glacial sediments at each well location is considered part of either the northern or southern gravel aquifer. This includes the intervening, less permeable silty sandy gravel and silt beds. Consequently, each aquifer is characterized by a less permeable and a more permeable section.

5.2 MAP OF POTENTIAL PATHWAYS

The distribution of undersaturated zones in the study area is not uniform. Potentiometric head measurements ranged from below the aquifer base to above the aquifer roof. Thus, the aquifers range from undersaturated to fully saturated and under pressure. (Fully saturated aquifers cannot transmit gas.)

Potentially gas-bearing zones within and surrounding the landfill were plotted by identifying the undersaturated water-bearing sediments. At this stage of the analysis, these zones must be considered only as potential gas migration pathways. Only after comparison with historical gas concentrations (see Section 5.3) can the conclusion be drawn that any potential pathway did contain gas. Figures G-3 through G-13 illustrate the potentially gas-bearing zones and identify those that are connected to the landfill. Figures G-4 through G-10 are geologic cross-sections of the landfill and its vicinity. Figure G-3 is a key to the locations of the cross-sections.

Figure G-13 shows the extent and thickness of the landfill-connected gas migration pathways and includes the elevations above mean sea level (AMSL) of both the potentiometric surface and the upper surface of each aquifer. The connected zones are generally at or above the elevation of the bottom of the landfill (255 feet AMSL). The landfill surface is approximately 350 to 370 feet AMSL.

5.2.1 General Distribution of Pathways

The set of undersaturated zones that connect to the landfill form a system of gas migration pathways through which landfill gas can move away from the landfill. These interconnected sediment layers are located mainly to the east and southeast of the landfill, with a small but notable lobe to the northwest. These pathways appear to occur almost exclusively within the upper gravel aquifer. As shown by these figures, the gravel pit into which the landfill was developed cuts through an undersaturated zone in the upper gravel aquifer.

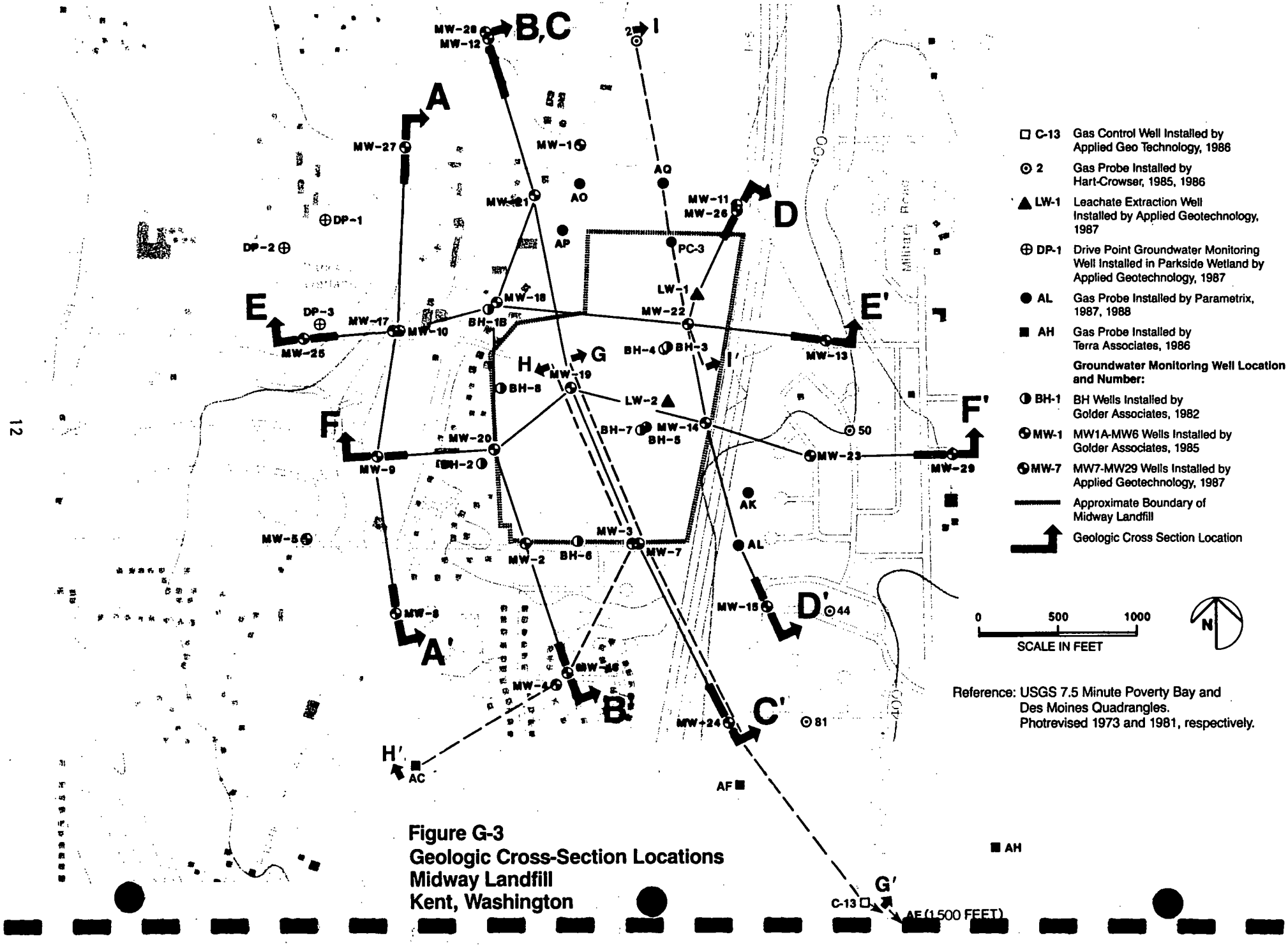
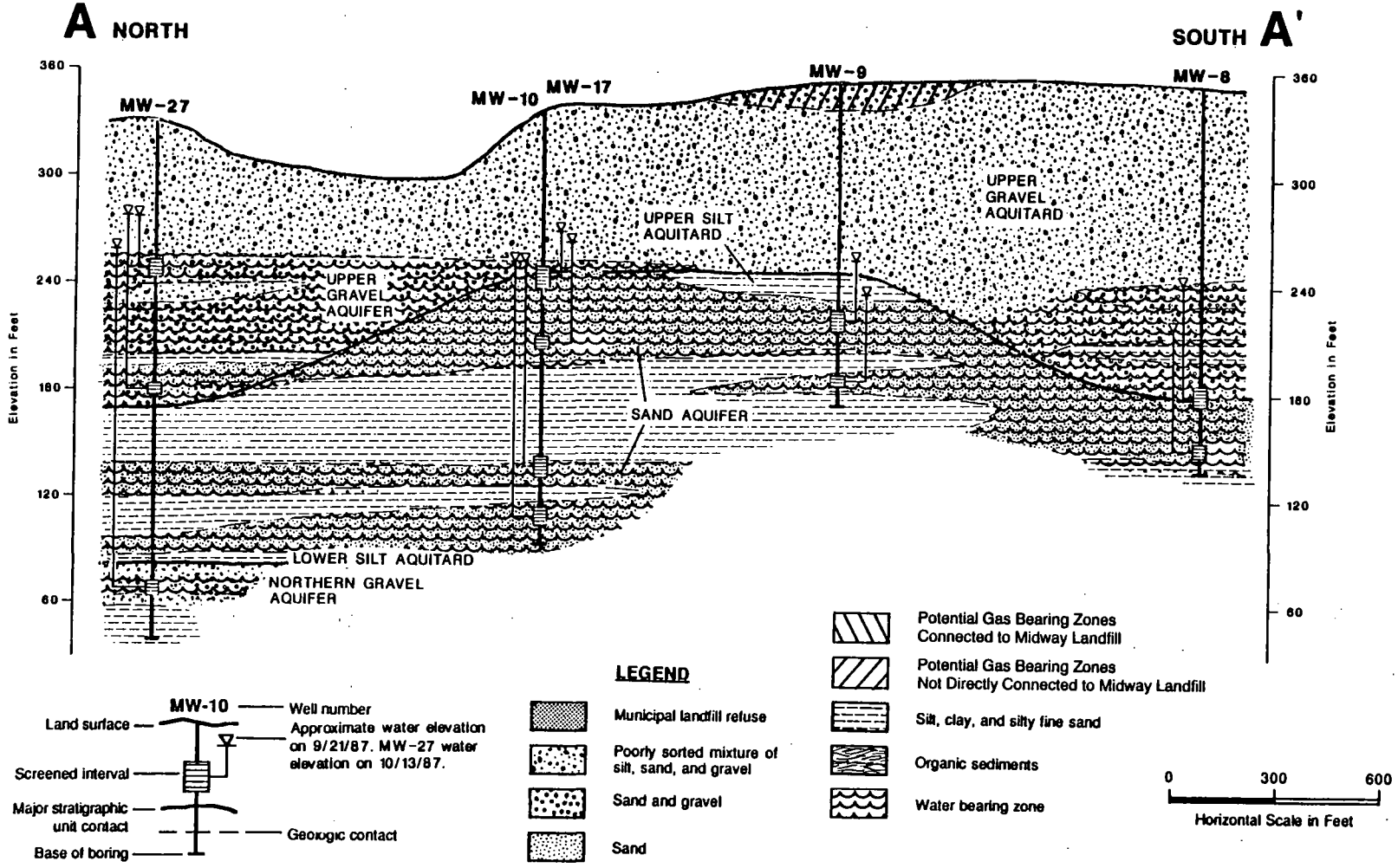


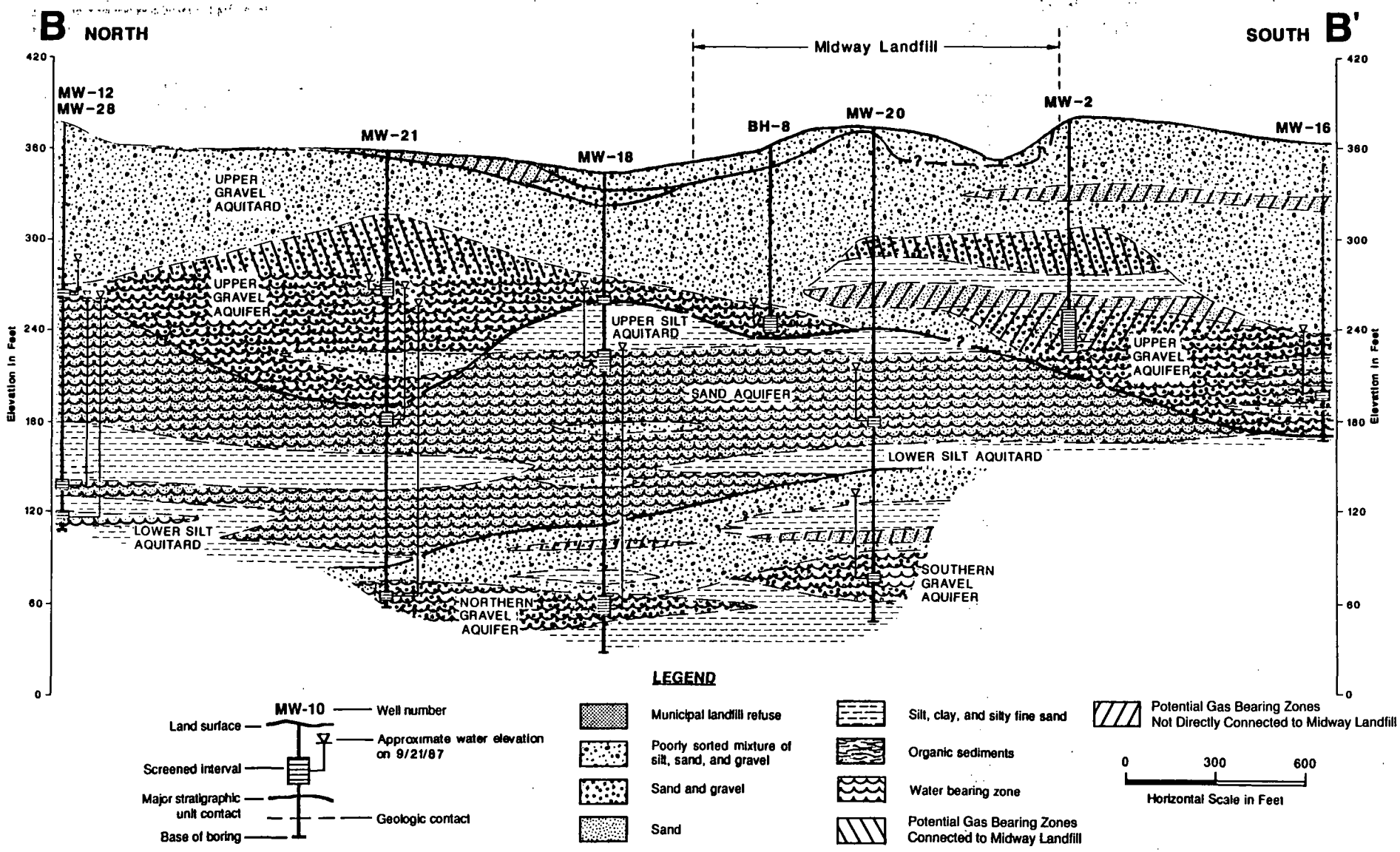
Figure G-3
Geologic Cross-Section Locations
Midway Landfill
Kent, Washington



NOTES:

1. For cross section location refer to Figure G1.
2. This cross section is a diagrammatic interpretation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

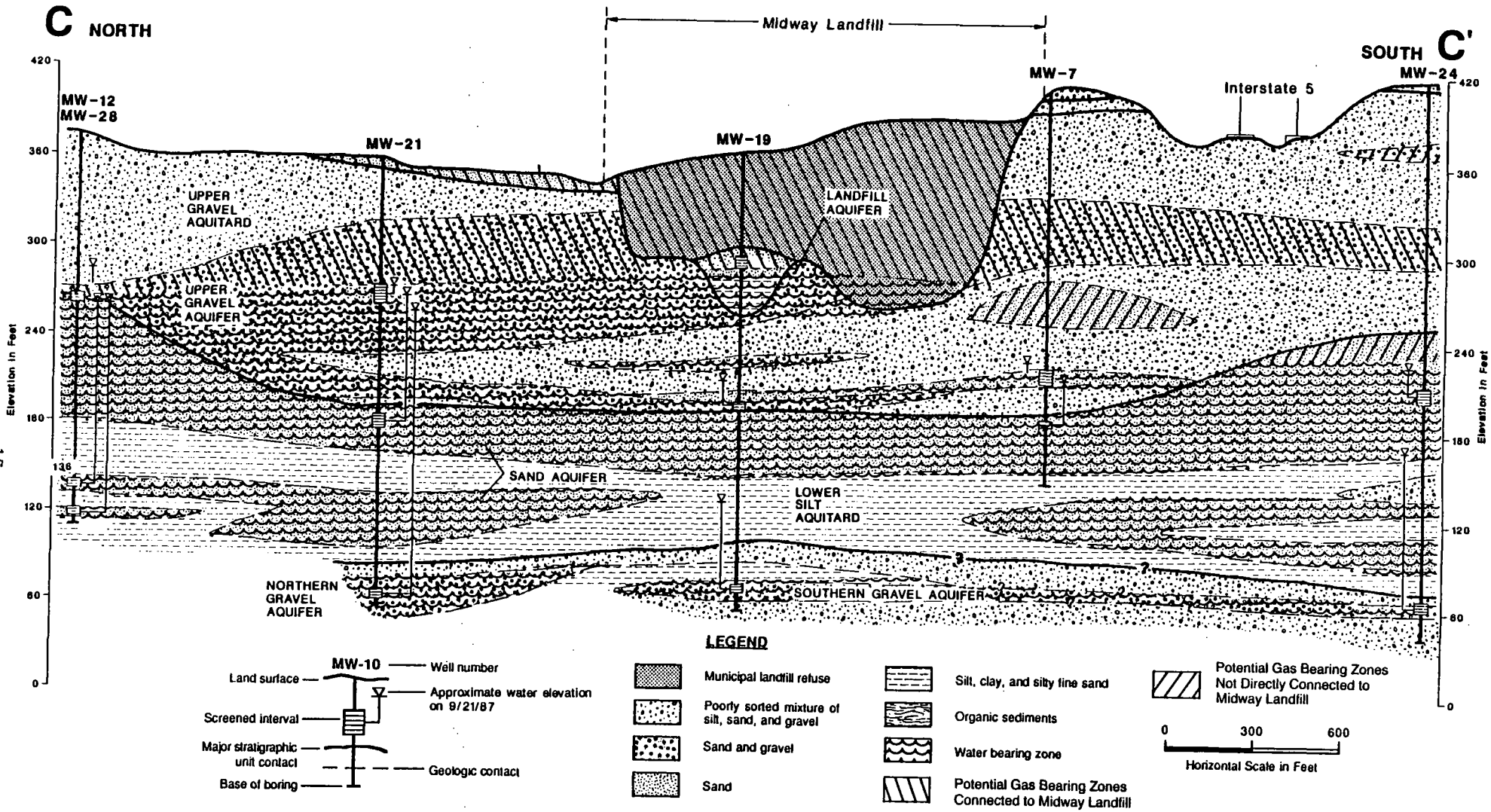
Figure G-4
Potential Gas Migration Pathways
Hydrogeologic Section A-A'
Midway Landfill
Kent, Washington



NOTES:

1. For cross section location *refer to Figure G1*.
2. This cross section is a diagrammatic interpretation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

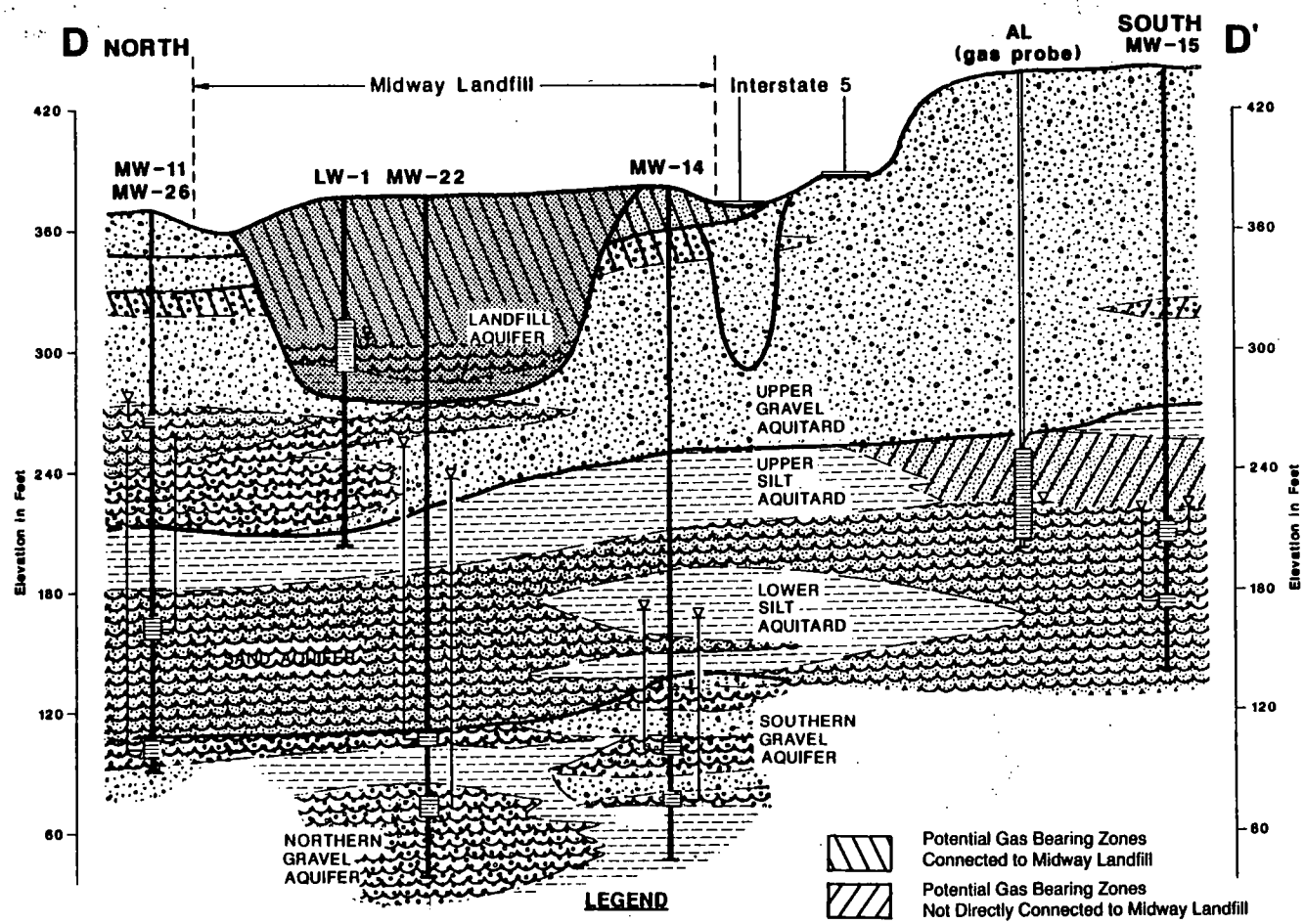
Figure G-5
Potential Gas Migration Pathways
Hydrogeologic Section B-B'
Midway Landfill
Kent, Washington

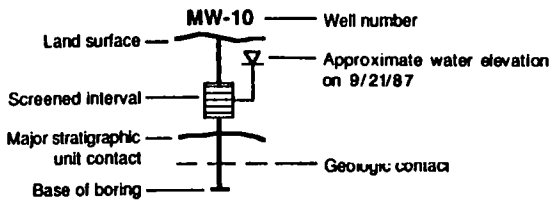


NOTES:

1. For cross section location refer to Figure G1.
2. This cross section is a diagrammatic interpretation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

Figure G-6
Potential Gas Migration Pathways
Hydrogeologic Section C-C'
Midway Landfill
Kent, Washington





LEGEND

- Municipal landfill refuse
- Poorly sorted mixture of silt, sand, and gravel
- Sand and gravel
- Sand
- Potential Gas Bearing Zones Connected to Midway Landfill
- Potential Gas Bearing Zones Not Directly Connected to Midway Landfill
- Silt, clay, and silty fine sand
- Organic sediments
- Water bearing zone

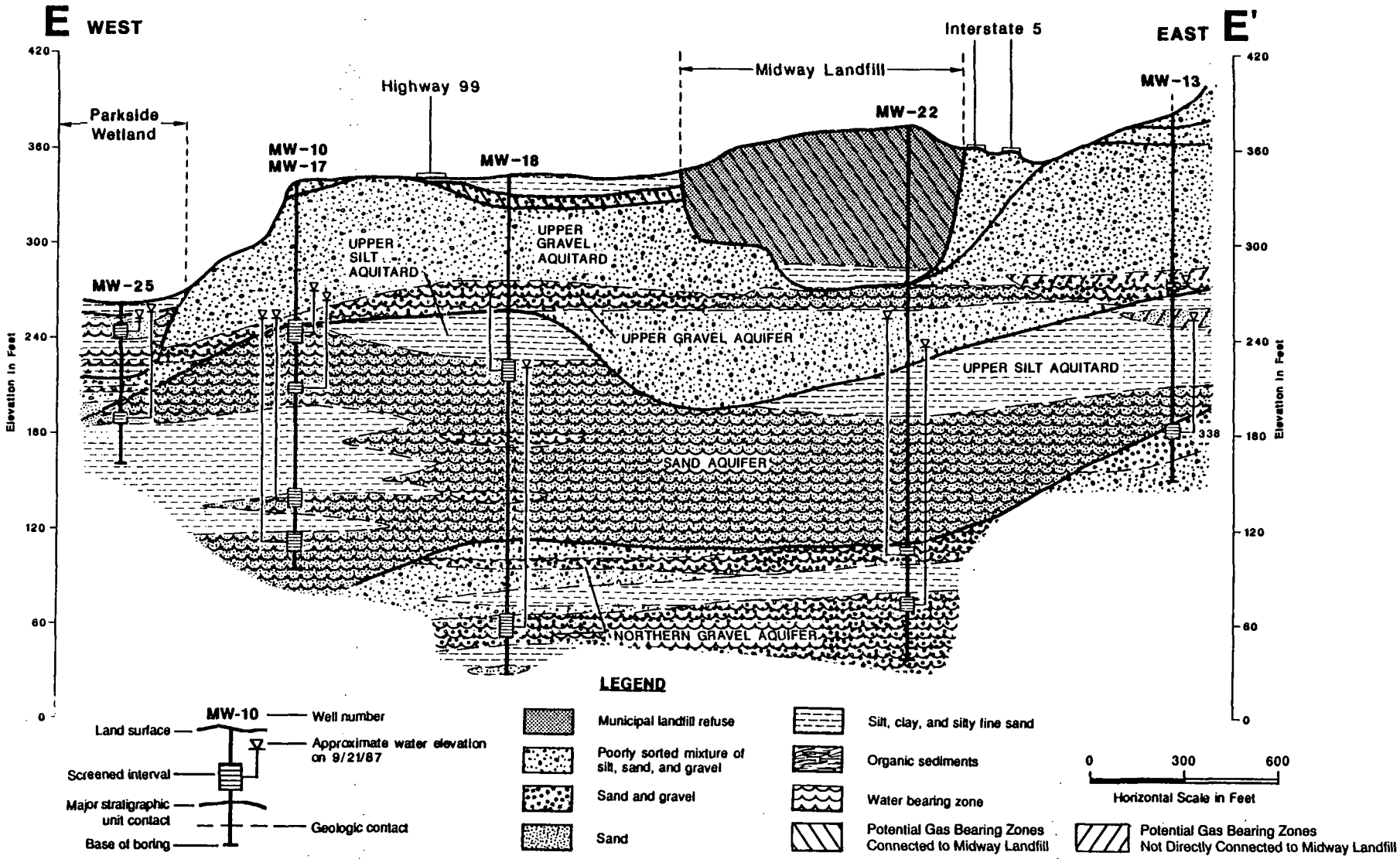
NOTE: LW-1 water level for 7/29/87.
AL water level for 7/3/87.

0 300 600
Horizontal Scale in Feet

NOTES:

1. For cross section location refer to Figure G1.
2. This cross section is a diagrammatic interpretation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

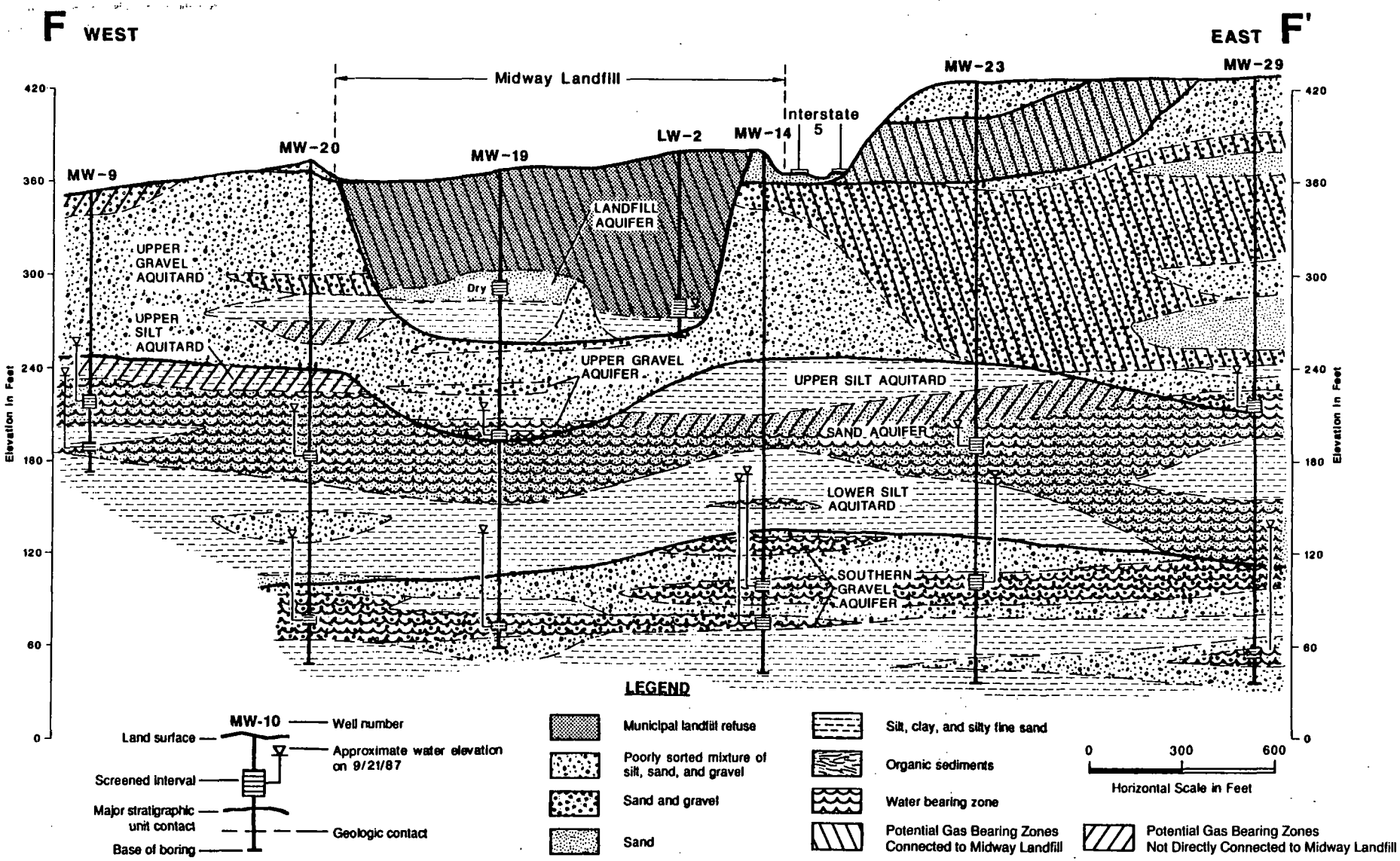
Figure G-7
Potential Gas Migration Pathways
Hydrogeologic Section D-D'
Midway Landfill



NOTES:

1. For cross section location refer to Figure G1.
2. This cross section is a diagrammatic interpretation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

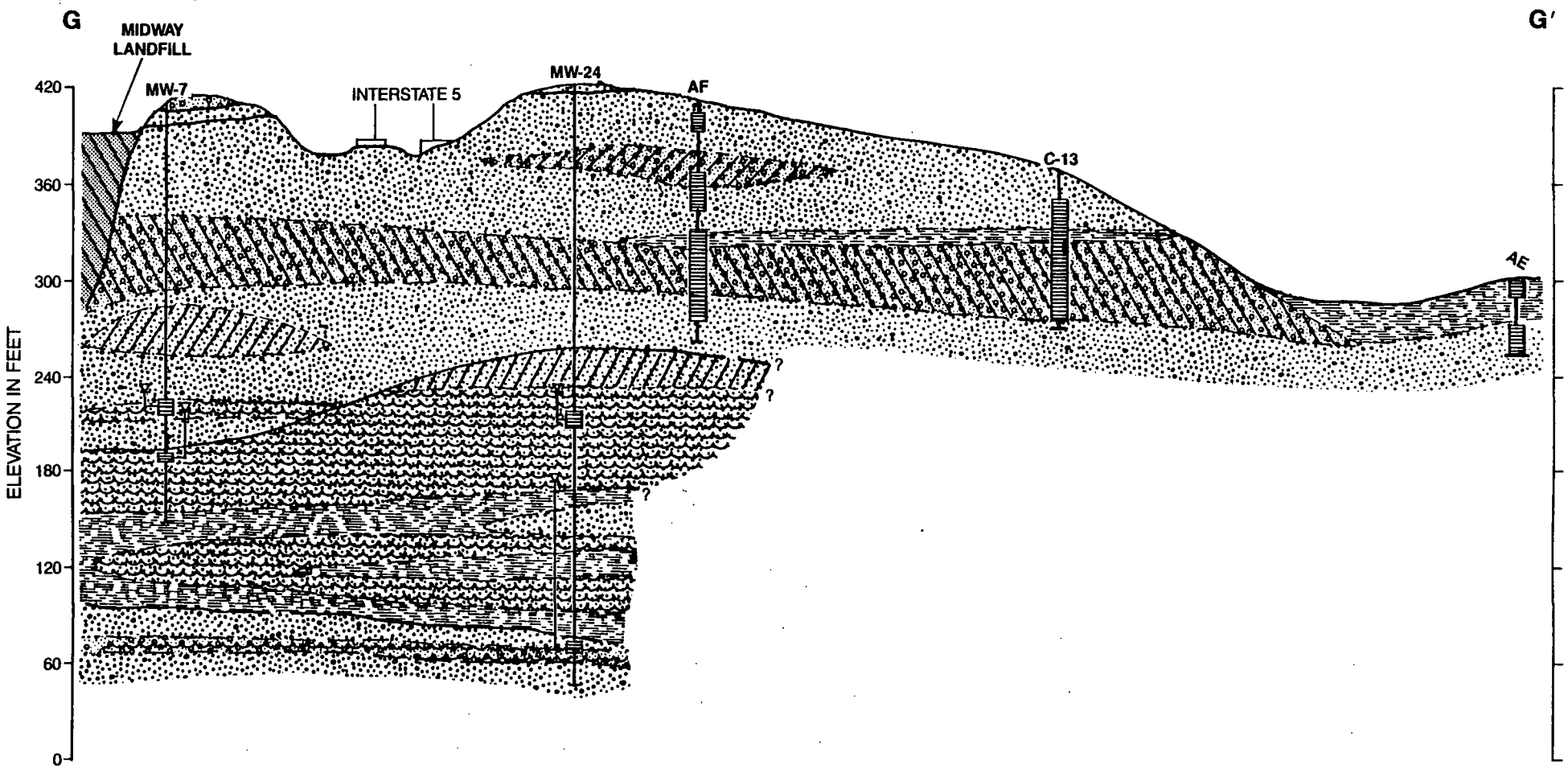
Figure G-8
Potential Gas Migration Pathways
Hydrogeologic Section E-E'
Midway Landfill
Kent, Washington

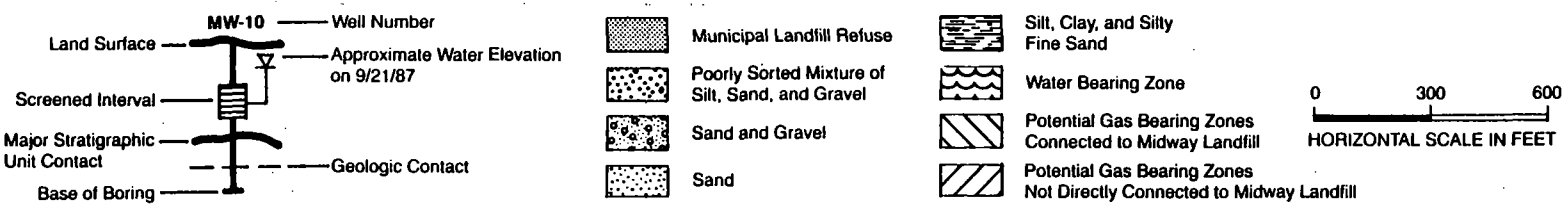


NOTES:

1. For cross section location refer to Figure G1.
2. This cross section is a diagrammatic interpretation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

Figure G-9
Potential Gas Migration Pathways
Hydrogeologic Section F-F'
Midway Landfill
Kent, Washington

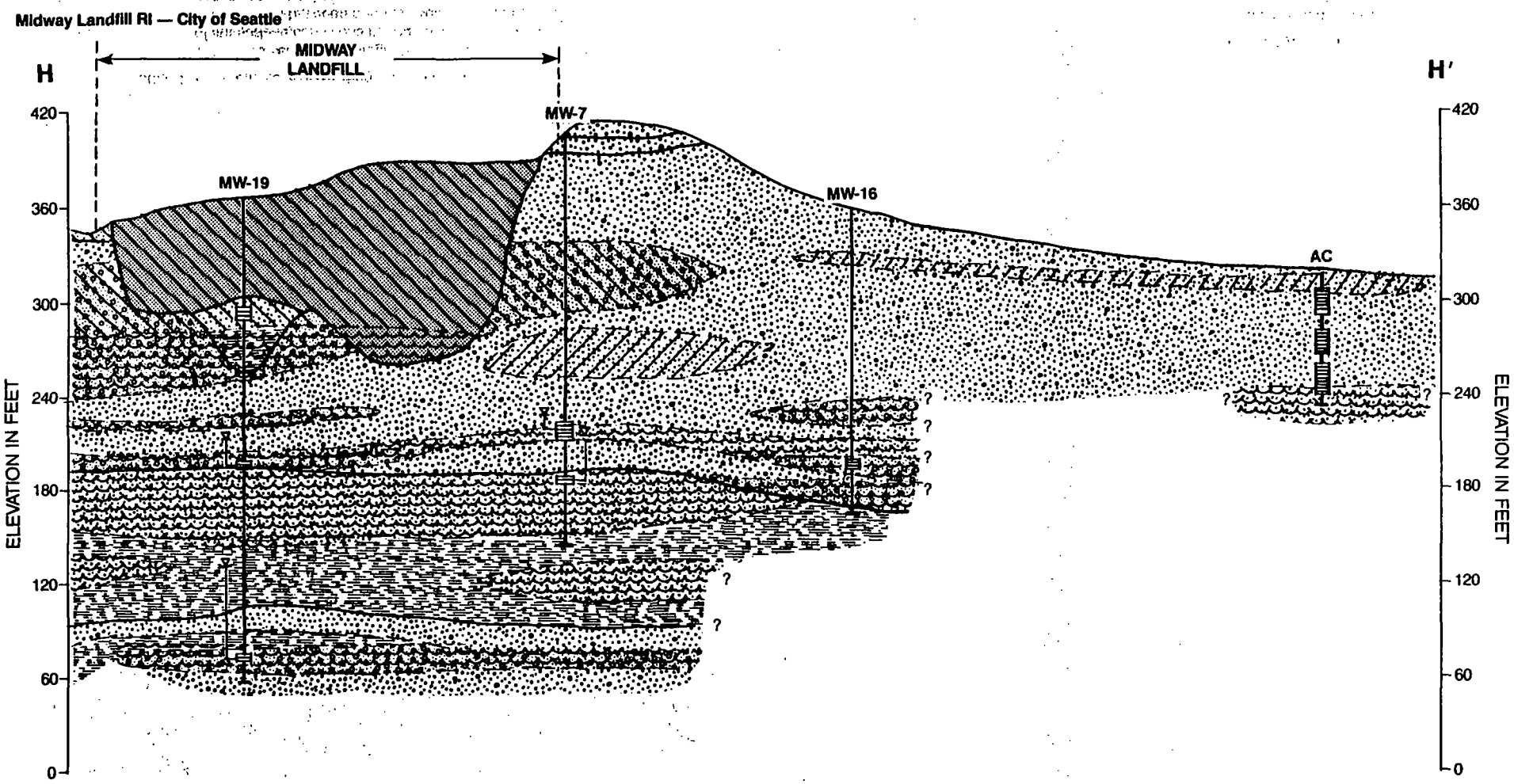


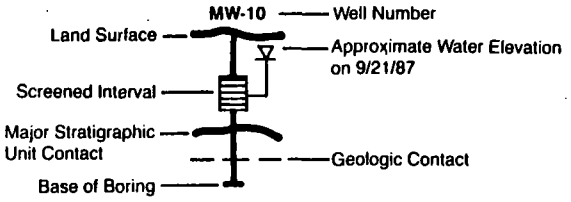


Notes: 1. For cross section location refer to Figure G-3.

2. This cross section is a diagrammatic interpertation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

Figure G-10. Potential Gas Migration Pathways Hydrogeologic Section G-G′





Municipal Landfill Refuse

Poorly Sorted Mixture of Silt, Sand, and Gravel

Sand and Gravel

Sand

Silt, Clay, and Silty Fine Sand

Water Bearing Zone

Potential Gas Bearing Zones Connected to Midway Landfill

Potential Gas Bearing Zones Not Directly Connected to Midway Landfill

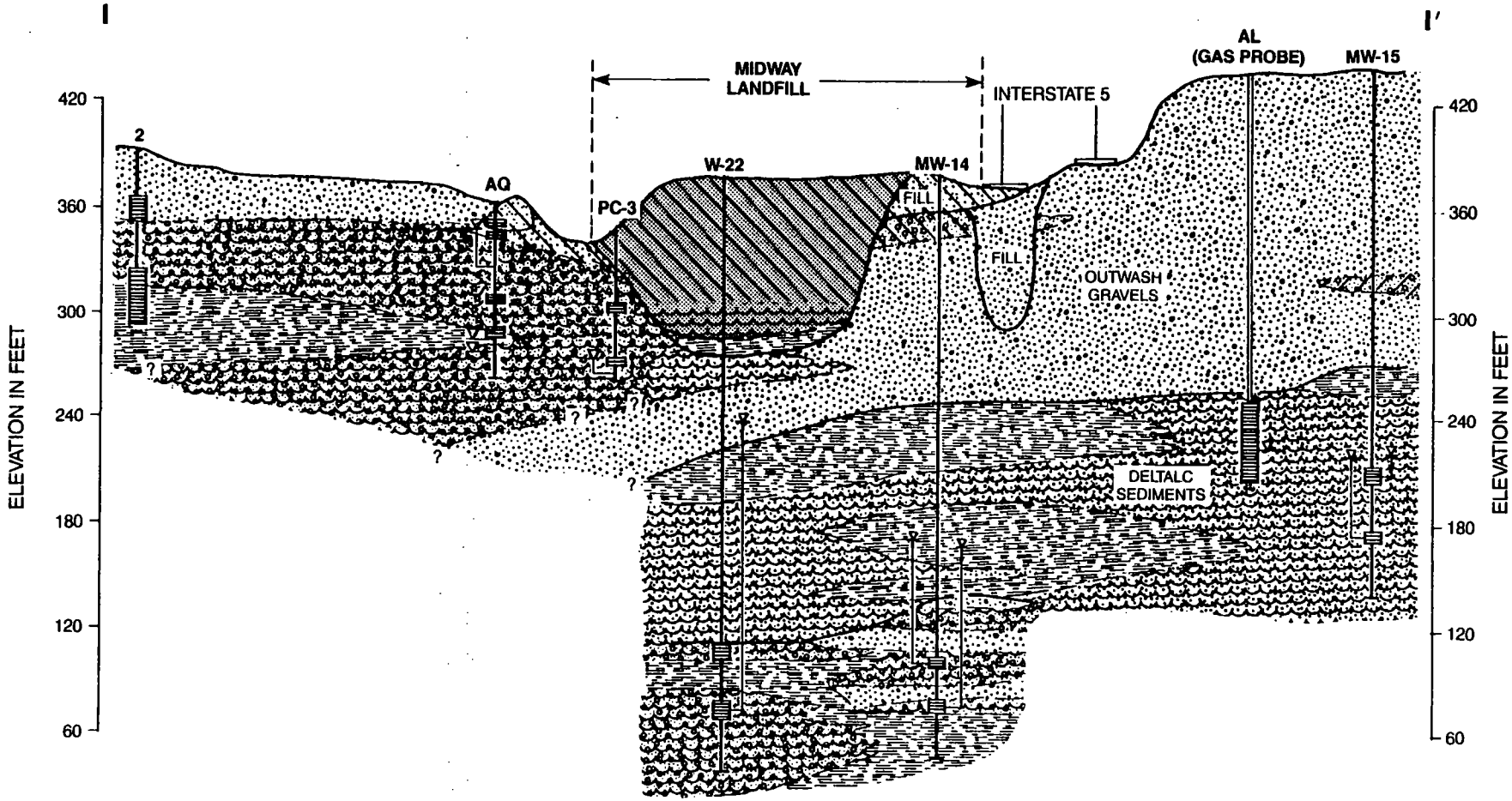
0 300 600

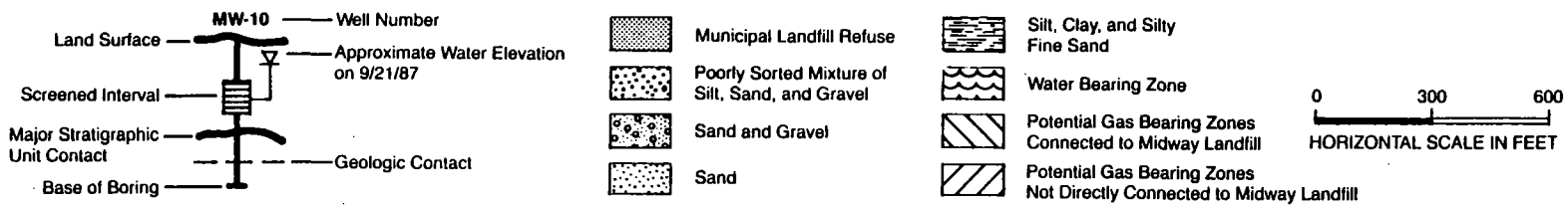
HORIZONTAL SCALE IN FEET

Notes: 1. For cross section location refer to Figure G-3.

2. This cross section is a diagrammatic interpertation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

Figure G-11. Potential Gas Migration Pathways Hydrogeologic Section H-H'



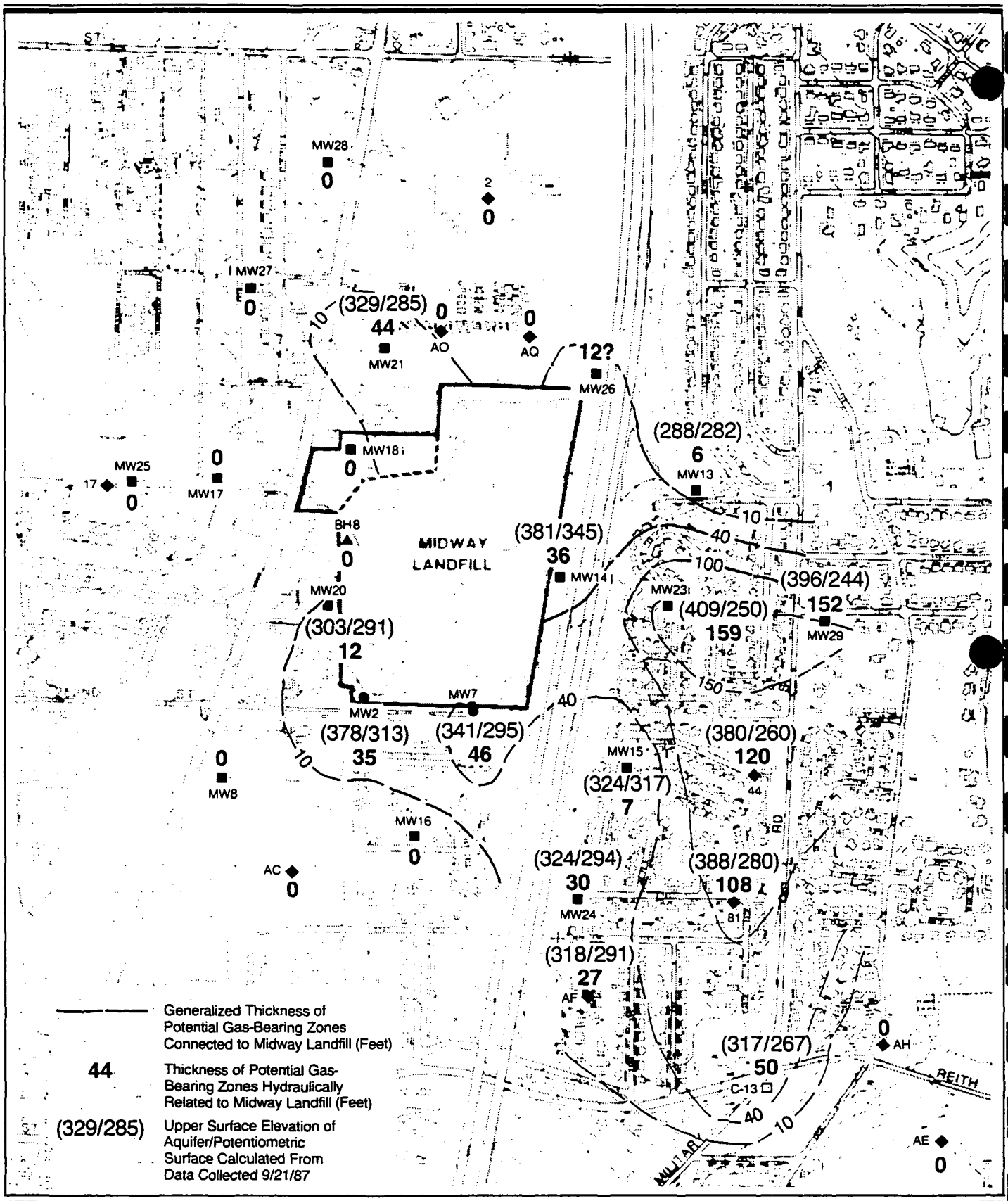


Notes: 1. For cross section location refer to Figure G-3.

2. This cross section is a diagrammatic interpertation of subsurface conditions based on interpolation and extrapolation between borings. Geologic and hydrologic conditions are substantially more complex than depicted.

Note: LW-1 water elevation on 7/29/87.
AL water elevation on 7/3/87.

Figure G-12.
Potential Gas Migration Pathways Hydrogeologic Section I-I'



SCALE IN FEET

0 500 1,000

N

- Gas Extraction Well
- Shallow Gas Probes
- Newer MW Wells (8-29)
- Older MW Wells (1-7)
- BH Series Wells (1-8)

Figure G-13.
Generalized Thickness of Potential Gas-Bearing Zones Connected to the Landfill Within the Upper Gravel Aquifer and Related Aquifers

Examples of large undersaturated units in the upper gravel aquifer are seen to the south of the landfill in Figures G-4, G-10, and G-11, and to the west of the landfill in G-9. Other undersaturated zones in the upper gravel aquifer that are connected to the landfill extend to the north, east, and south (see Figures G-5, G-6, G-7, and G-9).

The sand aquifer does not appear to be part of the gas migration system. It has much less total undersaturated area than the upper gravel aquifer. Also, undersaturated zones in the sand aquifer and upper gravel aquifer do not have areas of contact. The sand aquifer does contain small undersaturated zones, shown in Figures G-6, G-7, G-8, and G-9, that are not connected to the landfill. These isolated undersaturated zones appear where the roof of the sand aquifer is arched. Except in these arches, the potentiometric surface of the sand aquifer is above the roof of the aquifer.

Figure G-9 shows a zone in which the sand and upper gravel aquifers almost contact. An undersaturated zone in the sand aquifer is separated from a major undersaturated zone in the upper gravel aquifer by approximately 5 feet of clay or fill. This thin zone of sediment with low transmissivity would slow the potential movement of gas into the sand aquifer. Changes in barometric pressure would tend to move the gas horizontally rather than vertically. Also, there may be some standing water at the base of the upper gravel aquifer, creating a thin saturated zone with low gas-bearing potential. For these reasons, the sand aquifer is not considered to be directly connected to the landfill.

5.2.2 Specific Pathways

North and West

Figure G-6 shows a potential gas-bearing zone that extends northward past MW-21 and toward MW-12 and MW-28 but does not extend laterally as far west as MW-18.

Figure G-8 shows another migration path away from the landfill within a zone of sand and gravel extending west through MW-18 and appearing to surface near Highway 99.

In Figure G-12 it can be seen that a layer of relatively clean (low silt) sand and gravel of relatively high transmissivity extends from the landfill through Probes PC-3 and AQ to Probe 2. Because this sand and gravel layer is wet (fully saturated) or water-bearing (fully saturated and allowing noticeable movement of water), however, it acts as a barrier to landfill gas migration toward Probe 2. The cross section does not give stratigraphic clues to the origin of the gas found in the probe, but it does indicate that the landfill is not the probable source.

Similarly, Figure G-11 shows no pathway from the landfill toward gas Probe AC, which also has had high gas readings in the past. Probe AC is separated from the landfill by glacial till and till-like materials interspersed with thin layers of sand or sand and gravel. The thin sand layers in which gas has been detected in Probe AC do not connect back to the landfill.

East and South

A major pathway for gas migration is formed by the upper gravel aquifer where it extends east of the landfill approximately 1250 feet to Military Road (see Figure G-9). Gas may pass from the landfill through a relatively thin zone of sand and gravel in the vicinity of MW-14 and into a much thicker layer of sand in the vicinity of MW-23. This layer then branches into at least three zones that extend eastward toward MW-29. The main branch then joins a thick sand and gravel layer (also part of the upper gravel aquifer) running north-south beneath Military Road. The northern end of this pathway appears to decrease rapidly in thickness from over 150 feet to less than 10 feet between MW-23 and MW-13. It ends to the south of gas extraction well C-13, where it intercepts ground surface. As shown in Figure G-10, this sand and gravel layer also contacts a subsurface layer of silt that surrounds Probe AE. This silt layer is interpreted as a former peat bog. While it is a probable source of methane, it is also a unit of low transmissivity.

Gas that is detected in Probe AE or well C-13 or found to be exiting the outwash gravel layer along the slope is more likely to be generated by the former peat bog than the landfill. (This will be discussed further in Sections 5.4.3 and 5.4.4.)

Gas leaving the landfill to the east can also migrate into a layer of sand in the vicinity of MW-23 that trends eastward and upward toward the ground surface. This interception of the sand layer at the ground surface, which could also be thought of as a vent, occurs in the vicinity of Military Road and South 251st Street, between MW-23 and MW-15.

Another gas migration path, shown in Figure G-6, is within a zone of sand and gravel extending south from the landfill past monitoring wells MW-7 and MW-24. It is not known if this sediment layer reaches the ground surface.

5.3 HISTORICAL GAS CONCENTRATIONS

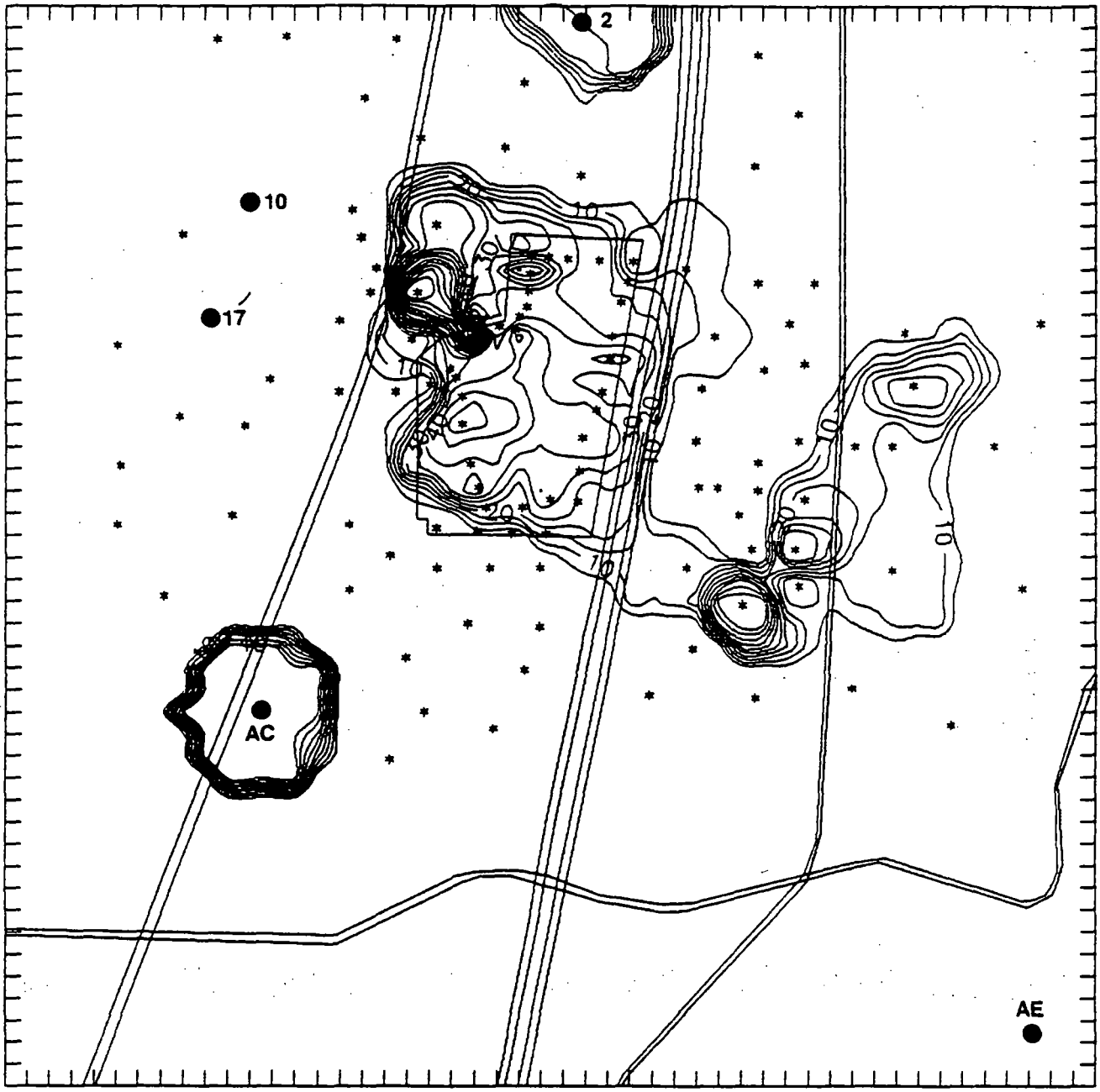
Gas concentration isopleths illustrate the distribution of subsurface gases by plotting data points from gas extraction wells and monitoring probes. Figures G-14 and G-15 show shallow and deep gas concentrations for February 1986. Figure G-16 shows deep gas concentrations for September 1986. The relation of these plotted concentrations to the migration pathways identified in Figures G-4 through G-12 will be discussed in Section 5.4 after consideration of the variables affecting gas movement.

5.4 VARIABLES THAT AFFECT GAS MOVEMENT

5.4.1 Physical Factors Related to the Landfill

Landfill Gas

After refuse has been in place one to two years, it begins to generate methane gas. For a particular deposit of refuse, the gas generation rate peaks two to five years after burial, depending on moisture content and air



Note: All sets of probes and wells may not be shown.

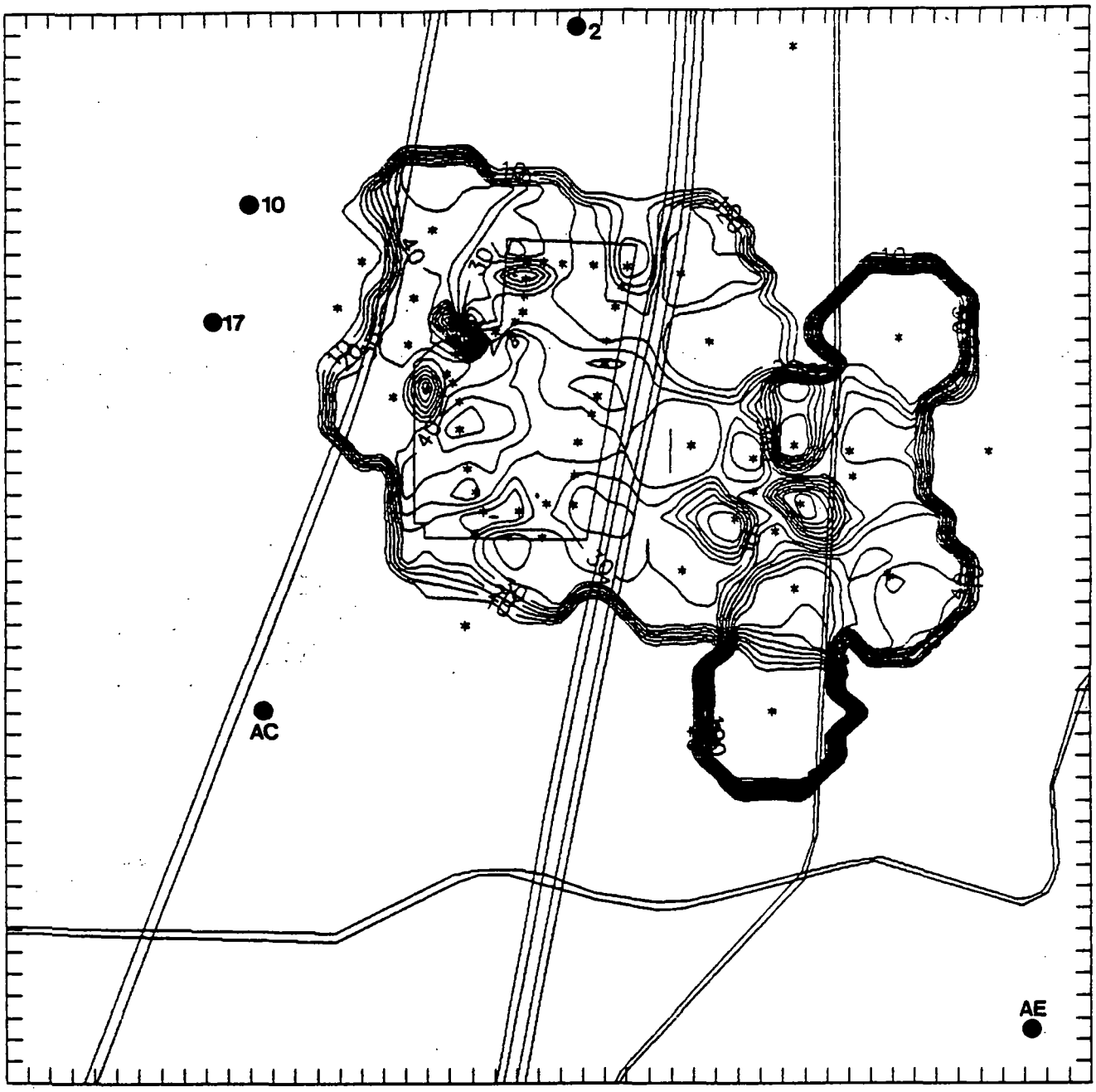
SCALE IN FEET

0 500 1,000

● Gas Probes 10 Feet Deep

* Gas Probes 40-100 Feet Deep and Offsite Control Wells

Figure G-14. Shallow Gas Concentration Isopleth, February, 1986



Note: All sets of probes and wells may not be shown.

SCALE IN FEET

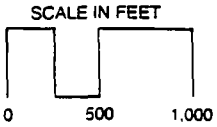
0 500 1,000

● Gas Probes 10 Feet Deep

* Gas Probes 40-100 Feet Deep and Offsite Control Wells

Figure G-15. Deep Gas Concentration Isopleth, February, 1986

Note: All sets of probes and wells may not be shown.



● Gas Probes 10 Feet Deep

* Gas Probes 40-100 Feet Deep and Offsite Control Wells

Figure G-16. Deep Gas Concentration Isopleth, September 1 to September 15, 1986

exclusion. After peaking, the rate for a particular deposit slowly decreases with time. In ten years, more than half of the total gas will usually have been generated. Generation at continually decreasing rates can extend thirty years and more.

The Midway Landfill is a combination of a large number of particular deposits begun in 1965 and ended in 1983. The landfill gas generation began in 1966 or 1967, increased as additional refuse was deposited, and peaked in about 1987.

As the landfill generates gas, a small positive pressure is created, pushing the gas away from the origin of generation. The gas will move fastest through paths of least resistance, which include porous portions of the solid waste, porous cover material, utility conduits, and layers of more permeable soil stratigraphy around the site.

Landfill Cover Material

During the years of landfill operation, the cover applied probably tended to be thin (0-12" thick), and often contained sands and gravels. This would allow the gas to vent through the cover relatively easily. Some loads of material with a high percentage of silts and clays were also received. Where those were used for cover, they would tend to restrict gas venting through the surface. Later, after additional layers of solid waste had been deposited, these silt-clay cover areas created perched water tables within the landfill. The amount and extent of perching increases during the rainy season. These perched water tables restrict gas movement within the landfill.

As the landfill neared the end of its active life for solid waste disposal, covering practices were changed. Over increasing areas of the site, the cover placed was thicker and was compacted better, and a portion of the cover material included a higher percentage of silts and clays. This reduced the ability of the gas to vent through the cover in those areas. Further reductions in cover permeability occur each winter when the cover is saturated by rainfall and when the water at the surface occasionally freezes.

Contacts Between the Upper Gravel Aquifer and the Landfill

The excavation in which the landfill was developed intercepts the upper gravel aquifer. This creates a path of direct access to the upper gravel aquifer. There is a good potential for gas to migrate from the landfill into the upper gravel aquifer, and from the aquifer back to the landfill.

5.4.2 Variable Physical Conditions or Forces

Barometric Pressure

Barometric pressure fluctuations, together with the gas generation pressure, produce complex gas migration dynamics. The low gas generation pressures in the landfill initially move the gas away from the points of origin through the paths of least resistance. The generation pressures are estimated to be

in the range of two inches of water column, based upon measurements in other landfills. Atmospheric pressure is measured with a barometer as inches of mercury. One inch of mercury equals 13.5 inches of water column. Changes in atmospheric pressure of -0.7 inches of mercury or -9.5 inches of water column are common during the winter months as high pressure ridges give way to low pressures during storms. This can create a relatively strong pressure differential between the air or gas within the soil or landfill, and the air at the ground surface.

The air or gas within the soil or the landfill tends to flow toward the ground surface through the paths of least resistance in response to this pressure differential. This is referred to as the expansion phase during a falling barometer. In the landfill prior to the operation of the active gas migration control system, the gas would vent to the atmosphere through the cover more rapidly where the cover was most permeable and where there were no perched water tables. In the soil around the landfill, there would be restricted but significant air or gas movement vertically from the undersaturated sand and upper gravel aquifers through the upper gravel aquitard to the ground surface. There would also be horizontal movements through the undersaturated upper sand and gravel aquifers toward areas where they contact the ground surface. The upper sand aquifer contacts the surface east of the landfill (Figure G-9), and the upper gravel aquifer contacts the surface along the west slope of the Kent valley. West of the site near Highway 99 the near-surface sand and gravel aquifer contacts the surface (Figure G-8). Similar horizontal components of gas and/or air movement would have occurred through lenses of permeable soil within the aquitards, and in thin sedimentary layers close to the ground surface.

During rising atmospheric pressures, similar gas/air movements take place, but in reverse directions. Air from the ground surface tends to move down into the soil both vertically and horizontally through the undersaturated aquifers described above. However, this reverse movement is not sufficient to push back all the landfill gas that has diffused away from the landfill through the soil pores during the expansion phase.

The combined effect of the generation pressures and the repeated expansion phases during falling barometers would be a pumping action within the soils, which, over time, could have moved the gas up to 2600 feet horizontally from the landfill (its maximum observed extent). Then gas would move to the soil surface in some areas with every storm front and falling barometer.

Operation of the active gas migration control system has created a vacuum in and around the landfill, eliminating the gas generation pressure, and moving the gas slowly back toward the landfill. Rising barometric conditions help the horizontal and vertical components of that movement, but the diffusion within the soil pores slows the process. Falling barometric conditions could still cause gas to vent to the ground surface if there are areas beyond the influence of the migration control system vacuum where gas in significant concentration remains in the ground. No instances of this are known.

Hydraulic Conductivity and Permeability

Where sediment layers are undersaturated there is a high positive correlation between their ability to transport gas or air and their ability to transport water. The ability to transport water is expressed in both hydraulic conductivity and permeability. Hydraulic conductivity is the rate of flow of fluids such as groundwater or gas through a porous medium. It is dependent on the physical properties of the fluid (kinematic viscosity) and the nature of the pore spaces. In aquifers, hydraulic conductivity is highly directional, because of the complex geometry of pore spaces in the nonuniform deposits characteristic of glacial outwash. That is, hydraulic conductivity will vary in such deposits depending on the direction of flow. Hydraulic conductivity is expressed in units of length/time as cm/sec, or in units of volume/time/area, as gal/day/ft^2.

Intrinsic permeability is a measure of the relative ease with which a porous material can transmit a fluid. It is a property of the porous material, and is independent of the nature of the fluid and the force causing movement. Intrinsic permeability is dependent on the size and shape of the pores present in the material. Permeability units are expressed in length units squared (L^2).

Tests for hydraulic conductivity and permeability performed by Applied Geotechnology, Inc. (1988) show good potential for gas migration within the undersaturated zones within both aquifers. Slug tests for hydraulic conductivity show values for the aquifers similar to those expected for clean to silty sand; in contrast, the upper gravel aquitard that lies above the upper gravel aquifer has a conductivity value similar to that expected for unweathered clay (Freeze and Cherry 1979).

According to AGI's tests, the hydraulic conductivity of the upper gravel aquifer is 5.5×10^{-4} cm/sec, which equates to 12 gal/day/ft^2. The hydraulic conductivity of the sand aquifer is 2.9×10^{-3} cm/sec, which equates to 62 gal/day/ft^2. In contrast, the hydraulic conductivity of the upper gravel aquitard (based on a single measurement) is 2.3×10^{-8} cm/sec, which equates to 0.00049 gal/day/ft^2. The results of AGI's permeability tests supported the results of the hydraulic conductivity tests. Both hydraulic conductivity and permeability correlate positively with mass flux.

Gas Concentrations and Mass Flux

Gas, air and water may be found in almost any sedimentary material; the speed with which these substances migrate (mass flux) will vary. A well drilled into any sedimentary material may have a high gas concentration, but the mass flux of gas through that sediment material and the time it took to reach that concentration will vary.

For example, a silt layer in contact with a source of gas will take in that gas, and over years will build up a large concentration. When a well is drilled into that silt, the disturbed sediment will release the gas and a high reading may be recorded. However, the mass flux in the silt is low, and the rate of movement from beyond the disturbed sediments is low. A completed

extraction well in a low mass flux sediment may only collect a low flow of gas. On the other hand, an extraction well in a high flux, gas bearing sediment may show a continuous high flow of gas, as the gas in that sediment is free to move toward the well.

Water Table Fluctuations and Gas Pockets

The movement of gas in aquifers may, in some situations, be controlled both by combinations of irregularities in the upper surface of gas-transmitting sediment layers and fluctuations in the water table. Gas may be trapped in pockets in these upper surfaces when the water level rises, and be released during periods of declining water table levels. Trapped gas may not be detected in nearby monitoring probes until the water table drops. Then the released gas can be detected. The smaller the irregularity in the upper surface, the smaller the chance that the gas pocket created will be detected. There are probably numerous such gas pockets within the study area.

Rising water tables during the winter in the sand and upper gravel aquifers may also help to move gas in the soil to the ground surface. Seasonal fluctuations have been in the range of 1 to 8 feet in most monitoring wells, but two wells near the western border of the site, BH-8 and MW-8A, varied 20 to 24 feet. This rising water would slowly push any gas in the soil toward the ground surface.

5.4.3 Variables in the Landfill Vicinity

Contacts Between Aquifers

It is unlikely that gas can migrate between the sand aquifer and the upper gravel aquifer without having to travel through groundwater. This is shown in the results of the groundwater and leachate well drilling program. Although the two aquifers have large areas of mutual contact, these contacts appear to be saturated. It is possible that undiscovered undersaturated zones are present through which migration can occur.

Surface Sedimentary Layers

Minor amounts of gas, whether generated within the landfill or entering the landfill from an outside source may travel for short distances within connected thin layers of sand or connected, relatively less well compacted sediments immediately below the ground surface. These thin layered sediments would be likely to transport or contain gas if in contact with the landfill or other source of gas. Non-intercepted layers would not receive gas directly from the landfill as they are isolated from the upper gravel or sand aquifers by the upper gravel aquitard. However, they may receive gas by vertical migration through aquitards as described below.

Interception of Aquifers by Ground Surface

Where undersaturated aquifers that may transmit gas extend to the ground surface, gas may escape or vent in significant quantities. One such vent

will be discussed later in Section 5.5. The landfill surface is another release point for gas.

Vertical Migration through Overlying Aquitards and Heterogeneities

The aquitards overlying the upper gravel aquifer and the sand aquifer appear to severely limit the vertical migration of gas between aquifers. In reality, these aquitards may be as saturated with gas as the aquifers, but the velocity at which the gas moves through the aquitard is reduced by 2 to 6 orders of magnitude because the hydraulic conductivity and permeability are low. For this reason, the aquitards release smaller quantities of gas to an overlying sediment or to the ground surface than do aquifers. Gas releases to the ground surface have apparently occurred up to 2000 feet east of the landfill and 600 feet west of the landfill, as shown on Figure G-11.

Heterogeneities in the sediments can also affect the speed and direction of gas movement through the sediments. These heterogeneities consist of variations in the range and sorting of grain sizes as well as the density of a sediment. Gas can migrate more easily through sediments with lower proportions of silts and clays, such as buried stream channels and other sediments deposited locally within a high energy environment; however, it would tend to move around sediments with greater proportions of silts and clays, such as buried lake beds, peat bogs, and other sediments deposited locally in a low energy environment.

Other Potential Sources of Gas

Interpretations of sediment cross-sections show the possible presence of buried peat bog deposits, lake beds and other buried wetland areas. These can be wherever a small, lens-shaped body of silt or clay is observed. Numerous small beds noted in the drilling logs may be composed of such fine-grained materials. An even greater number of such beds may have gone undetected. In one boring a tree over six inches thick was encountered at roughly 350 feet below the ground surface. Buried organic material not reached by oxygen may still be generating background levels of 200 ppm or more of methane after thousands of years. These concentrations are detected in probes farther from the landfill.

5.4.4 Gas Migration Control System

The present gas extraction system on the Midway Landfill is having an effect on the movement of landfill-generated gas in the proximity of the landfill.

The gas migration control system has been observed to pull landfill-generated gas that has migrated away from the landfill back toward the landfill. It appears that any sedimentary layer that has transmitted landfill-generated gas will also be influenced by the gas extraction system. The change in movement in any sediment layer is likely related to past relative mass flux and conductivity.

Data show that the gas extraction system has been particularly effective in the large gas migration pathways identified in this report. To the southeast of the landfill in a line from groundwater monitoring well MW-24 through Probe AF, extraction well C-13, and Probe AE (see Figures G-3 and G-10), and to the east of the landfill in a line through MW-23, Probes 50, 44 and 81, and Probes AH and AE (see Figure G-3 for well locations), the gas extraction system has been shown to lower methane levels in all wells except those apparently influenced by non-landfill sources of methane. Table 1 shows changes in methane levels in these wells over the two-year period from January 1986 to December 1987.

Table 1. Changes in off-site methane levels.

Southeast from MW-24 to Probe AE

	MW-24	AF	C-13	AE
January 1986	9%	15%	1.3%	13%
December 1987	3%	7%	0.086%	35%

South from MW-23 to Probe AE

	MW-23	50	44	81	AH	AE
January 1986	20%	1%	NA	2.7%	0.008%	13%
December 1987	7%	0.12%	NA	2.8%	0.01%	35%

Note: Units are percent gas by volume.

The increase in the methane level in Probe AE over this two-year period does not appear to be related to the landfill. The shallow completion of Probe AE is in the silt layer described in Section 5.2 and shown in Figure G-10, interpreted as a former peat bog. The deep completion is in a zone of poorly sorted gravel (glacial till), also containing sufficient silt to give it relatively low permeability. These hydrogeologic characteristics shown in cross section G-G' (Figure G-10) suggest both that the movement of landfill gas would be retarded in this area and that the influence of the negative pressure (vacuum) exerted by extraction well C-13 would be slight.

Both hypotheses are supported by gas pressure data from Probe AE. Monitoring probes that are under the influence of an active vacuum extraction system generally will show negative pressure in the deeper soil zones with slight fluctuations in response to barometric changes. Probe AE shows wide swings from positive to negative pressure in both deep and shallow zones whether C-13 is on or off. This indicates that C-13 is having little or no effect on Probe AE. While other factors that may be affecting Probe AE are not known, it can be said with some certainty that the landfill is probably not one of them.

5.5 DISCUSSION

It would appear that the undersaturated portions of the upper gravel aquifer formed the major gas migration pathway to the east and southeast of the landfill (Figure G-6 and G-9), allowing gas to migrate up to 2600 feet from the landfill. This affected area extended from I-5 to the east of Military Road and is demonstrated in Figure G-15 by the deep gas concentration isopleth for February 1986 (see Appendix B, Off-Site Gas Probes). The gas could have been drawn to the ground surface by the pumping action of barometric changes, contributing to the gas in shallow soils east of the landfill near Military Road shown on Figure G-14, the shallow gas concentration isopleth for February 1986. The undersaturated portion of the upper gravel aquifer does not extend to the southeast as far as Probe AE (see Figure G-3 and G-10). It does not appear that significant quantities of landfill gas would have migrated to the area around Probe AE; furthermore, fluctuations in methane levels and gas pressures over time in Probe AE suggest that this probe is beyond the influence of the gas migration control system and that the silt layer surrounding the probe is probably a former peat bog, which is itself a source of the methane detected in the probe.

The undersaturated portion of the upper gravel aquifer also could have been the major gas migration pathway to the south of the landfill, allowing gas to migrate up to 2000 feet from the landfill, as shown in Figure G-13. However, the upper gravel aquitard appears to have been impermeable enough to limit gas movement to the ground surface. Shallow gas has never been found in probes here (see Figure G-11). The affected area extends from the landfill to S. 259th Pl. between 29th Avenue S. and I-5. The undersaturated portion of the upper gravel aquifer does not extend to Probe AC southwest of the landfill, east of Highway 99 at about S.257th St. It does not appear that landfill gas would have migrated to the area around Probe AC, or that gas being generated in the vicinity of Probe AC would migrate any significant distance.

The undersaturated portion of the upper gravel aquifer also appears to be a gas migration pathway for a short distance west of the landfill (Figure G-12), but here again the upper gravel aquitard appears to have been impermeable enough to limit gas movement to the ground surface (Figure G-11). The area affected was from the landfill to Highway 99, between S. 249th St. and S. 252nd St.

And finally, the undersaturated portion of the upper gravel aquifer could have been a gas migration pathway for a limited distance northwest of the landfill (Figure G-12). However, the upper gravel aquitard and an overlying perched water table appear to have limited gas movement to the ground surface. The area affected was from the landfill north to about S. 244th St., between Highway 99 and 30th Avenue S. extended. The undersaturated portion of the upper gravel aquifer does not appear to extend to Probe 2, just south of the Midway Drive-in Theater. It does not appear that landfill gas would have migrated to the area around Probe 2, or that gas being generated in the vicinity of Probe 2 would migrate any significant distance.

The undersaturated portions of the upper gravel aquifer east of the landfill and the near-surface sand and gravel layer west of the landfill both probably contributed directly to gas migration away from the landfill and surface venting of gas into structures. Affected areas east of the landfill between 34th Ave S. and Military Road and west of the landfill between the landfill and Highway 99 appear on Figure G-11. The near-surface sand and gravel layer does not extend near the Parkside Wetland near Probes 10 and 17. It does not appear that landfill gas would have migrated to the area around Probes 10 and 17, or that gas being generated in the vicinity of Probes 10 and 17 would migrate any significant distance.

Pathways for gas transport may also exist in relatively less well compacted sediments near the ground surface, and in thin layers of sand. Other heterogeneities, such as those due to sediments deposited locally within a high energy environment, affect the speed and direction of gas movement and may allow vertical gas movement through the gravel aquitard to the ground surface in some areas.

The on-site gas migration control wells have established a strong vacuum influence in the undersaturated aquifers and aquitards underlying and surrounding the Midway Landfill. This vacuum is slowly pulling gas back to the site, and it appears that no geological conditions exist that would prevent the removal of gas from the remaining off-site areas. It does not appear that any additional migration control wells would be needed or even speed up the gas removal process. There are no indications of any geological migration pathways that are below the gas probe borings and that could affect the functioning of the gas migration control system.

6.0 CONCLUSIONS

This investigation indicates that physical conditions form gas migration conduits and influence the movement of subsurface gas in and around the Midway Landfill. These conditions permit the migration of subsurface gas from the landfill to the surrounding area, or from the surrounding area to the landfill. Among these conditions are the relative positions of and the contacts among the upper gravel aquifer, the sand aquifer, the near-surface sediment layers, and the landfill. Thin, shallow surface sediments may also be involved. These conditions had the following effects on gas migration prior to the operation of the gas migration control system:

- Gas migration occurred between the landfill and the upper gravel aquifer, as detected in probes east and south of the site.

- Gas movement occurred within zones of aquifers that are not totally saturated and are found extensively east, southwest, and south of the landfill, to a limited extent west and northwest of the landfill, and to a very limited extent north of the landfill.

- Gas movement occurred between aquifers, but at a slower rate.

- Only small amounts of gas could have migrated from the upper gravel aquifer to the ground surface, except where the upper gravel aquifer is intercepted by the landfill.

- Gas migration occurred in thin, shallow, near-surface sediment layers, as detected west of the site.

- Only small amounts of vertical migration through heterogeneous zones within less permeable sediments could have occurred, and there is no evidence that it did occur.

- There are no indications of any geological migration pathways that are below the gas probe borings and that could affect the functioning of the gas migration control system.

- It appears that no geological conditions exist that would prevent the removal of gas from the remaining off-site areas.

- It does not appear that any additional migration control wells would be needed or even speed up the gas removal process.

- Some gas appears to be generated off-site in the vicinity of Probes AC (southwest), AE (southeast), 10 and 17 (Parkside Wetland, west), or 2 (north). There is no indication that this gas would migrate any significant distance, either naturally or due to the influence of the migration control system, or that geologic gas migration pathways would have allowed large quantities of landfill gas to reach those areas.

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APPENDIX H

SPECIAL GAS CHARACTERIZATION

DRAFT

MIDWAY LANDFILL REMEDIAL INVESTIGATION

TECHNICAL MEMORANDUM

SPECIAL GAS CHARACTERIZATION

Prepared for:

CITY OF SEATTLE ENGINEERING DEPARTMENT
SOLID WASTE UTILITY

Prepared by:

PARAMETRIX, INC.
13020 Northup Way, Suite 8
Bellevue, WA 98005

March 23, 1988
PMX # 55-1550-11

PREFACE

This Draft Technical Memorandum was prepared as part of the Midway Landfill Remedial Investigation landfill gas studies. It is issued here as Appendix H of the Landfill Gas Technical Report. Recently collected additional data concerning tritium activity in on-site and off-site gas samples are currently being analyzed and will be incorporated into a final draft of the Special Gas Characterization Technical Memorandum to be issued separately.

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1.0 INTRODUCTION

1.1. GENERAL BACKGROUND

This Technical Memorandum discusses special gas characterization investigations conducted as part of the Midway Landfill RI under the direction of the Washington State Department of Ecology. The purpose of this particular study was to develop a method for distinguishing methane gas produced by the decomposition of Midway Landfill materials from methane gas produced by other sources (e.g., peat bogs, wetlands, or commercially supplied natural gas). The ability to distinguish between sources of gases with similar methane composition was considered essential to determine the source of gas products detected near the Midway Landfill site. Subsurface gases from the landfill and surrounding areas were analyzed for differences in activity levels of naturally occurring radioactive isotopes (carbon-14 and tritium).

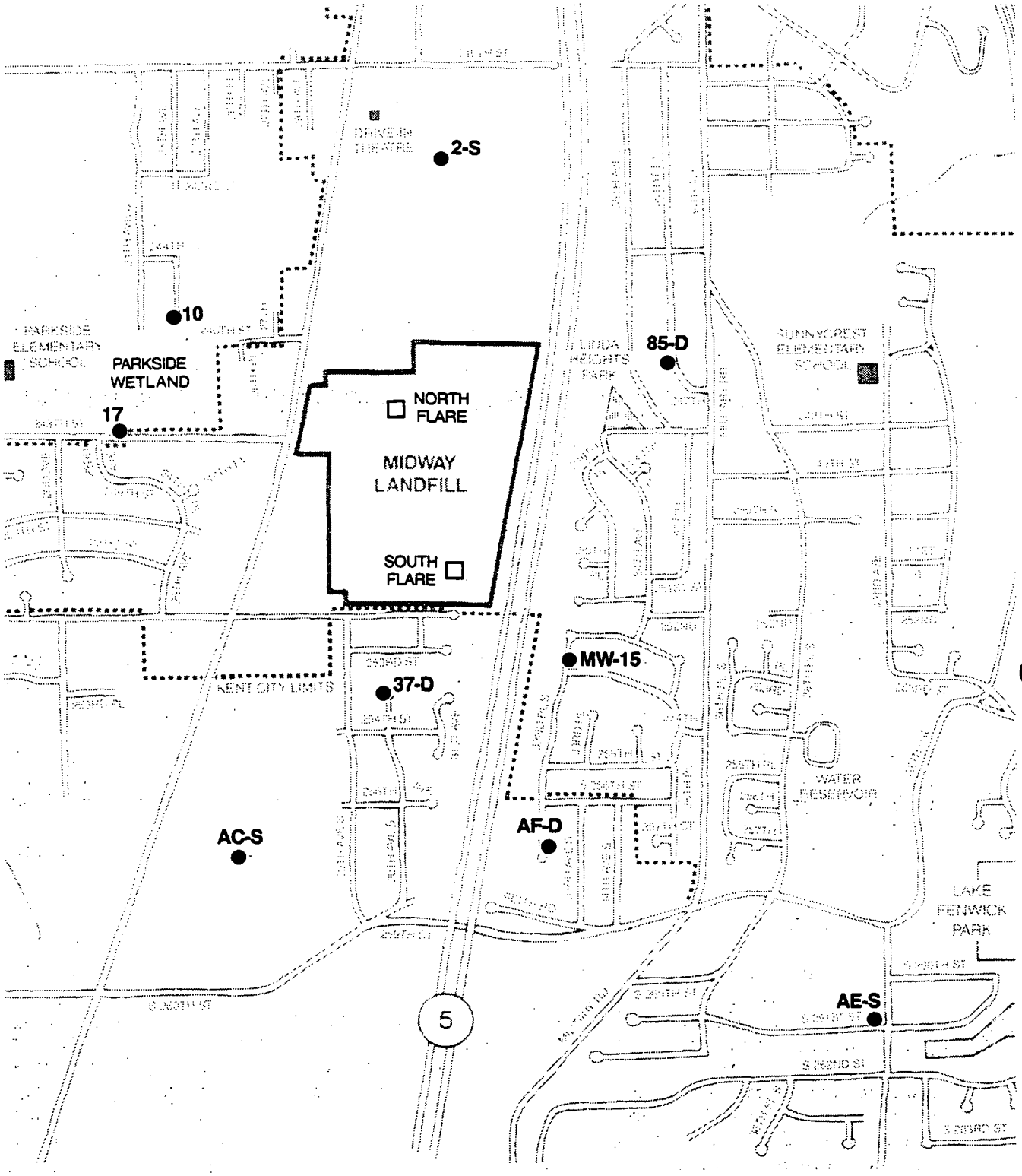
Combustible gases, predominantly methane, have been detected in both on-site and off-site subsurface gases. On-site combustible gases produced by the decomposition of the material in the landfill are being collected by a gas extraction well system and burned at two temporary flare installations on-site. Off-site migration of landfill gas is being monitored at numerous gas monitoring probes and off-site gas control wells located in neighborhoods surrounding the landfill. Off-site combustible gases are being controlled using both the on-site gas extraction system and off-site gas control wells.

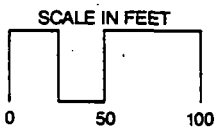
Some of the combustible gas detected off-site is believed to have migrated from the landfill. However, it is possible that the landfill is not the only source of gas detected off-site. Some of this gas may be originating from peat bogs, wetlands, commercially supplied natural gas, and other sources of combustible gas, such as the Parkside Wetland near probes 10 and 17 (Figure 1).

1.2 THEORETICAL BACKGROUND

Carbon-14 and tritium (^{3}H) are radioactive isotopes of nonradioactive carbon-12 and hydrogen (^{1}H). The proportion of carbon-14 and tritium occurring in nature is extremely small but measurable using sensitive radiation monitoring techniques. The monitoring instruments sense the bursts of energy or radiation that occur as the isotopes transform (decay) from their unstable radioactive forms (^{14}C and ^{3}H) to their more stable nonradioactive forms. Both carbon-14 and tritium existed in nature prior to the nuclear age. Since the advent of the nuclear age (about 1950), the ratio of ^{14}C to ^{12}C and ^{3}H to ^{1}H has increased substantially as a result of nuclear testing.

These radioactive isotopes are incorporated into the tissues of plants and animals in the same manner as nonradioactive ^{12}C and ^{1}H and in the same proportions as the isotopes occur in the atmosphere (in the case of carbon) and in rainwater (in the case of tritium) at the time of tissue growth. Once in the tissue, the proportions of ^{14}C to ^{12}C and ^{3}H to ^{1}H do not change





● Gas monitoring probes

Figure 1.
Location of Special Gas Characterization Sampling Points

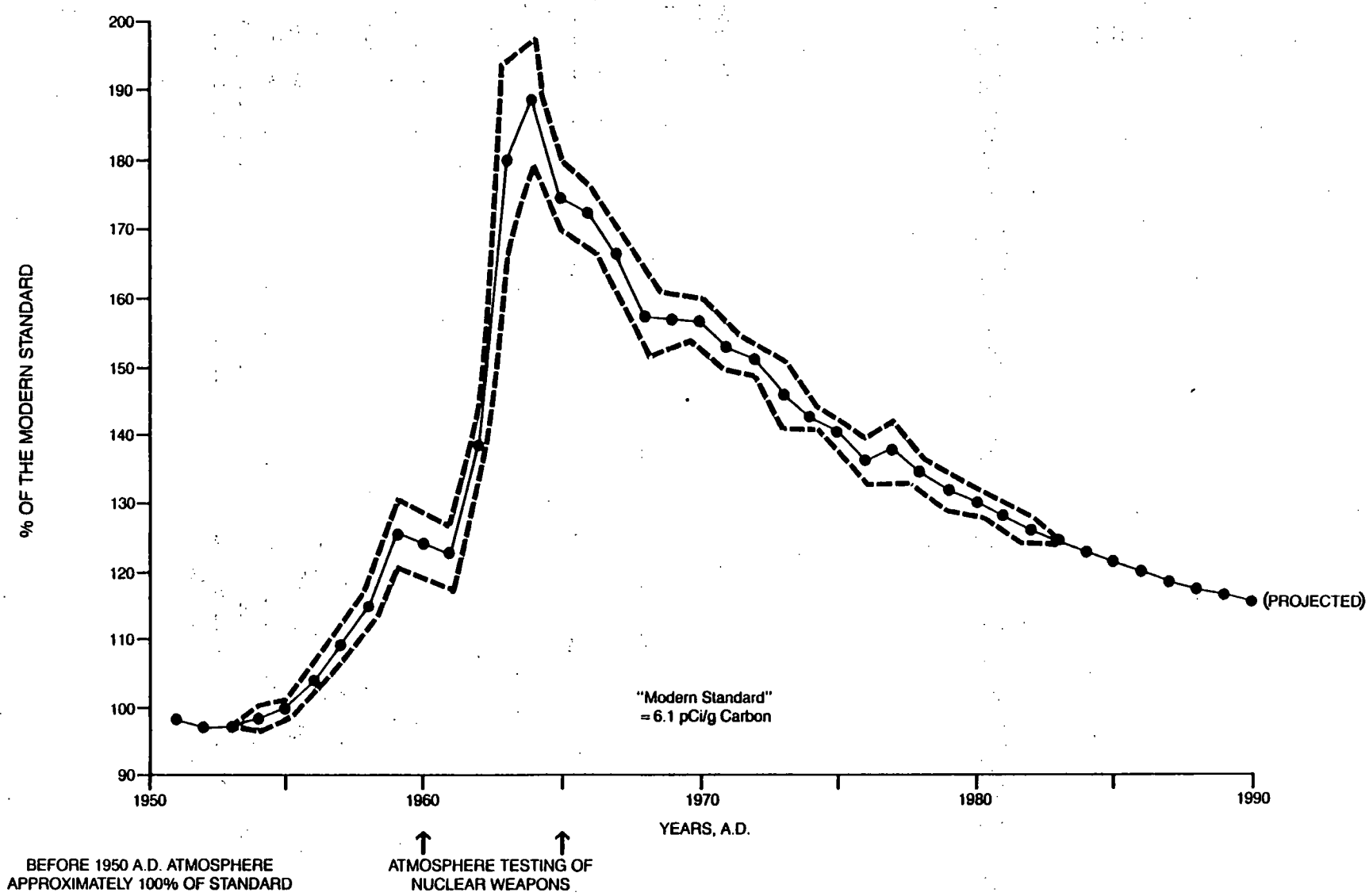
except through the decay of the unstable forms. By knowing both the ratios of $^{14}C:^{12}C$ and $^{3}H:^{1}H$ in prior years and the current level of radioactivity in plant and animal tissues, the age of any tissue or anything derived from that tissue can be estimated.

The original goal of the Midway Landfill radiological investigations was to establish the age of the subsurface gas samples collected from on-site and off-site locations by analyzing their carbon-14 content. It was believed that methane gas produced by the Midway Landfill would exhibit a higher level of carbon-14 activity, whereas methane gas produced by a peat bog or other natural source would exhibit a lower carbon-14 activity.

Prior to 1951, the ratio of carbon-14 to carbon-12 in the atmosphere was constant; the radioactivity level associated with that ratio was constant and was labeled Modern Standard Activity (MSA). MSA is defined as either 6.1 picoCuries per gram of carbon, or 13.56 disintegrations per minute (dpm) per gram of carbon. Above-ground nuclear weapons testing during the late 1950s through the mid-1960s increased the ratio of carbon-14 in the atmosphere (see Figure 2). Therefore, all plants and animals living since 1950 have an elevated level of carbon-14 that is more or less identical to the carbon-14 content of the atmosphere during their lifetimes. For example, agricultural products grown during 1987 will have carbon-14 activity of about 118% MSA (See Figure 2).

As discussed in Section 4.0 of this memorandum, carbon-14 analysis did not prove to be as valuable as had been hoped in distinguishing between methane from the landfill and methane from other sources. Therefore, tritium was investigated as a means for making the distinction.

The radioactive (tritium) and nonradioactive forms of hydrogen react chemically in the same way and are found in the same proportion in water as in the atmosphere. The small amount of tritium present and measurable in rainfall is considered the "background" level for this isotope in nature. Prior to the beginning of above-ground nuclear testing, tritium levels were at or below the current background levels of 15-20 tritium units (TU) measured in rainfall (TU = one tritium atom in 10×10^{18} hydrogen atoms). Between 1955 and 1970, tritium activity in rainfall ranged from background to as high as 1000 TU. Because tritium levels are extremely variable, no general curve like that for carbon-14 activity over time is available for tritium activity over time. However, groundwater or organic matter older than 30 years (prior to above-ground nuclear testing) would show less than 20% of its original level of tritium activity. Organic matter older than 100 years would contain tritium activity at levels that are nearly non-detectable. Thus, it would be expected that methane gas produced by a peat bog or other older sources would show lower levels of tritium activity than the gas produced by Midway Landfill.



Confidence Interval
+/– 1 Standard Deviation

Figure 2.
Carbon-14 Activity in the Atmosphere Over Time as a Percentage of the "Modern Standard"

2.0 OBJECTIVES

The objective of the special gas characterization segment of the Remedial Investigation was to determine whether the methane gas found off-site originated from the decomposition of Midway Landfill materials or from some other source. The purpose of this particular study was to establish the validity of a sampling and analysis method that would distinguish between methane produced in the landfill and methane produced by other sources, such as underlying peat deposits or natural gas lines.

3.0 METHODOLOGY

Five sampling rounds for methane gas were conducted between June and October of 1987. Samples were collected from the on-site flare system and from off-site subsurface soil probes that contained gas with relatively high levels of methane (10-45% methane or combustible gas) or which were known to be near wetland areas, such as probes 10 and 17 (see Figure 1). A sixth sampling round is currently in progress.

The first two sampling rounds (sets A and B) were conducted by Black & Veatch for the Department of Ecology and included the north and south flare feed lines on-site and probes 10 and 17 off-site. Sampling rounds three through six (sets C-F) were conducted by Parametrix under the direction of the City of Seattle. Sample sets C and D included the north and south flare feed lines and probe 85-D. Sample Set E included off-site probes 2-S, 17, 37-D, 85-D, AC-S, and AE-S, plus a sample of gas supplied by Washington Natural Gas from a furnace connection in a house owned by the City of Seattle in the Midway Landfill area. Sample Set F, the current round, includes the same sites as Set E, plus AF-D, the north and south flare feed lines, and monitoring well 15. (See Figure 1).

Sampling rounds for Sets E and F were added when it became apparent that the elevated beta activity found in the landfill gas was not attributable to carbon-14. Two gas analysis methods were used. Sample Set A was analyzed for total beta activity (carbon-14 and tritium). Sets B, C, and D were analyzed for carbon-14 beta activity only and Sets E and F for tritium activity only. Table 1 lists the location, date, collection method, analysis, laboratory, and collector of each sample set.

3.1 FIELD SAMPLING TECHNIQUES

All gas samples except those for Set D were collected in Tedlar bags using either a bellows-type foot pump or a Brailsford TD-2N high-efficiency electric pump. The Brailsford pump was necessary for samples that were taken from probes with a relatively high vacuum of gas maintained by nearby off-site gas control wells. The Tedlar bags were filled passively by creating a vacuum around the bag contained within a sealed housing ("Pelicase") and then allowing gas to enter the bag through Teflon tubing.

Evacuated stainless steel cylinders were used to collect gas samples for Set D at the request of Teledyne Isotopes, which performed the laboratory analyses for this set. Cylinders were hooked up to probes by fitting one end of a piece of Teflon tubing onto the gas cylinder valve and hooking the other end directly to the gas probe. The vacuum in the cylinder was of sufficient magnitude that the gas from the probe filled the cylinder until the pressures were equalized.

Table 1. Summary of sampling events conducted for special gas characterization.

Sample Set A - Collected by Black & Veatch for Ecology

Probes 10 and 17 and north and south flare feed lines.

Date of Collection	Collection Method	Analysis Performed	Laboratory
6/87	Tedlar Bag	Total Beta Activity (Carbon-14 and Tritium)	Krueger/ Geochron Laboratories

Sample Set B - Collected by Black & Veatch for Ecology

Probes 10 and 17 and south flare feed line.

Date of Collection	Collection Method	Analysis Performed	Laboratory
8/10/87	Tedlar Bag	Carbon-14 Activity	Krueger/ Geochron Laboratories

Sample Set C - Collected by Parametrix, Inc.

Probe 85-D and north and south flare feed lines.

Date of Collection	Collection Method	Analysis Performed	Laboratory
7/27/87	Tedlar Bag	Carbon-14 Activity	Krueger/ Geochron Laboratories

Sample Set D - Collected by Parametrix, Inc.

Probe 85-D and north and south flare feed lines.

Date of Collection	Collection Method	Analysis Performed	Laboratory
7/27/87	Evacuated Stainless Steel Cylinder	Carbon-14 Activity (Total Beta Activity)	Teledyne Isotopes

Table 1. (Continued)

Sample Set E - Collected by Parametrix, Inc.

Probes 2-S, 17, 37-D, 85-D, AC-S, AE-S, and methane from Washington Natural Gas.

Date of Collection	Collection Method	Analysis Performed	Laboratory
10/23/87	Tedlar Bag	Tritium Activity of Methane Hydrogen	Krueger/ Geochron Laboratories

Sample Set F - Collected by Parametrix, Inc.

Probes 2-S, 17, 37-D, 85-D, AC-S, AE-S, AF-D, MW-15, north and south flare feed lines, and methane from Washington Natural Gas.

Date of Collection	Collection Method	Analysis Performed	Laboratory
02/88	Tedlar Bag	Tritium Activity of Methane Hydrogen	Krueger/ Geochron Laboratories

Combustible gas levels were measured by a Gastech NP-204 Combustible Gas Indicator on the high (H) scale, which measures the percent of combustible gas present in the probe gas. This instrument was used to continuously monitor the composition of the gas as samples were being collected.

For all sample sets at least two liters of methane were required for laboratory analysis. The number of Tedlar bags collected for each sample was calculated based on the percentage of combustible gas found in the gas at each sample point as indicated by the Gastech NP-204. It was assumed for purposes of these calculations that all the combustible gas detected by the instrument was methane.

During collection of Sample Set E, combustible gas levels in the probe were measured before sample collection and then again immediately after sample collection. In the case of probe 37-D, the initial combustible gas reading was significantly higher than the final combustible gas reading. The laboratory reported that this sample did not contain methane when the laboratory received it. It is possible that probe 37-D was evacuated completely during collection of the sample and did not have time to recharge.

During collection of Sample Set F, the methane content of all probes was monitored continuously during sample collection by the Gastech NP-204.

3.2 LABORATORY ANALYSIS

Krueger/Geochron Laboratories analyzed all of the samples except Sample Set D, which was analyzed by Teledyne Isotopes as a control.

3.2.1 Carbon-14 Activity

Krueger/Geochron Laboratories

Methane was separated and purified from the bulk gas samples by passing the gas through a series of cryogenic traps and selectively freezing out methane. The methane was then oxidized to carbon dioxide by circulation over hot copper oxide wire. This step ensured removal of the original hydrogen, which could contain tritium, from the methane. The carbon dioxide was cryogenically trapped and reconverted to methane using tritium-free hydrogen. The methane was then purified by passing through a series of cryogenic traps which removed water, trapped the methane, and allowed the hydrogen to be vacuumed away. The sample was subsequently counted for carbon-14 beta activity for at least 1200 minutes (longer, if the activity was very low).

As Quality Assurance/Quality Control procedures for Krueger/Geochron, all laboratory analysis results were based on measurements relative to a standard. The standard was analyzed in a counter and all other measurements were reported as relative to this standard. The details of Krueger/Geochron Laboratories' Quality Assurance Plan are presented in Appendix H-1, "Laboratory Procedures Used in Radiocarbon Dating (C-14) at Geochron Laboratories" (Krueger/Geochron, 10 February 1984).

Teledyne Isotopes

Aliquots of gas were taken directly from the three sample containers and analyzed for tritium and carbon-14.

Tritium was analyzed by passing an aliquot of a known volume of sample mixed with a known volume of tritium-free hydrogen through a copper oxide furnace at 650°C. The hydrogen was converted to water, which was then collected in a cryogenic trap. The water volume was measured and its tritium activity then counted by liquid scintillation.

Carbon-14 was analyzed by passing an aliquot of known volume of sample through a copper oxide furnace at 650° C. All carbonaceous species were converted to carbon dioxide, which was then collected in a cryogenic trap. Subsequently, the carbon dioxide was purified by gas chromatography and transferred to an evacuated proportional counter. Methane (previously determined to be without carbon-14) was added to equalize pressure and the gas sample then counted in a proportional counter. It has been noted by Teledyne Isotopes that this process may also capture other isotopes, such as radon, which have a freezing temperature similar to that of carbon dioxide.

Quality Assurance/Quality Control procedures followed by Teledyne Isotopes are presented in Appendix H-2, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment" (U.S. Nuclear Regulatory Commission, Regulatory Guide 4.15, February 1979).

3.2.2 Tritium Activity

Tritium analysis was performed on methane hydrogens by Krueger/Geochron Laboratories. In this procedure, methane gas was purified from other gases by cryogenic trapping. The methane was then combusted to carbon dioxide and water by circulation over hot copper wire. The water, which contained the methane hydrogen, was collected and placed in a vial with chemical scintillants and counted in a low-level scintillation counter for tritium activity. Quality Assurance/Quality Control procedures were the same as discussed in Section 3.2.1 (See Appendix H-1).

4.0 RESULTS

The laboratory reports and analytical data are included as Appendices A and B of this memorandum.

4.1 SAMPLE SET A

Results of analysis of combined carbon-14 and tritium activity for Sample Set A are shown in Table 2.

Table 2. Results of analysis of combined beta activity from carbon-14 and tritium in Sample Set A.

Sample Location	dpm/gCarbon	Age
North Flare Feed Line	47.9 ± 0.66	353.8 ± 4.9% MSA*
South Flare Feed Line	38.61 ± 0.55	284.7 ± 4.0% MSA
Probe 17	15.17 ± 0.37	111.9 ± 2.7% MSA
Probe 17 (replicate)	16.64 ± 0.64	122.7 ± 2.8% MSA
Probe 10	16.95 ± 0.64	125.0 ± 4.7% MSA

dpm/gCarbon = disintegrations per minute per gram of carbon
MSA = modern standard activity
Samples collected by Black & Veatch for Ecology.
*Re-analysis of this sample using a technique that excluded tritium activity yielded a carbon-dating age of 113.1 ± 2.5% MSA.

The results indicate that the methane found in probes 10 and 17 was a product of decomposing materials of relatively recent origin (post-1950). Further, the methane samples collected from the flare system on the landfill contained beta activity elevated to roughly three times that of normal levels (modern standard activity). Unfortunately, the test method for this sample set measured only total beta activity. It did not distinguish beta activity caused by carbon-14 from that of tritium. Results of re-analysis of the sample collected from the North Flare Feed Line for carbon-14 only indicated that the age of the methane generated on-site was not significantly different from the age of the methane in samples collected from off-site probes 17 and 10. Therefore, the elevated activity found in on-site samples in Sample Set A was not due to increased levels of carbon-14. Further testing was required to determine the source of the elevated activity.

4.2 SAMPLE SET B

Results for carbon-14 analysis of Set B samples (See Table 3) show no increased activity in the samples collected from the on-site flares relative to activity in the off-site probes. This indicates that the increased

combined beta activity found in samples collected from the on-site flares (see Table 2) must be caused by tritium activity rather than carbon-14 activity. (See also the letter from the Department of Ecology to the City of Seattle, dated September 23, 1987, in Appendix H-1.)

Table 3. Results of carbon-14 analysis of Sample Set B performed by Krueger/Geochron Laboratories.

Sample Location	dpm/gCarbon	Age
North Flare Feed Line	15.32 ± 1.2	113.0 ± 8.9% MSA
Probe 17	14.91 ± 0.33	109.9 ± 2.5% MSA
Probe 17 (replicate)	15.65 ± 0.20	115.4 ± 1.4% MSA
Probe 10	14.89 ± 0.23	108.5 ± 3.6% MSA

dpm/gCarbon = disintegrations per minute per gram of carbon
MSA = modern standard activity
Samples collected by Black & Veatch for Ecology.

4.3 SAMPLE SETS C AND D

Results of the sample Set C analyses are summarized in Tables 4 and 5.

Table 4. Results of carbon-14 analysis of Sample Set C performed by Krueger/Geochron Laboratories.

Sample Location	pCi/gCarbon	dpm/gCarbon	Age
North Flare Feed Line	7.00 ± 0.24	15.53 ± 0.53	114.5 ± 3.9% MSA
South Flare Feed Line	6.81 ± 0.13	15.12 ± 0.28	111.5 ± 2.1% MSA
Probe 85-D	6.75 ± 0.14	14.99 ± 0.31	110.6 ± 2.3% MSA

pCi/gCarbon = picoCuries per gram of carbon
dpm/gCarbon = disintegrations per minute per gram of carbon
MSA = Modern Standard Activity
Samples collected by Parametrix.

Table 5. Results of carbon-14 analysis of Sample Set D performed by Teledyne Isotopes.

Sample Location	Analyzed 8/87 pCi/gCarbon	Analyzed 9/87 pCi/gCarbon
North Flare Feed Line	130	55.4
South Flare Feed Line	188	148
Probe 85-D	963	145

pCi/gCarbon = picoCuries per gram carbon
Samples collected by Parametrix.

The results of carbon-14 analysis of Sample Set C obtained by Krueger/Geochron Laboratories indicate that the methane in the landfill and off-site probe 85-D is relatively recent in origin. The levels of carbon-14 found in all three samples were not statistically different. Therefore, the methane gas obtained on-site and from off-site probe 85-D appears to be of about the same relatively modern age (see Figure 2). In addition, these results confirmed that the elevated activity found in landfill gas samples collected for Ecology (Table 2) was not due to carbon-14. The age dating obtained for on-site and off-site samples by combined beta activity vs. carbon-14 activity is compared in Table 6. The laboratory analysts believe that the beta activity originally observed to be roughly three times greater than normal levels was due to tritium.

Table 6. Comparison of results for combined beta activity vs. carbon-14.

Sample Location	Age--Combined Beta (Sample Set A)	Age--Carbon-14 Only (Sample Set B)
North Flare Feed Line	353.8 ± 4.9% MSA	113.0 ± 8.9% MSA
South Flare Feed Line	284.7 ± 4.0% MSA	N/A
Probe 17	111.9 ± 2.7% MSA	109.9 ± 2.5% MSA
Probe 17 (replicate)	122.7 ± 2.8% MSA	115.4 ± 1.4% MSA
Probe 10	125.0 ± 4.7% MSA	109.7 ± 1.7% MSA

N/A = not analyzed
Samples collected by Black & Veatch for Ecology.

Results of Krueger Geochron's analyses of Sample Sets B and C agreed well; however, Teledyne Isotopes' analysis of Sample Set D differed considerably from the other two. Teledyne Isotopes first delivered its results expressed

as picoCuries per liter of sample, rather than picoCuries per gram of carbon. This made it impossible to correlate Teledyne's results with those of Krueger/Geochron Laboratories. After Teledyne recalculated its results in units of picoCuries per gram of carbon, the results still did not agree with those of Krueger/Geochron.

When these discrepancies were brought to the attention of Teledyne Isotopes, the samples were analyzed again approximately 30 days later, with different results. Teledyne reported that the initial activities might have included activity from short-lived species, such as radon, because re-analysis of the samples produced results much lower than initially reported. High initial results would decrease over time due to the decay of radon, which may have been captured along with the carbon when the carbon dioxide was cryogenically trapped. Radon and carbon dioxide have similar freezing temperatures. Radon has a half-life of about three days, so it would have nearly disappeared in the 30 days between the first and second analyses of these samples.

4.4 SAMPLE SET E

The results of tritium analysis for Set E are presented in Table 7.

Tritium activity is below detection limits for all the samples analyzed except probe 85-D. The methane in probe 85-D shows tritium activity approximately one order of magnitude above the detection limit. Although a sample was also collected from probe 37-D, the laboratory reported that it did not contain methane.

Table 7. Results of tritium analysis of Sample Set E performed by Geochron Laboratories.

Sample Location	T.U.	pCi/gElementalHydrogen
Probe 85-D	336 ± 20	9.6 ± 0.5
Probe AE-S	<90*	<2.6
Probe 2-S	<22	<0.6
Probe 17	<22	<0.6
Probe AC-S	<17	<0.4
Probe 37-D	NA	NA
City House/WNG "Blank"	<18	<0.5

T.U. = Tritium Unit = 1 tritium atom in 10^{18} hydrogen atoms
pCi = picoCuries
* = elevated detection limit due to small sample size
NA = not analyzed
Samples collected by Parametrix.

The results for Sample Set F (in progress) are not yet available; they will be included in the final report.

5.0 CONCLUSIONS

The results show an insufficient difference in age (as measured by carbon-14 activity) between landfill methane and naturally occurring methane to use carbon-14 monitoring as a tool to differentiate between these sources.

Tritium monitoring, however, appears to show some promise as a tool for distinguishing between methane produced by the landfill and methane produced by other sources, as different levels of tritium activity have been measured in the on-site and off-site probes.

Methane found in probe 85-D shows tritium activity that exceeds background levels, indicating that it is gas produced from the decomposition of carbonaceous materials that were growing during the 1960s and 1970s. This elevated activity is not found in methane from natural gas sources, such as that from peat bogs and natural gas utilities, which is the product of much older material with very low tritium levels. Washington State Department of Ecology estimates that for 1985 background levels of tritium activity in water ranged from 600 to 1000 pCi/l. This translates to 5.4 to 9.0 pCi/g elemental hydrogen. Comparison of tritium activity in probe 85-D (9.6 $\pm$ 0.5 pCi/g elemental H) with the background level of tritium indicates that tritium in probe 85-D is elevated only slightly above background. Because Midway Landfill gas is derived from the decomposition of more recent materials it would be expected to have correspondingly high levels of tritium. Additional data for the Midway Landfill gas tritium levels will be generated from the February 1988 round of sampling activity and should help distinguish the different sources of methane. The data will be included in the final memorandum.

REFERENCES

Parametrix, Inc. 1988. Gas Characterization Technical Memorandum for Remedial Investigation, Midway Landfill, Kent, Washington. Prepared for Seattle Engineering Department, Solid Waste Utility.

APPENDIX H-1

LABORATORY RESULTS (ANALYTICAL DATA)
SAMPLES ANALYZED BY KRUEGER/GEOCHRON LABORATORIES

KEA BEATTY RINKER
Director

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Mail Stop PV-11 • Olympia, Washington 98504-8711 • (206) 459-6000

July 17, 1987

Mr. Mark Edens
Seattle Engineering Department, Solid Waste Utility
Suite 750 Dexter Horton Building
710 Second Avenue
Seattle, Washington 98104

Re: Midway Landfill

Dear Mark:

Attached for your information are the results of testing of tedlar bag samples of gas from the two flares on the Midway Landfill and probes 10 and 17 west of the landfill. The intent of this testing was to date the gas using its carbon-14 content to determine if the gas found in these probes is from the landfill or due to vegetative decomposition within the wetland.

These results indicate the methane in probes 10 and 17 is of modern composition. Thus, we cannot conclusively eliminate the landfill as a source of this gas based on these results alone. We encourage Seattle to proceed with the planned installation of additional probes in the wetland. However, it would appear the only way this issue will be clearly resolved is to install additional deep gas probes between the landfill the wetland. These probes are needed anyway to monitor the long-term performance of the west side of the gas control system. We request this work be included in the next phase of gas probe installation at the site.

More importantly, these tests indicate the methane emitted from the landfill is elevated in beta activity to roughly three times above normal levels. The test method used was unable to determine if this increase is due to carbon-14 or tritium isotopes present in the gas. The laboratory is currently performing additional tests to attempt to make that determination. Both of these isotopes are commonly utilized in medicine, research and industry.

Assuming the increased beta activity of the methane is due entirely to carbon-14, we have calculated the flare emission rates. Based on these preliminary calculations it would appear the emission rates are well below those allowed by federal and state regulations. Given the emission rates, the increase in beta activity would probably not be measurable off-site, even using the sensitive technique employed by Krueger Labs.

While these calculations are encouraging, these test results raise a concern of what other low-level wastes may have been disposed of in the Midway Landfill and what the potential is for exposure to them. Potential exposure pathways include not only the gas emissions, but also ground water and surface cover emissions. Accordingly, we request a meeting with the City of Seattle to discuss followup actions.

The Department of Ecology recognizes that federal and state regulations allow many low activity wastes to be disposed of at municipal landfills. As such, these test results at Midway may not be unusual. None the less, given the high profile of this site we feel followup steps are both prudent and necessary. We look forward to working with you to develop procedures and a schedule for accomplishing these tasks.

Sincerely,

Bill Wright

William E. Wright
Project Manager
Hazardous Waste Cleanup Program

WW:cp

cc: C. Sagerser, DSHS
C. Kleeberg, SKCHD

RECEIVED
ECOLOGY-HWCP

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

2 July 1987

Mike Housley
Black & Veatch Engineers
6240 S. Sprague Ave.
Tacoma, WA 98409-6896

Dear Mike,

Enclosed please find the reports of our C^{14} analyses on your recently submitted samples of methane. I am also enclosing a graph showing the C^{14} activity of atmosheric carbon dioxide since AD 1951. Prior to 1951 the atmosphere was more or less at 100% of the standard value. Open air testing of nuclear weapons from the late 1950's to the mid 1960's increased the level of C^{14} in the atmosphere. All plants and animals (and food garbage resulting) living since 1950 have a level of C^{14} more or less identical to the atmosphere during their lifetime. E.G.: agricultural products grown durin this year (1987) will have a C^{14} activity of about 118% of the modern standard.

Very old samples of carbon have lower C^{14} activities as measured today because they have lost C^{14} through radioactive decay. C^{14} has a half life of 5570 years and a mean life of 8036 years. Thus a sample of 5000 year old carbon has a C^{14} activity relative to the modern standard of (e to the power of (5000/ -8036))*100 or 53.7%.

Your two samples from the landfill, MLF-S-A and MLF-N-A, have activities much in excess of that ever reported for the atmosphere. This elevated activity is probably due to low-level biomedical tracers containing C^{14} or possibly H^3 which have been dumped in the site and are undergoing methanogenesis. Samples MLEP-10-A and MLEP-17A-A have C^{14} levels consistant with the atmosphere in recent years. Sample MLEP-17-A has an activity which is somewhat too low for recent atmosheric levels and may represent a mixture of old carbon with more recent.

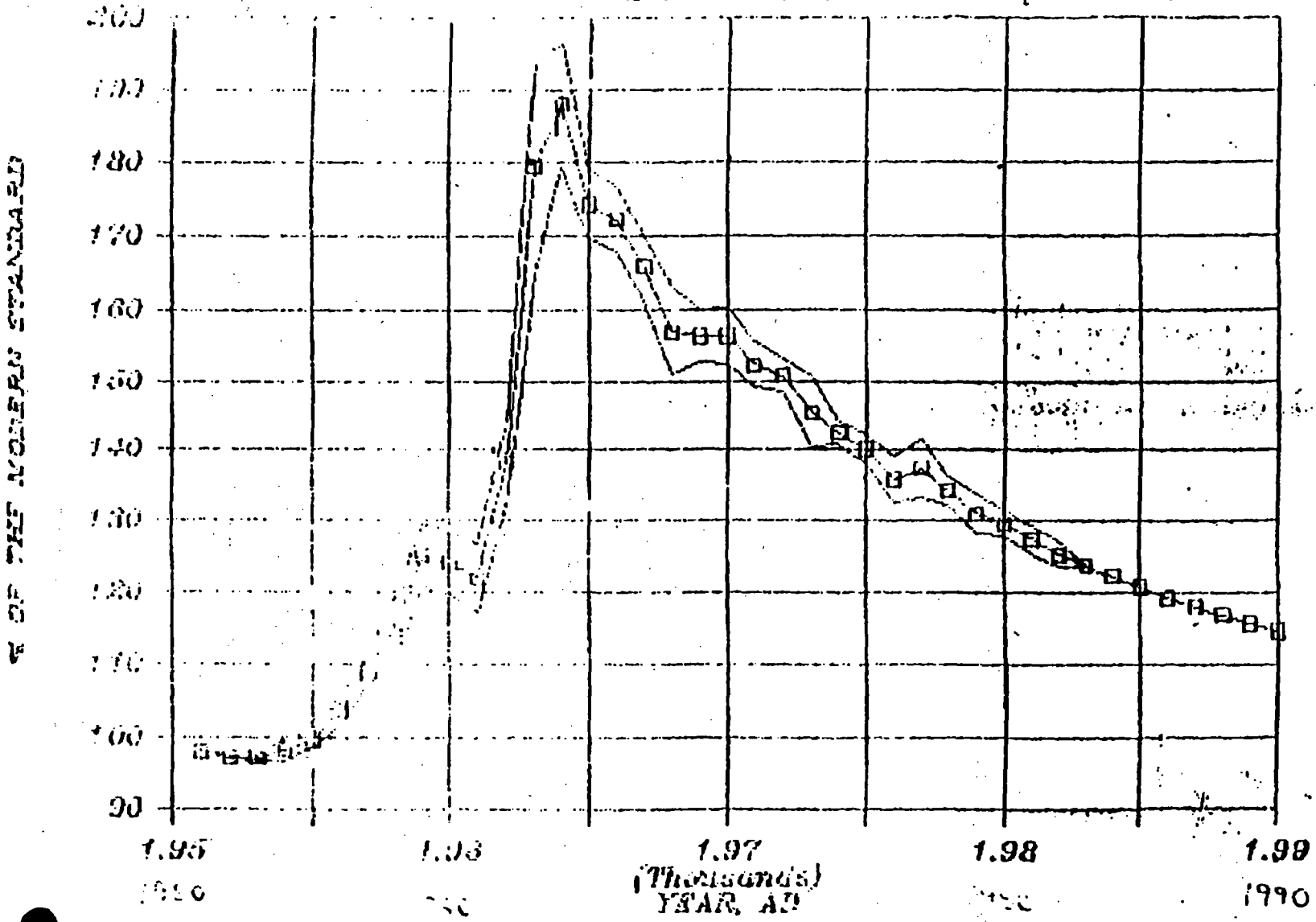
We will attempt to burn one or more of the two "hot" samples to determine if C^{14} or H^3 is responsible for the increased activity.

Sincerely yours,

Charles H. Sullivan

Charles H. Sullivan
C-14 Lab Manager
encl.

C 14 ACTIVITY IN THE ATMOSPHERE



KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13415	Date Received:	06-23-87
Your Reference:	Project No. 11889.404	Date Reported:	07-02-87
Submitted by:	Mike Housley Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: Sta. No. MLF-S-A, 6-22-87. Midway Landfill. South Flare inlet

AGE = (284.7 +/- 4.0)% of the modern standard activity
(38.61 +/- 0.55) dpm/g Carbon. disintegrations per minute/gram C.

Description: Sample of methane gas.

Pretreatment: Methane was extracted under vacuum and analysed. A small aliquot was sampled for C-13 analysis.

Comment:

$\delta^{13}C_{PDB}$ = -56.4 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13416	Date Received:	06-23-87
Your Reference:	Project No. 11889.404	Date Reported:	07-02-87
Submitted by:	Mike Housley Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: Sta. No. MLF-N-A, 6-22-87. Midway Landfill. North Flare

AGE = (353.8 +/- 4.9)% of the modern standard activity
(47.97 +/- 0.66) dpm/g Carbon.

Description: Sample of methane gas.

Pretreatment: Methane was extracted under vacuum and analysed. A small aliquot was sampled for C-13 analysis.

Comment:

$\delta^{13}C_{PDB}$ = -55.0 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13421	Date Received:	06-25-87
Your Reference:	Project No. 11889.404	Date Reported:	07-02-87
Submitted by:	Mike Housley Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: Sta. No. MLEP-10-A, 6-24-87. Midway Landfill. Probe 10

AGE = (125.0 +/- 4.7)% of the modern standard activity
(16.95 +/- 0.64) dpm/g Carbon.

Description: Sample of methane gas.

Pretreatment: Methane was extracted under vacuum and analysed. A small aliquot was sampled for C-13 analysis.

Comment:

$\delta^{13}C_{PDB}$ = -56.3 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13422	Date Received:	06-25-87
Your Reference:	Project No. 11889.404	Date Reported:	07-02-87
Submitted by:	Mike Housley Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: Sta. No. MLEP-17-A, 6-24-87. Midway Landfill. Probe 17

AGE = (111.9 +/- 2.7)% of the modern standard activity
(15.17 +/- 0.37) dpm/g Carbon.

Description: Sample of methane gas.

Pretreatment: Methane was extracted under vacuum and analysed. A small aliquot was sampled for C-13 analysis.

Comment:

$\delta^{13}C_{PDB}$ = -52.7 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13423	Date Received:	06-25-87
Your Reference:	Project No. 11889.404	Date Reported:	07-02-87
Submitted by:	Mike Housley Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: Sta. No. MLEP-17A-A, 6-24-87. Midway Landfill. Probe 17

AGE = (122.7 +/- 2.8)% of the modern standard activity
(16.64 +/- 0.39) dpm/g Carbon.

Description: Sample of methane gas.

Pretreatment: Methane was extracted under vacuum and analysed. A small aliquot was sampled for C-13 analysis.

Comment:

$\delta^{13}C_{PDB}$ = -50.3 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

RECEIVED AUG 2 0 1987

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

12 August 1987

Susan Turnblom
Parametrix, Inc.
13020 Northup Way
Suite 8
Bellevue WA 98005

Dear Susan,

Enclosed please find the reports of our C^{14} analyses on your recently submitted samples of methane. I am also enclosing a graph showing the C^{14} activity of atmosheric carbon dioxide since AD 1951. Prior to 1951 the atmosphere was more or less at 100% of the standard value. Open air testing of nuclear weapons from the late 1950's to the mid 1960's increased the level of C^{14} in the atmosphere. All plants and animals (and food garbage resulting) living since 1950 have a level of C^{14} more or less identical to the atmosphere during their lifetime. E.G.: agricultural products grown during this year (1987) will have a C^{14} activity of about 118% of the modern standard.

Very old samples of carbon have lower C^{14} activities as measured today because they have lost C^{14} through radioactive decay. C^{14} has a half life of 5570 years and a mean life of 8036 years. Thus a sample of 5000 year old carbon has a C^{14} activity relative to the modern standard of (e to the power of (5000/ -8036))*100 or 53.7%.

The three samples analysed, 85D, North and South all have C^{14} activities somewhat less than the atmosphere in recent years. This is due to the mixing of older carbon sources with more recent. The bulk of the carbon in the methane has come from recent carbon however.

Enclosed also is a copy of our general procedures used for C-14 analysis. The "pretreatment" for your samples consisted of purifying methane from the bulk gas. This is accomplished by passing the gas through a series of cryogenic traps and selectively freezing-out methane. The methane is then oxidized to carbon dioxide by circulation over hot copper oxide wire. This step removes the original hydrogen, containing tritium, from the methane. The carbon dioxide is then reconverted to methane using tritium-free hydrogen as described in our procedures. This is because methane is the form in which we analyse most samples for C^{14} activity.

The procedures document also briefly describes the delta C^{13} notation which appears on the bottom of our report forms.

If you need additional information regarding these analyses please contact me.

Sincerely yours,

Charles H. Sullivan

Charles H. Sullivan
C-14 Lab Manager
encl.

LABORATORY PROCEDURES USED IN RADIOCARBON DATING (C-14) AT GEOCHRON LABORATORIES

Krueger Enterprises Inc.
Geochron Laboratories Division
24 Blackstone St.
Cambridge, MA 02139

(617) 876-3691

Written by: Charles H. Sullivan

Charles H. Sullivan
Manager, Radiocarbon Laboratory
10 February 1984

Checked by: Harold W. Krueger

Harold W. Krueger
President, Krueger Enterprises, Inc.
10 February 1984

RADIOCARBON DATING

Radiocarbon dating is widely used for determining the antiquity of archaeological and geological samples back to about 40,000 years ago. The measurement of radiocarbon is also useful as an indicator of the residence time of waters and as an indicator of the chemical authenticity of certain foodstuffs. Radiocarbon dating is conventionally undertaken by the conversion of a carbon-bearing sample to a form suitable for determining its relative C^{14} content by counting the beta-decay events which occur when C^{14} atoms decay to N^{14}. Samples are converted to carbon dioxide which is either used directly or converted to methane, acetylene, or benzene depending on the form preferred by the laboratory. Gases are analyzed in proportional gas counters; benzene is analyzed in a liquid scintillation counter.

RECEIPT OF SAMPLES

LOG-IN AND REPORTING PROCEDURES

When samples are received, they are unpacked and checked against the sample list (when provided). The number appearing on the sample itself is considered authoritative if discrepancies are found. Each sample is then assigned a Geochron sample number from a roll of pre-printed sequentially numbered labels, thus eliminating any chance of two different samples receiving the same number.

Information on each sample is then entered on computer and includes the following:

- GX-xxxxx (lab number)
- Customer name and affiliation
- Date received
- Customer reference
- Sample description
- Type and condition of sample
- Nature of chemical pretreatment to be applied (if any)

This information is stored on magnetic disk and hardcopy is printed for use as a lab data reference sheet.

All customer-submitted papers, the lab data sheets, and the lab number labels are stored in a folder labeled with the customer's name. This folder is placed with the samples in a container which is labeled on its exterior with the lab numbers of the samples, the customer's name, and the date of receipt. The container is then placed in a storage area to await pretreatment. A card listing the customer, type of analysis to be performed, date received, and Geochron sample numbers is placed on a master sample control board in the main lab office.

As the analyses are completed, the results are entered on the data reference sheet. Computations are made and the final results are printed out on a standard form. All pertinent data are included on this form, which is self-explanatory. The customer folder is then sent back to the office for processing. The original report is proofread against the reference sheet by the office staff. Five photocopies of the completed standard form are made: one is sent to the customer with the original; one is attached to the rest of the material for that particular job in the customer's file; and three are filed sequentially by Geochron sample number in archives stored, for safety, in three separate locations.

The original report, one photocopy, any correpondence, and the invoice are sent together to the customer by first class mail. The file containing the information from the completed job is stored in an alphabetical system by customer's name and affiliation.

PRETREATMENT

Samples are generally processed in order by lab number. When a sample is due for processing the customer's sample identification is again checked against our lab number. The sample then proceeds through pretreatment identified only by its GX-xxxxx (lab-number) label.

The nature of the pretreatment applied for contaminant removal depends mainly on the type of sample material. Our pretreatments are essentially the same as those used by many other radiocarbon dating labs. In general, most organic samples from archaeological or geological contexts are given sequential treatment with dilute acid and dilute base solutions in order to remove, respectively, contaminant carbonates and humates.

Certain materials, such as barium carbonate precipitated from groundwater, need no pretreatment and are analyzed directly.

PREPARATION OF COUNTING GAS

Samples are converted to carbon dioxide by combustion in pure oxygen or by acid hydrolysis. The carbon dioxide is purified and collected by passing through a series of cryogenically cooled traps. Geochron Labs analyzes samples in the form of methane which is prepared by reacting the carbon dioxide with hydrogen at 475° C in the presence of a ruthenium catalyst.

Upon completion of the reaction the methane is purified and separated from excess hydrogen and water of reaction by passing through a series or cryogenic traps which remove water, trap methane, and allow the hydrogen to be vacuumed away. The methane is then transferred to a vacuum flask for storage of the sample gas. The flask is labeled with the lab number, the customer name, dates of reaction, and the volume of methane. The flask is then transferred to the counting room to await loading into one of several proportional counters.

DETERMINATION OF C^{14} ACTIVITY

Samples of methane are counted in proportional counters especially designed for the detection of C^{14} decay events. The counters are shielded in lead and are surrounded by annular guard counters operating in anticoincidence with the sample counters in order to reduce external radiation background to very low levels.

The sample is counted for C^{14} beta activity for at least 1200 minutes, longer if activity is very low.

Ages are calculated by comparing the beta activity of the sample to that of the international standard , NBS oxalic acid (SRM-4990). Calculations used are identical to those outlined in Stuiver and Polach, "Reporting of ^{14}C Data", Radiocarbon, 19(3):355-363, 1977.

Utilizing the accepted half-life of C^{14} of 5570 years the age is calculated as follows:

$$\text{AGE} = (\text{mean-life of } C^{14}) * \ln \frac{\text{Sample activity}}{\text{Standard activity}}$$

where the mean life of C^{14} is 8036 years and the standard activity has been normalized to the assumed activity of wood formed in the years A.D. 1950.

The percent modern notation reported for geochemical samples is calculated simply as:

$$\%\ \text{modern } C^{14} = 100 * \frac{\text{Sample activity}}{\text{Standard activity}}$$

The error assigned to the age assessment takes into account the uncertainty due to the random nature of C^{14} decay in the sample, the error due to background count fluctuations in the proportional counters, and the precision with which the activity of the standard is known.

BACKGROUND, STANDARD, AND C^{13} MEASUREMENTS

Measurement of the background radiation flux in the counters is necessary in order to account for detected radiation which is not due to C^{14} decay events. The background count-rate is determined by counting a methane sample prepared from very old marble which no longer contains detectable C^{14}. A background measurement is made in each counter approximately every eighth day.

Standard activity is determined by periodic counting of methane prepared from the original NBS oxalic acid standard (SRM-4990) or the newly issued replacement standard, NBS Research Material RM-49.

The value used for the modern standard in the age calculation is actually 95% of the observed activity of the standard normalized for isotopic fractionation effects to a delta C^{13} value of -19‰ wrt PDB.*

Precise dating requires that the C^{14} activity of the sample be corrected for possible isotopic fractionation. This is also done by measuring the C^{13}/C^{12} ratio and correcting the C^{14} content accordingly. The fractionation of C^{14} relative to C^{12} is considered to be twice that of C^{13} relative to C^{12}. Samples are normalized to a C^{13} value of -25‰ wrt PDB** as follows:

$$\text{Samp. activity } (C^{13} \text{ corrected}) = \text{Samp. activity (uncorrected)} * \left(1 - \frac{2(25 + \text{sample delta } C^{13})}{1000}\right)$$

** C^{13} measurements are made on a small aliquot of the sample gas by analysis in a mass-spectrometer. The results are reported in delta notation relative to a standard known as PDB. The calculation of delta values is as follows:

$$\text{delta } C^{13} \text{ sample o/oo} = \left(\frac{C^{13}/C^{12} \text{ sample}}{C^{13}/C^{12} \text{ PDB}} - 1\right) * 1000$$

where the ratio of C^{13}/C^{12} in the PDB standard is 0.011237.

AGE REPORT FORM

The radiocarbon age of each sample is reported on a standard form (see Appendix 1). All pertinent data is included on the form and is self-explanatory. Two copies of this report are sent to the customer, one copy is placed in the customer's file, and three copies are bound in permanent logs and stored at Geochron and other locations for safety.

The customer's file containing all documentation is then filed by customer name or affiliation in a central file system.

Any excess sample is labeled with its lab number and is archived for possible future reference.

RECEIVED AUG 20 1987

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13520	Date Received:	07-28-87
Your Reference:	Project 55-1550-11.	Date Reported:	08-12-87
Submitted by:	Susan Turnblom Parametrix, Inc. 13020 Northup Way Suite 8 Bellevue, WA 98005		

Sample Name: Sample 85-D.

AGE = (110.6 +/- 2.3)% of the modern standard activity
(14.99 +/- 0.31) dpm/g Carbon. (6.75 +/- 0.14) picocuries/g Carbon

Description: Sample of gas.

Pretreatment: Methane was separated from other gases and purified. The methane was then oxidized to carbon dioxide by combustion over hot copper oxide. The carbon dioxide was purified and reconverted to methane for the analysis.

Comment:

$\delta^{13}C_{PDB}$ = -48.7 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13521	Date Received:	07-28-87
Your Reference:	Project 55-1550-11.	Date Reported:	08-12-87
Submitted by:	Susan Turnblom Parametrix, Inc. 13020 Northup Way Suite 8 Bellevue, WA 98005		

Sample Name: Sample SOUTH.

AGE = (111.5 +/- 2.1)% of the modern standard activity
(15.12 +/- 0.28) dpm/g Carbon. (6.81 +/- 0.13) picocuries/g Carbon

Description: Sample of gas.

Pretreatment: Methane was separated from other gases and purified. The methane was then oxidized to carbon dioxide by combustion over hot copper oxide. The carbon dioxide was purified and reconverted to methane for the analysis.

Comment:

$\delta^{13}C_{PDB}$ = -60.0 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13522	Date Received:	07-28-87
Your Reference:	Project 55-1550-11.	Date Reported:	08-12-87
Submitted by:	Susan Turnblom Parametrix, Inc. 13020 Northup Way Suite 8 Bellevue, WA 98005		

Sample Name: Sample NORTH.

AGE = (114.5 +/- 3.9)% of the modern standard activity
(15.53 +/- 0.53) dpm/g Carbon. (7.00 +/- 0.24) picocuries/g Carbon

Description: Sample of gas.

Pretreatment: Methane was separated from other gases and purified. The methane was then oxidized to carbon dioxide by combustion over hot copper oxide. The carbon dioxide was purified and reconverted to methane for the analysis.

Comment:

$\delta^{13}C_{PDB}$ = -52.4 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

REA BEATTY RINKER
Director

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Mail Stop PV-11 • Olympia, Washington 98504-8711 • (206) 459-6000

RECEIVED
SEP 25 1987
SOLID WASTE UTILITY

September 23, 1987

Lin Robinson, Project Manager
Seattle Engineering Department
Solid Waste Utility
Dexter Horton Building, Suite 750
710 Second Avenue
Seattle, Washington 98104

Dear Lin:

I have enclosed the final results of Ecology's radiocarbon dating of methane gas at and near the Midway Landfill. The results from proper analyses indicate that the methane from the on-site flares and the probes in the wetland has a relatively uniform ^{14}C activity, which is approximately 110% of the atmospheric level observed in 1950. Therefore, we are unable to discern any difference in the methane from these two locations on the basis of ^{14}C results alone.

However, if you will recall the results from our initial sampling of these locations, there does appear to be a difference in the ^{3}H content of the landfill flare methane and the wetland probe methane. Our initial samples were improperly analyzed in such a manner that ^{3}H interference was not eliminated.

The improper analyses of the landfill flares indicated a ^{14}C level of approximately 300% of the modern standard activity. This dropped to about 110% once ^{3}H interference was eliminated. The wetland probes showed a ^{14}C activity of about 120% initially. Proper analysis dropped this to only the 110% range.

Krueger Enterprises acknowledges that, qualitatively, the two locations (landfill flares vs. wetland probes) do appear to have separate sources of methane. They placed the qualitative qualifier on this assessment because their radiation counters are not specifically calibrated to detect ^{3}H. They did, however, believe that the large differences in the results for the on-site flares, between the two sampling rounds, did in fact indicate the presence of substantially more ^{3}H in these samples than in the wetland samples which displayed no significant change despite the differences in the method of analysis.

Krueger also assured us that ^{3}H was the only form of interference during the first round of analyses, and the lab feels that ^{3}H may be an effective tracer for future gas investigations at the Midway site.

Please call me if you have any questions regarding this data. I hope you find this information to be useful in the remedial investigation.

Sincerely,

Bill Wright

William E. Wright, Project Manager
Landfill Cleanup Section
Hazardous Waste Cleanup Program

WEW

cc: Pete Kmet, Ecology
Neil Thompson, EPA
Terese Richmond, Office of the Attorney General
Mark Snyder, Black & Veatch

BLACK & VEATCH
ENGINEERS-ARCHITECTS
TEL. (206) 472-2433
6240 SOUTH SPRAGUE AVENUE
TACOMA, WASHINGTON 98409-6819

Midway Landfill RI
Gas Carbon Dating

B&V Project 11889.407
September 21, 1987

RECEIVED
SEP 22 1987
ECOLOGY-HWCP

Washington Dept. of Ecology
Mail Stop PV-11
Olympia, WA 98504-8711

Attention: Mr. Bill Wright

Gentlemen:

Enclosed is the final laboratory report on the C14 testing of landfill gas at Midway. Analyses were performed for the following samples:

Location	Sample Number
Probe 10	MLEP-10-B
Probe 17	MLEP-17-B & MLEP-17A-B
South Flare	MLF-S-B

Please give us a call if you have any questions or comments.

Very truly yours,

BLACK & VEATCH

Mark G. Snyder, P.E.

MGS:njp

cc: J. Swanberg, Ecology (w/encl.)
P. Kmet, Ecology (w/encl.)
P.B. MacRoberts/Project File (w/encl.)

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SEP 2 1987
BLACK & VEATCH

15 September 1987

Mark Snyder
Black & Veatch
6240 S. Sprague Ave.
Tacoma WA 98409

Dear Mark,

Enclosed please find the reports of our C^{14} analyses on your recently submitted samples of methane. I am also enclosing a graph showing the C^{14} activity of atmospheric carbon dioxide since AD 1951. Prior to 1951 the atmosphere was more or less at 100% of the standard value. Open air testing of nuclear weapons from the late 1950's to the mid 1960's increased the level of C^{14} in the atmosphere. All plants and animals (and food garbage resulting) living since 1950 have a level of C^{14} more or less identical to the atmosphere during their lifetime. E.G.: agricultural products grown during this year (1987) will have a C^{14} activity of about 118% of the modern standard.

Very old samples of carbon have lower C^{14} activities as measured today because they have lost C^{14} through radioactive decay. C^{14} has a half life of 5570 years and a mean life of 8036 years. Thus a sample of 5000 year old carbon has a C^{14} activity relative to the modern standard of (e to the power of (5000/ -8036))*100 or 53.7%.

The four samples analysed, MLEP-17-B, MLEP-17A-B, MLEP-10-B and MLF-S-B all have C^{14} activities somewhat less than the atmosphere in recent years. This is due to the mixing of older carbon sources with more recent. The bulk of the carbon in the methane has come from recent carbon however.

Enclosed also is a copy of our general procedures used for C-14 analysis. The "pretreatment" for your samples consisted of purifying methane from the bulk gas. This is accomplished by passing the gas through a series of cryogenic traps and selectively freezing-out methane. The methane is then oxidized to carbon dioxide by circulating over hot cooper oxide wire. This step removes the original hydrogen from the methane which contains tritium. The carbon dioxide is then reconverted to methane as described in our procedures. This is because methane is the form in which we analyse most samples for C^{14} activity.

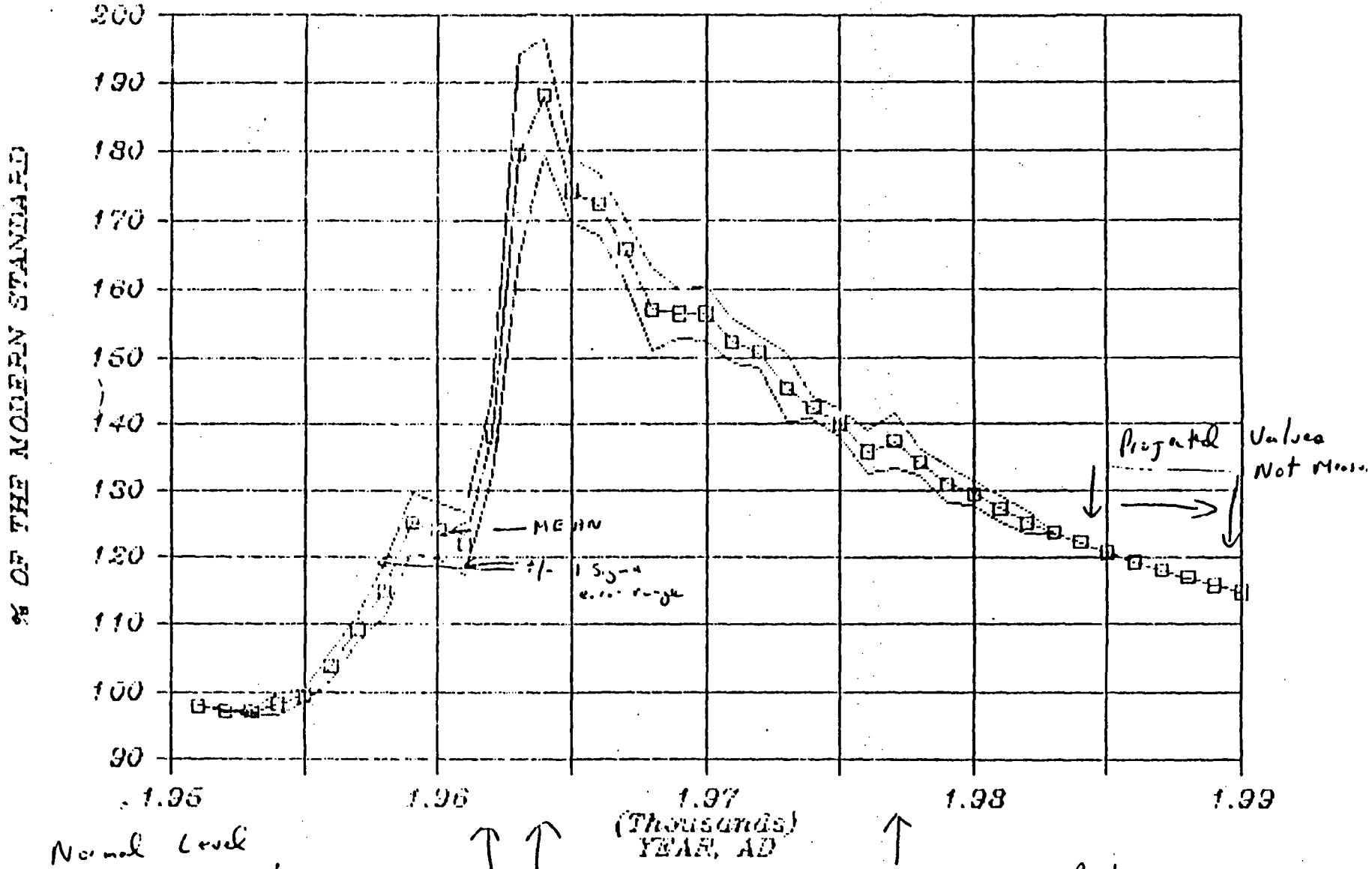
I am also sending an ammended report on sample GX-13416 (Your # MLF-N-A) which was originally submitted by Mike Housley and which was analysed as methane without stripping-off the tritium-containing hydrogen.

For samples MLEP-17-B and MLEP-10-B we also separated carbon dioxide from the bulk gas as submitted, converted this to methane and analysed for C^{14}. The activity of the carbon dioxide is essentially the same as for the methane.

Sincerely yours,

Charles H. Sullivan
C-14 Lab Manager
encl.

C-14 ACTIVITY IN THE ATMOSPHERE



LABORATORY PROCEDURES USED IN RADIOCARBON DATING (C-14) AT GEOCHRON LABORATORIES

Krueger Enterprises Inc.
Geochron Laboratories Division
24 Blackstone St.
Cambridge, MA 02139

(617) 876-3691

Written by: Chas. H. Sullivan

Charles H. Sullivan
Manager, Radiocarbon Laboratory
10 February 1984

Checked by: Harold W. Krueger

Harold W. Krueger
President, Krueger Enterprises, Inc.
10 February 1984

RADIOCARBON DATING

Radiocarbon dating is widely used for determining the antiquity of archaeological and geological samples back to about 40,000 years ago. The measurement of radiocarbon is also useful as an indicator of the residence time of waters and as an indicator of the chemical authenticity of certain foodstuffs. Radiocarbon dating is conventionally undertaken by the conversion of a carbon-bearing sample to a form suitable for determining its relative C^{14} content by counting the beta-decay events which occur when C^{14} atoms decay to N^{14}. Samples are converted to carbon dioxide which is either used directly or converted to methane, acetylene, or benzene depending on the form preferred by the laboratory. Gases are analyzed in proportional gas counters; benzene is analyzed in a liquid scintillation counter.

RECEIPT OF SAMPLES

LOG-IN AND REPORTING PROCEDURES

When samples are received, they are unpacked and checked against the sample list (when provided). The number appearing on the sample itself is considered authoritative if discrepancies are found. Each sample is then assigned a Geochron sample number from a roll of pre-printed sequentially numbered labels, thus eliminating any chance of two different samples receiving the same number.

Information on each sample is then entered on computer and includes the following:

- GX-xxxxx (lab number)
- Customer name and affiliation
- Date received
- Customer reference
- Sample description
- Type and condition of sample
- Nature of chemical pretreatment to be applied (if any)

This information is stored on magnetic disk and hardcopy is printed for use as a lab data reference sheet.

All customer-submitted papers, the lab data sheets, and the lab number labels are stored in a folder labeled with the customer's name. This folder is placed with the samples in a container which is labeled on its exterior with the lab numbers of the samples, the customer's name, and the date of receipt. The container is then placed in a storage area to await pretreatment. A card listing the customer, type of analysis to be performed, date received, and Geochron sample numbers is placed on a master sample control board in the main lab office.

As the analyses are completed, the results are entered on the data reference sheet. Computations are made and the final results are printed out on a standard form. All pertinent data are included on this form, which is self-explanatory. The customer folder is then sent back to the office for processing. The original report is proofread against the reference sheet by the office staff. Five photocopies of the completed standard form are made: one is sent to the customer with the original; one is attached to the rest of the material for that particular job in the customer's file; and three are filed sequentially by Geochron sample number in archives stored, for safety, in three separate locations.

The original report, one photocopy, any correpondence, and the invoice are sent together to the customer by first class mail. The file containing the information from the completed job is stored in an alphabetical system by customer's name and affiliation.

PRETREATMENT

Samples are generally processed in order by lab number. When a sample is due for processing the customer's sample identification is again checked against our lab number. The sample then proceeds through pretreatment identified only by its GX-xxxxx (lab-number) label.

The nature of the pretreatment applied for contaminant removal depends mainly on the type of sample material. Our pretreatments are essentially the same as those used by many other radiocarbon dating labs. In general, most organic samples from archaeological or geological contexts are given sequential treatment with dilute acid and dilute base solutions in order to remove, respectively, contaminant carbonates and humates.

Certain materials, such as barium carbonate precipitated from groundwater, need no pretreatment and are analyzed directly.

PREPARATION OF COUNTING GAS

Samples are converted to carbon dioxide by combustion in pure oxygen or by acid hydrolysis. The carbon dioxide is purified and collected by passing through a series of cryogenically cooled traps. Geochron Labs analyzes samples in the form of methane which is prepared by reacting the carbon dioxide with hydrogen at 475° C in the presence of a ruthenium catalyst.

Upon completion of the reaction the methane is purified and separated from excess hydrogen and water of reaction by passing through a series or cryogenic traps which remove water, trap methane, and allow the hydrogen to be vacuumed away. The methane is then transferred to a vacuum flask for storage of the sample gas. The flask is labeled with the lab number, the customer name, dates of reaction, and the volume of methane. The flask is then transferred to the counting room to await loading into one of several proportional counters.

DETERMINATION OF C^{14} ACTIVITY

Samples of methane are counted in proportional counters especially designed for the detection of C^{14} decay events. The counters are shielded in lead and are surrounded by annular guard counters operating in anticoincidence with the sample counters in order to reduce external radiation background to very low levels.

The sample is counted for C^{14} beta activity for at least 1200 minutes, longer if activity is very low.

Ages are calculated by comparing the beta activity of the sample to that of the international standard , NBS oxalic acid (SRM-4990). Calculations used are identical to those outlined in Stuiver and Polach, "Reporting of ^{14}C Data", Radiocarbon, 19(3):355-363, 1977.

Utilizing the accepted half-life of C^{14} of 5570 years the age is calculated as follows:

$$\text{AGE} = (\text{mean-life of } C^{14}) * \ln \frac{\text{Sample activity}}{\text{Standard activity}}$$

where the mean life of C^{14} is 8036 years and the standard activity has been normalized to the assumed activity of wood formed in the years A.D. 1950.

The percent modern notation reported for geochemical samples is calculated simply as:

$$\%\ \text{modern } C^{14} = 100 * \frac{\text{Sample activity}}{\text{Standard activity}}$$

The error assigned to the age assessment takes into account the uncertainty due to the random nature of C^{14} decay in the sample, the error due to background count fluctuations in the proportional counters, and the precision with which the activity of the standard is known.

BACKGROUND, STANDARD, AND C^{13} MEASUREMENTS

Measurement of the background radiation flux in the counters is necessary in order to account for detected radiation which is not due to C^{14} decay events. The background count-rate is determined by counting a methane sample prepared from very old marble which no longer contains detectable C^{14}. A background measurement is made in each counter approximately every eighth day.

Standard activity is determined by periodic counting of methane prepared from the original NBS oxalic acid standard (SRM-4990) or the newly issued replacement standard, NBS Research Material RM-49.

The value used for the modern standard in the age calculation is actually 95% of the observed activity of the standard normalized for isotopic fractionation effects to a delta C^{13} value of -19‰ wrt PDB.

Precise dating requires that the C^{14} activity of the sample be corrected for possible isotopic fractionation. This is also done by measuring the C^{13}/C^{12} ratio and correcting the C^{14} content accordingly. The fractionation of C^{14} relative to C^{12} is considered to be twice that of C^{13} relative to C^{12}. Samples are normalized to a C^{13} value of -25‰ wrt PDB** as follows:

$$\text{Samp. activity } (C^{13} \text{ corrected}) = \text{Samp. activity (uncorrected)} * \left(1 - \frac{2(25 + \text{sample delta } C^{13})}{1000}\right)$$

** C^{13} measurements are made on a small aliquot of the sample gas by analysis in a mass-spectrometer. The results are reported in delta notation relative to a standard known as PDB. The calculation of delta values is as follows:

$$\text{delta } C^{13} \text{ sample o/oo} = \left(\frac{C^{13}/C^{12} \text{ sample}}{C^{13}/C^{12} \text{ PDB}} - 1\right) * 1000$$

where the ratio of C^{13}/C^{12} in the PDB standard is 0.011237.

AGE REPORT FORM

The radiocarbon age of each sample is reported on a standard form (see Appendix 1). All pertinent data is included on the form and is self-explanatory. Two copies of this report are sent to the customer, one copy is placed in the customer's file, and three copies are bound in permanent logs and stored at Geochron and other locations for safety.

The customer's file containing all documentation is then filed by customer name or affiliation in a central file system.

Any excess sample is labeled with its lab number and is archived for possible future reference.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
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AMMENDED REPORT

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13416 -M	Date Received:	06-23-87
Your Reference:	Project No. 11889.404	Date Reported:	09-15-87
Submitted by:	Mike Housley Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: Sta. No. MLF-N-A, 6-22-87. Midway Landfill.

AGE = (113.1 +/- 2.5)% of the modern standard activity
(15.33 +/- 0.34) dpm/g Carbon.

Description: Sample of methane gas.

Pretreatment: Methane was purified from the sample, oxidized over hot cupric oxide wire to remove hydrogen, reconverted to methane with tritium-free hydrogen and analysed for C-14.

Comment:

00031515

$\delta^{13}C_{PDB}$ = -59.4 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

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GEOCHRON LABORATORIES DIVISION
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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13574 -M	Date Received:	08-10-87
Your Reference:	Project No. 11889.407	Date Reported:	09-15-87
Submitted by:	Mark Snyder Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: MLEP-17-B. 8-6-87. Midway Landfill.

AGE = (115.4 +/- 1.4)% of the modern standard activity
(15.65 +/- 0.20) dpm/g Carbon.

Description: Sample of gas, mostly methane and carbon dioxide.

Pretreatment: Methane was purified from the sample, oxidized over hot cupric oxide wire to remove hydrogen, reconverted to methane with tritium-free hydrogen and analysed for C-14.

Comment:

$\delta^{13}C_{PDB}$ = -56.3 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged [illegible] statistical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13576 -M	Date Received:	08-10-87
Your Reference:	Project No. 11889.407	Date Reported:	09-15-87
Submitted by:	Mark Snyder Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: MLEP-10-B. 8-6-87. Midway Landfill.

AGE = (108.5 +/- 3.6)% of the modern standard activity
(14.71 +/- 0.50) dpm/g Carbon.

Description: Sample of gas, mostly methane and carbon dioxide.

Pretreatment: Methane was purified from the sample, oxidized over hot cupric oxide wire to remove hydrogen, reconverted to methane with tritium-free hydrogen and analysed for C-14.

Comment:

$\delta^{13}C_{PDB}$ = -53.2 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13575 -M	Date Received:	08-10-87
Your Reference:	Project No. 11889.407	Date Reported:	09-15-87
Submitted by:	Mark Snyder Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: MLEP-17A-B. 8-6-87. Midway Landfill.
1 of 2 bags received ripped open.

AGE = (109.9 +/- 2.5)% of the modern standard activity
(14.91 +/- 0.33) dpm/g Carbon.

Description: Sample of gas, mostly methane and carbon dioxide.

Pretreatment: Methane was purified from the sample, oxidized over hot cupric oxide wire to remove hydrogen, reconverted to methane with tritium-free hydrogen and analysed for C-14.

Comment:

$\delta^{13}C_{PDB}$ = -55.2 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13576 -C	Date Received:	08-10-87
Your Reference:	Project No. 11889.407	Date Reported:	09-15-87
Submitted by:	Mark Snyder Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: MLEP-10-B. 8-6-87. Midway Landfill.

AGE = (109.7 +/- 1.7)% of the modern standard activity
(14.89 +/- 0.23) dpm/g Carbon.

Description: Sample of gas, mostly methane and carbon dioxide.

Pretreatment: Carbon dioxide was purified from the sample and converted to methane for the analysis.

Comment:

$\delta^{13}C_{PDB}$ = -16.5 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	GX- 13581 -M	Date Received:	08-12-87
Your Reference:	Project No. 11889.407	Date Reported:	09-15-87
Submitted by:	Mark Snyder Black & Veatch Engineers 6240 S. Sprague Ave. Tacoma, WA 98409-6896		

Sample Name: MLF-N-B. 8-11-87. Midway Landfill.
This sample replaces the previously submitted sample we have designated GX-13573.

AGE = (113.0 +/- 8.9)% of the modern standard activity
(15.32 +/- 1.2) dpm/g Carbon.

Description: Sample of gas, mostly methane and carbon dioxide. Very small amt. of methane in bag.

Pretreatment: Methane was purified from the sample, oxidized over hot cupric oxide wire to remove hydrogen, reconverted to methane with tritium-free hydrogen and analysed for C-14.

Comment:

$\delta^{13}C_{PDB}$ = -46.1 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

received 11/30/87

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION
24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

20 November 1987

Tim Morley
Parametrix, Inc.
13020 Northup Way, Suite 8
Bellevue, WA 98005

Dear Tim,

Enclosed are the results of our tritium analyses on the methane hydrogens from the Midway landfill project. As we discussed on the phone, your sample, Probe 37-D did not contain any methane. The City House sample had about 1500 cc of methane, sample AE-S had about 200 cc of methane, and all the others had about 800 to 900 cc of methane. We would have liked to have had about 5000 cc for each sample but the amounts recovered were just adequate for counting.

Our procedures were as follows:

1) Methane gas was purified from other gases by cryogenic trapping.

2) The methane was combusted to carbon dioxide and water by circulation over hot copper oxide wire.

3) The water, containing the methane hydrogen, was collected.

4) The water was placed in a vial with chemical scintillants and counted in a low-level scintillation counter for tritium activity.

Our standard was NBS standard reference water sample # 4361.
Our background is prepared by combusting petrochemical methane (which does not contain tritium) and collecting the water.

We are reporting the results in Tritium Units and picocuries per gram of elemental hydrogen.

If you have any questions please contact me.

Sincerely yours,

Charles H. Sullivan
C-14 Lab Manager

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TRITIUM ANALYSES

For: Parametrix
Bellevue, WA

Analysed by: Geochron Labs
Krueger Enterprises
Cambridge, MA

GEOCHRON LAB #	PARAMETRIX ID	TU	pC/g OF ELEMENTAL HYDROGEN
T-4029	CITY HOUSE	< 18	< 0.5
T-4030	PROBE 85-D	336 +/- 20	9.6 +/- 0.5
T-4031	PROBE AE-S	< 90	< 2.6
T-4032	PROBE 2-S	< 22	< 0.6
T-4033	PROBE 17	< 22	< 0.6
T-4034	PROBE 37-D	SAMPLE DID NOT CONTAIN METHANE	
-4035	PROBE AC-S	< 17	< 0.4

A Tritium Unit (TU) is 1 tritium atom in ~~10(18)~~ 10^{18} hydrogen atoms.

A pC is 2.22 distintegrations per minute.

Errors are 1 sigma and are on counting statistics only.

TRITIUM ANALYSES

For: Parametrix
Bellevue, WA

Analysed by: Geochron Labs
Krueger Enterprises
Cambridge, MA

GEOCHRON LAB #	PARAMETRIX ID	TU	pC/g OF ELEMENTAL HYDROGEN
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A pC is 2.22 distintegrations per minute.

Errors are 1 sigma and are on counting statistics only.

APPENDIX H-2

LABORATORY RESULTS (ANALYTICAL DATA)
SAMPLES ANALYZED BY TELEDYNE ISOTOPES

TELEDYNE ISOTOPES

REPORT OF ANALYSIS

Additional Data 08/13/87
RUN DATE 08/06/87

WORK ORDER NUMBER	CUSTOMER P.O. NUMBER	DATE RECEIVED	DELIVERY DATE	PAGE 1
3-1255		07/28/87	08/30/87	

S M TURNBLOM
PARAMETRIX INC
13020 NORTHUP WAY SUITE 8
BELLEVUE WASHINGTON 98005

G A S

TELEDYNE SAMPLE NUMBER	CUSTOMER'S IDENTIFICATION	STA NUM	COLLECTION-DATE START DATE	START TIME	STOP DATE	STOP TIME	NUCLIDE	ACTIVITY	NUCL-UNIT-% U/M *	MID-COUNT TIME DATE	MID-COUNT TIME TIME	VOLUME - UNITS ASH-WGHT-% *	LAB.
07442	NORTH ON SITE FEED LN		07/27	1350			TOT H-3	L.T. 5.0 E 01	PCI/LITER *	08/04			2
							TOT C-14	2.7 +-0.3 E 01	PCI/LITER *	08/04			2
07443	SOUTH ON SITE FEED LN		07/27	1420			TOT H-3	L.T. 5.0 E 01	PCI/LITER *	08/03			2
							TOT C-14	4.22+-0.42E 01	PCI/LITER *	08/03			2
07444	85-D OFFSITE GAS PRBE		07/27	1515			TOT H-3	L.T. 5.0 E 01	PCI/LITER *	08/05			2
							TOT C-14	1.23+-0.12E 02	PCI/LITER *	08/05			2

LAST PAGE OF REPORT

APPROVED BY H. KING 08/06/87

SEND 1 COPIES TO PA715S S M TURNBLOM

2 - GAS LAB. 3 - RADIO CHEMISTRY LAB. 4 - GE(LI) GAMMA SPEC LAB. 5 - TRITIUM GAS/L.S. LAB.

TI #	C-14 (pCi/g carbon)
07442	14.6 +- 1.6
07443	78.1 +- 7.8
07444	228 +- 23

VOID SMTurnblom 2/3/88

J. Martin 8-13-87

RECEIVED AUG 17

RECEIVED 1987

U.S. NUCLEAR REGULATORY COMMISSION

Revision 1
February 1979

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 4.15

QUALITY ASSURANCE FOR RADIOLOGICAL MONITORING PROGRAMS (NORMAL OPERATIONS) — EFFLUENT STREAMS AND THE ENVIRONMENT

A. INTRODUCTION

This guide describes a method acceptable to the NRC staff for designing a program to assure the quality of the results of measurements of radioactive materials in the effluents and the environment outside of nuclear facilities during normal operations.

The NRC regulations that require the control of releases of radioactive materials from nuclear facilities, that require the measurements of radioactive materials in the effluents and environment outside of these facilities, that require quality assurance programs and establish quality assurance requirements for certain facilities, or that authorize license conditions not otherwise authorized in the regulations are as follows:

Section 20.106, "Radioactivity in Effluents to Unrestricted Areas," of 10 CFR Part 20, "Standards for Protection Against Radiation," provides that a licensee shall not release to an unrestricted area radioactive materials in concentrations that exceed limits specified in 10 CFR Part 20 or as otherwise authorized in a license issued by the Commission. Section 20.201, "Surveys," of 10 CFR Part 20 further requires that a licensee conduct surveys, including measurements of levels of radiation or concentrations of radioactive materials, as necessary to demonstrate compliance with the regulations in 10 CFR Part 20.

Paragraph (c) of Section 20.1, "Purpose," of 10 CFR Part 20 states that every reasonable effort should be made by NRC licensees to maintain radiation exposure, and releases of radioactive materials in effluents to unrestricted areas, as far below the limits specified in Part 20 as is reasonably achievable, taking into account the state of technology and the economics of improvements in relation to public health and safety and to the utilization of atomic energy in the public interest.

Section 30.34, "Terms and Conditions of Licenses," of 10 CFR Part 30, "Rules of General Applicability to Licensing of Byproduct Material," provides that the Commission may incorporate in any byproduct material license such terms and conditions as it deems appropriate or necessary in order to protect health.

Section 40.41, "Terms and Conditions of Licenses," of 10 CFR Part 40, "Licensing of Source Material," provides that the Commission may incorporate in any source material license such terms and conditions as it deems appropriate or necessary to protect health.

Section 50.50, "Issuance of Licenses and Construction Permits," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," provides that each operating license for a nuclear power plant issued by the Nuclear Regulatory Commission will contain such conditions and limitations as the Commission deems appropriate and necessary.

Section 70.32, "Conditions of Licenses," of 10 CFR Part 70, "Special Nuclear Material," provides that the Commission may incorporate such terms and conditions as it deems appropriate or necessary to protect health.

Section IV.B of Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that licensees establish an ap-

*Lines indicate substantive changes from previous issue.

USNRC REGULATORY GUIDES

Regulatory Guides are issued to describe and make available to the public methods acceptable to the NRC staff of implementing specific parts of the Commission's regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applicants. Regulatory Guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission.

Comments and suggestions for improvements in these guides are encouraged at all times, and guides will be revised, as appropriate, in accordance with comments and to reflect new information or experience. This guide was revised as a result of substantive comments received from the public and NRC staff.

Comments should be sent to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch.

The guides are issued in the following ten broad divisions:

1. Power Reactors
2. Research and Test Reactors
3. Fuels and Materials Facilities
4. Environmental and Siting
5. Materials and Plant Protection
6. Products
7. Transportation
8. Occupational Health
9. Antitrust and Financial Review
10. General

Requests for single copies of issued guides (which may be reproduced) or for placement on an automatic distribution list for single copies of future guides in specific divisions should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Director, Division of Technical Information and Document Control.

propriate surveillance and monitoring program to provide data on quantities of radioactive material released in liquid and gaseous effluents and to provide data on measurable levels of radiation and radioactive materials in the environment. Section III.B of Appendix I to 10 CFR Part 50 provides certain effluent and environmental monitoring requirements with respect to radioactive iodine if estimates of exposure are made on the basis of existing conditions and if potential changes in land and water usage and food pathways could result in exposures in excess of the guidelines of Appendix I to 10 CFR Part 50.

General Design Criterion 60, "Control of releases of radioactive materials to the environment," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 requires that nuclear power plant designs provide means to control suitably the release of radioactive materials in gaseous and liquid effluents. General Design Criterion 64, "Monitoring radioactivity releases," of Appendix A to 10 CFR Part 50 requires that nuclear power plant designs provide means for monitoring effluent discharge paths and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.

General Design Criterion 1, "Quality standards and records," of Appendix A to 10 CFR Part 50 requires that a quality assurance program be established for those structures, systems, and components of a nuclear power plant that are important to safety in order to provide adequate assurance that they will satisfactorily perform their safety functions.

Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components of these facilities that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

The need of quality assurance is implicit in all requirements for effluent and environmental monitoring, and this need has been widely recognized. Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants;" Regulatory Guide 4.1, "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants;" Regulatory Guide 4.8, "Environmental Technical Specifications for Nuclear Power Plants;" and Regulatory Guide 4.14, "Measuring, Evaluating, and Reporting Radioactivity in Releases of Radioactive Material in Liquid and Airborne Effluents From Uranium Mills," all give some guidance on means for assuring the quality of the measurements of radioactive materials in effluents and the environment outside of nuclear facilities. More complete and extensive guidance on this subject is provided in this document for nuclear power reactor facilities and for other facilities for which radiological monitoring is required by the NRC. This guidance does not identify separately the activities that are within the scope of Appendix B to 10 CFR Part 50. However, this guidance is intended to be consistent with the requirements of Appendixes A and B to 10 CFR Part 50 in that quality assurance requirements should be consistent with the importance of the activity. For the monitoring of production and utilization facilities that is within the scope of Appendix B to 10 CFR Part 50, other regulatory guides that provide guidance on meeting the quality assurance requirements of Appendix B to 10 CFR Part 50 should also be consulted.

B. DISCUSSION[1]

As used in the context of this guide, quality assurance comprises all those planned and systematic actions that are necessary to provide adequate confidence in the results of a monitoring program, and quality control comprises those quality assurance actions that provide a means to control and measure the characteristics of measurement equipment and processes to established requirements; therefore, quality assurance includes quality control.

To assure that radiological monitoring measurements are reasonably valid, organizations performing these measurements have found it necessary to establish quality assurance programs. These programs are needed for the following reasons: (1) to identify deficiencies in the sampling and measurement processes to those responsible for these operations so that corrective action can be taken, and (2) to obtain some measure of confidence in the results of the monitoring programs in order to assure the regulatory agencies and the public that the results are valid.

Existing published guidance on specific quality assurance actions that are applicable to radiological monitoring is limited and, in general, is restricted to quality control practices for radioanalytical laboratories (Refs. 1-5). However, quality assurance should be applied to all steps of the monitoring process, which may include sampling, shipment of samples, receipt of samples in the laboratory, preparation of samples, measurement of radioactivity, data reduction, date evaluation, and reporting of the monitoring results.

[1]Definitions of special terms used in this guide are given in the glossary on page 4.15-10.

The scope of this guide is limited to the elements of a quality assurance program, which is a planned, systematic, and documented program that includes quality control. Guidance on principles and good practice in the monitoring process itself and guidance on activities that can affect the quality of the monitoring results (e.g., design of facilities and equipment) are outside the scope of this guide. However, some references are provided to documents that do provide some guidance in these areas. The citation of these references does not constitute an endorsement of all of the guidance in these documents by the NRC staff. Rather, these references are provided as sources of information to aid the licensee and the licensee's contractors in developing and maintaining a monitoring program.

Every organization actually performing effluent and environmental monitoring, whether an NRC licensee or the licensee's contractor, should include the quality assurance program elements presented in this guide.

C. REGULATORY POSITION

The quality assurance program of each organization performing effluent or environmental monitoring of nuclear facilities for normal operations should be documented by written policies and procedures and records. These documents should include the elements given in this section.

In addition to its own program, a licensee should require any contractor or subcontractor performing monitoring activities for the licensee to provide a quality assurance program and to routinely provide program data summaries (sufficiently detailed to permit ongoing quality assurance program evaluation by the licensee) consistent with the provisions of this guide, as follows:

1. Organizational Structure and Responsibilities of Managerial and Operational Personnel

The structure of the organization as it relates to the management and operation of the monitoring program(s), including quality assurance policy and functions, should be presented. The authorities, duties, and responsibilities of the positions within this organization down to the first-line supervisory level should be described. This should include responsibilities for review and approval of written procedures and for the preparation, review, and evaluation of monitoring data and reports.

Persons and organizations performing quality assurance functions should have sufficient authority and organizational freedom to identify quality problems; to initiate, recommend, or provide solutions; and to verify implementation of solutions.

2. Specification of Qualifications of Personnel

The qualifications of individuals performing radiological monitoring to carry out their assigned functions should be specified and documented (e.g., as in a job description).

An indoctrination and orientation program, appropriate to the size and complexity of the organization and to the activities performed, should provide that (a) personnel performing quality-related activities are trained and qualified in the principles and techniques of the activities performed, (b) personnel are made aware of the nature and goals of the quality assurance program, and (c) proficiency of personnel who perform activities affecting quality is maintained by retraining, reexamining, and recertifying or by periodic performance reviews, as appropriate.

3. Operating Procedures and Instructions

Written procedures should be prepared, reviewed, and approved for activities involved in carrying out the monitoring program, including sample collection; packaging, shipment, and receipt of samples for offsite analysis; preparation and analysis of samples; maintenance, storage, and use of radioactivity reference standards; calibration and checks of radiation and radioactivity measurement systems; and reduction, evaluation, and reporting of data. Individuals who review and approve these procedures should be knowledgeable in the subjects of the procedures.

Guidance on principles and good practice in many of these activities is presented in NRC regulatory guides (Refs. 6-9) and other publications (Refs. 2-5, 10-35). In addition to these publications, Scientific Committee 18A of the NCRP has prepared NCRP Report 58, "A Handbook of Radioactivity Measurements Procedures," (Ref. 36) that is a revision of NCRP Report 28, NBS Handbook 80, "A Manual of Radioactivity Procedures."

4. Records

The records necessary to document the activities performed in the monitoring program should be specified in the quality assurance program.

One key aspect of quality control is maintaining the ability to track and control a sample in its progress through the sequence of monitoring processes. Records to accomplish this should cover the following processes: field and inplant collection of samples for subsequent analysis, including sample description; sample receipt and laboratory identification coding; sample preparation and radiochemical processing (e.g., laboratory notebooks); radioactivity measurements of samples, instrument backgrounds, and analytical blanks; and data reduction and verification.

Quality control records for laboratory counting systems should include the results of measurements of radioactive check sources, calibration sources, backgrounds, and blanks.

Records relating to overall laboratory performance should include the results of analysis of quality control samples such as analytical blanks, duplicates, interlaboratory cross-check samples and other quality control analyses; use of standards (radioactivity) to prepare working standards; preparation and standardization of carrier solutions; and calibration of analytical balances.

Additional records that are needed should include the calibration of inline radiation detection equipment, air samplers, and thermoluminescence dosimetry systems; verification and documentation of computer programs; qualifications of personnel; and results of audits.

The minimum period of retention of the records should be specified. For nuclear power plants, requirements for record retention are given in the plant technical specifications. In general, for other types of facilities, only the final results of the monitoring programs need be retained for the life of the facility.

5. Quality Control in Sampling (Including Packaging, Shipping, and Storage of Samples)

Continuous sampling of liquids and gases involves the measurement of sample flow rates and/or sample volumes. The accuracy of the devices used for this purpose should be determined on a regularly scheduled basis, and adjustments should be made as needed to bring the performance of the devices within specified limits. The results of these calibrations should be recorded. The frequency of these calibrations should be specified and should be based on the required accuracy, purpose, degree of usage, stability characteristics, and other conditions affecting the measurement. Procedures for continuous sampling should use methods that are designed to ensure that the sample is representative of the material volumes sampled. The collection efficiencies of the samplers used should be documented; usually such documentation is available from manufacturers of the sampling equipment.

Procedures for grab samples should include steps designed to ensure that the sample is representative of the material sampled. Replicate grab samples should be taken periodically to determine the reproducibility of sampling.

Procedures for sampling, packaging, shipping, and storage of samples should be designed to maintain the integrity of the sample from time of collection to time of analysis. Aqueous samples may present a particular problem in this regard, and one of the most severe problems has been encountered with aqueous samples of radioactive wastes from operating nuclear reactors (Ref. 23).

Guidance on the principles and practice of sampling in environmental monitoring is provided in several publications (Refs. 2, 4, 5, 21, 23-31, 33, 35, 37). In addition, workers at the National Bureau of Standards (NBS) have published the results of a survey of information on sampling, sample handling, and long-term storage for environmental materials (Ref. 15). Some guidance on the principles and practice of air sampling is provided in References 17, 19, 24, 28-31, 33. Guidance on the principles and practice of water sampling is provided in numerous publications (Refs. 13, 14, 25-27, 35, 37).

6. Quality Control in the Radioanalytical Laboratory

6.1 Radionuclide Reference Standards—Use for Calibration of Radiation Measurements Systems

Reference standards are used to determine counting efficiencies for specific radionuclides or, in the case of gamma-ray-spectrometry systems, to determine counting efficiency as a function of gamma-ray energy. A counting efficiency value is used to convert a sample counting rate to the decay rate of a radionuclide or to a radionuclide concentration. Guidance on the calibration and usage of germanium detectors for measurement of gamma-ray emission rates of radionuclides has been prepared as an ANSI standard (Ref. 38). For converting gamma-ray emission rates to nuclear decay rates, two reports from the Oak Ridge National Laboratory (Refs. 39 and 40) provide useful compilations of gamma-ray intensities and other nuclear decay data for radionuclides in routine releases from nuclear fuel cycle facilities. The data from Reference 40 are included in NCRP Report 58 (Ref. 36).

Radionuclide standards that have been certified by NBS or standards that have been obtained from suppliers who participate in measurement assurance activities with NBS[2]

[2]Satisfactory measurement assurance interactions between source suppliers and NBS involve two basic mechanisms: (1) The supplier submits a calibrated radioactivity source (preferably selected from a batch or prepared series of sources) to NBS for confirmation that the supplier's calibration value agrees with NBS results within certain specified limits or (2) NBS provides calibrated radioactivity sources of undisclosed activity (test samples) to a supplier who is able to make activity or emission-rate measurements on the source that agree within certain specified limits with the measurements of NBS. For the routine production of commercial radioactivity standards, the first mechanism is preferable to the second but is not always feasible. These two mechanisms are used both in Measurements Assurance Programs (MAPs) with key laboratories and in other measurement assurance activities.

Two key laboratory source suppliers participate in MAPs with NBS and use both of the two basic mechanisms: (1) The NRC reference laboratory for the Confirmatory Measurements Program (for effluent monitoring) of the NRC Office of Inspection and Enforcement and (2) The EPA Environmental Monitoring and Support Laboratory in Las Vegas, which prepares and

should be used when such standards are available. In these measurement assurance activities, the supplier's calibration value should agree with the NBS value within the overall uncertainty stated by the supplier in its certification of the same batch of sources (when these are sampled for measurement by NBS) or in its certification of similar sources.

An "International Directory of Certified Radioactive Materials" has been published by the International Atomic Energy Agency (Ref. 41).

Acceptable standards for certain natural radionuclides may be prepared from commercially available high-purity chemicals. For example, potassium-40 standards for gross beta-particle measurements or gamma-ray spectrometry may be prepared gravimetrically from dried reagent-grade potassium chloride.

The details of the preparation of working standards from certified standard solutions should be recorded. The working standard should be prepared in the same form as the unknown samples, or close approximation thereto.

Efficiency calibrations should be checked periodically (typically monthly to yearly) with standard sources. In addition, these checks should be made whenever the need is indicated, such as when a significant change in the measurement system is detected by routine measurements with a check source.

6.2 Performance Checks of Radiation Measurement Systems

Determination of the background counting rate and the response of each radiation detection system to appropriate check sources should be performed on a scheduled basis for systems in routine use. The results of these measurements should be recorded in a log and plotted on a control chart. Appropriate investigative and corrective action should be taken when the measurement value falls outside the predetermined control value.

A check source for determining changes in counting rate or counting efficiency should be of sufficient radiochemical purity to allow correction for decay but need not have an accurately known disintegration rate, i.e., need not be a standard source.

For systems in which samples are changed manually, check sources are usually measured daily. For systems with automatic sample changers, it may be more convenient to include the check source within each batch of samples and thus obtain a measurement of this source within each counting cycle. For proportional counter systems, the plateau(s) or response(s) to the check source(s) should be checked after each gas change. Background measurements should be made frequently, usually daily or before each use, to ensure that levels are within the expected range. For systems with automatic sample changers, background measurements should be included within each measurement cycle.

For alpha- and gamma-ray-spectrometry systems, energy-calibration sources (i.e., a source containing a radionuclide, or mixture of radionuclides, emitting two or more alpha or gamma rays of known energies) are counted to determine the relationship between channel number and alpha- or gamma-ray energy. The frequency of these energy calibration checks depends on the stability of the system but usually is in the range of daily to weekly. The results of these measurements should be recorded and compared to predetermined limits in order to determine whether or not system gain and zero level need adjustment. Adjustments should be made as necessary.

Additional checks needed for spectrometry systems are the energy resolution of the system and the count rate (or counting efficiency) of a check source. These should be determined periodically (usually weekly to monthly for energy resolution and daily to weekly for count rate) and after system changes, such as power failures or repairs, to determine if there has been any significant change in the system. The results of these measurements should be recorded.

6.3 Analysis of Quality Control Samples

The analysis of quality control samples provides a means to determine the precision and accuracy of the monitoring processes and includes both intralaboratory and interlaboratory measurements.

The analysis of replicate samples (containing significant detectable activity) provides a means to determine precision; the analysis of

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distributes calibrated radioactivity standards primarily to laboratories involved in radiological environmental monitoring. Additionally, seven major radiopharmaceutical manufacturers (some of which supply radioactivity standards commercially) participate in a MAP organized by the Atomic Industrial Forum and NBS. In this MAP, NBS distributes standards as test samples to the manufacturer (second mechanism) and receives certified samples from the manufacturer for verification by NBS (first mechanism).

Measurement assurance interactions that use the first mechanism are available via special NBS calibration services. NBS will, on request and for a fee, perform calibrations of representative samples of standards provided by the supplier for NBS confirmation of the supplier's reported values. Calibration services are available for a large variety of radionuclides provided certain requirements (as to sample stability and suitable activity range) are met. Measurement assurance interactions that use the second mechanism are available via the issuance of test standards by NBS. For a nominal charge (beyond the price of the standard), NBS radioactivity Standard Reference Materials (SRMs) can be purchased as test sources of undisclosed activity that can be used to demonstrate agreement, within certain specified limits, between the source supplier's measurements and those of NBS. A Report of Test (for the first mechanism) or a Report of Measurement (second mechanism), containing both the source supplier's and NBS values, is issued by NBS to document the source supplier's participation in the measurement assurance activity.

samples containing known concentrations of radionuclides provides a means to determine accuracy. The analysis of laboratory blanks provides a means to detect and measure radioactive contamination of analytical samples, a common source of error in radiochemical analysis of low-level samples. The analysis of analytical blanks also provides information on the adequacy of background subtraction, particularly for environmental samples.

The fraction of the analytical effort needed for the analysis of quality control samples depends to a large extent on (1) the mixture of sample types in a particular laboratory in a particular time period and (2) the history of performance of that laboratory in the analysis of quality control samples. However, for environmental laboratories, it is found that at least 5%, and typically 10%, of the analytical load should consist of quality control samples.

6.3.1 Intralaboratory Analyses

Replicate samples, usually duplicates, should be analyzed routinely. These replicates should be prepared from samples that are as homogeneous as possible, such as well-stirred or mixed liquids (water or milk) and solids (dried, ground, or screened soil, sediment, or vegetation; or the ash of these materials). These samples may be replicates of monitoring program samples, replicates of reference test materials, or both. The size and other physical and chemical characteristics of the replicate samples should be similar to those of single samples analyzed routinely.

The analysis of the replicate samples as blind replicates is desirable but is not practicable for all laboratories or for all types of samples. For example, in small laboratories it may not be practicable to prevent the analysts from being aware that particular samples are replicates of one another.

Obtaining true replicates of all types of samples also is not practicable. For example, obtaining replicate samples of airborne materials usually is not practicable on a routine basis because it requires either a separate sampling system or splitting a single sample (e.g., cutting a filter in half). Use of replicate samplers usually is not economically feasible and splitting of samples results in replicates that do not represent the usual sample size or measurement configuration (counting geometry) for direct measurement. However, simulated samples of airborne materials may be prepared in replicate and submitted for analysis as unknowns.

Analysis of intralaboratory blank and spiked samples is an important part of each environmental laboratory's quality control program. To check for contamination from reagents and other sources, known analytical blank samples should be included frequently in groups of unknown environmental samples that are analyzed radiochemically. Spiked and blank samples should be submitted for analysis as unknowns to provide an intralaboratory basis for estimating the accuracy of the analytical results. These blanks and spikes may include blind replicates.

6.3.2 Interlaboratory Analyses

Analysis of effluent and environmental samples split with one or more independent laboratories is an important part of the quality assurance program because it provides a means to detect errors that might not be detected by intralaboratory measurements alone. When possible, these independent laboratories should be those whose measurements are traceable to NBS.[3]

Analysis of split field samples, such as samples of milk, water, soil or sediment, and vegetation, is particularly important in environmental monitoring programs to provide an independent test of the ability to measure radionuclides at the very low concentrations present in most environmental samples.

The NRC Office of Inspection and Enforcement conducts a Confirmatory Measurements Program for laboratories of licensees that measure nuclear reactor effluents. The analyses of liquid waste holdup tank samples, gas samples, charcoal cartridges, and stack particulate filters are included in this program. The results of the licensee's measurements of samples split with the NRC are compared to those of an NRC reference laboratory whose measurements are traceable to the National Bureau of Standards. Thus the results of this comparison provide to the NRC an objective measure of the accuracy of the licensee's analyses.

Laboratories of licensees or their contractors that perform environmental measurements should participate in the EPA's Environmental Radioactivity Laboratory Intercomparison Studies (Cross-check) Program, or an equivalent program. This participation should include all of the determinations (sample medium/radionuclide combinations) that are both offered by EPA and included in the licensee's environmental monitoring program. Participation in the EPA program provides an objective measure of the accuracy of the analyses because the EPA measurements are traceable to the National Bureau of Standards. If the mean result of a cross-check analysis exceeds the control limit as defined by EPA (Ref. 42), an investigation should be made to determine the reason for this deviation and corrective action should be taken

[3] NBS and NRC staffs recognize the need for a clearer definition of the term "traceability" as it applies to radiation and radioactivity measurements. These staffs are working together to develop such a statement, which will be published separately.

as necessary. Similarly, an investigation and any necessary corrective action should take place if the "normalized range," as calculated by EPA, exceeds the control limit, as defined by EPA. A series of results that is within the control limits but that exhibits a trend toward these limits may indicate a need for an investigation to determine the reason for the trend.

6.4 Computational Checks

Procedures for the computation of the concentration of radioactive materials should include the independent verification of a substantial fraction of the results of the computation by a person other than the one performing the original computation. For computer calculations, the input data should be verified by a knowledgeable individual. All computer programs should be documented and verified before initial routine use and after each modification of the program. The verification process should include verification, by a knowledgeable individual, of the algorithm used and test runs in which the output of the computer computation for given input can be compared to "true" values that are known or determined independently of the computer calculation. Documentation of the program should include a description of the algorithm and, if possible, a current listing of the program. Guidelines for the documentation of digital computer programs are given in ANSI N413-1974 (Ref. 43).

7. Quality Control for Continuous Effluent Monitoring Systems

Guidance on specification and performance of onsite instrumentation for continuously monitoring radioactivity in effluents is given in ANSI N13.10-1974 (Ref. 18).

The specified frequency of calibration for a particular system should be based on considerations of the nature and stability of that system. For nuclear power plants, specific requirements for calibrations and checks of particular effluent monitoring systems usually are included in the technical specifications for the plant.

Initial calibration of each measuring system should be performed using one or more of the reference standards that are certified by the National Bureau of Standards or standards that have been obtained from suppliers that participate in measurement assurance activities with NBS (see footnote 2). These radionuclide standards should permit calibrating the system over its intended range of energy and rate capabilities. For nuclear power plants, sources that have been related to this initial calibration should be used to check this initial calibration at least once per 18 months (normally during refueling outages).

Periodic correlations should be made during operation to relate monitor readings to the concentrations and/or release rates of radioactive material in the monitored release path. These correlations should be based on the results of analyses for specific radionuclides in grab samples from the release path.

Any flow-rate measuring devices associated with the system should be calibrated to determine actual flow rates at the conditions of temperature and pressure under which the system will be operated. These flow rate devices should be recalibrated periodically.

Whenever practicable, a check source that is actuated remotely should be installed for integrity checks of the detector and the associated electrical system.

8. Review and Analysis of Data

Procedures for review and analysis of data should be developed. These procedures should cover examination of data from actual samples and from quality-control activities for reasonableness and consistency. These reviews should be performed on a timely basis. General criteria for recognizing deficiencies in data should be established.

Provisions should be made for investigation and correction of recognized deficiencies and for documentation of these actions.

9. Audits

Planned and periodic audits should be made to verify implementation of the quality assurance program. The audits should be performed by individuals qualified in radiochemistry and monitoring techniques who do not have direct responsibilities in the areas being audited.

Audit results should be documented and reviewed by management having responsibility in the area audited. Followup action, including reaudit of deficient areas, should be taken where indicated.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant or licensee proposes an acceptable alternative method, the staff will use the methods described herein in evaluating an applicant's or licensee's capability for and performance in complying with specified portions of the Commission's regulations after March 30, 1979.

If an applicant or licensee wishes to use the method described in this regulatory guide on or before March 30, 1979, the pertinent portions of the application or the licensee's performance will be evaluated on the basis of this guide.

GLOSSARY

Accuracy–a qualitative concept in the statistical treatment of measurement data used to describe the agreement between the central tendency of a set of numbers and their correct value (or the accepted reference value). It is also used to describe the agreement between an individual value and the correct value (or the accepted reference value).

Analytical Blank (Sample)–ideally, a sample having all of the constituents of the unknown sample except those to be determined. In radioanalytical practice, the term often refers to the radiochemical processing of carrier(s) or tracers without the sample matrix material.

"Blind" Replicate (Sample)–replicate samples that are not identified as replicates to the persons performing the analysis.

Calibration–the process of determining the numerical relationship between the observed output of a measurement system and the value, based on reference standards, of the characteristics being measured.

Calibration Source–any radioactive source that is used for calibration of a measurement system.

Check Source (or instrument check source or performance check source)–a radioactive source used to determine if the detector and all electronic components of the system are operating correctly.

Instrument Background–the response of the instrument in the absence of a radioactive sample or other radioactive source.

Precision–a qualitative concept in the statistical treatment of measurement data used to describe the dispersion of a set of numbers with respect to its central tendency.

Quality Assurance (QA)–the planned and systematic actions that are necessary to provide adequate confidence in the results of a monitoring program.

Quality Control (QC)–those quality assurance actions that provide a means to control and measure the characteristics of measurement equipment and processes to established requirements. Thus, quality assurance includes quality control.

Reference Test Material–a large batch of homogeneous material from which aliquots may be taken for interlaboratory comparisons or for internal use by the laboratory. The material must be uniform but need not be standardized.

Spiked Sample–a sample to which a known amount of radioactive material has been added. Generally, spiked samples are submitted as unknowns to the analysts.

Split Sample–a homogeneous sample that is divided into parts, each of which is analyzed independently by separate laboratory organizations.

Standard (radioactive) Source–a radioactive source having an accurately known radionuclide content and radioactive decay rate or rate of particle or photon emission.

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TELEDYNE ISOTOPES
50 VAN BUREN AVENUE
WESTWOOD, NEW JERSEY 07675
(201) 664-7070
TELEX 134474 TDYISOT WTWD

September 17, 1987

Mr. Tom Morley
Parametrix Inc.
13020 Northup Way, Suite 8
Bellevue, Washington 98005

Dear Mr. Morley:

We analyzed each of three gas samples for H-3 and C-14 from aliquots taken directly from the sample containers. We did not separate methane from each sample and then analyze the methane only as the other laboratory did. Therefore, there is no reason to expect the results to be the same.

The analysis for tritium is performed by passing an aliquot of known volume of the sample mixed with a known volume of non-tritiated hydrogen through a copper oxide furnace at approximately 650° C. The mixture is continuously cycled through the furnace for at least an hour, assuring that all hydrogenous species in the sample and the added hydrogen have been converted to water. The water is collected in a cryogenic trap. Upon completion of the water collection, the volume of water is determined and a measured volume of it is counted by liquid scintillation for the tritium activity.

The analysis for carbon-14 is performed by passing an aliquot of known volume of the sample through a copper oxide furnace at approximately 650° C. The sample is continuously cycled through the furnace for at least an hour, assuring that all the carbonaceous species are converted to CO_2. The CO_2 is collected in a cryogenic trap. The CO_2 is then purified by gas chromatography. A measured volume of CO_2 is transferred to an evacuated 100 cc proportional counter and methane (previously determined to be without C-14) is added so that the pressure in the proportional counter is at one atmosphere.

An EPA tritium standard is used for the calibration of the liquid scintillators. A NBS Kr-85 gas standard is used for the calibration of the 100 cc proportional counters.

ISOTOPES

For over twenty-five years our principal market for radiological services has been the nuclear utility industry. Therefore our quality control and quality assurance programs have been developed and maintained in compliance with the US Nuclear Regulatory Commission's 10CFR50, Appendix B and Regulatory Guide 4.5. The latter describes in detail the features we follow.

We are reanalyzing the samples and will report the results as soon as available.

Sincerely,

J. David Martin

J. David Martin Ph.D.
Vice President - Technical

JDM:cm

Enc.

D240-812

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TELEDYNE ISOTOPES
50 VAN BUREN AVENUE
WESTWOOD, NEW JERSEY 07675
(201) 664-7070
TELEX 134474 TDYISOT WTWD

September 25, 1987

Mr. Tom Morley
Parametrix Inc.
13020 Northup Way, Suite 8
Bellevue, Washington 98005

Dear Mr. Morley:

This letter is a continuation of my letter dated September 17, 1987. In that letter, I stated that we were reanalyzing the samples. We did so because of the high levels of C-14 relative to normal environmental values and because initial specific activity measurements on two of the samples indicated that there was more radioactivity in the two samples than accounted for from the C-14 activity. The specific activity is performed by loading a few cc of sample into a 100 cc proportional counter, adding methane (which does not contain either C-14 or H-3), and counting the mixture. The comparison of the specific activity with the C-14 activity is summarized below:

TI Sample	Specific Activity (pCi/ℓ)	Initial C-14 (pCi/ℓ)
07442	Not measured	27.1
07443	265 (07/29)	42.2
07444	303 (08/06)	123
07444	<40 (09/10)	-

The specific activity must have been due to a short lived isotope-possibly Rn-222 based on the results for TI 07444.

Our convention for reporting radioactivity in a gas sample is in picocuries per liter of sample. That unit of measure was used for the H-3 and C-14 results on W03-1255. At a later date, and at the request of your company, we provided an alternate measurement unit (pCi/g of carbon) for the C-14 results. Upon review of the data we find that the C-14 results were reported incorrectly in the units of pCi/g of carbon. To convert from pCi/cc of CO_2 to pCi/g of carbon, the relationship of 1867 cc of CO_2 is equivalent to 1 g of carbon must be used. The table below provides results in various units for the analyses previously performed:

Units should be pCi not pCi/l
Dorothy of Dave Martin 9/28/87

ISOTOPES

TI Sample	Volume of CO_2 in detector (cc)	C-14 activity (pCi/ℓ)	C-14 (pCi/cc CO_2)	C-14 (pCi/gC)
07442	8.29	0.575	0.0694	130
07443	8.24	0.828	0.100	188
07444	8.47	4.37	0.516	963

As I mentioned earlier in this letter we reanalyzed the three samples with following results:

TI Sample	Volume of CO_2 in detector (cc)	C-14 activity (pCi/ℓ)	C-14 (pCi/cc CO_2)	C-14 (pCi/gC)
07442	8.10	0.240	0.0296	55.4
07443	8.10	0.639	0.0788	148
07444	8.10	0.631	0.0779	145

The reanalysis results were lower than the initial results for each sample possibly due to the short lived species, although the processing should have removed all isotopes except C-14.

Sincerely,

J. David Martin

J. David Martin Ph.D.
Vice President - Technical

JDM:cm

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