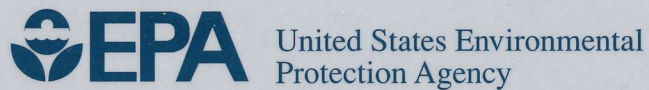
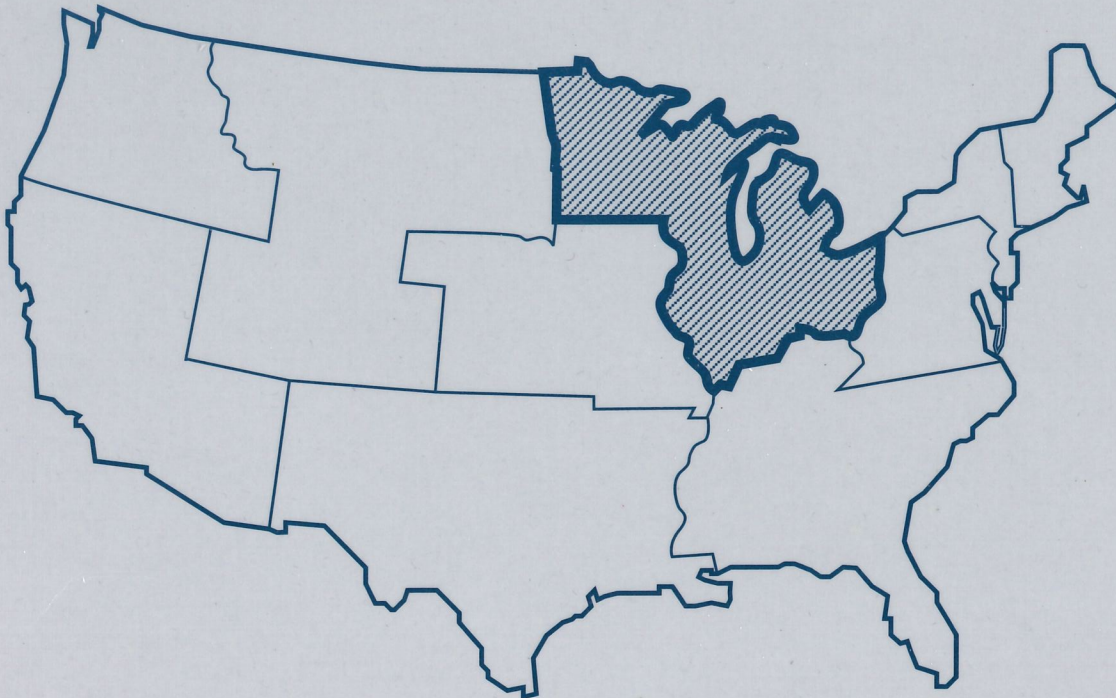


ARCS V

Remedial Activities at Uncontrolled Hazardous Waste Sites in Region V



814
632 013 360 RR CORR
IN SITU BIOREMEDIATION FINAL REPORT
ONALASKA MUNICIPAL LANDFILL
Town of Onalaska, Wisconsin
Remedial Action
WA 79-5HL5/Contract No. 68-W8-0040
July 30, 1997





CH2MHILL



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Suite 1600
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August 1, 1997

104194.CV.DE

Mr. Lawrence Lester
Wisconsin Department of Natural Resources
101 S. Webster Street
P.O. Box 7921
Madison, WI 53707-7921

FID
632 013 360
RR CORR

Dear Mr. Lester:

Subject: Remedial Action
In Situ Bioremediation Final Report
Onalaska Municipal Landfill
WA 79-5HL5, Contract No. 68-W8-0040

Enclosed is one copy of the Onalaska Municipal Landfill In Situ Bioremediation Final Report.

Please call if you have any questions.

Sincerely,

CH2M HILL

Jim Fisher / JFC

Jim Fisher, P.E.
Site Manager

MKE\10017377.DOC

Enclosure

- c: Stephan Nathan, PO/U.S. EPA (w/o enclosure)
- Peggy Hendrixson, CO/ U.S. EPA (w/o enclosure)
- Alpheus Sloan III, PM/MKE (w/o enclosure)
- Ike Johnson, APM-OPNS/MKE (w/o enclosure)
- John Fleissner, QAM/MKE (w/o enclosure)
- Cherie Wilson, AA,/MKE (w/o enclosure)
- Carrie West/MKE (w/o enclosure)



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RR CORR

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Subject: Remedial Action
In Situ Bioremediation Final Report
Onalaska Municipal Landfill
WA 79-5HL5, Contract No. 68-V

Enclosed is one copy of the Onalaska Municipal Landfill Remedial Action Report.

Please call if you have any questions.

Sincerely,

CH2M HILL

Jim Fisher / JFC
Jim Fisher, P.E.
Site Manager

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John Fleissner, QAM/MKE (w/c
Cherie Wilson, AA,/MKE (w/o
Carrie West/MKE (w/o enclosure)

**TO: GEORGE
MICKELSON
TRR/3**

**From: L. LESTER
SCR**

FID
632 013 360 RR CORR
IN SITU BIOREMEDIATION FINAL REPORT

ONALASKA MUNICIPAL LANDFILL

Town of Onalaska, Wisconsin

Remedial Action

WA 79-5HL5/Contract No. 68-W8-0040

July 30, 1997

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Introduction

Purpose of the Report

The Onalaska Municipal Landfill in situ bioremediation system initiated operation in late May 1994. This report summarizes system operations, data collection, and data interpretation.

Background

The Onalaska Municipal Landfill site is located in the Onalaska Township, a rural area near La Crosse, Wisconsin. It consists of a former municipal landfill about 8 acres in area and an adjacent property where the groundwater contamination plume has migrated. The site was operated from the 1960s to 1970s as a sand and gravel quarry. Industrial wastes, including naphtha-based solvents, were disposed of at the site.

Investigations conducted at the site in 1989 found that the groundwater is contaminated primarily with volatile organic compounds (VOCs), and that groundwater contaminants migrated toward the Black River. The investigations also determined that a 3- to 5-foot layer of soil in the vadose zone immediately above the water table and downgradient from the landfill is contaminated with petroleum hydrocarbon solvents. Much of the hydrocarbon contamination appears to be related to the naphtha disposed of at the site. The hydrocarbons migrated out of the disposal area and smeared through the vadose zone soil with fluctuations in groundwater elevation. The zone of nonaqueous phase liquid (NAPL) contamination extends over an area estimated to be more than 4 acres within and immediately southwest of the landfill. The 2 to 2.5 acres of contamination that extend beyond the landfill are targeted for in situ bioremediation. The depth to the NAPL contamination is about 8 to 12 feet in this area. It was not considered technically feasible to address the contamination within the landfill through in situ methods because of the potential for aerobic subsurface conditions to cause landfill smoldering. Figure 1-1 presents the estimated extent of the NAPL contamination.

As described in the feasibility study for cleanup of the site, the in situ bioremediation system was to consist of the injection of air into the NAPL contamination to stimulate the naturally occurring aerobic microbes to affect a higher rate of contaminant biodegradation. This technology is typically referred to as bioventing.

Prevalence and Source Tracing of PFAS in Shallow Groundwater Used for Drinking Water in Wisconsin, USA

Matthew Silver,* William Phelps, Kevin Masarik, Kyle Burke, Chen Zhang, Alex Schwartz, Miaoyan Wang, Amy L. Nitka, Jordan Schutz, Tom Trainor, John W. Washington, and Bruce D. Rheineck*



Cite This: <https://doi.org/10.1021/acs.est.3c02826>



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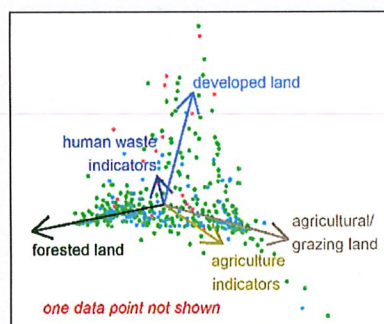
Metrics & More

Article Recommendations

Supporting Information

ABSTRACT: Samples from 450 homes with shallow private wells throughout the state of Wisconsin (USA) were collected and analyzed for 44 individual per- and polyfluoroalkyl substances (PFAS), general water quality parameters, and indicators of human waste as well as agricultural influence. At least one PFAS was detected in 71% of the study samples, and 22 of the 44 PFAS analytes were detected in one or more samples. Levels of PFOA and/or PFOS exceeded the proposed Maximum Contaminant Levels of 4 ng/L, put forward by the U.S. Environmental Protection Agency (EPA) in March 2023, in 17 of the 450 samples, with two additional samples containing PFHxS \geq 9 ng/L (the EPA-proposed hazard index reference value). Those samples above the referenced PFAS levels tend to be associated with developed land and human waste indicators (artificial sweeteners and pharmaceuticals), which can be released to groundwater via septic systems. For a few samples with levels of PFOA, PFOS, and/or PFHxS > 40 ng/L, application of wastes to agricultural land is a possible source. Overall, the study suggests that human waste sources, septic systems in particular, are important sources of perfluoroalkyl acids, especially ones with \leq 8 perfluorinated carbons, in shallow groundwater.

KEYWORDS: PFAS occurrence, emerging contaminants, human waste sources, septic system effluent, waste land application, agricultural sources, source water protection



450 samples from shallow private wells

- PFOA \geq 4 ng/L, PFOS \geq 4 ng/L and/or PFHxS \geq 9 ng/L
- PFAS detected
- no PFAS detected

1. INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) are a large group of synthetic chemicals used in consumer, firefighting, and industrial products since the 1950s that pose a threat to drinking water supplies. In the past decade, environmental occurrence studies have found that PFAS occur ubiquitously in many environmental media, including treated wastewater,^{1,2} surface water,^{3,4} soil,^{5,6} and precipitation.^{7–9} In previous site- or region-specific investigations, PFAS have been found in groundwater, with concentrations varying over several orders of magnitude.¹⁰ Groundwater is the source of about 39% of the water supplied by public water systems in the United States as well as the source of water for private wells, which are used by about 15% of the population.¹¹ Based on results from the U.S. Environmental Protection Agency's (EPA) Third Unregulated Contaminant Monitoring Rule (UCMR3) sampling of municipal water systems conducted in 2013–2015, it was estimated that drinking water supplies exceed the 2016 EPA Health Advisory Level of 70 ng/L PFOA + PFOS for ~6 million U.S. residents.¹² Incorporation of more recent data indicates that PFOA + PFOS in U.S. drinking water may exceed 1 ng/L for more than 200 million people in the United States.¹³ In a recent survey of

select groundwater aquifers used as a source of drinking water in the eastern United States, one or more PFAS were detected in 47% of 254 samples.¹⁴ In March 2023, the EPA proposed¹⁵ maximum contaminant levels (MCLs) of 4 ng/L for PFOA and 4 ng/L for PFOS, as well as a hazard index MCL goal that includes four additional PFAS.

Considering the importance of groundwater to drinking water supplies, more remains to be learned about the prevalence of PFAS, where they are found, and contributions from different sources. There are numerous potential types of sources of PFAS in groundwater. The source type that has received perhaps the most attention is aqueous film-forming foams (AFFFs), which are designed to be used on flammable liquid fires. AFFF discharges in training exercises and fire response are known to be

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SECTION 2

Remedial Action Goals

The in situ treatment system is designed to enhance the degradation of organic contaminants in the vadose zone immediately downgradient from the landfill. This area is known as the zone of NAPL contamination. No treatment standards or health-based cleanup criteria have been established for NAPL-contaminated soil at this site. However, the Record of Decision (ROD) defines a cleanup goal of 80 to 95 percent reduction of the organic contaminant mass in the soils. The organic contaminant mass in this case is the petroleum-based and petroleum-related constituents in the soil. Because the NAPL contamination could act as a source of benzene, toluene, ethylbenzene, and xylene (BTEX) contaminants in groundwater, a secondary goal of the treatment system is to reduce the BTEX contaminant loading to the groundwater. No specific time has been established for accomplishment of the remedial action goals, although the ROD specifies that in situ bioremediation be performed for at least two 200-day treatment seasons.

Treatment System Description

The objective of the treatment system is to inject air into the zone of NAPL contamination at a rate that maintains aerobic conditions within the soil. However, the air injection is kept to a minimum to limit the potential for aeration of waste within the landfill, drying of the soil, and volatilization of organic contaminants.

The treatment system consists of 29 vertical air injection wells (AW-01 through AW-29) connected by a header piping network supplied with air from a single aeration well blower. The 2-inch-diameter air injection wells are spaced on 40- to 50-foot centers throughout the NAPL zone and installed with the screened interval spanning the 3- to 5-foot-thick NAPL layer. Each well is connected to the header piping by a lateral pipe with a valve that is used to modulate the air supply to specific areas in response to the rate of oxygen consumption in each area. The system is designed to provide 100 to 420 standard cubic feet per minute (scfm) of air to maintain aerobic conditions throughout the zone of NAPL contamination. Figure 1-1 shows the layout of the treatment system.

Six soil gas probe nests (GM-01 through GM-06) with two probes per nest are installed between the injection wells (see Figure 1-1). The probes are used to measure soil gas pressure and to withdraw soil gas samples for oxygen, carbon dioxide, methane, and vapor phase hydrocarbon analyses. The probes are constructed of 1-inch-diameter Schedule 40 PVC pipe and have 1 foot of well screen. At each nest, one probe is placed at the top and bottom of the NAPL zone. Both probes are encased in a 6-inch-diameter outer casing for protection.

Summary of Results

Summary of System Startup

The objectives for the bioventing system startup and initial operations were to:

- Evaluate initial soil gas conditions before system startup
- Verify that the design flow and injection pressures are sufficient to aerate the vadose zone soil
- Balance flows between the various air injection wells
- Perform initial oxygen uptake (soil respiration) studies to assess the rate of hydrocarbon degradation

Initial Soil Gas Sampling

Analyses of the soil gas composition (oxygen, carbon dioxide, methane, and organic vapors) provides key information about existing biological activity before system startup. Depleted oxygen concentrations suggest that microbial activity, and hence hydrocarbon biodegradation, may be oxygen limited. Because aerobic activity produces carbon dioxide, higher carbon dioxide concentrations are often observed in areas where there is or has been significant aerobic activity. The presence of methane and carbon dioxide could suggest anaerobic biological activity or the migration of landfill gas from the landfill to the bioventing target area (discussed later). The amount of organic vapors can indicate the amount of hydrocarbons present in the soil.

Sampling Procedure

Each air injection well (AW-1 through AW-29) and each soil gas probe (GM-01 through GM-06) was purged of soil gas with a vacuum pump, and a soil gas sample was analyzed for oxygen, carbon dioxide, methane, and organic vapors. Soil gases were measured with a GasTech Infra-Red Gas Analyzer.

Results of Startup Data

Based on an interpretation of the initial soil gas analysis results from May 24, 1994 (Table 4-1), it appeared that the bioventing target area could be divided into three subareas (Figure 4-1). Area A is the target zone north and east of the clarifier. It is characterized by low, but not depleted, oxygen concentrations. Oxygen concentrations in this area ranged from 9 to 19.1 percent. Carbon dioxide concentrations were elevated, but were less than 7 percent. Methane was not detected above 1 percent. Based on this data and the site investigation data, these soils appear affected by hydrocarbons, but appear generally less contaminated than other soil. There appears to be ongoing microbial activity, and the activity may not be limited by the availability of oxygen in the soil gas.

Area B is the area south of the treatment building and north of AW-26 (Figure 4-1). Oxygen was significantly depleted in this area, with many oxygen measurements less than 2 percent. The carbon dioxide concentrations ranged up to 17.5 percent. Microbial activity in this area appeared to be limited by the low levels of oxygen. Methane ranged up to 29 percent (see AW-22). However, almost all other methane concentrations were less than 5 percent, suggesting that the 29 percent concentration is an anomaly, possibly caused by the localized migration of landfill gas around AW-22. Based on previous data collected during the site investigation, Area B appears to be the most contaminated area within the bioventing target zone.

Area C is the southeastern portion of the treatment zone, extending from AW-26 to AW-29. Its soil gas parameters and degree of hydrocarbon contamination appear similar to that of Area A. Whereas some oxygen depletion was observed, there appeared to be sufficient oxygen to sustain microbial activity.

Summary of Operations Since Startup

The objectives for the bioventing system continuing operations were to:

- Balance flows between the various air injection wells
- Verify that the design flow and injection pressures are sufficient to aerate the vadose zone soil
- Continue to evaluate soil gas conditions during system operation
- Perform oxygen uptake (soil respiration) studies to assess the rate of hydrocarbon degradation

Air Injection Flow Rates

During the system operation, the flow rates into each air injection well was measured to determine the total flow rate of the system. The resulting flow rates for each well for those dates are shown in Table 4-2. Varying flow rates were observed between each well as the valves were opened or closed to modify the effectiveness of the system. Based on initial soil gas pressure readings and ongoing soil gas composition analyses, it appeared that Area A required less flow to maintain sufficient oxygen levels. Thus overall flows were reduced in Area A and increased in Areas B and C by turning off AW-1, 2, 3, 6, 7, 9, and 10 initially. Total system flow has been maintained between 270 to 320 scfm. Given the soil pore volume in the bioventing target area, this correlates to 1.3 pore volume exchanges per day. As discussed below, this flow easily maintained aerobic conditions in almost the entire target area.

Air Injection Well Influence

The air injection wells were placed about 40 to 50 feet apart. Based on estimates of the soil air permeability, it was predicted during the design that this spacing would result in the entire target zone being aerated. The movement of air flow through the target zone is assessed through two methods. The first of these methods is performed by measuring the pressure in the soil gas probes. As the air is injected into the soil, a resulting pressure field is

set up around each air injection well. The radial extent of the pressure field indicates the distance to which the injected air is reaching. Soil gas pressures were measured at each soil gas probe with a Dwyer Magnehelic Gauge. Whereas a single pressure measurement cannot be used to assess gas flow direction and velocity, it can confirm that the location of sampling is generally within the influence of an air injection well. The results of pressure readings in the soil gas probes are shown in Table 4-3.

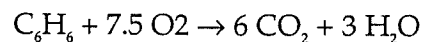
Average pressures during the operation of the system ranged from 0.09 to 0.69 inches of water, which is about 10 percent of the pressure in the air injection wells. The propagation of pressure through the vadose zone soil suggests little resistance to air flow and high air permeability. The deeper soil gas probes tend to have higher pressures than the shallow soil gas probes, suggesting that the air flow is moving as intended through the lower portion of the vadose zone (e.g., smear zone), and not short circuiting to the ground surface.

The second method of assessing soil gas movement is through changes in soil gas composition during bioventing. As air is injected into the target zone, the composition of the soil gas eventually approaches atmospheric conditions (i.e., 21 percent oxygen and 0.1 percent carbon dioxide). Table 4-4 shows changes in soil gas composition at each of the monitoring probes since the start of bioventing.

Bioventing has resulted in oxygen concentrations steadily increasing each year (Table 4-4). Carbon dioxide concentrations have decreased from 10 percent to less than 1 percent for most monitoring points in 1996 and 1997. Average methane concentrations decreased from 1.4 percent in May to 0.1 percent. This suggests that no further landfill gas is migrating into the treatment zone and that soil gas conditions are aerobic.

Soil Respiration Study

The overall objective of aerating the target zone soil is to increase the rate of hydrocarbon biodegradation. An assessment of the hydrocarbon biodegradation rate can be made from the stoichiometry of hexane mineralization (hexane is a common petroleum hydrocarbon). If hexane is completely biodegraded, it is mineralized to carbon dioxide and water as shown in the following equation:



When this stoichiometric relationship is converted to a mass relationship, each pound of hydrocarbon (hexane) that is biodegraded requires 3.5 pounds of oxygen. The objective of the soil respiration study is to assess the rate of oxygen uptake and correlate that rate to an equivalent amount of hydrocarbon biodegradation.

During the operation of the system, nine 48- to 72-hour oxygen uptake studies were undertaken in which the air injection system was shut down and the rate of oxygen uptake was measured in the shallow and deep piezometers at GM-01, GM-02, GM-03, GM-04, GM-05, and GM-06. Uptake studies were also performed at AW-17 and AW-19. The resulting oxygen decreases are shown in Table 4-5.

In Area A, the average uptake of oxygen decreased from 2.78 percent per day in November 1994 to 0.3 percent per day in February 1997. The percentage of carbon dioxide and methane in soil gas also decreased throughout the studies and was measured at 0 and 0.1 percent,

respectively, during the last oxygen uptake study. Carbon dioxide percentage in soil gas was measured at 4.9 to 9.2 percent and methane at 0.1 to 0.3 percent during initial system startup in this area (Figure 4-3).

In Area B, an average oxygen uptake from 3.40 percent per day in November 1994 to 0.3 percent per day in February 1997 was observed during the uptake studies. The percentage of carbon dioxide and methane in soil gas also decreased throughout the studies and was measured at 0 and 0.2 percent, respectively, during the last oxygen uptake study. Carbon dioxide percentage in soil gas was measured at 0.7 to 17.9 percent and methane at 0.1 to 13.4 percent during initial system startup in this area (Figure 4-4).

In Area C, the average oxygen uptake was from 1.9 percent per day in November 1994 to 0.10 percent per day in February 1997. The percentage of carbon dioxide and methane in soil gas also decreased throughout the studies and was measured at 0 and 0.2 percent, respectively, during the last oxygen uptake study. Carbon dioxide percentage in soil gas was measured at 2.3 percent and methane at 0 percent during initial system startup in this area (Figure 4-5).

Based upon the 3-year average uptake concentrations of oxygen in the soil gas during the operation of the bioventing system, the average concentration of hydrocarbons degraded was calculated. The average hydrocarbon degradation rate was approximately 1 mg/kg/day for Areas A and B. In Area C, the average hydrocarbon degradation rate was calculated to be about 0.50 mg/kg/day (Table 4-5).

The total mass of hydrocarbons removed from each area was calculated to be 7,780 kg in Area A, 11,000 kg in Area B, and 1,247 kg in Area C.

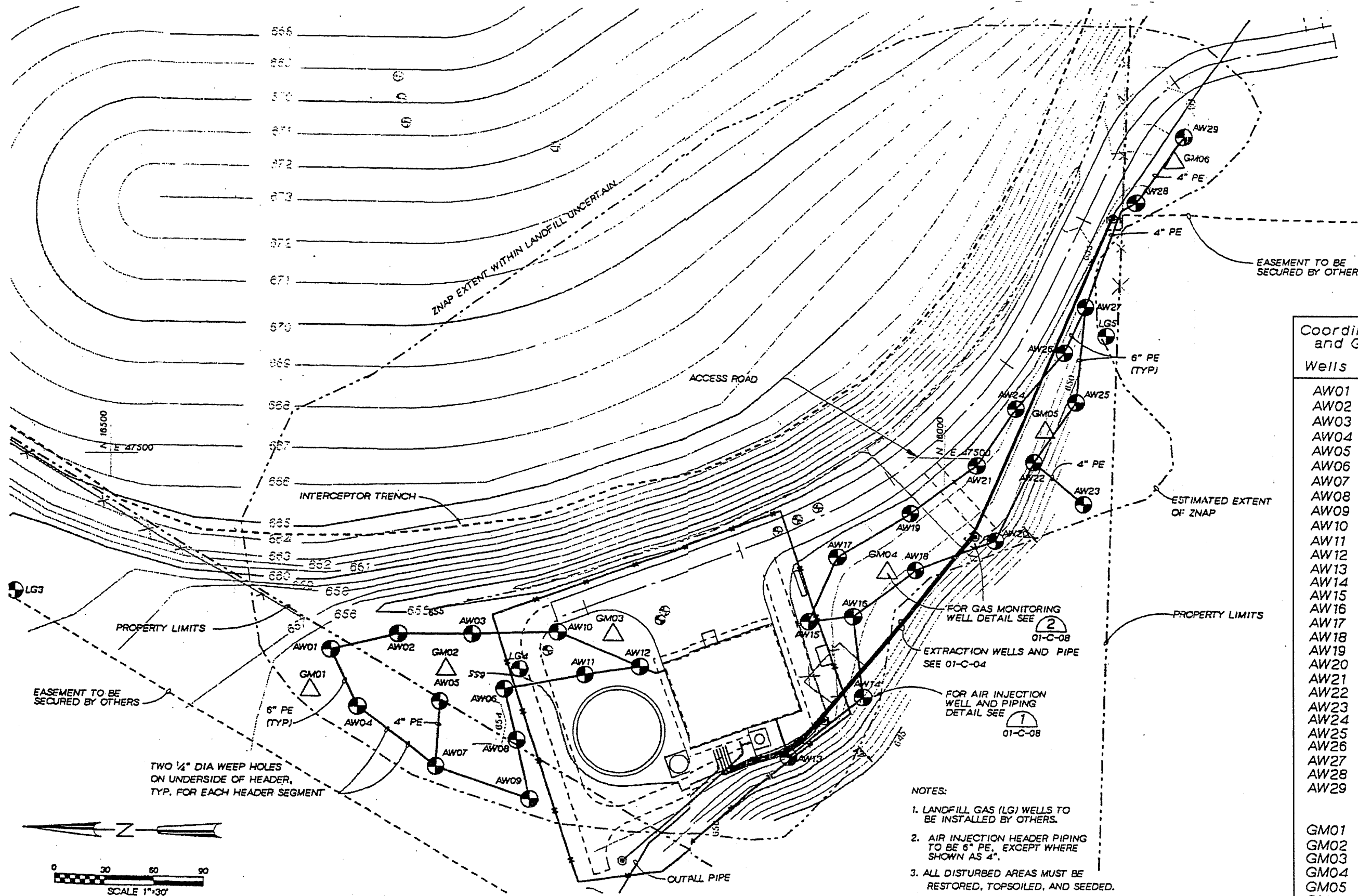
Conclusions

The following conclusions were drawn from the evaluation of oxygen uptake studies:

- Oxygen uptake has decreased to a point where active aeration is no longer required to maintain aerobic conditions in subsurface soils
- This is confirmed by very low levels of methane and carbon dioxide
- As significant amounts of hydrocarbons contamination have been reduced at the site, biological degradation of hydrocarbons has slowed at the site but will continue as indicated by the oxygen uptake studies
- Degradation of hydrocarbons at the site has slowed to a rate where natural diffusion of atmospheric gases into soils at the site should maintain near atmospheric soil gas conditions

Recommendations

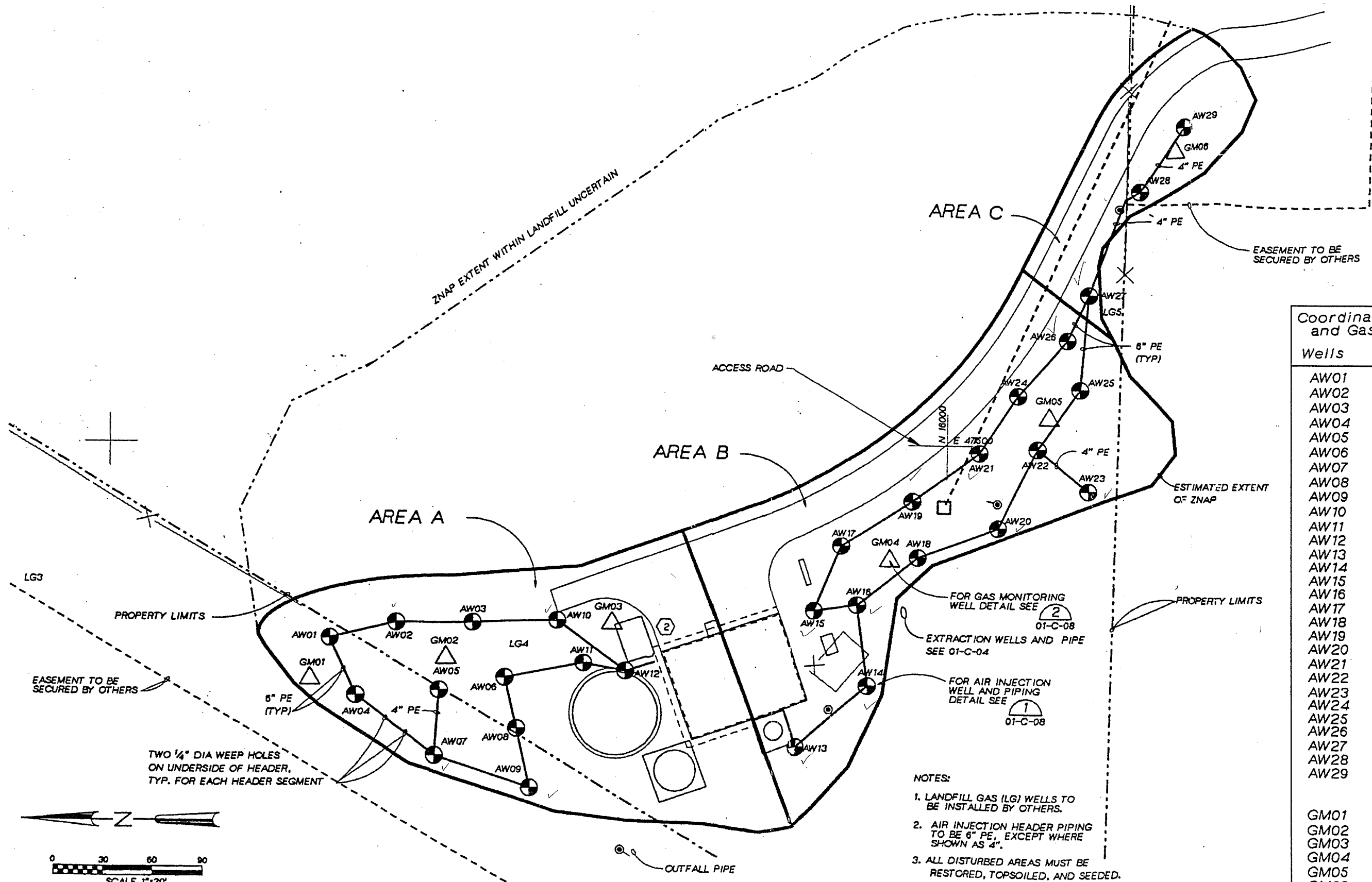
Based on the observations and evaluation of data gathered during the operation of the Onalaska Municipal Landfill bioremediation system, it is recommended that the air injection system remain inactive. An oxygen uptake study should be performed to confirm that soil gas remains near atmospheric conditions and that the degradation of organic contamination continues.



Coordinates for Air Injection and Gas Monitoring Wells		
Wells	Northing	Easting
AW01	16367	47380
AW02	16327	47390
AW03	16282	47390
AW04	16351	47346
AW05	16302	47349
AW06	16263	47357
AW07	16305	47310
AW08	16256	47326
AW09	16248	47290
AW10	16232	47391
AW11	16216	47366
AW12	16183	47371
AW13	16089	47316
AW14	16046	47353
AW15	16078	47398
AW16	16052	47402
AW17	16062	47437
AW18	16016	47431
AW19	16020	47465
AW20	15969	47449
AW21	15980	47495
AW22	15946	47498
AW23	15915	47472
AW24	15957	47530
AW25	15920	47535
AW26	15928	47565
AW27	15915	47593
AW28	15886	47657
AW29	15859	47696
GM01	16379	47357
GM02	16298	47370
GM03	16199	47392
GM04	16033	47431
GM05	15939	47518
GM06	15864	47683

- NOTES:
1. LANDFILL GAS (LG) WELLS TO BE INSTALLED BY OTHERS.
 2. AIR INJECTION HEADER PIPING TO BE 6" PE, EXCEPT WHERE SHOWN AS 4".
 3. ALL DISTURBED AREAS MUST BE RESTORED, TOPSOILED, AND SEEDDED.

FIGURE 1-1
AIR INJECTION HEADER PIPING AND
WELL LOCATION PLAN
ONALASKA



Coordinates for Air Injection and Gas Monitoring Wells		
Wells	Northing	Easting
AW01	16367	47380
AW02	16327	47390
AW03	16282	47390
AW04	16351	47346
AW05	16302	47349
AW06	16263	47357
AW07	16305	47310
AW08	16256	47326
AW09	16248	47290
AW10	16232	47391
AW11	16216	47366
AW12	16191	47361
AW13	16089	47316
AW14	16046	47353
AW15	16078	47398
AW16	16052	47402
AW17	16062	47437
AW18	16016	47431
AW19	16020	47465
AW20	15969	47449
AW21	15980	47495
AW22	15946	47498
AW23	15915	47472
AW24	15957	47530
AW25	15920	47535
AW26	15928	47565
AW27	15915	47593
AW28	15886	47657
AW29	15859	47696
GM01	16379	47357
GM02	16298	47370
GM03	16199	47392
GM04	16033	47431
GM05	15939	47518
GM06	15864	47683

- NOTES:
1. LANDFILL GAS (LG) WELLS TO BE INSTALLED BY OTHERS.
 2. AIR INJECTION HEADER PIPING TO BE 8" PE, EXCEPT WHERE SHOWN AS 4".
 3. ALL DISTURBED AREAS MUST BE RESTORED, TOPSOILED, AND SEED.

FIGURE 4-1
BIOVENTING TARGET SUB-AREAS
ONALASKA

Table 4-1
 Summary of Soil Gas Composition, Before Startup
 5/24/94

	O ₂	CO ₂	CH ₄	LEL
Area A				
AW01	16.5	3.5	0.2	4
AW02	9	6.9	0.1	2
AW03	10.3	6.5	0.2	4
AW04	13.9	2.9	0.4	8
AW05	11	4.6	0.1	2
AW06	15.4	5.1	0.2	4
AW07	19.1	0.5	0.3	6
AW08	15.4	4.4	0.1	2
AW09	18	2.6	0.2	4
AW10	19	0.8	0	0
AW11	15	2.4	0.3	6
AW12	16	2.5	0.1	0
GM01S	15.9	4.9	0.3	6
GM01D	16.2	4.9	0.3	6
GM02S	10.6	6.2	0.2	4
GM02D	6.7	6.4	0.2	4
GM03S	8.1	9.2	0.1	2
GM03D	15.2	5.2	0.1	2
Gas Composition Area A				
	13.96	4.42	0.19	3.67
Area B				
AW13	12.2	4.6	0	0
AW14	2.2	7.3	2.2	54
AW15	3.3	4.7	4.9	98
AW16	11.5	5.3	0.9	14
AW17	0.7	9.7	3.5	68
AW18	11	0.2	8.8	1
AW19	10.8	5.7	0.7	6
AW20	4.8	10.2	0.2	1
AW21	1.1	13.1	0.8	12
AW22	2	11.6	29	100
AW23	17.9	2.8	0.1	4
AW24	0.7	11	1.7	12
AW25	7.1	9.3	0	0
AW26	11.3	7.6	0	0
GM04S	0.2	17.6	1.1	22
GM04D	0.6	17.9	13.4	286
GM05S	0.7	0.7	0.3	4
GM05D	0.3	14.8	0.9	18
Gas Composition Area B				
	5.47	8.56	3.81	38.89
Area C				
AW27	4.8	9	0.1	2
AW28	17.6	1.9	0	0
AW29	18.8	1.5	0	0
GM06S	17.7	2.3	0	0
GM06D	17.4	2.3	0	0
Gas Composition Area C				
	15.26	3.40	0.02	0.40
All concentrations shown as percentages				

Table 4-2
Summary of Air Injection Flow Rates

Date	5/24/94	6/2/94	6/16/94	6/29/94	7/11/94	7/20/94	7/26/94	4/19/95	2/5/97
AW01	18.68	NA	NA	NA	NA	NA	NA	NA	NA
AW02	15.39	NA	NA	NA	NA	NA	NA	NA	NA
AW03	12.09	NA	NA	NA	NA	NA	NA	NA	NA
AW04	12.09	18.13	25.50	26.38	17.25	23.52	2.42	22.00	24.18
AW05	19.78	25.28	35.17	35.17	39.56	38.47	36.27	22.00	23.08
AW06	10.44	24.18	NA	NA	NA	NA	NA	NA	NA
AW07	24.18	25.28	NA	NA	NA	NA	NA	NA	NA
AW08	0.09	0.09	0.00	0.07	0.04	0.22	0.07	0.04	0.33
AW09	16.49	20.88	NA	NA	NA	NA	NA	NA	NA
AW10	16.49	NA	NA	NA	NA	NA	NA	NA	NA
AW11	10.99	17.58	27.91	NA	2.20	24.18	27.48	11.00	12.09
AW12	13.19	17.58	24.84	NA	23.08	24.62	25.94	11.00	13.74
AW13	5.50	8.24	13.41	NA	9.12	9.34	11.54	9.90	17.58
AW14	0.22	0.15	0.22	0.07	0.09	0.15	0.55	0.11	0.22
AW15	0.22	0.07	0.22	0.40	3.30	1.21	0.66	0.33	0.44
AW16	1.10	0.09	1.21	0.81	3.96	1.54	0.77	0.66	1.10
AW17	10.99	12.64	15.83	14.84	17.91	17.58	15.83	24.20	12.09
AW18	0.88	1.54	3.74	3.96	1.76	2.86	4.18	3.08	7.03
AW19	13.19	18.02	12.09	10.99	13.85	12.64	12.09	22.00	24.18
AW20	12.09	14.84	15.72	16.49	20.88	20.22	18.68	11.00	12.09
AW21	17.58	18.68	12.09	11.32	14.51	13.19	12.64	26.40	19.78
AW22	2.64	3.30	9.45	9.45	3.85	6.04	7.69	5.72	12.64
AW23	0.00	0.00	0.00	0.07	0.00	0.07	0.07	0.07	0.20
AW24	6.59	7.69	12.75	11.76	10.99	11.54	11.87	12.10	16.49
AW25	9.89	11.54	15.39	14.18	15.39	21.43	14.84	17.60	18.02
AW26	12.09	14.29	18.13	16.05	19.23	18.90	17.58	25.30	24.18
AW27	8.79	12.09	16.70	15.39	14.95	16.49	16.27	11.00	12.09
AW28	9.34	20.88	17.36	14.84	18.02	17.36	16.05	24.64	22.20
AW29	20.33	23.08	10.44	16.49	21.43	19.34	20.00	11.00	10.44
Total Flow	301.32	316.14	288.16	218.68	271.37	300.91	273.45	271.15	284.18

Units in scfm

Table 4-3
Summary of Soil Gas Pressure¹

Probe	5/24/94	5/25/94	6/2/94	6/16/94	6/29/94	7/11/94	7/26/94	2/5/97	Average
GM01S	0.16	0.08	0.07	0.08	0.07	0.08	0.08	0.06	0.09
GM01D	0.16	0.08	0.08	0.08	0.07	0.08	0.07	0.06	0.09
GM02S	0.4	0.29	0.27	0.21	0.24	0.26	0.22	0.14	0.25
GM02D	0.45	0.38	0.37	0.28	0.28	0.36	0.27	0.17	0.32
GM03S	0.2	0.2	0.2	0.2	0.23	0.32	0.22	0.21	0.22
GM03D	0.48	0.44	0.41	0.46	0.49	0.705	0.51	0.25	0.47
GM04S	0.33	0.3	0.28	0.32	0.27	0.45	0.35	0.5	0.35
GM04D	0.58	0.64	0.6	0.66	0.68	0.92	0.74	0.72	0.69
GM05S	0.4	0.46	0.4	0.47	0.45	0.72	0.47	0.42	0.47
GM05D	0.58	0.64	0.6	0.62	0.65	0.94	0.7	0	0.59
GM06S	0.14	0.17	0.16	0.14	0.14	0.195	0.12	0.08	0.14
GM06D	0.15	0.17	0.16	0.15	0.155	0.25	0.13	0.08	0.16

Units in inches of water.

1) Soil gas pressures were measured during active bioventing.

Table 4-4
Summary of Soil Gas Composition During System Operation
Page 1 of 2

	5/18/94				5/24/94				6/2/94				11/2/94				5/18/95			
	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL
GM01S	15.9	4.9	0.3	6	16.1	1.2	0.1	6	16.1	5.2	0.4	6	18.5	0.2	0	NM	20.9	0.1	NM	NM
GM01D	16.2	4.9	0.3	6	15.9	5.6	0.3	4	18.1	4.5	0.2	3	14.7	2.8	0	NM	20.8	0.1	NM	NM
GM02S	10.6	6.2	0.2	4	21.3	1	0	4	21.2	0.5	0.4	6	18.7	0.1	0	NM	20.8	0	NM	NM
GM02D	6.7	6.4	0.2	4	20.9	0.6	0.5	12	20.8	0.5	1.6	40	13.4	1.7	0	NM	20.8	0	NM	NM
GM03S	8.1	9.2	0.1	2	19.2	6.4	0.2	4	19.6	5.2	0.2	3	16.7	1.9	0	NM	16.1	1.8	NM	NM
GM03D	15.2	5.2	0.1	2	21.8	0.1	0.2	4	21	0	0.2	3	17.5	0.3	0	NM	18.7	0.1	NM	NM
GM04S	0.2	17.6	1.1	22	0.5	17.9	1.9	38	2.5	17.4	8.4	172	17.5	1.5	0	NM	18.6	1.6	NM	NM
GM04D	0.6	17.9	13.4	286	1.1	19.1	7.6	170	1.5	17.8	1.9	40	16.7	2.2	0	NM	14.2	2.3	NM	NM
GM05S	0.7	0.7	0.3	4	NM	NM	NM	NM	17.3	7.6	0.3	0.2	17.7	0.04	0	NM	19.1	0.2	NM	NM
GM05D	0.3	14.8	0.9	18	20.9	0.4	0.2	6	21	0.2	0.2	4	17.3	0.1	0	NM	19.8	0	NM	NM
GM06S	17.7	2.3	0	0	21.4	0	0.2	4	21	0	0.2	4	17.8	0.3	0	NM	20.2	0	NM	NM
GM06D	17.4	2.3	0	0	21.4	0	0.2	4	21	0	0.2	4	14.9	2.2	0	NM	19.5	0.1	NM	NM

Comments Initial Startup

NM = Not measured

Table 4-4
 Summary of Soil Gas Composition During System Operation
 Page 2 of 2

	5/18/94				7/21/95				7/24/95				7/1/96				2/5/97			
	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL	O ₂	CO ₂	CH ₄	LEL
GM01S	15.9	4.9	0.3	6	0.9	9.9	0.1	NM	17.5	2.7	0.1	NM	20.4	0	0	NM	20.9	0	0	0
GM01D	16.2	4.9	0.3	6	0	11.6	0	NM	15.1	3.3	0.1	NM	20.4	0	0	NM	20.7	0.1	0	0
GM02S	10.6	6.2	0.2	4	1.1	9	0.1	NM	19.5	0.4	0.1	NM	20.5	0	0	NM	20.7	0	0	0
GM02D	6.7	6.4	0.2	4	0	12.1	0.6	NM	19.6	0.1	0.1	NM	20.5	0	0	NM	20.6	0	0	0
GM03S	8.1	9.2	0.1	2	5	13.2	0.1	NM	13.5	0.8	0.1	NM	20	0.8	0	NM	19.4	1	0	0
GM03D	15.2	5.2	0.1	2	0	10.6	1.1	NM	19.5	0.2	0.2	NM	8.4	0	0	NM	20.3	0.1	0	0
GM04S	0.2	17.6	1.1	22	0	12	0.6	NM	3.5	11.5	0	NM	18.8	1.7	0	NM	20.4	0.7	0	0
GM04D	0.6	17.9	13.4	286	0	12.3	6.6	NM	16.4	0.7	0.1	NM	19.9	0.4	0	NM	21	0	0	0
GM05S	0.7	0.7	0.3	4	0	10.4	0	NM	18.7	3.4	0	NM	20.4	0	0	NM	21.1	0	0	0
GM05D	0.3	14.8	0.9	18	0	9.2	0.9	NM	13.9	0	0	NM	20.2	0.2	0	NM	21.1	0	0	0
GM06S	17.7	2.3	0	0	5.1	9.9	0	NM	19	0.7	0	NM	20.3	0	0	NM	21.2	0	0.1	0
GM06D	17.4	2.3	0	0	1.5	11.5	0	NM	18.5	1	0	NM	20.3	0	0	NM	21.1	0	0.1	0

Comments Initial Startup

NM = Not measured

Table 4-5
Summary of Oxygen Uptake
Percent Change/Day

	Aug 1994	Nov 1994	July 1995	July 1996	Feb 1997	3-Year Average
Area A						
GM01S	1.1	3.00	0.08	0.06	0.13	0.87
GM01D	3.0	2.40	0.58	0.06	0.03	1.21
GM02S	0.7	2.63	0.65	0.18	0.03	0.84
GM02D	2.3	2.87	1.50	0.08	0.00	1.35
GM03S	3.2	3.07	1.03	1.36	0.00	1.73
GM03D	2.3	2.73	1.15	1.20	0.00	1.48
Average Change	2.1	2.78	0.83	0.49	0.03	1.25
Total Hydrocarbon degradation mg/kg/day	1.7	2.2	0.7	0.4	0.0	0.995
Area B						
GM04S	1.3	1.90	0.60	0.30	0.00	0.82
GM04D	0.0	5.07	0.60	1.00	0.03	1.34
GM05S	2.0	2.17	1.10	0.62	0.03	1.18
GM05D	4.7	4.47	0.28	0.14	0.03	1.91
Average Change	2.0	3.40	0.64	0.52	0.03	1.31
Total Hydrocarbon degradation mg/kg/day	1.6	2.7	0.5	0.4	0.0	1.05
Area C						
GM06S	NM	2.00	0.43	0.12	0.10	0.66
GM06D	NM	1.80	0.88	0.08	0.10	0.71
Average Change	0.0	1.90	0.65	0.10	0.10	0.69
Total Hydrocarbon degradation mg/kg/day	0.0	1.5	0.5	0.1	0.1	0.55
Total Average Change In Oxygen Levels	2.0	2.69	0.71	0.37	0.05	1.08
NM = Not measured						

Figure 4-2

Area A Average Percent Oxygen Uptake Change

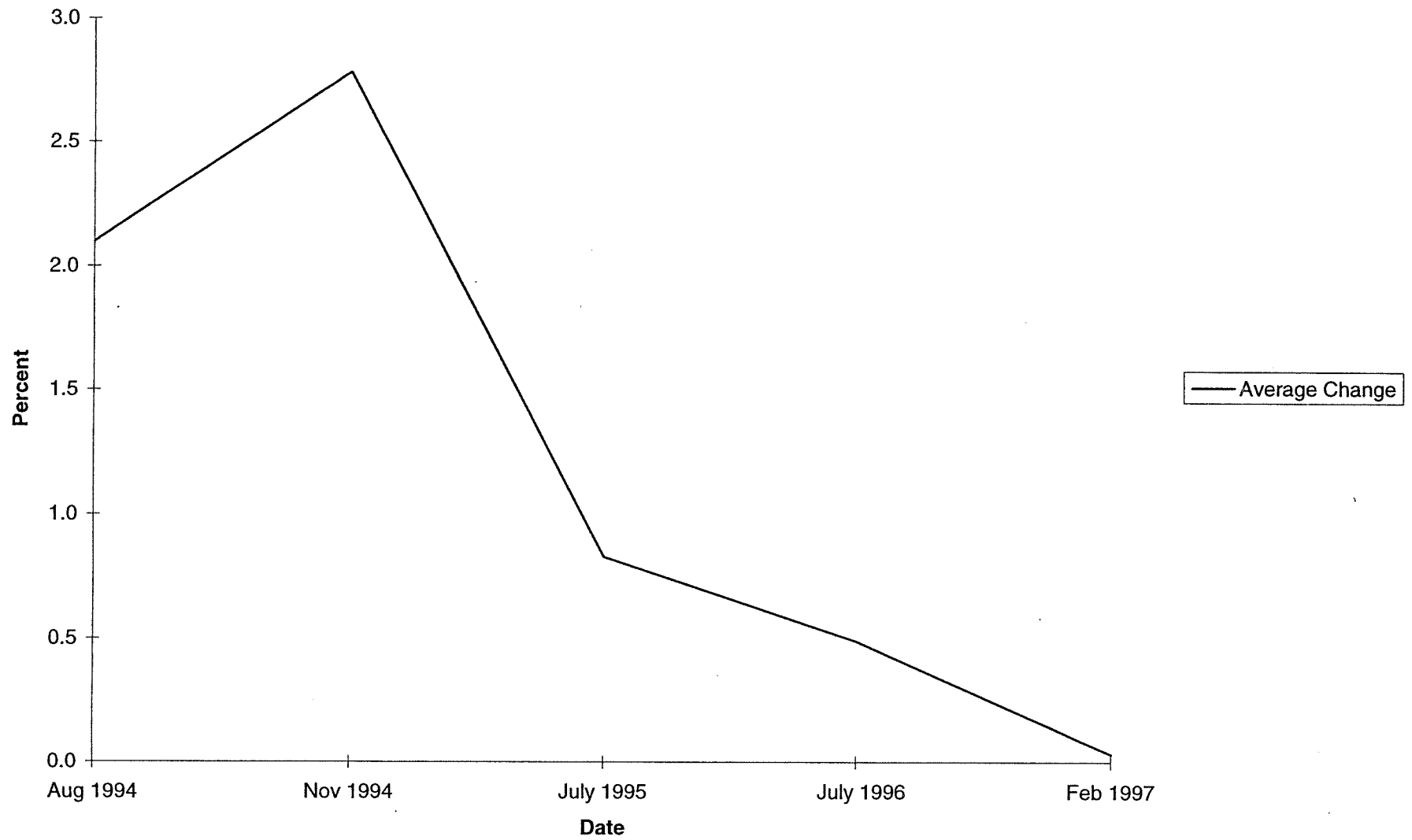


Figure 4-3

Area B Average Percent Oxygen Uptake Change

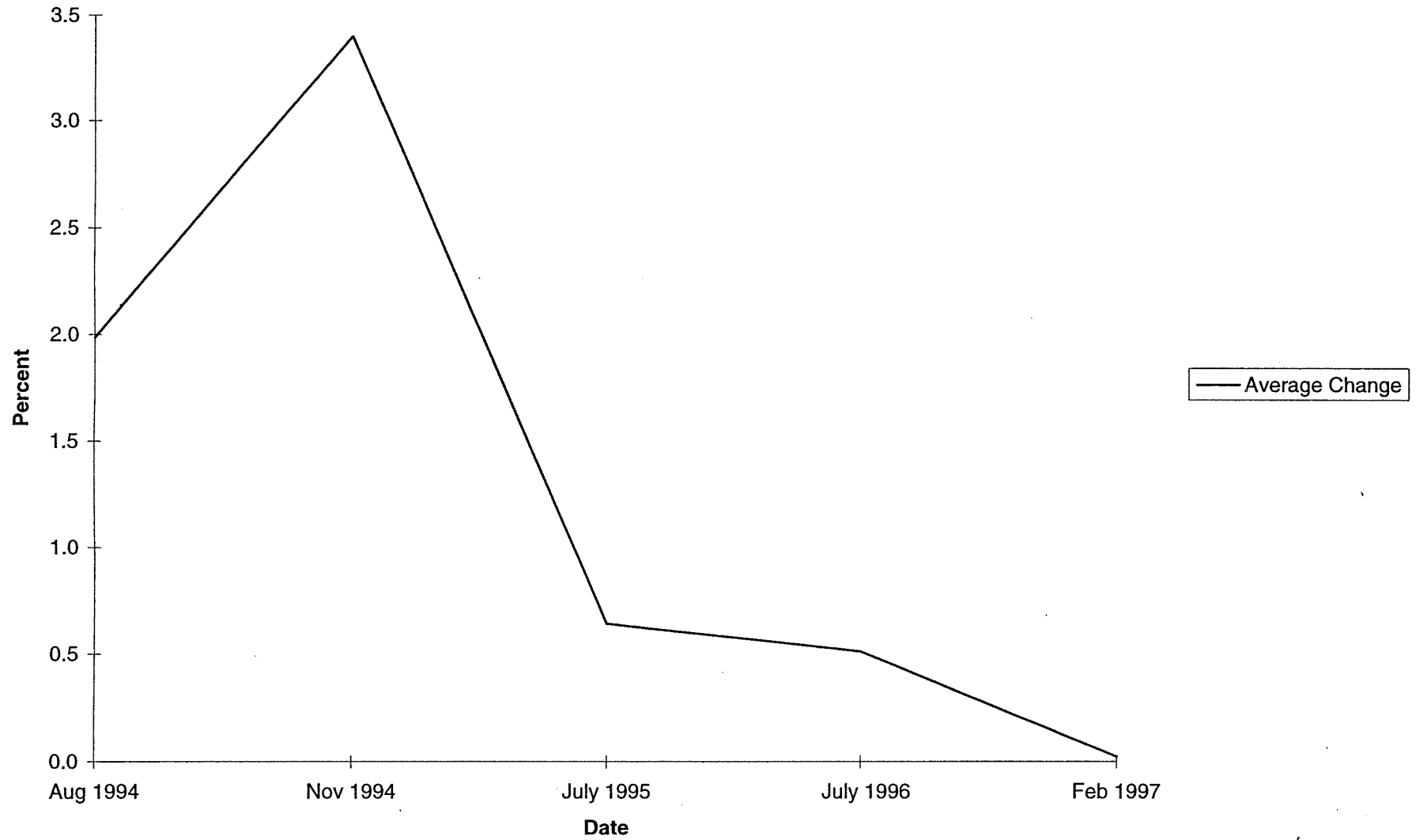


Figure 4-4

Area C Average Percent Oxygen Uptake Change

