LANDFILL GAS INVESTIGATION REPORT
BROOKFIELD AVENUE LANDFILL REMEDIATION
OPERABLE UNIT 1
STATEN ISLAND, NEW YORK

Prepared for

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2.6 Long-term Testing Procedures

The purpose of the long-term testing program was to determine sustainable landfill gas extraction rates and landfill gas composition during conditions likely to be more representative of long-term system operation under the prevailing conditions. Separate long-term tests were conducted at GEW-1 and GEW-5. As with the short-term tests, the one or two extraction wells nearest the well being tested were closed during the long-term tests to minimize the potential for interferences due to overlapping zones of influence. The other wells were opened as needed to provide sufficient flow to prevent damage to the blower.

In order to evaluate long-term conditions, the extraction rates used during the long-term testing program were slightly less than (at GEW-1) or approximately equal to (at GEW-5) the rates used during the short-term tests. Measured flow rates ranged from 71 scfm to 74 scfm for GEW-1 and from 49 scfm to 55 scfm for GEW-5. Pressure, landfill gas temperature and landfill gas composition were measured at the gas extraction well being tested and at each shallow and deep pressure probe associated with that well. Measurements were collected once per week during the three-week test period at each gas extraction well. Pressure measurements were collected using Magnehelic differential pressure gauges and the landfill gas temperature was measured using a temperature probe or thermometer. The landfill gas composition, including percent methane, percent oxygen, percent carbon dioxide and percent nitrogen (by balance), was measured using a Landtec GEM 500 meter.

According to the approved work plan, the flow rate from the gas extraction well was to be slightly increased each week after the readings were collected. However, since the weekly readings at each gas extraction well indicated that methane concentrations were decreasing over time, the flow rate was not adjusted for either well during the long-term testing program. In addition, as noted above, even though two of the shallow pressure probes around GEW-5 showed vacuum at a flow rate of 20.9 scfm, concerns regarding potential equipment damage prevented reduction of the flow rate below approximately 50 scfm for long-term operation of the system.

3.2.1 Gas Extraction Well (GEW-1) Short-term Testing Results

Prior to the start of the 24-hour short-term testing, a series of sequential tests were performed over a two-day period to determine the maximum flow rate at which infiltration of ambient air into the landfill mass would be minimized or avoided. Infiltration into the landfill mass was checked by monitoring the gauge pressures of the shallow pressure probes. As a result of the testing, a flow rate of 85 cubic feet per minute was found to be a short-term flow rate at which the methane concentration of the extracted landfill gas did not materially deteriorate from the methane concentrations measured during the status test phase. A summary of the short-term flow calibration results is presented in Table 3-2.

Once the maximum flow was determined, a 24-hour short-term test was conducted to estimate the average radius of influence for the gas extraction well at the operating flow rate. As described in USEPA Method 2E, the average maximum radius of influence (R_{ma}) is calculated where the average final absolute pressure (P_{fa}) of the deep pressure probes was less than or equal to the initial average pressure (P_{ia}) determined during the static testing events. That is, the internal landfill pressure under extraction conditions is measured as being less than the internal landfill pressure conditions which prevail when no withdrawal is occurring (static conditions). The measured reduction in internal landfill pressure is attributed to the influence of gas withdrawal via the extraction well.

Based upon this criterion and the field data, the average radius of influence was calculated to be 137 feet from GEW-1 at a flow rate of 85 scfm. A summary of the 24-hour short-term testing results is presented in Table 3-3.

3.2.2 Gas Extraction Well (GEW-5) Short-term Testing Results

Prior to the start of the 24-hour short-term testing, a series of sequential tests were performed over a two-day period to determine the maximum flow rate at which infiltration of ambient air into the landfill mass would be minimized or avoided. Infiltration into the landfill mass was checked by monitoring the gauge pressures of the shallow pressure probes for vacuum.

Table 3-2

GEW-1 - SUMMARY OF SHORT-TERM FLOW SELECTION RESULTS BROOKFIELD AVENUE LANDFILL

Test Interval	Well / Pressure Probe Designation	Flow Rate *(scfm)*	Gauge Pressure *(in H_2O)*	Landfill Gas Composition (%)			
				CH_4	CO_2	O_2	N_2 *(Bal.)*
Run 1	GEW-1	60.8	-2.20	29.9	19.4	0.8	49.9
	S1-1A	--	0.05	--	--	--	--
	S1-1B	--	0.05	--	--	--	--
	S1-1C	--	0.00	--	--	--	--
Run 2	GEW-1	60.5	-2.10	33.5	20.5	0.2	45.8
	S1-1A	--	0.02	--	--	--	--
	S1-1B	--	0.05	--	--	--	--
	S1-1C	--	0.00	--	--	--	--
Run 3	GEW-1	64.1	-2.30	33.1	20.6	0.3	46.0
	S1-1A	--	0.03	--	--	--	--
	S1-1B	--	0.03	--	--	--	--
	S1-1C	--	0.00	--	--	--	--
Run 4	GEW-1	100.5	-4.00	28.3	20.6	1.0	50.1
	S1-1A	--	0.01	--	--	--	--
	S1-1B	--	0.02	--	--	--	--
	S1-1C	--	0.00	--	--	--	--
Run 5	GEW-1	84.4	-3.10	28.3	20.7	0.5	50.5
	S1-1A	--	0.01	--	--	--	--
	S1-1B	--	0.03	--	--	--	--
	S1-1C	--	-0.03	--	--	--	--
Run 6	GEW-1	84.3	-3.20	28.4	20.6	0.0	51.0
	S1-1A	--	0.00	--	--	--	--
	S1-1B	--	0.00	--	--	--	--
	S1-1C	--	-0.03	--	--	--	--

Table 3-3

GEW-1 - SUMMARY OF 24-HOUR SHORT-TERM TESTING RESULTS
BROOKFIELD AVENUE LANDFILL

Test Interval	Well / Pressure Probe Designation *(Distance from GEW-1)*	Flow Rate *(scfm)*	Gauge Pressure *(in H_2O)*	Landfill Gas Composition (%)			
				CH_4	CO_2	O_2	N_2 *(Bal.)*
After 18.5 Hours of Steady State Operation	GEW-1	85.0	-2.90	29.2	20.6	0.2	50.0
	S1-1A *(10')*	--	0.00	0.0	0.3	19.7	80.0
	S1-1B *(10')*	--	0.02	0.0	0.0	18.4	81.6
	S1-1C *(10')*	--	-0.03	0.0	0.3	19.7	80.0
	D1-1A *(50')*	--	-0.28	0.0	0.9	20.0	79.1
	D1-2A *(100')*	--	-0.22	0.0	0.0	20.6	79.4
	D1-3A *(150')*	--	0.00	0.0	0.7	20.1	79.2
	D1-1B *(50')*	--	-0.90	36.1	15.5	4.6	43.8
	D1-2B *(100')*	--	-0.60	7.0	2.9	17.2	72.9
	D1-3B *(150')*	--	-0.40	47.8	18.1	0.2	33.9
	D1-1C *(50')*	--	-0.60	41.4	15.9	1.7	41.0
	D1-2C *(100')*	--	0.03	0.0	1.6	17.6	80.8
	D1-3C *(150')*	--	0.04	0.0	4.5	13.0	82.5
After 23.5 Hours of Steady State Operation	GEW-1	85.0	-2.60	28.3	20.3	0.2	51.2
	S1-1A *(10')*	--	0.00	0.0	0.2	20.8	79.0
	S1-1B *(10')*	--	0.00	0.0	0.0	19.0	81.0
	S1-1C *(10')*	--	-0.03	0.2	0.8	19.8	79.2
	D1-1A *(50')*	--	-0.24	0.0	0.3	21.2	78.5
	D1-2A *(100')*	--	-0.17	0.0	0.3	20.9	78.8
	D1-3A *(150')*	--	0.00	0.0	0.4	20.7	78.9
	D1-1B *(50')*	--	-0.80	35.5	15.5	4.4	44.6
	D1-2B *(100')*	--	-0.55	9.2	3.3	16.8	70.7
	D1-3B *(150')*	--	-0.39	46.6	17.7	0.2	35.5
	D1-1C *(50')*	--	-0.75	39.8	15.5	1.8	42.9
	D1-2C *(100')*	--	0.00	0.0	1.2	18.4	80.4
	D1-3C *(150')*	--	0.00	0.0	2.9	13.0	84.1
After 31 Hours of Steady State Operation	GEW-1	85.0	-2.60	26.8	20.5	0.4	52.3
	S1-1A *(10')*	--	0.03	0.0	0.1	20.7	79.2
	S1-1B *(10')*	--	0.03	0.0	0.0	18.7	81.3
	S1-1C *(10')*	--	0.00	0.0	0.4	19.9	79.7
	D1-1A *(50')*	--	-0.24	0.0	0.0	21.0	79.0
	D1-2A *(100')*	--	-0.18	0.0	0.3	20.7	79.0
	D1-3A *(150')*	--	0.00	0.0	0.4	20.7	78.9
	D1-1B5 *(50')*	--	-0.80	34.3	15.1	5.0	45.6
	D1-2B *(100')*	--	-0.60	8.0	3.1	17.0	71.9
	D1-3B *(150')*	--	-0.41	47.8	18.0	0.2	34.0
	D1-1C *(50')*	--	-0.78	36.6	14.7	2.7	46.0
	D1-2C *(100')*	--	0.02	0.0	1.1	18.9	80.0
	D1-3C *(150')*	--	0.03	0.0	3.6	14.8	81.6

: Suggests the influence of subsurface air infiltration

Given that mechanical concerns for the existing extraction system precluded the performance of short-term testing at flow rates as low as 21 scfm, the short-term testing was performed at a flow rate of 56 scfm, which was considered acceptable to safeguard the mechanical integrity of the existing equipment.

During the performance of the short-term testing, it was found that the landfill area of GEW-5 did not respond well to the extraction effort as exemplified by a significant reduction in methane concentration from the static conditions to the short-term extraction conditions. Static test conditions revealed an average methane concentration at well GEW-5 of 38.7%. During the performance of the short-term testing flow selection process and short-term withdrawal testing, the methane concentration was noted to continually decline over time from 33.8% to 11.5%. These conditions would suggest that the withdrawal rates exceed the generation rates. The data also suggests the effects of infiltration of ambient air were experienced as indicated by an increase in oxygen concentrations over time. A summary of the short-term flow selection results is presented in Table 3-4.

Using an extraction rate of 56 scfm, a 24-hour short-term test was conducted to evaluate the average maximum radius of influence for the gas extraction well. The operation of extraction well GEW-5 at a short-term extraction rate of 56 scfm demonstrates that, under the prevailing conditions, the rate of withdrawal is excessive. A review of the short-term testing data reveals that the methane concentration decreased significantly when compared to the static test results and the early stages of the short-term testing. The methane concentration was noted to continuously decline as the short-term testing progressed.

Based upon an extraction rate of 56 scfm, the calculations of Method 2E would suggest that the realized radius of influence was on the order of 150 feet. However, the deterioration of gas quality necessitates a lower extraction rate and consequently, a smaller radius of influence. A summary of the 24-hour short-term testing results is presented in Table 3-5.

Table 3-5

GEW-5 - SUMMARY OF 24-HOUR SHORT-TERM TESTING RESULTS BROOKFIELD AVENUE LANDFILL

Test Interval	Well / Pressure Probe Designation *(Distance from Well)*		Flow Rate *(scfm)*	Gauge Pressure *(in H_2O)*	Landfill Gas Composition (%)			
					CH_4	CO_2	O_2	N2 *(Bal.)*
After 16.5 Hours of Steady State Operation	GEW-5		56.0	-3.50	12.0	18.5	1.7	67.8
	S5-1A	*(10')*	--	-0.30	0.1	2.4	13.4	84.1
	S5-1B	*(10')*	--	0.02	0.0	0.0	21.0	79.0
	S5-1C	*(10')*	--	-0.70	0.0	0.0	21.0	79.0
	D5-1A	*(50')*	--	0.02	0.0	2.0	18.6	79.4
	D5-2A	*(100')*	--	0.00	0.0	0.0	20.9	79.1
	D5-3A	*(150')*	--	0.03	0.0	0.0	20.7	79.3
	D5-1B	*(50')*	--	0.01	0.0	0.9	20.2	78.9
	D5-2B	*(100')*	--	-0.09	13.5	7.8	3.6	75.1
	D5-3B	*(150')*	--	-0.05	3.4	17.0	0.3	79.3
	D5-1C	*(50')*	--	-0.05	0.0	0.0	20.9	79.1
	D5-2C	*(100')*	--	-0.25	0.0	2.1	19.2	78.7
	D5-3C	*(150')*	--	-0.25	0.0	2.4	20.4	77.2
After 23.5 Hours of Steady State Operation	GEW-5		56.0	-3.30	11.7	17.9	1.8	68.6
	S5-1A	*(10')*	--	-0.25	0.0	0.8	20.4	78.8
	S5-1B	*(10')*	--	-0.02	0.0	0.0	21.1	78.9
	S5-1C	*(10')*	--	-0.60	0.0	0.0	21.3	78.7
	D5-1A	*(50')*	--	0.00	0.0	1.6	19.2	79.2
	D5-2A	*(100')*	--	0.00	0.0	0.0	21.2	78.8
	D5-3A	*(150')*	--	0.02	0.0	0.0	20.6	79.4
	D5-1B	*(50')*	--	0.00	0.0	0.8	20.5	78.7
	D5-2B	*(100')*	--	-0.08	15.6	9.4	0.6	74.4
	D5-3B	*(150')*	--	0.05	3.0	16.9	0.2	79.9
	D5-1C	*(50')*	--	-0.05	0.0	0.0	20.9	79.1
	D5-2C	*(100')*	--	-0.24	0.0	2.2	19.2	78.6
	D5-3C	*(150')*	--	-0.22	0.0	0.4	20.6	79.0
After 31 Hours of Steady State Operation	GEW-5		56.0	-4.20	11.5	18.1	2.2	68.2
	S5-1A	*(10')*	--	-0.29	0.0	2.1	14.5	83.4
	S5-1B	*(10')*	--	0.01	0.0	0.0	20.7	79.3
	S5-1C	*(10')*	--	-0.70	0.0	0.0	20.7	79.3
	D5-1A	*(50')*	--	0.00	0.0	1.9	18.9	79.2
	D5-2A	*(100')*	--	0.00	0.0	0.0	20.9	79.1
	D5-3A	*(150')*	--	0.02	0.0	0.0	20.3	79.7
	D5-1B	*(50')*	--	0.01	0.0	1.0	19.9	79.1
	D5-2B	*(100')*	--	-0.09	15.8	10.0	1.2	73.0
	D5-3B	*(150')*	--	-0.04	2.4	17.3	0.2	80.1
	D5-1C	*(50')*	--	-0.06	0.0	0.0	20.6	79.4
	D5-2C	*(100')*	--	-0.23	0.0	1.2	19.6	79.2
	D5-3C	*(150')*	--	-0.24	0.0	0.3	20.4	79.3

: Suggests the influence of subsurface air infiltration

The topography in the area of extraction well GEW-5 introduces the slope effects associated with an extraction well situated close to the landfill side slopes. The area to the east of well GEW-5 slopes downward at a rate of approximately 10 to 12 percent. This declining ground surface promotes surface air infiltration during extraction. These effects are most apparent in the deep probes along radial lines A and C, which run roughly parallel to the slope. Radial line B is roughly perpendicular to the slope and more closely approximates conditions central to the landfill.

It is clear that the overall radius of influence for well GEW-5 is compromised by the proximity of the landfill side slope in that the area and presents an unbalanced set of conditions. The relatively shallow depth of waste in this area (25 feet) serves to compound this condition in that there is limited latitude to provide a deep screen setting to compensate for the slope.

3.3 Long-term Testing Results

The purpose of the long-term testing was to determine sustainable landfill gas extraction rates (Q_f) and landfill gas composition during conditions likely to be more representative of long term system operation. Determining an appropriate landfill gas generation rate is a significant aspect of the design of the gas collection and treatment system for the Brookfield Avenue Landfill because it provides a basis for sizing of the gas collection and treatment system components. Separate long-term tests were conducted at GEW-1 and GEW-5.

3.3.1 Gas Extraction Well (GEW-1) Long-term Testing Results

As described in USEPA Method 2E, the landfill gas generation constant (k) is calculated using the following formula:

$$ke^{-k} A_{avg} - (5.256 \times 10^5) \frac{Q_f}{2 L_o' M_r} = 0$$

The following values were used to determine the sustainable landfill gas extraction rate for the portion of the Brookfield Avenue Landfill affected by GEW-1.

1. A_{avg} - Average age of the solid waste tested – 26 years (CDM, FS, 2001)

2. Q_f - Final stabilized flow rate – 2.05 m^3 per minute or 72 scfm (WFC, LFG Investigation, 2002)

3. L_o – Methane generation potential – 170.00 m^3 per megagram (default value USEPA, Method 2E, 1996)

4. L_o' – Revised methane generation potential to account for the amount of non decomposable material 1% in the landfill –168.30 m^3 per megagram (CDM, FS, 2001)

5. M_r – Mass of decomposable solid waste affected by GEW-1 – 10,167 megagrams (CDM, RI, 1997)

Based on the model inputs and assumptions, the calculated methane generation rate constant (k) for GEW-1 is approximately 0.012 $year^{-1}$. This value represents approximately 24.0% of the Method 2E assumed or default value of 0.05 $year^{-1}$ and supports that the landfill has passed its peak generation period, which was in the 1980's as projected in the Analysis of Methane Potential at New York State Sanitary Landfill Sites issued by Gas Recovery Systems Inc. (1981). This condition can be attributed to the age of the waste and suggests that the methane generation capacity will gradually decline during the post closure period, subject to conditions imposed by the construction of the capping system. A summary of the long-term testing results is presented in Table 3-6.

3.3.2 Gas Extraction Well (GEW-5) Long-term Testing Results

As described in USEPA Method 2E, the landfill gas generation constant (k) is calculated using the following formula:

$$ke^{-k\,A_{avg}} - (5.256 \times 10^5)\,\frac{Q_f}{2\,L_o'\,M_r} = 0$$

Table 3-6

GEW-1 - SUMMARY OF LONG-TERM TESTING RESULTS
BROOKFIELD AVENUE LANDFILL

Test Interval	Well / Pressure Probe Designation	Flow Rate *(scfm)*	Gauge Pressure *(in H_2O)*	Landfill Gas Composition (%)			
				CH_4	CO_2	O_2	N_2 *(Bal.)*
After 208 Hours of Continuous Operation	GEW-1	72.0	-2.10	20.5	19.5	0.4	59.6
	S1-1A	--	0.30	0.0	0.0	20.3	79.7
	S1-1B	--	0.20	0.0	0.0	16.5	83.5
	S1-1C	--	-0.60	0.0	4.6	12.9	82.5
	D1-1A	--	-0.21	0.0	2.0	18.2	79.8
	D1-2A	--	-0.14	0.0	0.2	20.1	79.7
	D1-3A	--	0.00	0.0	0.2	20.2	79.6
	D1-1B	--	-0.65	41.7	19.3	0.5	38.5
	D1-2B	--	-0.48	35.5	10.7	3.1	50.7
	D1-3B	--	-0.35	47.3	18.2	0.0	34.5
	D1-1C	--	-0.60	38.5	16.3	0.2	45.0
	D1-2C	--	-1.00	0.0	3.3	14.7	82.0
	D1-3C	--	-1.20	0.0	5.4	10.7	83.9
After 362 Hours of Continuous Operation	GEW-1	74.0	-2.10	19.0	19.3	0.3	61.4
	S1-1A	--	0.02	0.0	0.1	20.8	79.1
	S1-1B	--	0.90	0.0	0.0	9.8	90.2
	S1-1C	--	0.02	0.0	0.3	20.4	79.3
	D1-1A	--	-0.22	0.0	3.7	16.4	79.9
	D1-2A	--	-0.14	0.0	0.1	20.6	79.3
	D1-3A	--	0.00	0.0	0.0	20.7	79.3
	D1-1B	--	-0.60	43.7	18.8	0.4	37.1
	D1-2B	--	-0.40	43.4	15.6	0.1	40.9
	D1-3B	--	-0.28	48.3	17.4	0.1	34.2
	D1-1C	--	-0.50	41.1	15.9	0.2	42.8
	D1-2C	--	-0.30	0.0	4.1	14.1	81.8
	D1-3C	--	-0.40	0.0	6.3	9.2	84.5
After 530 Hours of Continuous Operation	GEW-1	71.0	-2.20	19.2	19.3	0.5	61.0
	S1-1A	--	0.02	0.0	0.2	20.0	79.8
	S1-1B	--	0.02	0.0	0.0	18.4	81.6
	S1-1C	--	-1.00	0.0	2.2	17.4	80.4
	D1-1A	--	-0.26	0.0	0.1	20.4	79.5
	D1-2A	--	-0.14	0.0	0.2	20.2	79.6
	D1-3A	--	0.00	0.0	0.2	20.1	79.7
	D1-1B	--	-0.70	32.4	12.6	6.3	48.7
	D1-2B	--	-0.50	23.2	8.9	8.8	59.1
	D1-3B	--	-0.38	50.4	17.3	0.1	32.2
	D1-1C	--	-0.68	37.9	16.5	0.0	45.6
	D1-2C	--	0.02	0.0	2.2	16.4	81.4
	D1-3C	--	0.02	0.0	5.5	10.3	84.2

: Suggests the influence of subsurface air infiltration

The following values were used to determine the sustainable landfill gas extraction rate for the portion of the Brookfield Avenue Landfill affected by GEW-5.

1. A_{avg} - Average age of the solid waste tested – 26 years (CDM, FS, 2001)
2. Q_f - Final stabilized flow rate – 1.47 m^3 per minute or 52 scfm (WFC, LFG Investigation, 2002)
3. L_o – Methane generation potential – 170.00 m^3 per megagram (default value USEPA, Method 2E, 1996)
4. $L_o^{'}$ – Revised methane generation potential to account for the amount of non decomposable material 1% in the landfill –168.30 m^3 per megagram (CDM, FS, 2001)
5. M_r – Mass of decomposable solid waste affected by GEW-1 – 7,759 megagrams (CDM, RI, 1997)

Based on the model input data and assumptions, the calculated methane generation rate constant (k) for GEW-5 is approximately 0.013 $year^{-1}$. This value represents approximately 26.0% of the Method 2E assumed or default value of 0.05 $year^{-1}$. As in the case of well GEW-1, this calculated value suggests that the peak generation of methane has passed and that a long, gradual decline in methane generation should be observed in the post closure period. A summary of the long- term testing results is presented in Table 3-7.

Table 3-7

GEW-5 - SUMMARY OF LONG-TERM TESTING RESULTS
BROOKFIELD AVENUE LANDFILL

Test Interval	Well / Pressure Probe Designation	Flow Rate *(scfm)*	Gauge Pressure *(in H_2O)*	Landfill Gas Composition (%)			
				CH_4	CO_2	O_2	N_2 *(Bal.)*
After 134 Hours of Continuous Operation	GEW-5	55.0	-3.80	7.6	14.3	5.1	73.0
	S5-1A	--	-0.20	0.0	3.0	8.2	88.8
	S5-1B	--	0.02	0.0	0.8	19.5	79.7
	S5-1C	--	-0.62	0.0	0.0	21.0	79.0
	D5-1A	--	0.00	0.0	1.7	19.4	78.9
	D5-2A	--	0.00	0.0	0.0	21.1	78.9
	D5-3A	--	0.04	0.0	0.7	19.8	79.5
	D5-1B	--	0.00	0.0	0.9	19.9	79.2
	D5-2B	--	-0.10	8.3	12.2	1.5	78.0
	D5-3B	--	-0.05	0.0	13.0	3.1	83.9
	D5-1C	--	-0.05	0.0	0.0	20.9	79.1
	D5-2C	--	-0.18	0.0	0.7	20.1	79.2
	D5-3C	--	-0.19	0.0	0.1	20.8	79.1
After 326 Hours of Continuous Operation	GEW-5	49.0	-3.50	6.0	14.0	5.4	74.6
	S5-1A	--	-0.10	0.0	0.0	21.0	79.0
	S5-1B	--	0.00	0.1	1.3	18.4	80.2
	S5-1C	--	-0.55	0.1	0.0	21.9	79.1
	D5-1A	--	0.00	0.0	2.3	17.9	79.8
	D5-2A	--	0.02	0.0	0.0	20.3	79.7
	D5-3A	--	0.02	0.0	1.2	19.0	79.8
	D5-1B	--	0.00	0.1	1.5	18.7	79.7
	D5-2B	--	-0.07	0.3	0.3	19.4	80.0
	D5-3B	--	-0.03	0.0	1.0	17.6	81.4
	D5-1C	--	-0.05	0.0	0.0	20.6	79.4
	D5-2C	--	-0.10	0.0	1.2	19.3	79.5
	D5-3C	--	-0.11	0.0	0.3	20.3	79.4
After 495 Hours of Continuous Operation	GEW-5	53.0	-3.70	5.0	14.5	5.1	75.4
	S5-1A	--	-0.10	0.0	1.3	19.9	78.8
	S5-1B	--	0.02	0.0	1.7	18.3	80.0
	S5-1C	--	-0.72	0.0	0.0	20.9	79.1
	D5-1A	--	-0.20	0.0	2.6	17.7	79.7
	D5-2A	--	0.10	0.0	0.3	21.0	78.7
	D5-3A	--	0.10	0.0	0.0	20.8	79.2
	D5-1B	--	0.02	0.0	1.3	19.9	78.8
	D5-2B	--	0.02	3.3	15.2	0.1	81.4
	D5-3B	--	0.03	0.0	2.5	16.2	81.3
	D5-1C	--	0.02	0.0	0.0	21.1	78.9
	D5-2C	--	0.02	0.0	0.9	20.0	79.1
	D5-3C	--	0.02	0.0	0.0	21.1	78.9

: Suggests the influence of subsurface air infiltration

4.0 FINDINGS AND CONCLUSIONS

The performance of the field testing program provides insight into the dynamics of landfill gas generation which prevail at the Brookfield Avenue Landfill. The Brookfield Avenue Landfill should be considered an old landfill in that the average age of the waste is in excess of 25 years. The landfill is also of shallow construction given that the unsaturated depth of waste ranges from zero feet at the perimeter to a maximum of approximately 32 feet. The portion of the waste mass which lies below the water table is discounted given that the water table is typically considered as a boundary to the flow or migration of landfill gas.

The field testing program demonstrates that methane is still being actively generated at the site and that the peak generation period since cessation of the landfilling activity has already passed. The testing program also demonstrates that an extended extraction well radius of influence (on the order of 150 feet) can be attained at high landfill gas extraction rates. However, the quality of gas (concentration of methane) decreases over time at the high extraction rates, which indicates the need for lower extraction rates and a smaller radius of influence to maintain a higher quality of gas to sustain a ground flow for the treatment of landfill gas before release to the ambient air.

Based on the test results, in all likelihood, the landfill is in the phase of landfill generation where a slow, gradual decline in generation will prevail. Under the current, uncapped conditions, the landfill is exposed to a ready source of moisture in the form of percolated precipitation and the generated gas has a ready pathway for release through surface venting.

The construction of the proposed landfill capping system will alter the dynamics of the landfill over time. As the landfill capping system is constructed, the cap will reduce the potential for surface venting and promote the opportunity for lateral migration in the surrounding unsaturated soils. The cap will also provide a low permeability barrier minimizing the opportunity for percolation of moisture into the waste mass. Over time, the reduction in percolation will serve to lower the moisture content of the waste mass below existing levels. This reduction in moisture content will result in a reduction in the annual rate of generation and an associated lengthening of the period of generation. The reduction in moisture content will not be immediate following the placement of the capping system and will take a period of time for the waste mass to evolve to post closure conditions.

During the construction of the landfill capping system, the active generation of landfill gas will continue, in a manner similar to present conditions, while the area available for surface venting is diminished. This condition will necessitate that landfill gas management measures, either temporary or permanent, be implemented concurrent with the cap construction.

The varying conditions of landfill gas management which will prevail during cap construction and the post closure period will require that system flexibility be a primary design element. Landfill gas modeling performed by CDM as part of the Remedial Investigation/ Feasibility Study (RI/FS) projected that at a landfill moisture content of 45 percent, landfill gas would be generated at the rate of 762 scfm through calendar year 2004, then diminish to a rate of 350 scfm by calendar year 2015 and ultimately decline to a rate of 50 scfm by calendar year 2020. As a second run using a landfill moisture content of 42 percent, the model projected that landfill gas would be generated at a reduced rate, but over a longer period of time. Under these conditions, the landfill gas generation rate was calculated to be 494 scfm through year 2025, diminish to less than 350 scfm around year 2035 and be nominal by year 2050.

The modeling presented above projects a gas generation rate of 762 scfm over the landfill area of 132 acres. Equally apportioning this flow rate over the landfill area provides a uniform extraction rate of 5.8 scfm per acre.

The field testing which was performed suggests that the waste mass is sufficiently permeable to allow the draw from an extraction well to reach out 150 feet, albeit at extraction rates which are excessive for the rate of landfill gas generated by the affected sphere of influence. Acknowledging that the landfill capping system will serve to reduce the opportunity for surface air infiltration, extraction wells operating at less than the tested extraction rates should provide a larger radius of influence than the prevailing conditions will permit.

It should also be noted that a slurry wall extending into groundwater will be constructed around the entire perimeter of the landfill which will mitigate the lateral off-site migration of landfill gas. The slurry wall together with the geomembrane liner over the landfill will encapsulate the landfill. Therefore, the design of the gas extraction and treatment system for the Brookfield Avenue Landfill will be for the control of surface emissions and odors. As a result, the system gas extraction flow rate will be designed to match the modeled gas generation rate with flexibility to either increase or decrease the extraction rate based on actual field conditions after installation of the landfill cap and gas management system.

Based on an extraction rate of 5.8 cfm per acre, the spacing for active landfill gas extraction wells is approximately 200 feet on center or roughly one extraction well per acre, which is typical for design of a landfill gas extraction system. As such, the number of extraction wells is estimated to be in the range of 130 to 145 wells. The exact number of wells is subject to a finite system layout which is compatible with the final grading plan and the proposed end use plan.

As described above, the average extraction rate from each extraction well is estimated to be 5.8 cfm to match the projected landfill gas generation rate of 762 cfm in 2004. The actual withdrawal rate from each well will be adjusted as part of the startup balancing effort to coordinate the rate of withdrawal from the specific well with the capacity of the sphere of influence for that well to generate landfill gas.

Given that the landfill gas as a compressible fluid will expand as it travels in the collection piping system in the presence of increasing vacuums towards the blower, the required blower capacity measured as inlet cubic feet per minute (icfm) will exceed this flow rate. The actual capacity of the blower system is subject to the layout of the landfill gas collection system and the hydraulic analysis of the system.

Based on the landfill gas methane concentrations measured during the testing program and the existing IRM, the landfill gas management system will consider provisions for imported supplemental fuel to elevate the BTU content of the gas sufficiently to sustain a reliable burn in the proposed ground flares. Typically, the input gas quality to a ground flare must be at least 30 percent methane to allow for the stable and reliable combustion necessary to thermally destroy nonmethane organic compounds (NMOCs) and odorous compounds associated with the landfill gas. The results from this field testing and the operating history of the existing interim remedial measure suggest that this quality of landfill gas will not likely be realized in the future. As an alternate to providing supplemental fuel to continuously operate the flares, intermittent operation of the system will also be considered in development of the final design.

The layout of the proposed landfill gas collection system will provide for a buried collection system to be compatible with the proposed end use. The collection piping will be constructed of butt fused high density polyethylene piping. The piping will have a standard dimensional ratio (SDR) of 17.0 to provide sufficient wall strength. The collection piping will be arranged as a branched system to minimize the head losses associated with the conveyance of the gases. Branch piping will connect to a series of extraction wells and will be backsloped towards one of the branch wells to allow for the natural drainage of condensate to the well and the waste mass. Each wellhead will be housed in a below-grade structure incorporated into the landfill capping system. Each wellhead will be fitted with a throttling valve and sampling ports for measuring pressure, temperature and landfill gas composition.

The proposed landfill gas extraction wells will be constructed of 6-inch diameter slotted PVC Schedule 80 well screen. Screen slots will be 0.080 inches (80 slot) with a coarse well gravel to minimize the potential for clogging of the slots. For vertical extraction wells, the wells will be drilled to a depth of 50 to 75 percent of the waste depth as measured to the boundary of the water table. The borehole will be 24 inches in diameter. Each well will include a cross detail and horizontal slotted pipe to intersect the gas venting layer of the capping system in order to relieve gas from the underside of the geomembrane.

While the above describes construction of a vertical gas extraction well system, based on the end use plan, the evacuation of landfill gas may also be achieved by the construction of horizontal wells beneath the geomembrane lines. The placement of the horizontal wells will be

APPENDIX A

USEPA METHOD 2E

Method 2E—Determination of Landfill Gas; Gas Production Flow Rate

1. Applicability and Principle

1.1 Applicability. This method applies to the measurement of landfill gas (LFG) production flow rate from municipal solid waste (MSW) landfills and is used to calculate the flow rate of nonmethane organic compounds (NMOC) from landfills. This method also applies to calculating a site-specific k value as provided in § 60.754(a)(4). It is unlikely that a site-specific k value obtained through Method 2E testing will lower the annual emission estimate below 50 Mg/yr NMOC unless the Tier 2 emission estimate is only slightly higher than 50 Mg/yr NMOC. Dry, arid regions may show a more significant difference between the default and calculated k values than wet regions.

1.2 Principle. Extraction wells are installed either in a cluster of three or at five locations dispersed throughout the landfill. A blower is used to extract LFG from the landfill. LFG composition, landfill pressures near the extraction well, and volumetric flow rate of LFG extracted from the wells are measured and the landfill gas production flow rate is calculated.

2. Apparatus

2.1 Well Drilling Rig. Capable of boring a 0.6 meters diameter hole into the landfill to a minimum of 75 percent of the landfill depth. The depth of the well shall not exceed the bottom of the landfill or the liquid level.

2.2 Gravel. No fines. Gravel diameter should be appreciably larger than perforations stated in sections 2.10 and 3.2 of this method.

2.3 Bentonite.

2.4 Backfill Material. Clay, soil, and sandy loam have been found to be acceptable.

2.5 Extraction Well Pipe. Polyvinyl chloride (PVC), high density polyethylene (HDPE), fiberglass, stainless steel, or other suitable nonporous material capable of transporting landfill gas with a minimum diameter of 0.075 meters and suitable wall-thickness.

2.6 Wellhead Assembly. Valve capable of adjusting gas flow at the wellhead and outlet, and a flow measuring device, such as an in-line orifice meter or pitot tube. A schematic of the wellhead assembly is shown in figure 1.

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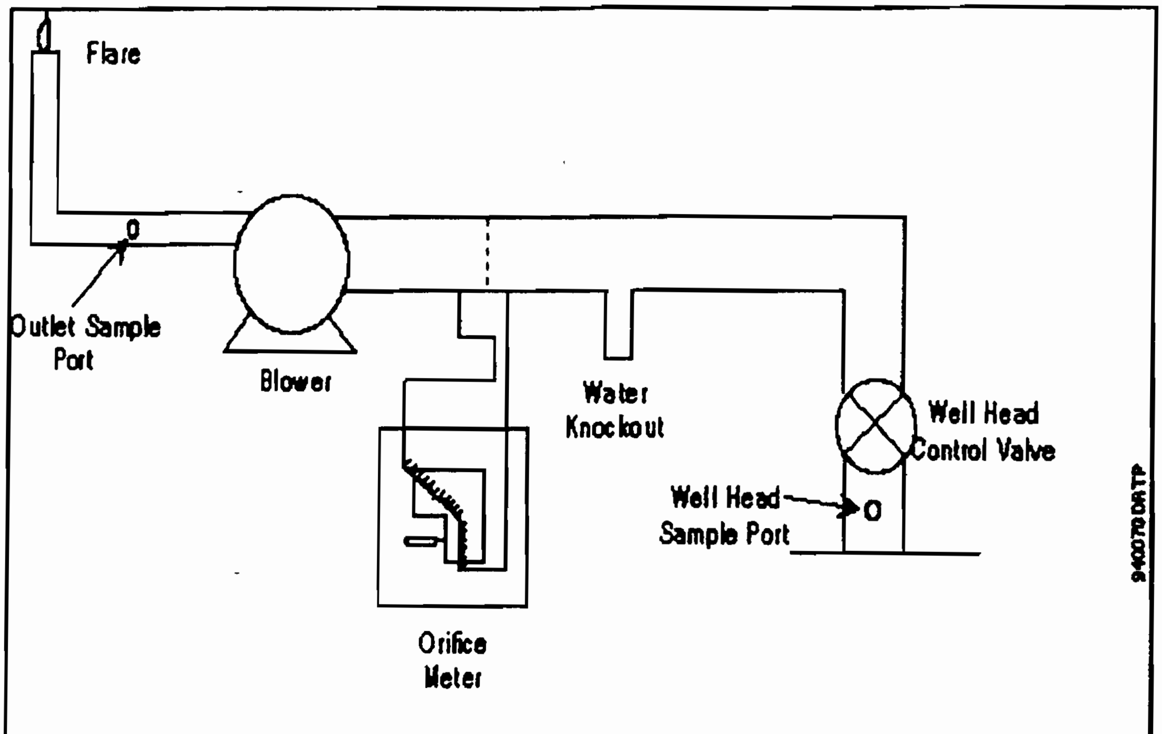

Figure 1. Schematic of above ground well head assembly.

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2.7 Cap. PVC, HDPE, fiberglass, stainless steel, or other suitable nonporous material capable of transporting landfill gas with a suitable wall-thickness.

2.8 Header Piping. PVC, HDPE, fiberglass, stainless steel, or other suitable nonporous material capable of transporting landfill gas with a suitable wall-thickness.

2.9 Auger. Capable of boring a 0.15 to 0.23 meters diameter hole to a depth equal to the top of the perforated section of the extraction well, for pressure probe installation.

2.10 Pressure Probe. PVC or stainless steel (316), 0.025 meters. Schedule 40 pipe. Perforate the bottom two thirds. A minimum requirement for perforations is slots or holes with an open area equivalent to four 6.0 millimeter diameter holes spaced 90° apart every 0.15 meters.

2.11 Blower and Flare Assembly. A water knockout, flare or incinerator, and an explosion-proof blower, capable of extracting LFG at a flow rate of at least 8.5 cubic meters per minute.

2.12 Standard Pitot Tube and Differential Pressure Gauge for Flow Rate Calibration with Standard Pitot. Same as Method 2, sections 2.1 and 2.8.

2.13 Gas flow measuring device. Permanently mounted Type S pitot tube or an orifice meter.

2.14 Barometer. Same as Method 4, section 2.1.5.

2.15 Differential Pressure Gauge. Water-filled U-tube manometer or equivalent, capable of measuring within 0.02 mm Hg, for measuring the pressure of the pressure probes.

3. Procedure

3.1 Placement of Extraction Wells. The landfill owner or operator shall either install a single cluster of three extraction wells in a test area or space five wells over the landfill. The cluster wells are recommended but may be used only if the composition, age of the solid waste, and the landfill depth of the test area can be determined. CAUTION: Since this method is complex, only experienced personnel should conduct the test. Landfill gas contains methane, therefore explosive mixtures may exist at or near the landfill. It is advisable to take appropriate safety precautions when testing landfills, such as installing explosion-proof equipment and refraining from smoking.

3.1.1 Cluster Wells. Consult landfill site records for the age of the solid waste, depth, and composition of various sections of the landfill. Select an area near the perimeter of the landfill with a depth equal to or greater than the average depth of the landfill and with the average age of the solid waste between 2 and 10 years old. Avoid areas known to contain nondecomposable materials, such as concrete and asbestos. Locate wells as shown in figure 2.

Because the age of the solid waste in a test area will not be uniform, calculate a weighted average to determine the average age of the solid waste as follows.

$$A_{avg} = \sum_{i=1}^{n} f_i A_i$$

where,

A_{avg}=average age of the solid waste tested, year

f_i=fraction of the solid waste in the i^{th} section

A_i=age of the i^{th} fraction, year

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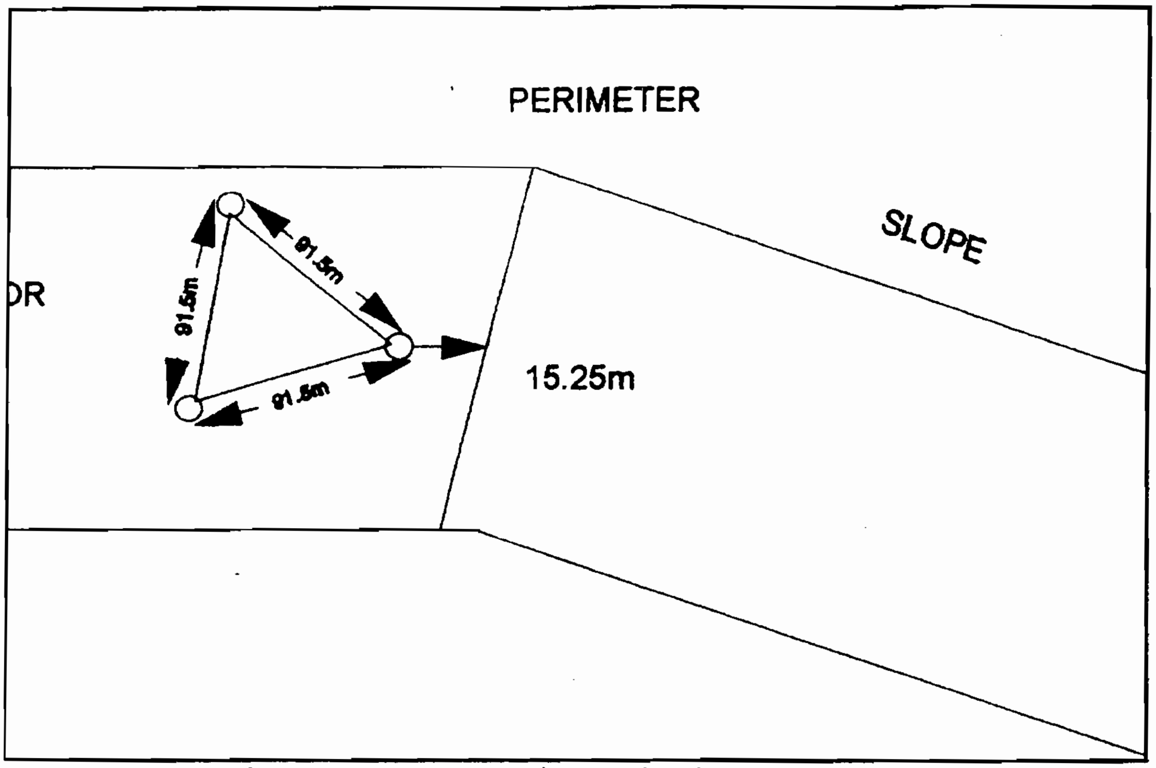

Figure 2. Location of Cluster Wells

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3.1.2 Equal Volume Wells. This procedure is used when the composition, age of solid waste, and landfill depth are not well known. Divide the portion of the landfill that has had waste for at least 2 years into five areas representing equal volumes. Locate an extraction well near the center of each area. Avoid areas known to contain nondecomposable materials, such as concrete and asbestos.

3.2 Installation of Extraction Wells. Use a well drilling rig to dig a 0.6 meters diameter hole in the landfill to a minimum of 75 percent of the landfill depth, not to exceed the bottom of the landfill or the water table. Perforate the bottom two thirds of the extraction well pipe. Perforations shall not be closer than 6 meters from the cover. Perforations shall be holes or slots with an open area equivalent to 1.0 centimeter diameter holes spaced 90 degrees apart every 0.1 to 0.2 meters. Place the extraction well in the center of the hole and backfill with 2.0 to 7.5 centimeters gravel to a level 0.3 meters above the perforated section. Add a layer of backfill material 1.2 meters thick. Add a layer of bentonite 1.0 meter thick, and backfill the remainder of the hole with cover material or material equal in permeability to the existing cover material. The specifications for extraction well installation are shown in figure 3.

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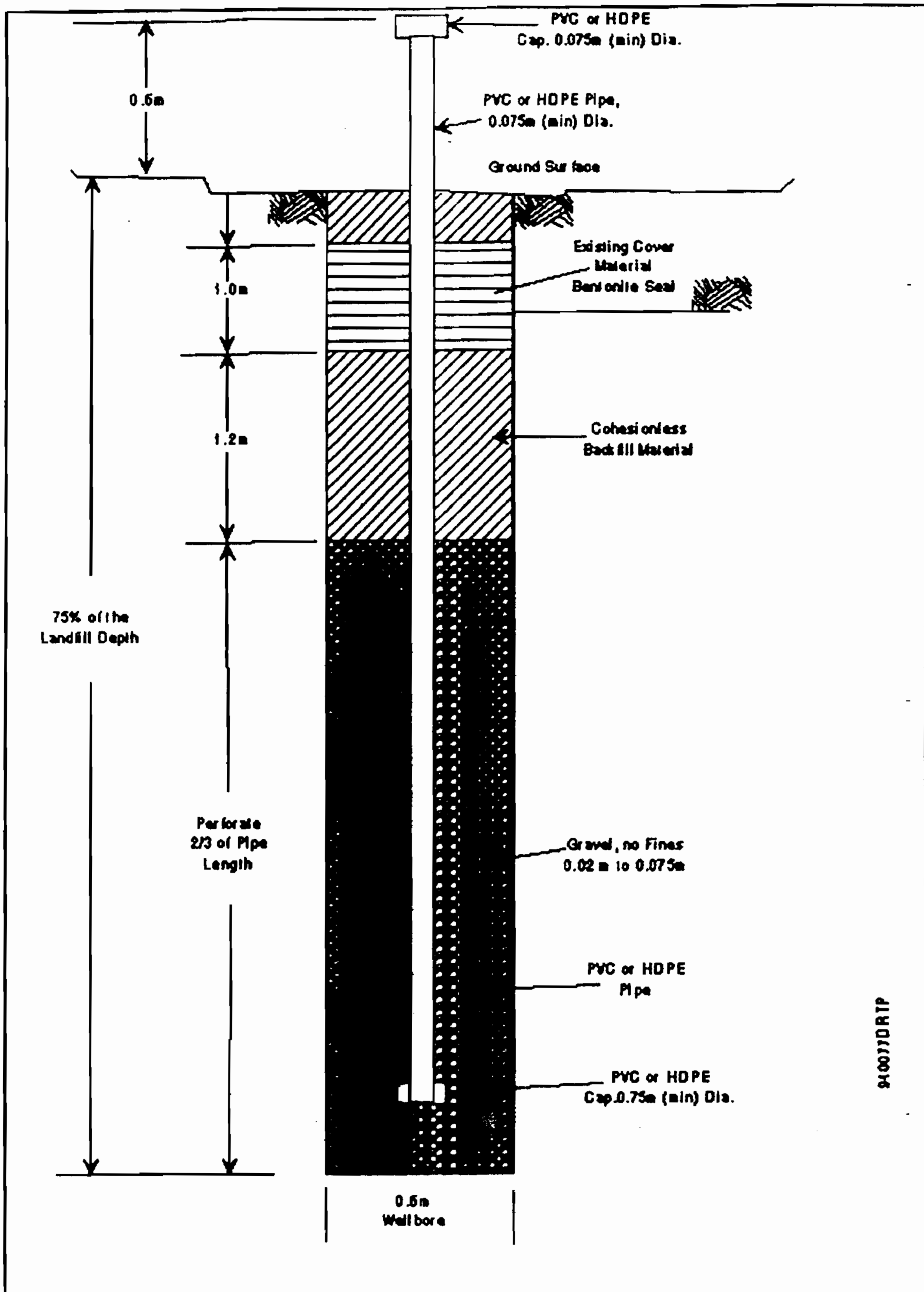

Figure 3. Gas extraction well.

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3.3 Pressure Probes. Shallow pressure probes are used in the check for infiltration of air into the landfill, and deep pressure probes are used to determine the radius of influence. Locate the deep pressure probes along three radial arms approximately 120 degrees apart at distances of 3, 15, 30, and 45 meters from the extraction well. The tester has the option of locating additional pressure probes at distances every 15 meters beyond 45 meters. Example placements of probes are shown in figure 4.

The probes located 15, 30, and 45 meters from each well, and any additional probes located along the three radial arms (deep probes), shall extend to a depth equal to the top of the perforated section of the extraction wells. Locate three shallow probes at a distance of 3 m from the extraction well. Shallow probes shall extend to a depth equal to half the depth of the deep probes.

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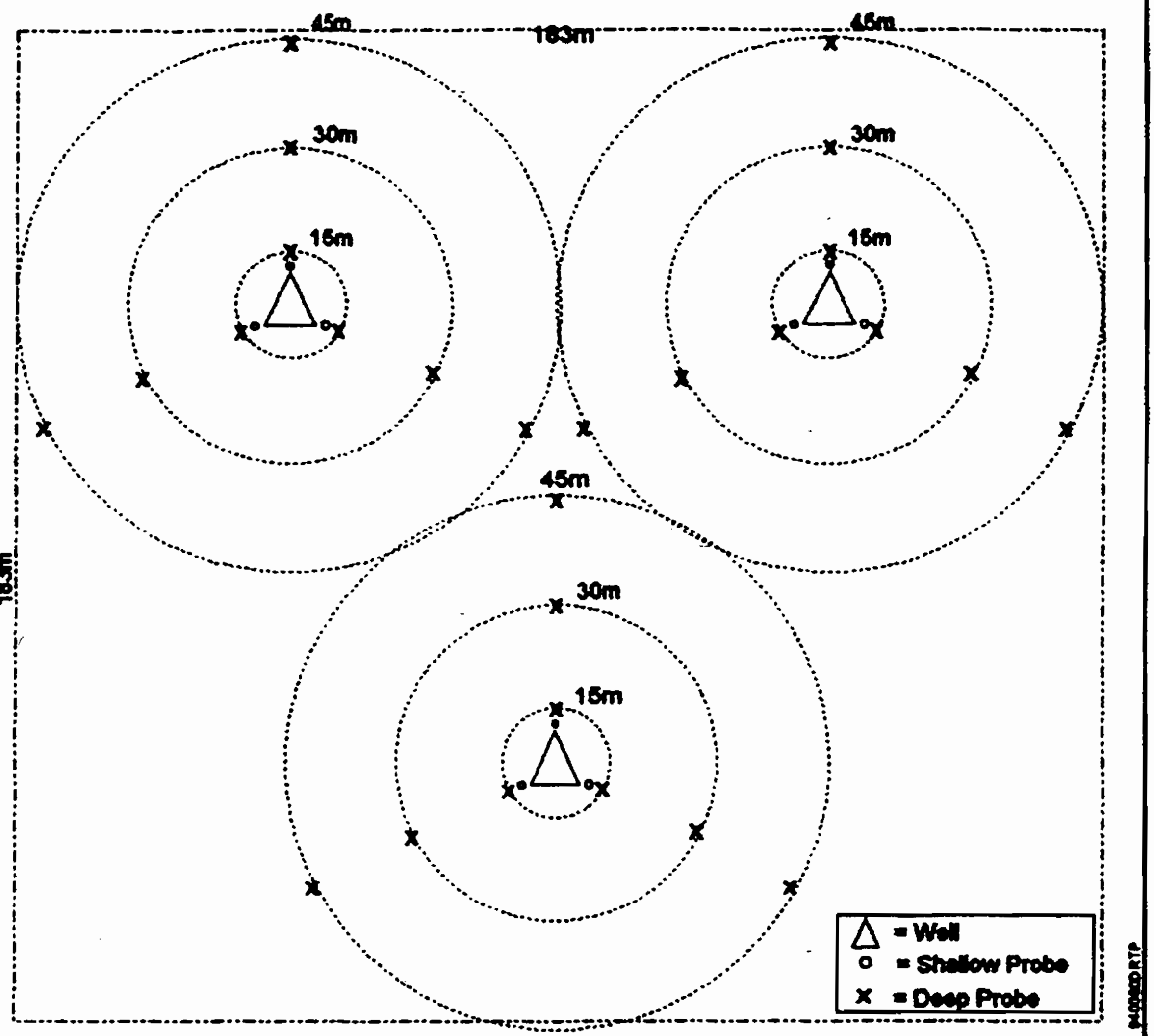

Figure 4. Cluster well configuration.

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Use an auger to dig a hole, approximately 0.15 to 0.23 meters in diameter, for each pressure probe. Perforate the bottom two thirds of the pressure probe. Perforations shall be holes or slots with an open area equivalent to four 6.0 millimeter diameter holes spaced 90 degrees apart every 0.15 meters. Place the pressure probe in the center of the hole and backfill with gravel to a level 0.30 meters above the perforated section. Add a layer of backfill material at least 1.2 meters thick. Add a layer of bentonite at least 0.3 meters thick, and backfill the remainder of the hole with cover material or material equal in permeability to the existing cover material. The specifications for pressure probe installation are shown in figure 5.

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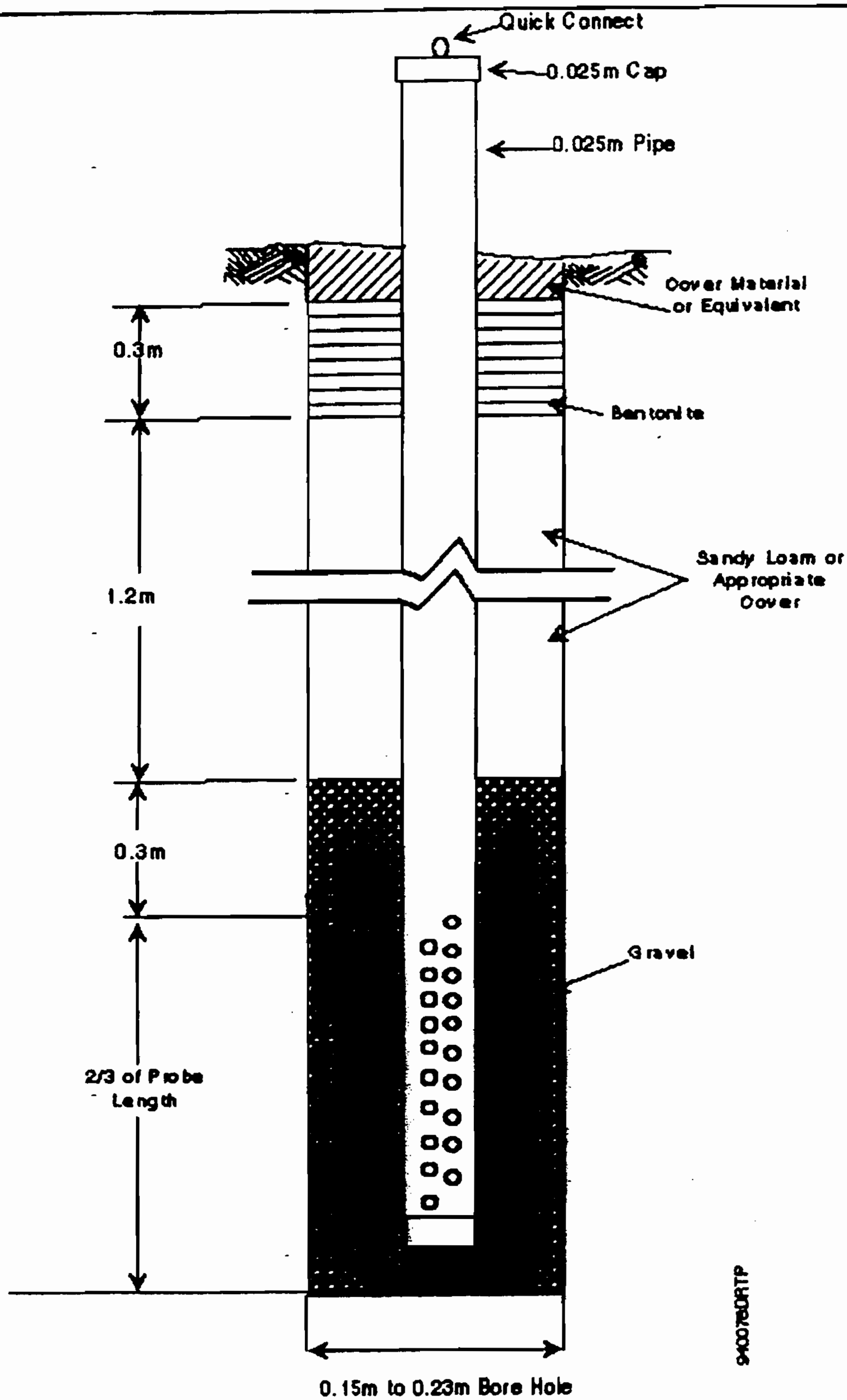

Figure 5. Pressure probe.

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3.4 LFG Flow Rate Measurement. Determine the flow rate of LFG from the test wells continuously during testing with an orifice meter. Alternative methods to measure the LFG flow rate may be used with approval of the Administrator. Locate the orifice meter as shown in figure 1. Attach the wells to the blower and flare assembly. The individual wells may be ducted to a common header so that a single blower and flare assembly and flow meter may be used. Use the procedures in section 4.1 to calibrate the flow meter.

3.5 Leak Check. A leak check of the above ground system is required for accurate flow rate measurements and for safety. Sample LFG at the wellhead sample port and at a point downstream of the flow measuring device. Use Method 3C to determine nitrogen (N_2) concentrations. Determine the difference by using the formula below.

$$\text{Difference}=C_o-C_w$$

where,

C_o=concentration of N_2 at the outlet, ppmv
C_w=concentration of N_2 at the wellhead, ppmv

The system passes the leak check if the difference is less than 10,000 ppmv. If the system fails the leak check, make the appropriate adjustments to the above ground system and repeat the leak check.

3.6 Static Testing. The purpose of the static testing is to determine the initial conditions of the landfill. Close the control valves on the wells so that there is no flow of landfill gas from the well. Measure the gauge pressure (P_g) at each deep pressure probe and the barometric pressure (P_{bar}) every 8 hours for 3 days. Convert the gauge pressure of each deep pressure probe to absolute pressure by using the following equation. Record as P_i.

$$P_i=P_{bar}+P_g$$

where,

P_{bar}=Atmospheric pressure, mm Hg
P_g=Gauge pressure of the deep probes, mm Hg
P_i=Initial absolute pressure of the deep probes during static testing, mm Hg

3.6.1 For each probe, average all of the 8 hr deep pressure probe readings and record as P_{ia}. The P_{ia} is used in section 3.7.6 to determine the maximum radius of influence.

3.6.2 Measure the LFG temperature and the static flow rate of each well once during static testing using a flow measurement device, such as a Type S pitot tube and measure the temperature of the landfill gas. The flow measurements should be made either just before or just after the measurements of the probe pressures and are used in determining the initial flow from the extraction well during the short term testing. The temperature measurement is used in the check for infiltration.

3.7 Short Term Testing. The purpose of short term testing is to determine the maximum vacuum that can be applied to the wells without infiltration of air into the landfill. The short term testing is done on one well at a time. During the short term testing, burn LFG with a flare or incinerator.

3.7.1 Use the blower to extract LFG from a single well at a rate at least twice the static flow rate of the respective well measured in section 3.6.2. If using a single blower and flare assembly and a common header system, close the control valve on the wells not being measured. Allow 24 hours for the system to stabilize at this flow rate.

3.7.2 Check for infiltration of air into the landfill by measuring the temperature of the LFG at the wellhead, the gauge pressures of the shallow pressure probes, and the LFG N_2 concentration by using Method 3C. CAUTION: Increased vacuum at the wellhead may cause infiltration of air into the landfill, which increases the possibility of a landfill fire. Infiltration of air into the landfill may occur if any of the following conditions are met: the LFG N_2 concentration is more than 20 percent, any of the shallow probes have a negative gauge pressure, or the temperature has increased above 55°C or the maximum established temperature during static testing. If infiltration has not occurred, increase the blower vacuum by 4 mm Hg, wait 24 hours, and repeat the infiltration check. If at any time, the temperature change exceeds the limit, stop the test until it is safe to proceed. Continue the above steps of increasing blower vacuum by 4 mm Hg, waiting 24 hours, and checking for infiltration until the concentration of N_2 exceeds 20 percent or any of the shallow probes have a negative gauge pressure, at which time reduce the vacuum at the wellhead so that the N_2 concentration is less than 20 percent and the gauge pressures of the shallow probes are positive. This is the maximum vacuum at which infiltration does not occur.

3.7.3 At this maximum vacuum, measure P_{bar} every 8 hours for 24 hours and record the LFG flow rate as Q_s and the probe gauge pressures for all of the probes as P_f. Convert the gauge pressures of the deep probes to absolute pressures for each 8-hour reading at Q_s as follows:

$$P=P_{bar}+P_f$$

where,

P_{bar}=Atmospheric pressure, mm Hg
P_f=Final absolute pressure of the deep probes during short term testing, mm Hg
P=Pressure of the deep probes, mm Hg

3.7.4 For each probe, average the 8-hr deep pressure probe readings and record as P_{fa}.

3.7.5 For each probe, compare the initial average pressure (P_{ia}) from section 3.6.1 to the final average pressure (P_{fa}). Determine the furthermost point from the wellhead along each radial arm where $P_{fa} \leq P_{ia}$. This distance is the maximum radius of influence (ROI), which is the distance from the well affected by the vacuum. Average these values to determine the average maximum radius of influence (R_{ma}).

The average R_{ma} may also be determined by plotting on semi-log paper the pressure differentials (P_{fa}-P_{ia}) on the y-axis (abscissa) versus the distances (3, 15, 30 and 45 meters) from the wellhead on the x-axis (ordinate). Use a linear regression analysis to determine the distance when the pressure differential is zero. Additional pressure probes may be used to obtain more points on the semi-long plot of pressure differentials versus distances.

3.7.6 Calculate the depth (D_{st}) affected by the extraction well during the short term test as follows. If the computed value of D_{st} exceeds the depth of the landfill, set D_{st} equal to the landfill depth.

$$D_{st}=WD + R_{ma}^2$$

where,

D_{st}=depth, m
WD=well depth, m
R_{ma}=maximum radius of influence, m

3.7.7 Calculate the void volume for the extraction well (V) as follows.

$$V=0.40\ \pi\ R_{ma}^2\ D_{st}$$

where,

V=void volume of test well, m^3
R_{ma}=maximum radius of influence, m
D_{st}=depth, m

3.7.8 Repeat the procedures in section 3.7 for each well.

3.8 Calculate the total void volume of the test wells (V_v) by summing the void volumes (V) of each well.

3.9 Long Term Testing. The purpose of long term testing is to determine the methane generation rate constant, k. Use the blower to extract LFG from the wells. If a single blower and flare assembly and common header system are used, open all control valves and set the blower vacuum equal to the highest stabilized blower vacuum demonstrated by any individual well in section 3.7. Every 8 hours, sample the LFG from the wellhead sample port, measure the gauge pressures of the shallow pressure probes, the blower vacuum, the LFG flow rate, and use the criteria for infiltration in section 3.7.2 and Method 3C to check for infiltration. If infiltration is detected, do not reduce the blower vacuum, but reduce the LFG flow rate from the well by adjusting the control valve on the wellhead. Adjust each affected well individually. Continue until the equivalent of two total void volumes (V_v) have been extracted, or until V_t=2 V_v.

3.9.1 Calculate V_t, the total volume of LFG extracted from the wells, as follows.

$$V_t=\sum_{i=1}^{n} 60\, Q_i\, t_{vi}$$

where,

V_t=total volume of LFG extracted from wells, m^3
Q_i=LFG flow rate measured at orifice meter at the i^{th} interval, cubic meters per minute
t_{vi}=time of the i^{th} interval, hour (usually 8)

3.9.2 Record the final stabilized flow rate as Q_f. If, during the long term testing, the flow rate does not stabilize, calculate Q_f by averaging the last 10 recorded flow rates.

3.9.3 For each deep probe, convert each gauge pressure to absolute pressure as in section 3.7.4. Average these values and record as P_{sa}. For each probe, compare P_{ia} to P_{sa}. Determine the furthermost point from the wellhead along each radial arm where $P_{sa} \leq P_{ia}$. This distance is the stabilized radius of influence. Average these values to determine the average stabilized radius of influence (R_{sa}).

3.10 Determine the NMOC mass emission rate using the procedures in section 5.

3.11 Deactivation of pressure probe holes. Upon completion of measurements, if pressure probes are removed, restore the integrity of the landfill cover by backfilling and sealing to prevent venting of LFG to the atmosphere or air infiltration.

4. Calibrations

Gas Flow Measuring Device Calibration Procedure. Locate a standard pitot tube in line with a gas flow measuring device. Use the procedures in Method 2D, section 4, to calibrate the orifice meter. Method 3C may be used to determine the dry molecular weight. It may be necessary to calibrate more than one gas flow measuring device to bracket the landfill gas flow rates. Construct a calibration curve by plotting the pressure drops across the gas flow measuring device for each flow rate versus the average dry gas volumetric flow rate in cubic meters per minute of the gas. Use this calibration curve to determine the volumetric flow from the wells during testing.

5. Calculations

5.1 Nomenclature.

A_{avg}=average age of the solid waste tested, year

A_i=age of solid waste in the ith fraction, year

A=age of landfill, year

A_r=acceptance rate, megagrams per year

C_{NMOC}=NMOC concentration, ppmv as hexane (C_{NMOC}=C_t/6)

C_t=NMOC concentration, ppmv (carbon equivalent) from Method 25C

D = depth affected by the test wells, m

D_{st}=depth affected by the test wells in the short term test, m

D_{LF}=landfill depth, m

f = fraction of decomposable solid waste in the landfill

f_i=fraction of the solid waste in the i^{th} section

k=methane generation rate constant, $year^{-1}$

L_o=methane generation potential, cubic meters per megagram

L_o=revised methane generation potential to. account for the amount of nondecomposable material in the landfill, cubic meters per megagram

M_i=mass of solid waste of the i^{th} section, megagrams

M_r=mass of decomposable solid waste affected by the test well, megagrams

M_w=number of wells

P_{bar}=atmospheric pressure, mm Hg

P_g=gauge pressure of the deep pressure probes, mm Hg

P_i=initial absolute pressure of the deep pressure probes during static testing, mm Hg

P_{ia}=average initial absolute pressure of the deep pressure probes during static testing, mm Hg

P_f=final absolute pressure of the deep pressure probes during short term testing, mm Hg

P_{fa}=average final absolute pressure of the deep pressure probes during short term testing, mm Hg

P_s=final absolute pressure of the deep pressure probes during long term testing, mm Hg

P_{sa}=average final absolute pressure of the deep pressure probes during long term testing, mm Hg

[illegible] flow rate, cubic meters per

Q_f=final stabilized flow rate, cubic meters per minute

Q_i=LFG flow rate measured at orifice meter during the i^{th} interval, cubic meters per minute

Q_s=maximum LFG flow rate at each well determined by short term test, cubic meters per minute

Q_t=NMOC mass emission rate, cubic meters per minute

R_m=maximum radius of influence, m

R_{ma}=average maximum radius of influence, m

R_s=stabilized radius of influence for an individual well, m

R_{sa}=average stabilized radius of influence, m

t_i=age of section i, year

t_t=total time of long term testing, year

V=void volume of test well, m^3

V_r=volume of solid waste affected by the test well, m^3

V_t=total volume of solid waste affected by the long term testing, m^3

V_v=total void volume affected by test wells, m^3

WD=well depth, m

ρ=solid waste density, m^3 (Assume 0.64 megagrams per cubic meter if data are unavailable)

5.2 Use the following equation to calculate the depth affected by the test well. If using cluster wells, use the average depth of the wells for WD. If the value of D is greater than the depth of the landfill, set D equal to the landfill depth.

$D=WD+R_{sa}$

5.3 Use the following equation to calculate the volume of solid waste affected by the test well.

$V_r=R_{sa}^2 \pi D$

5.4 Use the following equation to calculate the mass affected by the test well.

$M_r=V_r\rho$

5.5 Modify L_o to account for the nondecomposable solid waste in the landfill.

$L_o'=f L_o$

5.6 In the following equation, solve for k by iteration. A suggested procedure is to select a value for k, calculate the left side of the equation, and if not equal to zero, select another value for k. Continue this process until the left hand side of the equation equals zero, #0.001.

$$ke^{-k}A_{avg} - \left(5.256\times10^5\right)\frac{Q_f}{2\ L_o'\ M_r} = 0$$

5.7 Use the following equation to determine landfill NMOC mass emission rate if the yearly acceptance rate of solid waste has been consistent (±10 percent) over the life of the landfill.

$Q_t = 2\ L_o'\ A_r\ (1 - e^{-k} A)\ C_{NMOC}\ /\ (5.256 \times 10^{11})$

5.8 Use the following equation to determine landfill NMOC mass emission rate if the acceptance rate has not been consistent over the life of the landfill.

$$Q_t = \frac{2\ kL_o'\ C_{NMOC}}{\left(5.256\times10^{11}\right)}\sum^{n} M_i e^{-kt_i}$$

6. Bibliography

1. Same as Method 2, appendix A, 40 CFR part 60.

2. Emcon Associates, Methane Generation and Recovery from Landfills. Ann Arbor Science, 1982.

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4. Mandeville and Associates, Procedure Manual for Landfill Gases Emission Testing.

5. Letter and attachments from Briggum, S., Waste Management of North America, to Thorneloe, S., EPA. Response to July 28, 1988 request for additional information. August 18,1988.

6. Letter and attachments from Briggum, S., Waste Management of North America, to Wyatt, S., EPA. Response to December 7, 1988 request for additional information. January 16, 1989.

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PLATE 1

LANDFILL GAS PRESSURE PROBE LOCATIONS