DOE/RL-2015-20
Revision 1

Annual Operations and Monitoring Report for UPR-100-N-17: March 2014- February 2015

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Executive Summary

Bioremediation of deep vadose zone petroleum contamination at the UPR-100-N-17 waste site, located within the 100-NR-1 Operable Unit, was initiated in November 2012. The *Interim Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*[1] identified in situ bioremediation as the selected remedy for cleanup of petroleum located below 4.6 m (15 ft) of surrounding grade. Oxygen is supplied to the vadose zone providing a source of energy for aerobic hydrocarbon degrading bacteria to metabolize petroleum contamination. A bioventing system is operating to supply approximately 250 ft^3/min of air to the subsurface via two injection wells, 199-N-167 and 199-N-172. Based on previous studies, the radius of influence for each injection well is approximately 61 m (200 ft). The bioventing system has been in continuous operation with Phase II testing since startup in November 2012 through September 2014, with the exception of periodic short-term shutdowns for maintenance and respirometry test events. The operation and maintenance of the system transitioned from Washington Closure Hanford (WCH) to CH2M HILL Plateau Remediation Company (CHPRC) on October 1, 2014, when the system changed from Phase II testing to routine operation. The bioventing system was shut down from September 30, 2014, through December 3, 2014, while CHPRC completed activities to bring the system current with contractor electrical and mechanical requirements, developed procedures, and implemented training to support full-scale operation of the system.

This annual summary report describes the operation of the bioventing system from March 2014 through February 2015 and includes a summary of performance for the bioremediation remedy. Biodegradation rates calculated from respirometry testing exhibited a declining trend from the initial rates calculated in March 2010 of approximately 0.97 mg/kg-day down to 0.23 mg/kg-day calculated in January 2015. Calculations using the respirometry data indicate that approximately 438 mg/kg of petroleum have been removed from impacted soils during the 2 years of system operation, which is based on data collected from Well 199-N-169.

[1] EPA/ROD/R10-99/112, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Seattle, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r1099112.pdf.

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List of Terms

bgs	below ground surface
CHPRC	CH2M HILL Plateau Remediation Company
EPH	extractable petroleum hydrocarbon
N/A	not applicable
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
ppm	parts per million
ppmv	parts per million by volume
PVC	polyvinyl chloride
TPH	total petroleum hydrocarbon
WCH	Washington Closure Hanford

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1 Introduction

CH2M HILL Plateau Remediation Company (CHPRC) provides operation, maintenance, and monitoring for the UPR-100-N-17 bioventing system at the Hanford Site's 100-N Area. The bioventing system was transitioned on October 1, 2014, from Washington Closure Hanford (WCH) as a Phase II testing operation to the CHPRC for routine operation.

This annual report summarizes the bioventing system operations and monitoring for the period from March 2014 through February 2015. System operations were conducted using WCH-576, *Operations and Maintenance Manual, Phase II Testing – Bioremediation Design for Deep Zone Petroleum Contamination (UPR-100-N-17)* at the 100-N Area. Monitoring activities were conducted in accordance with Appendix H of DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area* ("Phase II Testing/Performance Monitoring Plan for the UPR-100-N-17 Bioremediation"). The *Interim Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-99/112) identifies in situ bioremediation (using supplied oxygen, bacteria, and nutrients) as the selected remedy for cleanup of petroleum located below 4.6 m (15 ft) of surrounding grade. Currently, only oxygen is supplied to the vadose zone, providing a source of energy for aerobic hydrocarbon degrading bacteria to metabolize petroleum contamination. The implementation of the remediation is described in DOE/RL-2005-93.

Monitoring activities included the semiannual groundwater sampling, monthly soil gas measurements, and two in situ respirometry test events.

1.1 Site Location

The UPR-100-N-17 waste site is located within the Hanford Site 100-NR-1 Operable Unit (OU), approximately 192 m (630 ft) northeast of the N Reactor (Figure 1-1). The site is an unplanned release of diesel oil that occurred at the 166-N Tank Farm sometime between August 1965 and September 1966. The diesel fuel release was from a 10 cm (4 in.) pipeline in the tank farm and was located approximately 140 m (460 ft) from the Columbia River. The presence of light, nonaqueous-phase liquid was discovered beneath the facility in March 1967, when evidence of oil was observed at the bank of the Columbia River (100-N-65 waste site), approximately 100 m (328 ft) northwest of the 166-N Tank Farm. Additional releases of both diesel and Bunker C occurred during operations. The location of documented petroleum releases is shown in Figure 1-1.

1.2 Site History

The bioventing system was installed at the UPR-100-N-17 waste site to remediate deep vadose zone petroleum-contaminated soils identified within the 100-NR-1 OU. The Phase II bioventing system was started on November 27, 2012. The system was transitioned to CHPRC on October 1, 2014, for routine operations.

Groundwater at the site is also contaminated and is addressed as part of the 100-NR-2 OU. A detailed history of the waste site is provided in DOE/RL-2005-93.

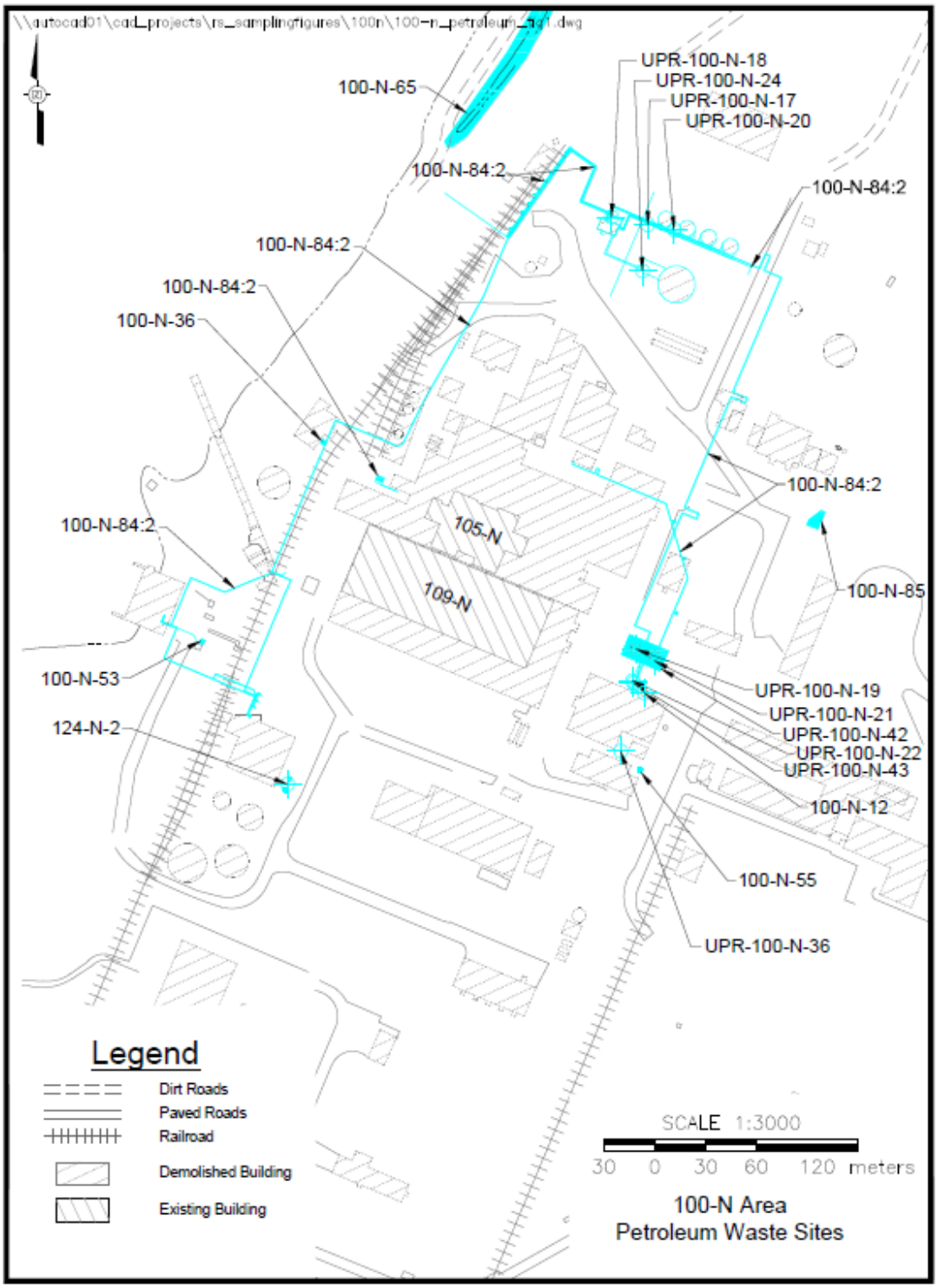


Figure 1-1. Map Showing the Locations of the 100-N Area Petroleum Waste Sites

1.3 Delineation of Impacted Soils

Prior to construction of the Phase II bioventing system, the extent of petroleum-contaminated soil was based on historical information, including that provided in DOE/RL-95-111, *Corrective Measures Study for the 100-NR-1 and 100-NR-2 Operable Units*; the results of sampling during installation of seven pilot test bioventing wells (WCH-370, *Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17)*); and the Phase I bioventing pilot study (WCH-490, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*). Field observations and sampling performed during removal and remediation of the 100-N-84:2 Bunker C and diesel pipelines during 2012 and 2013 provided additional information regarding the extent of petroleum-impacted soil. Figure 1-2 provides a conceptual model for the site. An estimated 58,349 bank cubic meters of petroleum-contaminated soil was removed from petroleum-contaminated waste sites at the 100-N Area excavated to a depth of 4.6 m (15 ft) and disposed of at the Environmental Restoration Facility.

Figure 1-3 shows the extent of excavation and soil removal that was performed by WCH near the UPR-100-N-17 waste site. Backfill of these excavations was initiated in July 2014 and was completed in September 2014, with revegetation completed in December 2014 (Figure 1-4).

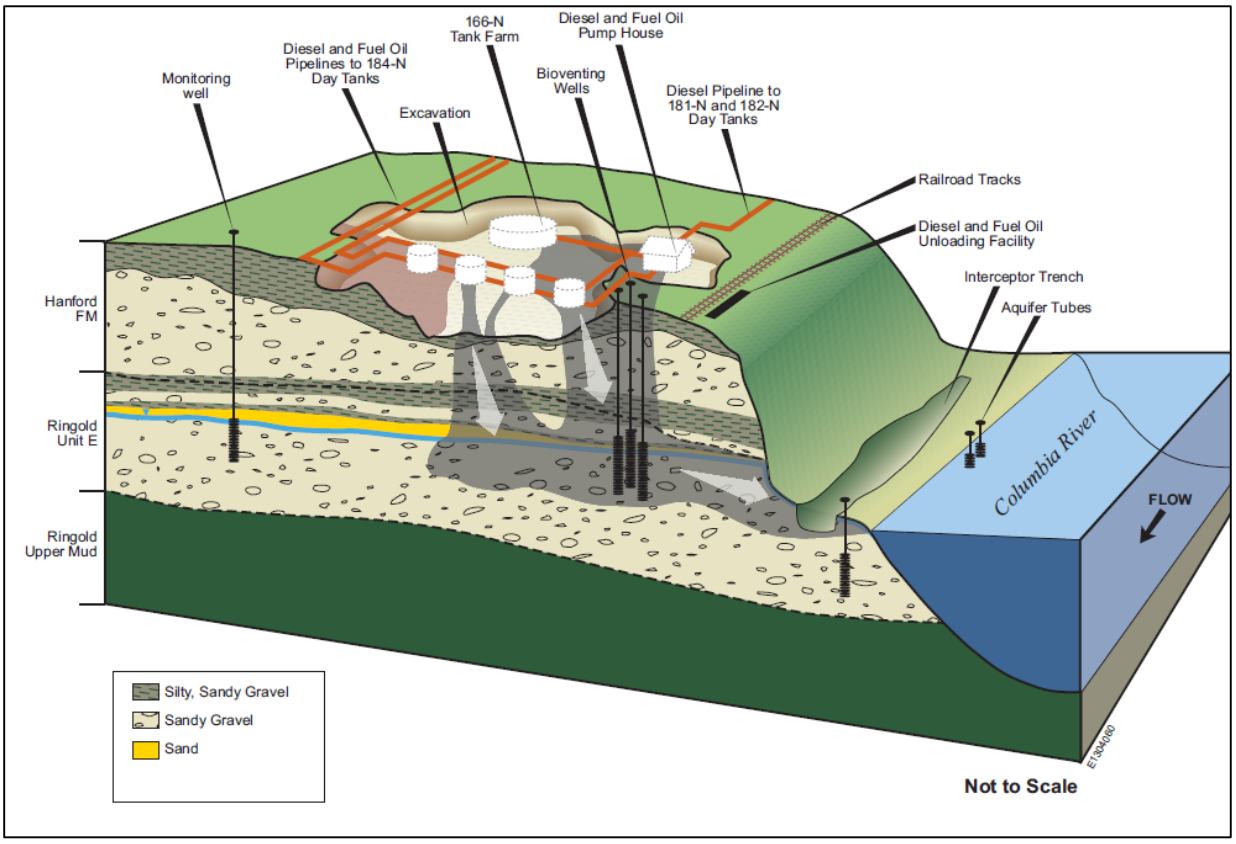


Figure 1-2. Conceptual Model of Petroleum Contamination at the 100-N Area

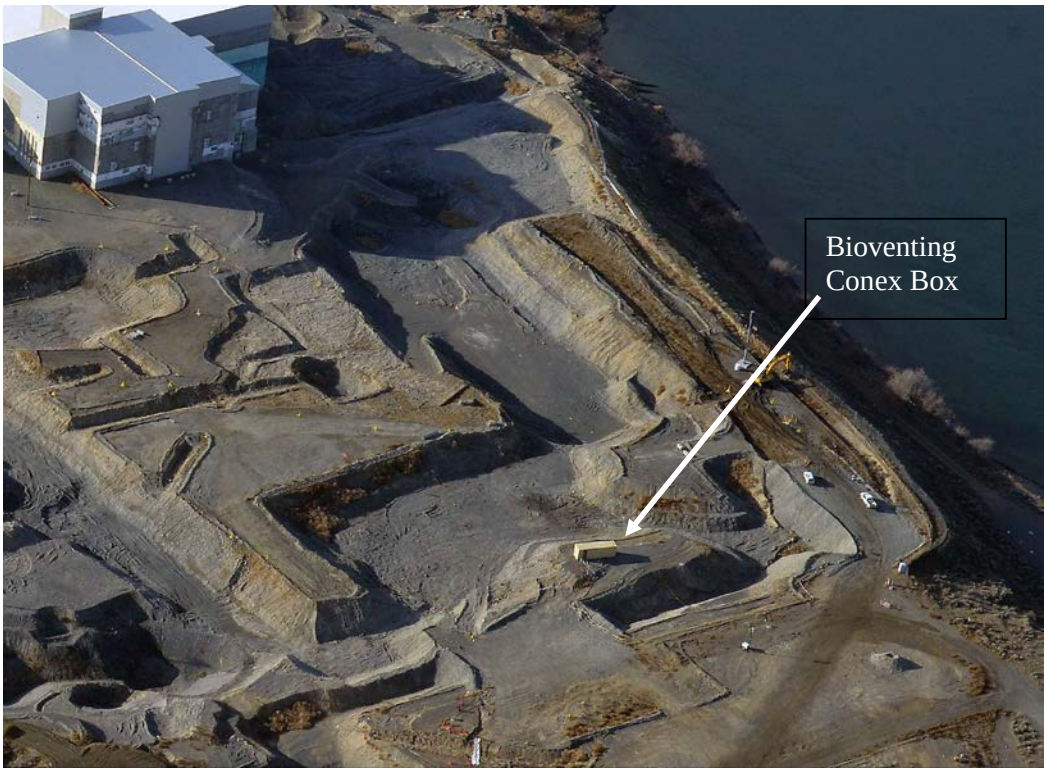


Figure 1-3. Aerial View of the UPR-100-N-17 Bioventing System Location (January 2014)

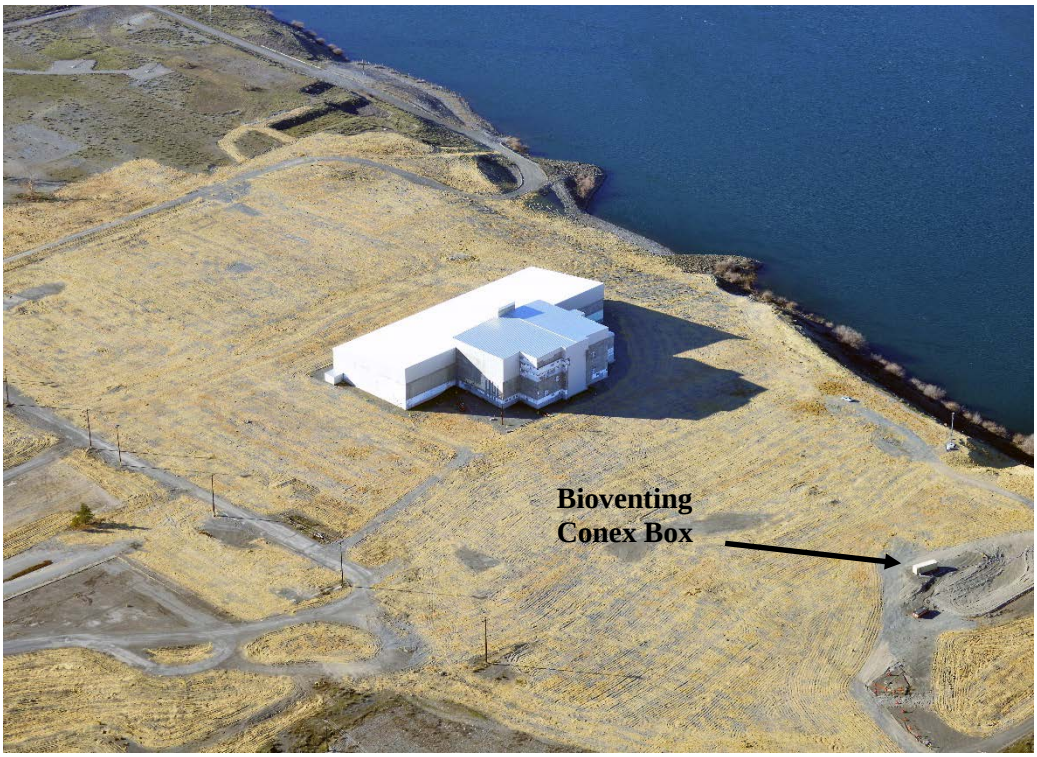


Figure 1-4. Aerial View of the 100-N Area after Backfill and Revegetation (December 2014)

2 Bioventing System Description

The bioremediation system at the UPR-100-N-17 waste site consists of a blower system housed within a conex container that can operate 24 hours per day continuously. The airflow induced by the blower system enhances the biodegradation of the petroleum-contaminated soils. Details on the design criteria and equipment selection are provided in WCH-576.

Three ROTRON[2] model DR808AY72MX blowers supply air to the two injection wells. Each blower is a 7.5 horsepower, 208-230/480 volt alternating-current regenerative blower. Each blower is connected to a header pipeline that connects to a main airline, leading to each of the treatment wells, 199-N-167 and 199-N-172. The injection wells are constructed of four inch Schedule 40 polyvinyl chloride (PVC) and are screened from approximately 16.8 to 22.9 m (55 to 75 ft). Photographs of the bioventing system are provided in Figures 2-1 and 2-2.

Other system components include the following:

- Pressure, vacuum, and temperature gauges
- In-line air filters
- A remote telemetry and alarm messaging system
- A 480-volt control panel

Figure 2-1. Bioventing System Conex Box

[2] ROTRON® is a registered trademark of Ametek, Inc., Kent, Ohio.

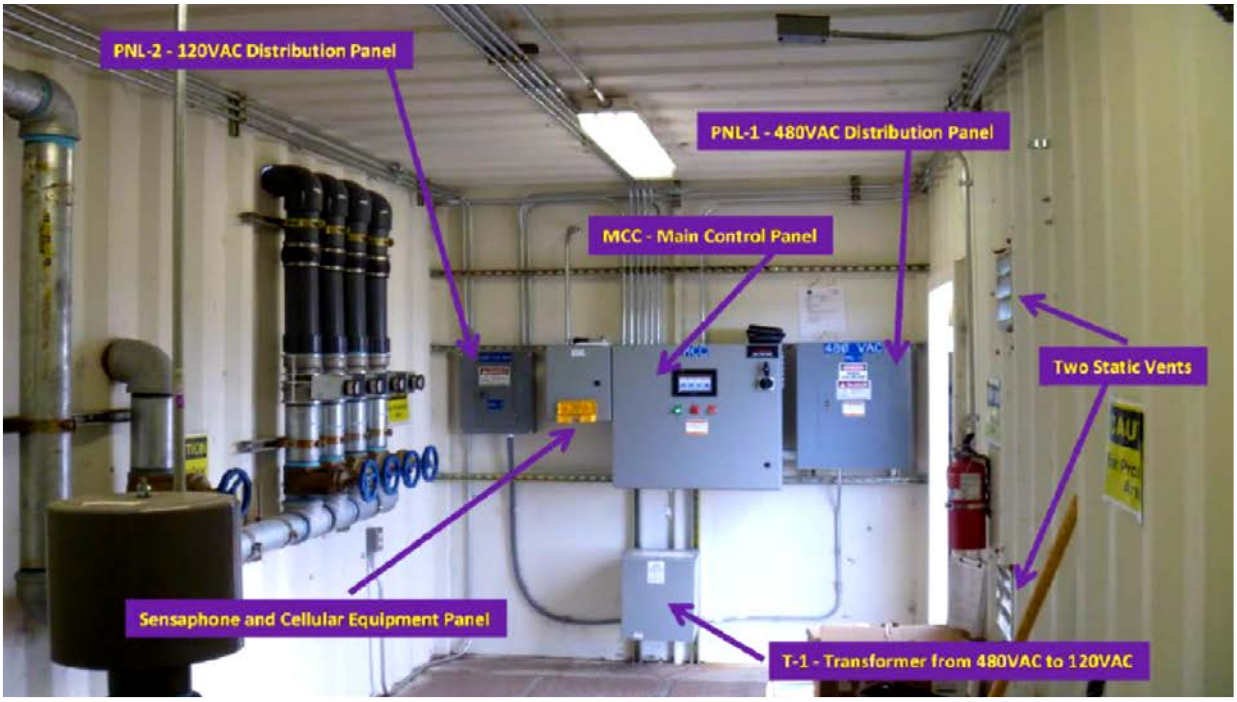


Figure 2-2. Interior of Bioventing System Conex Box

2.1 Bioremediation Wells

Seven bioventing wells were drilled and constructed in 2009. Five of the wells were drilled to a depth of approximately 25 m (82 ft) below surface grade and completed as deep vadose zone wells, with well screens from approximately 16.8 to 22.9 m (55 to 75 ft). Two of the wells were drilled to 10.1 m (33 ft) depth and completed as shallow wells, with well screens from 3 to 10 m (10 to 33 ft) (WCH-370). Table 2-1 provides a summary of the Phase I bioremediation well construction details. Figure 2-3 shows the locations of the bioventing wells and groundwater monitoring wells.

The Phase II bioventing system uses Wells 199-N-167 and 199-N-172 as air injection wells. Two of the bioremediation wells (199-N-169 and 199-N-171) are used for soil gas monitoring.

Table 2-1. Bioventing Well Information

Well Name	Depth (ft bgs)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Depth to Groundwater (ft bgs)
199-N-166 (SIW-1)	33.0	10	30	N/A
199-N-167 (DIW-1)[a]	83.0	53	78	71.6[d]
199-N-168 (SMP-1)	33.0	10	30	N/A
199-N-169 (DMP-1)[b]	83.0	53	78	71.9[d]
199-N-170 (DMP-2)[c]	83.0	54	79	70.2[e]
199-N-171 (DMP-3)[b]	82.4	55	80	71.6[d]
199-N-172 (DMP-4)[a]	82.0	57	77	71.4[d]

a. This well is an injection well for bioventing.

b. This well is a monitoring well for bioventing.

c. This well was decommissioned to support shallow zone remediation work.

d. Measured on January 21, 2015.

e. Measured on May 20, 2011.

bgs = below ground surface
N/A = not applicable
DIW = deep injection well
SIW = shallow injection well
DMP = deep monitoring well
SMP = shallow monitoring well

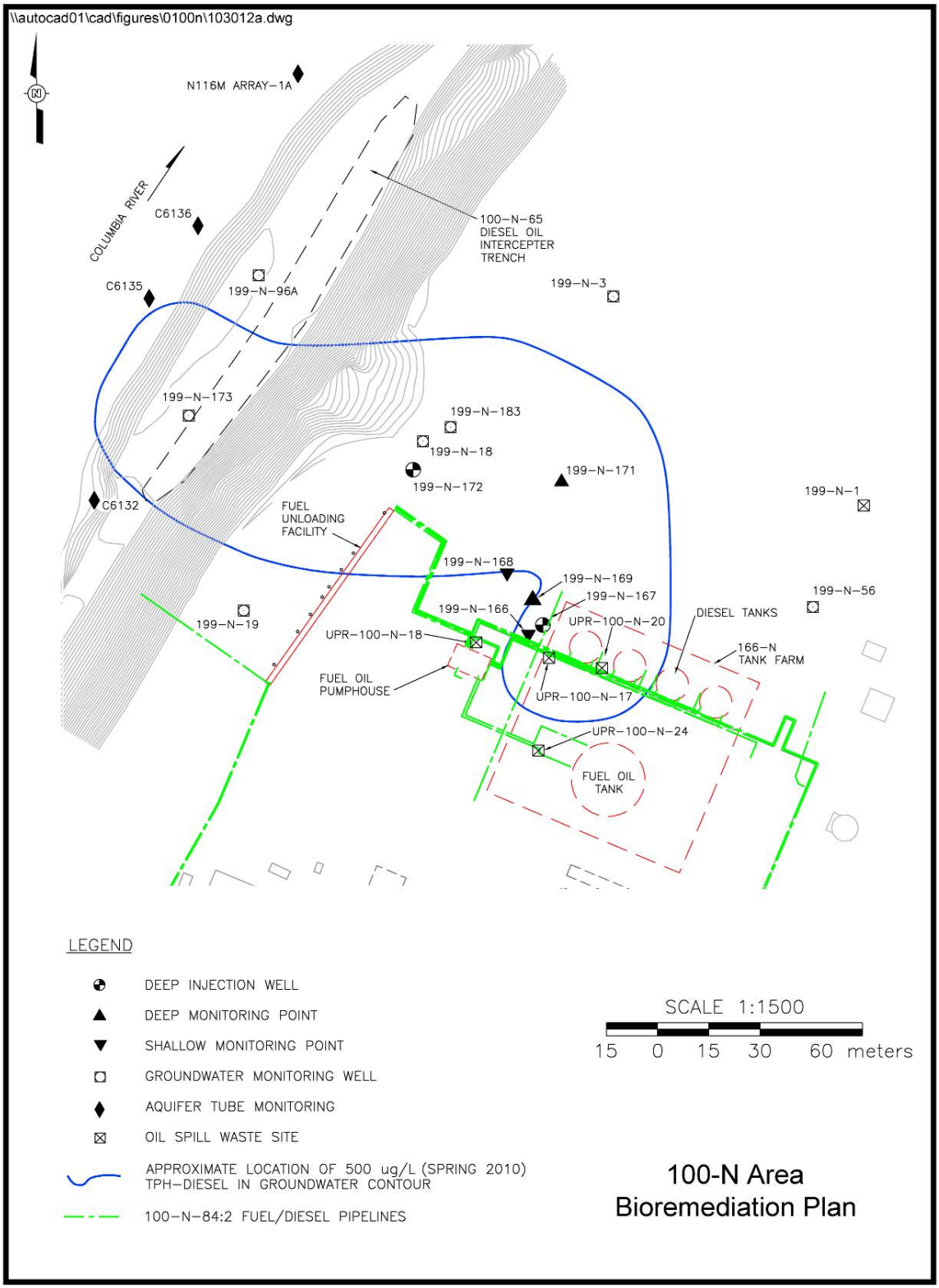


Figure 2-3. Locations of the Bioventing System Wells

3 Bioventing System Operation and Performance

This chapter describes the startup and operations of the bioventing system and the monthly soil gas measurements, as well as two respirometry tests that were conducted (one test from June 2014 through July 2014, and the second test from December 2014 through January 2015).

3.1 System Downtime

The operating times of the bioventing system from March 1, 2014, through February 28, 2015, are presented in Table 3-1. The system ran for a total of 5,243 hours. From March through June 2014, the system ran continuously with no shut downs occurring. The system was offline for 868 hours for the June 2014 respirometry test and for 1,013 hours for the January 2015 respirometry test. On September 30, 2014, the system was shut down to support transition from WHC Phase II testing to CHPRC routine operations. Further discussion of this transition is provided in Section 3.2.

As reported in the April 2014 annual report (WCH-600, *Annual Operations and Monitoring Report for UPR-100-N-17: November 2012 – February 2014*), the blowers were routinely shut down in the late afternoon in summer 2013 to prevent overheating associated with high ambient temperatures. In October 2013, the thermostat for the high-temperature system shutoff was relocated inside the conex box in attempt to obtain a more accurate temperature reading from within the conex box and to reduce the amount of system downtime in warmer months. Relocation of the thermostat corrected this problem, and the blowers were shut down for approximately 6 hours during the 2014 summer months.

3.2 System Transition

On October 1, 2014, the bioventing system was transitioned from a Phase II testing operation managed by WCH to CHPRC for routine operations. As part of this transition, the system was shut down from October 1, 2014, through December 3, 2014, to allow for a number of activities to be completed to support routine operations. The plastic biovent manifold piping on the outside of the conex box was replaced with steel. Procedures for CHPRC operations were prepared, and training plans were developed and delivered to operators.

3.3 System Maintenance

In March 2014, a failed air pressure gauge on Well 199-N-167 was replaced. On June 19, 2014, a camera survey of Well 199-N-169 was performed while the bioventing system was shut down for the June 2014 respirometry test. The survey was performed to evaluate the integrity of the well casing and screen, and to confirm that cracks or other damage to the casing are not present since monthly oxygen measurements in this well are at ambient levels. The survey results did not detect any damage to the well casing or screen.

During the system shutdown period from September 30, 2014, through December 3, 2014, for transition of the system to CHPRC, annual maintenance was performed and included blower, gauge, and electrical inspection, filter replacement, a reconfiguration of the Sensaphone[3] monitoring system to log on an hourly frequency and use an updated callout number, and replacement of the injection manifold and wellhead PVC piping with steel piping.

[3] Sensaphone is a registered trademark of Phonetics, Inc., Aston, Pennsylvania.

Table 3-1. UPR-100-N-17 Bioventing System Operating Times (March 2014 – February 2015)

Date On	Time On	Date Off	Time Off	Blower Operational Hours Between Time On and Time Off*	Total Blower Operational Hours	Comments
3/1/14	—	6/2/14	8:46	2,241	2,241	System shut down on 6/2/14 to perform June 2014 respirometry test.
System shut off from June 2, 2014, through July 8, 2014 (868 hours), to support June 2014 respirometry test.						
7/8/14	12:56	9/30/14	14:35	1,941	4,182	Blower was shut down for approximately 7 hours during this time (6 hours due to blowers shutting down to prevent overheating, 1 hour was associated with shutting off the system to perform assessment supporting transition of operations to CHPRC.
System shut off on September 30, 2014, to support transition from WCH Phase II testing to CHPRC routine operations.						
12/3/14	1400	12/15/14	9:00	283	4,465	System turned on in preparation for December 2014 respirometry test.
System shut off from December 15, 2014, through January 26, 2014 (1,013 hours), to support respirometry test.						
1/26/15	1400	—	—	—	—	Continuously running since 1/26/15 (778 hours).
				Total hours	**5,243**	November March 1, 2014, through February 28, 2015.

* Time estimated to nearest hour.

CHPRC = CH2M HILL Plateau Remediation Company

WCH = Washington Closure Hanford

3.4 Monthly Injection Well Measurements

Table 3-2 provides a summary of the monthly airflow rates and pressure readings for the two injection wells, 199-N-167 and 199-N-172.

Table 3-2. Monthly Air Injection Well Measurements

Date	Time	Pressure Gauge Reading (in. H_2O)	Air Flow Rate at Manifold Valve (ft^3/min)
Injection Well 199-N-167			
3/12/2014	8:05	8 (gauge not functioning; replaced in March)	195
4/9/2014	11:10	18	210
5/14/2014	10:50	25	250
System shut off June 2, 2014, through July 8, 2014, during respirometry test.			
8/13/2014	10:43	23	250
9/10/2014	10:01	23	250
System shut off September 30, 2014, through December 3, 2014, for transition from WCH to CHPRC for routine operation.			
12/3/15	13:30	20	240
System shut off December 15, 2014, through January 26, 2015, during respirometry test.			
3/1/15	8:45	19	195
Injection Well 199-N-172			
3/12/2014	7:53	47	225
4/9/2014	10:53	40	220
5/14/2014	10:17	40	250
System shut off June 2, 2014, through July 8, 2014, during respirometry test.			
8/13/2014	10:13	46	250
9/10/2014	9:06	45	250
System shut off September 30, 2014, through December 3, 2014, for transition from WCH to CHPRC for routine operation.			
12/3/15	13:30	45	250
System shut off December 15, 2014 through January 26, 2015 during respirometry test.			
3/1/15	8:45	42	220

CHPRC = CH2M HILL Plateau Remediation Company

WCH = Washington Closure Hanford

3.5 Monthly Soil Gas Measurements

Two monitoring wells, 199-N-169 and 199-N-171, were installed as deep vadose bioremediation monitoring wells. The monitoring wells were installed to measure vapor concentrations of oxygen, carbon dioxide, methane, total organic hydrocarbons, and injection pressure in the vadose zone. The monitoring wells are fitted with a connection for a vacuum sampling pump. These wells are constructed of two inch diameter PVC with slotted screen, from 16.3 to 23.9 m (53.5 to 78.4 ft) below surface grade for Well 199-N-169 and 16.7 to 24.3 m (54.8 to 79.7 ft) below surface grade for Well 199-N-171. Clean silica sand was used to fill the annular space around the screen. Above the screen, hydrated bentonite, followed by a grout seal, was placed to isolate the screens from the surface.

The monitoring wells are sampled monthly, with the results reported in the monthly unit managers' meeting minutes. Table 3-3 provides a summary of the monthly measurements for soil gas collected for the monitoring wells. Figure 3-1 provides a graph of the oxygen and carbon dioxide measurement data. No monthly measurements were taken during the time that the bioventing system was shut off from September 30, 2014, through December 3, 2014. However, prior to restarting the system on December 3, 2014, carbon dioxide and oxygen measurements were taken from the monitoring wells. These measurements indicate that microbial degradation of petroleum is occurring, and Well 199-N-171 continues to show good response. Well 199-N-169 maintained high oxygen levels, even after the system was shut down for 2 months. Microbial response measurements may be higher at Well 199-N-171 because it is located along the axis of the petroleum groundwater plume.

Table 3-3. Monthly Vapor Monitoring Data

Date	Time	Barometric Pressure (in. Hg)	Temperature (°F)	O_2 %	CO_2 (ppm)	VOC (ppmv)	Methane (% LEL)	Pressure (in. H_2O)
Monitoring Well 199-N-169								
3/12/2014	8:00	29.98	25	20.9	470	2.7	0	1.3
4/9/2014	11:03	29.60	57	20.9	660	0.5	0	1.2
5/14/2014	10:32	29.78	61	20.9	840	0.9	0	1.15
8/13/2014	11:00	29.40	68	20.9	520	0.7	0	1.2
9/10/2014	10:05	29.66	65	20.9	410	0.3	0	NR
12/15/14	9:10	29.6	34	21.0	0*	NR	0	NR
3/2/15	8:45	29.8	44	20.9	360	1.6	0	NR
Monitoring Well 199-N-171								
3/12/2014	7:30	29.96	25	20.9	5,520	97.7	0	0.44
4/9/2014	10:30	29.61	57	20.4	5,560	73.0	0	0.0
5/14/2014	9:39	29.80	61	20.1	5,670	61.0	0	0.39
8/13/2014	8:18	29.39	68	19.8	6,520	65.3	0	0.35
9/10/2014	8:45	29.65	65	19.1	6,180	50.5	0	NR

Table 3-3. Monthly Vapor Monitoring Data

Date	Time	Barometric Pressure (in. Hg)	Temperature (°F)	O_2 %	CO_2 (ppm)	VOC (ppmv)	Methane (% LEL)	Pressure (in. H_2O)
12/15/14	8:39	29.6	44	20.9	2,000*	NR	0	NR
3/2/15	8:45	29.8	44	20.0	7,020	33.4	0	NR

* December 2014 vapor monitoring was conducted during the fall 2014 respirometry test. The CO_2 meter used for the respirometry test has higher range with less precision than meter used for normal monthly vapor sampling. This is because of the higher CO_2 values anticipated from respiration during the respirometry test. The meter used for the respirometry test measures CO_2 in 0.1% increments (1,000 ppmv), so records 0% for ambient air.

LEL = lower explosive limit

ppmv = part per million vapor

NR = not reported

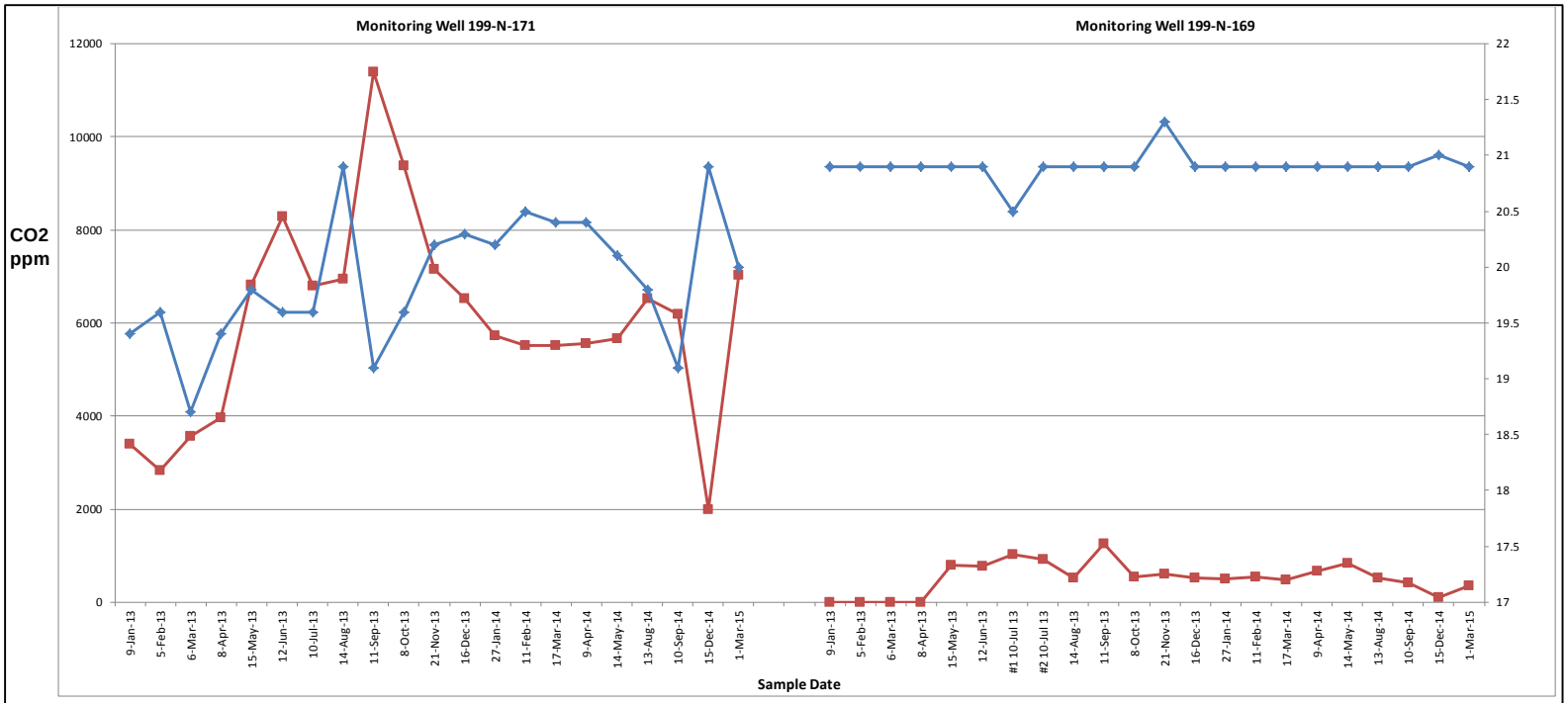
VOC = volatile organic compound

3.6 Respirometry Tests

Two in situ respirometry tests were performed during calendar year 2014 to measure microbial respiration rates and estimate biodegradation rates. The tests were performed from June 2 through July 8, 2014, and from December 15, 2014, through January 26, 2015, with each test initiated after the system was shut off. Field measurements of oxygen, carbon dioxide, total vapor hydrocarbons, and methane were collected from the six wells in the monitoring program:

- 199-N-167 (bioventing air injection well)
- 199-N-169 (bioventing monitoring well)
- 199-N-171 (bioventing monitoring well)
- 199-N-172 (bioventing air injection well)
- 199-N-183 (groundwater monitoring well)
- 199-N-18 (groundwater monitoring well)

The results of the respirometry tests, including field measurements, are provided in Appendix A. The respirometry measurements were used to calculate biodegradation rates for each well. Table 3-4 presents a comparison of the biodegradation rates for the respirometry tests conducted in 2010 (pilot test), 2012, 2014, and 2015. The rates exhibit a declining trend from the initial rates measured in 2010.



BIOVENT WELL SAMPLE RESULTS

Well #	Date	O2%	CO2 ppm
199-N-171	9-Jan-13	19.4	3400
	5-Feb-13	19.6	2840
	6-Mar-13	18.7	3570
	8-Apr-13	19.4	3960
	15-May-13	19.8	6820
	12-Jun-13	19.6	8290
	10-Jul-13	19.6	6800
	14-Aug-13	20.9	6940
	11-Sep-13	19.1	11400
	8-Oct-13	19.6	9380
	21-Nov-13	20.2	7160
	16-Dec-13	20.3	6520
	27-Jan-14	20.2	5720
	11-Feb-14	20.5	5520
	17-Mar-14	20.4	5520
	9-Apr-14	20.4	5560
	14-May-14	20.1	5670
	13-Aug-14	19.8	6520
	10-Sep-14	19.1	6180
	15-Dec-14	20.9	2000
	1-Mar-15	20	7020

Well #	Date	O2%	CO2 ppm
199-N-169	9-Jan-13	20.9	0
	5-Feb-13	20.9	0
	6-Mar-13	20.9	0
	8-Apr-13	20.9	0
	15-May-13	20.9	800
	12-Jun-13	20.9	780
	#1 10-Jul 13	20.5	1020
	#2 10-Jul 13	20.9	920
	14-Aug-13	20.9	530
	11-Sep-13	20.9	1250
	8-Oct-13	20.9	550
	21-Nov-13	21.3	600
	16-Dec-13	20.9	530
	27-Jan-14	20.9	500
	11-Feb-14	20.9	550
	17-Mar-14	20.9	470
	9-Apr-14	20.9	660
	14-May-14	20.9	840
	13-Aug-14	20.9	520
	10-Sep-14	20.9	410
	15-Dec-14	21	100
	1-Mar-15	20.9	360

O2% CO2 ppm

Figure 3-1. Chart of Monthly Soil Vapor Monitoring Results

Table 3-4. Comparison of Biodegradation Rates Calculated from In Situ Respiration Testing

Monitoring Well	Biodegradation Rate (mg/kg-day)				
	January 2015	July 2014	January 2014	December 2012	March 2010
199-N-167	-0.05	-0.06	-0.01	-0.15	-0.99
199-N-169	-0.23	-0.09	-0.07	-0.28	-0.97
199-N-171	-0.23	-0.09	-0.05	-9.82	-0.37
199-N-172	-0.05	-0.02	-0.01	-0.14	-0.54
199-N-183	N/A	N/A	-0.09	Not tested	Not tested
199-N-18	N/A	N/A	N/A	Not tested	Not tested

N/A = not applicable; oxygen depletion insignificant and biodegradation not calculated

3.7 Bioventing System Costs

This section summarizes the costs for the UPR-100-N-17 bioventing system for March 2014 through February 2015. The primary categories of expenditures are as follows:

- **Capital construction:** Includes the oversight labor, material, and subcontractor fees for capital equipment and modifications to the system.
- **Project support:** Includes project coordination-related activities and consultation, as required, during the course of the modification and operation of the system. Includes costs associated with transitioning the system from WCH to CHPRC.
- **Operations and maintenance:** Includes facility supplies, labor, and supervision costs associated with operating the system. It also includes the costs associated with routing field and engineering support as required during the course of the system operation and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis, as required in accordance with the performance monitoring plan (DOE/RL-2005-93, Appendix H). It also includes respirometry testing, microbial laboratory studies, and monthly monitoring of well gases.

Figure 3-2 shows the relative costs for the bioventing system for calendar year 2014 through February 2015. In comparing the costs reported in the April 2014 annual report (WCH-600), it is estimated that approximately $50,000 in additional cost over the previous year was spent to support transition of the bioventing system from Phase II testing under WHC to full-scale operation under CHPRC.

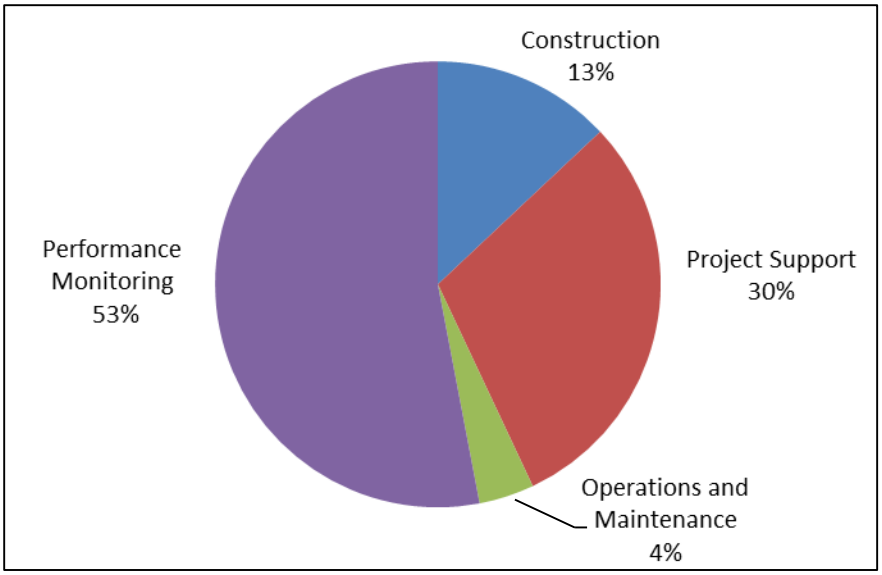


Figure 3-2. Bioventing System Cost ($500,000) Breakdown (by Percentage)

4 Groundwater Monitoring

Groundwater monitoring well sampling was performed as specified in Appendix H of DOE/RL-2005-93. The monitoring well network includes one upgradient well (100-N-56), two bioventing wells (199-N-169 and 199-N-171), five groundwater monitoring wells (199-N-19, 199-N-183, 199-N-173, 199-N-96A, and 199-N-3), and two aquifer tubes (N116-mArray-OA and C6132). Aquifer Tube C6135 was not sampled because it required repairs that had not been made at the time of sample collection. Aquifer Tube N116-mArray-OA was not sampled in January 2015 because it also required repairs. The monitoring well locations are shown in Figure 2-3. A summary of the groundwater monitoring well network and applicable analytical parameters is provided in Table 4-1.

4.1 Sampling Performed During This Reporting Period

Groundwater samples were collected semiannually in the fall and spring to account for seasonal low and high groundwater table elevations. The results of the June 2014 and January 2015 groundwater sampling are provided in Tables 4-2 through 4-9. Table 4-10 provides a summary of groundwater elevations for each well as measured at the time of sampling.

4.1.1 Geochemical Indicators

Geochemical variations in the groundwater sample results provide evidence of the types of biodegradation processes that are occurring in the saturated zone. In general, geochemical species serve as electron acceptors, and they are reduced during the microbial degradation (i.e., oxidation) of petroleum hydrocarbons.

During microbial degradation of petroleum, the dissolved oxygen concentrations steadily decrease until anaerobic conditions prevail. Once anaerobic conditions exist and multiple electron acceptors (i.e., oxidizers) are available, microorganisms preferentially use the electron acceptor that is thermodynamically most favorable. The general order of preference for anaerobic hydrocarbons biodegradation is as follows:

- Denitrification (reduction of nitrate), with the eventual production of molecular nitrogen
- Reduction of manganese from Mn^{4+} to Mn^{2+}
- Reduction of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+})
- Sulfate reduction, with eventual production of sulfide
- Reduction of carbon dioxide and generation of methane

These microbial processes generally segregate into distinct zones dominated by oxygen, nitrate, ferric iron, sulfate, and carbon dioxide reduction. Furthermore, given the different electron acceptors consumed and final products produced, it is theoretically possible to differentiate the “zones” of microbial processes across the smear zone.

Table 4-1. Summary Table of Groundwater Monitoring Well Network

Analytical Parameters[a]		Bioventing Air Injection Wells		Bioventing Monitoring Wells							Aquifer Tubes			Upgradient Well
		199-N-167	199-N-172	199-N-169	199-N-171	199-N-3	199-N-183	199-N-96A	199-N-173	199-N-19	116m Array-0A	C6132	C6135	199-N-56
Laboratory methods	TPH-diesel range	X	X	X	X	X	X	X	X	X	X	X	X	X
	TPH-gasoline range	X	X	X	X	X	X	X	X	X	X	X	X	X
	Oil and grease	X	X	X	X	X	X	X	X	X	X	X	X	X
	Anions	X	X	X	X	X	X	X	X	X	X	X	X	X
	ICP metals	X	X	X	X	X	X	X	X	X	X	X	X	X
	Alkalinity	X	X	X	X	X	X	X	X	X	X	X	X	X
	PAH	X	X	X	X	X	X	X	X	X	X	X	X	X
Field methods	Dissolved oxygen	X	X	X	X	X	X	X	X	X	X	X	X	X
	Oxidation-reduction potential	X	X	X	X	X	X	X	X	X	X	X	X	X
	pH	X	X	X	X	X	X	X	X	X	X	X	X	X
	Conductivity	X	X	X	X	X	X	X	X	X	X	X	X	X
	Temperature	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sheen/odor[b]	X	X	X	X	X	X	X	X	X	X	X	X	X

Note: Sample collection will be semiannually occurring at low river stage and after high river stage.

a. All analyses will be performed on nonfiltered groundwater samples.

b. Prior to purging well for sample collection, a transparent bailer will be used to collect a grab sample to evaluate the presence of sheen.

ICP = inductively coupled plasma

TPH = total petroleum hydrocarbon

PAH = polycyclic aromatic hydrocarbon

Table 4-2. Groundwater Sample Results for Petroleum Hydrocarbons (June 2014)

Well Name	Sample Number	Date	Oil and grease			Total Petroleum Hydrocarbons - Gasoline (C6-C10)			Total Petroleum Hydrocarbons - Diesel (C10-C20)			Total Petroleum Hydrocarbons - Motor Oil (C20-C36)		
			mg/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2WVR1	6/17/14	1.66	B	1.45	16.7	U	16.7	762		49	752		49
199-N-169	B2WVR4	6/17/14	2.11	B	1.47	16.7	U	16.7	1920		52.1	699		52.1
199-N-171	B2WVR7	6/17/14	2.96	B	1.43	33.7	J	16.7	4680	D	100	1580	D	100
199-N-172	B2WVT0	6/17/14	1.87	B	1.38	16.7	U	16.7	3980		49	1870		49
199-N-173	B2WVT3	6/17/14	1.45	B	1.45	16.7	U	16.7	3320	D	102	3680	D	102
199-N-183	B2WVT6	6/17/14	1.54	B	1.44	16.7	U	16.7	1740		53.2	695		53.2
199-N-19	B2WVT9	6/17/14	1.46	B	1.46	16.7	U	16.7	108	J	50	277	J	50
199-N-3	B2WVV2	6/17/14	1.37	U	1.37	16.7	U	16.7	51	U	51	51	U	51
199-N-56	B2WVV5	6/17/14	1.37	B	1.37	16.7	U	16.7	77.3	J	53.2	71.5	J	53.2
199-N-96A	B2WVV8	6/17/14	1.47	B	1.47	16.7	U	16.7	51	U	51	51	U	51
C6132	B2WVW1	6/11/14	2.04	B	1.43	16.7	U	16.7	48.1	U	48.1	48.1	U	48.1
N116mArray-0A	B2WVW4	6/11/14	1.98	B	1.54	16.7	U	16.7	50	U	50	343	J	50

Table 4-3. Groundwater Sample Results for Petroleum Hydrocarbons (January 2015)

Well Name	Sample Number	Date	Oil and grease			Total Petroleum Hydrocarbons - Gasoline (C6-C10)			Total Petroleum Hydrocarbons - Diesel (C10-C20)			Total Petroleum Hydrocarbons - Motor Oil (C20-C36)		
			mg/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2Y640	1/21/15	1.76	B	1.37	16.7	U	16.7	447		52.6	364		52.6
199-N-169	B2Y643	1/20/15	1.39	U	1.39	16.7	U	16.7	576		53.2	402		53.2
199-N-171	B2Y646	1/20/15	1.95	B	1.37	27.8	J	16.7	2880		53.8	980		53.8
199-N-172	B2Y649	1/21/15	1.63	B	1.43	16.7	U	16.7	2500		54.3	938		54.3
199-N-173	B2Y652	1/21/15	1.36	U	1.36	16.7	U	16.7	647		52.6	832		52.6
199-N-183	B2Y655	1/20/15	1.34	U	1.34	16.7	U	16.7	1060		48.1	328		48.1
199-N-19	B2Y658	1/21/15	1.37	U	1.37	16.7	U	16.7	103	J	47.6	221		47.6
199-N-3	B2Y661	1/21/15	1.48	B	1.38	16.7	U	16.7	47.6	U	47.6	47.6	U	47.6
199-N-56	B2Y664	1/20/15	1.68	B	1.39	16.7	U	16.7	75.9	J	47.6	75.7	J	47.6
199-N-96A	B2Y667	1/21/15	1.9	B	1.33	16.7	U	16.7	52.1	U	52.1	77.5	J	52.1
C6132	B2Y670	1/21/15	1.35	U	1.35	16.7	U	16.7	48.1	U	48.1	120	J	48.1

Table 4-4. Groundwater Sample Results for Anions (June 2014)

Well Name	Sample Number	Date	Alkalinity			Bromide			Chloride			Fluoride			Nitrate			Nitrite			Phosphate			Sulfate		
			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM		
			mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL
199-N-167	B2WVR1	6/17/14	239		0.73																					
199-N-167	B2WVR2	6/17/14				0.29		0.067	52.2	D	1.34	0.185	B	0.03	8.41	D	0.165	0.038	U	0.038	0.067	U	0.067	181	D	2.66
199-N-169	B2WVR4	6/17/14	290		0.73																					
199-N-169	B2WVR5	6/17/14				0.26		0.067	42.1	D	1.68	0.145	B	0.03	0.997		0.033	0.132		0.038	0.067	U	0.067	204	D	3.33
199-N-171	B2WVR7	6/17/14	461		0.73																					
199-N-171	B2WVR8	6/17/14				0.27		0.067	30.4	D	0.335	0.103	B	0.03	0.238	D	0.165	0.038	U	0.038	0.067	U	0.067	80.8	D	0.67
199-N-172	B2WVT0	6/17/14	380		0.73																					
199-N-172	B2WVT1	6/17/14				0.45		0.067	82.8	D	3.35	0.14	B	0.03	0.466		0.033	0.0702	B	0.038	0.067	U	0.067	608	D	6.65
199-N-173	B2WVT3	6/17/14	208		1.45																					
199-N-173	B2WVT4	6/17/14				0.07	U	0.067	5.62		0.067	0.136	B	0.03	7.12	D	0.33	0.0645	B	0.038	0.067	U	0.067	87	D	1.33
199-N-183	B2WVT6	6/17/14	481		0.73																					
199-N-183	B2WVT7	6/17/14				0.28		0.067	34.6	D	0.335	0.113	B	0.03	0.213	D	0.165	0.038	U	0.038	0.067	U	0.067	67	D	0.67
199-N-19	B2WVT9	6/17/14	171		0.73																					
199-N-19	B2WVV0	6/17/14				0.22	B	0.067	60.3	D	1.34	0.267	B	0.03	18.4	D	0.66	0.038	U	0.038	0.067	U	0.067	159	D	2.66
199-N-3	B2WVV2	6/17/14	295		1.45																					
199-N-3	B2WVV3	6/17/14				0.27		0.067	27.4	D	0.67	0.143	B	0.03	19.4	D	0.33	0.0598	B	0.038	0.067	U	0.067	145	D	1.33
199-N-56	B2WVV5	6/17/14	334		1.45																					
199-N-56	B2WVV6	6/17/14				0.36		0.067	37.7	D	0.67	0.0999	B	0.03	19.8	DX	0.33	0.038	U	0.038	0.067	U	0.067	131	D	1.33
199-N-96A	B2WVV8	6/17/14	71.4		0.73																					
199-N-96A	B2WVV9	6/17/14				0.07	U	0.067	1.61		0.067	0.106	B	0.03	0.341		0.033	0.038	U	0.038	2.96		0.067	9.68		0.13
C6132	B2WVW1	6/11/14	65.2		0.73																					
C6132	B2WVW2	6/11/14				0.07	U	0.067	1.17		0.067	0.148	B	0.03	0.237		0.033	0.038	U	0.038	0.067	U	0.067	8.42		0.13
N116mArray-0A	B2WVW4	6/11/14	51.4		1.45																					
N116mArray-0A	B2WVW5	6/11/14				0.07	U	0.067	1.07		0.067	0.124	B	0.03	0.233		0.033	0.038	U	0.038	0.067	U	0.067	8.2		0.13

Table 4-5. Groundwater Sample Results for Anions (January 2015)

Well Name	Sample Number	Date	Alkalinity			Bromide			Chloride			Fluoride			Nitrate			Nitrite			Phosphate			Sulfate		
			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM			GENCHEM		
			mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL	mg/L	Q	PQL
199-N-167	B2Y640	1/21/15	268		1.45																					
199-N-167	B2Y641	1/21/15				0.36	D	0.134	51.4	D	0.67	0.102	B	0.03	7.26	D	0.33	0.0882	B	0.038	0.075	B	0.067	211	D	2.66
199-N-169	B2Y643	1/20/15	267		1.45																					
199-N-169	B2Y644	1/20/15				0.32	D	0.134	40.6	D	0.67	0.0811	B	0.03	8.35	D	0.33	0.355	0	0.038	0.067	U	0.067	167	D	1.33
199-N-171	B2Y646	1/20/15	391		1.45																					
199-N-171	B2Y647	1/20/15				0.26	D	0.134	28	D	0.67	0.0622	B	0.03	0.033	U	0.033	0.038	U	0.038	0.067	U	0.067	217	D	2.66
199-N-172	B2Y649	1/21/15	476		1.45																					
199-N-172	B2Y650	1/21/15				0.35	D	0.134	60.3	D	0.67	0.0879	B	0.03	0.033	U	0.033	0.038	U	0.038	0.067	U	0.067	219	D	2.66
199-N-173	B2Y652	1/21/15	370		1.45																					
199-N-173	B2Y653	1/21/15				0.26	D	0.134	59.3	D	0.67	0.115	B	0.03	1.66	DX	0.33	0.0442	B	0.038	0.067	U	0.067	157	D	1.33
199-N-183	B2Y655	1/20/15	419		0.73																					
199-N-183	B2Y656	1/20/15				0.26	D	0.134	30.4	D	0.67	0.0781	B	0.03	0.094	BD	0.066	0.0524	B	0.038	0.067	U	0.067	106	D	1.33
199-N-19	B2Y658	1/21/15	173		0.73																					
199-N-19	B2Y659	1/21/15				0.25	B	0.067	75.5	D	0.67	0.144	B	0.03	15.3	D	0.33	0.038	U	0.038	0.067	U	0.067	157	D	1.33
199-N-3	B2Y661	1/21/15	215		0.73																					
199-N-3	B2Y662	1/21/15				0.31		0.067	27.7	D	0.67	0.0409	B	0.03	16	D	0.33	0.038	U	0.038	0.068	B	0.067	139	D	1.33
199-N-56	B2Y664	1/20/15	345		0.73																					
199-N-56	B2Y665	1/20/15				0.26		0.067	29.3	D	1.34	0.033	U	0.03	18.5	D	0.66	0.038	U	0.038	0.067	U	0.067	114	D	2.66
199-N-96A	B2Y667	1/21/15	71.9		1.45																					
199-N-96A	B2Y668	1/21/15				0.07	U	0.067	1.81	0	0.067	0.0512	B	0.03	0.723	0	0.033	0.038	U	0.038	3.61	DX	0.134	11.6	0	0.13
C6132	B2Y670	1/21/15	65.1		0.73																					
C6132	B2Y671	1/21/15				0.07	U	0.067	2.7	0	0.067	0.175	B	0.03	0.76	0	0.033	0.038	U	0.038	0.067	U	0.067	14	0	0.13

Table 4-6. Groundwater Sample Results for Metals (June 2014)

Well Name	Sample Number	Date	Aluminum			Antimony			Arsenic			Barium			Beryllium			Bismuth			Boron			Cadmium		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2WVR1	6/17/14	164	B	68	3.5	U	3.5	10.7	B	5	107		1	1	U	1	0.5	U	0.5	26.5	B	15	1	U	1
199-N-169	B2WVR4	6/17/14	68	U	68	5.07	B	3.5	5	U	5	104		1	1	U	1	0.5	U	0.5	21.6	B	15	1	U	1
199-N-171	B2WVR7	6/17/14	95.7	B	68	7.65	B	3.5	7.49	B	5	181		1	1	U	1	0.5	U	0.5	22.7	B	15	1.55	B	1
199-N-172	B2WVT0	6/17/14	68	U	68	3.5	U	3.5	6.3	B	5	134		1	1	U	1	0.5	U	0.5	27.5	B	15	1	U	1
199-N-173	B2WVT3	6/17/14	68	U	68	3.5	U	3.5	5	U	5	131		1	1	U	1	0.5	U	0.5	15.4	B	15	1	U	1
199-N-183	B2WVT6	6/17/14	68	U	68	4.54	B	3.5	5	U	5	187		1	1	U	1	0.5	U	0.5	22.9	B	15	1	U	1
199-N-19	B2WVT9	6/17/14	68	U	68	6.32	B	3.5	5	U	5	63.9		1	1	U	1	0.5	U	0.5	27.2	B	15	1	U	1
199-N-3	B2WVV2	6/17/14	68	U	68	5.21	B	3.5	6.49	B	5	137		1	1	U	1	0.5	U	0.5	29.8	B	15	1	U	1
199-N-56	B2WVV5	6/17/14	68	U	68	4.92	B	3.5	6.5	B	5	89.1		1	1	U	1	0.5	U	0.5	43.5	B	15	1	U	1
199-N-96A	B2WVV8	6/17/14	68	U	68	8.18	B	3.5	6.25	B	5	17.7		1	1	U	1	0.5	U	0.5	15	U	15	1	U	1
C6132	B2WVW1	6/11/14	68	U	68	3.5	U	3.5	5.31	B	5	11.3		1	1	U	1	0.5	U	0.5	15	U	15	1	U	1
N116mArray-0A	B2WVW4	6/11/14	68	U	68	4.29	B	3.5	6.59	B	5	17		1	1	U	1	0.5	U	0.5	15	U	15	1	U	1

Well Name	Sample Number	Date	Calcium			Chromium			Cobalt			Copper			Iron			Lead			Lithium			Magnesium		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2WVR1	6/17/14	132000		50	8.52		1	1	U	1	9.76	B	3	295		30	3.3	U	3.3	8.87	B	2	23400		110
199-N-169	B2WVR4	6/17/14	146000		50	7.01		1	2.99	B	1	48.6		3	30	U	30	3.3	U	3.3	9.58	B	2	26600		110
199-N-171	B2WVR7	6/17/14	159000		50	16.1		1	1	U	1	20.2		3	3040		30	3.88	B	3.3	7.82	B	2	29400		110
199-N-172	B2WVT0	6/17/14	265000		50	2.2	B	1	1.43	B	1	28.2		3	708		30	3.3	U	3.3	9.39	B	2	57100		110
199-N-173	B2WVT3	6/17/14	83400		50	1	U	1	1	U	1	6.74	B	3	30	U	30	3.3	U	3.3	2	U	2	19900		110
199-N-183	B2WVT6	6/17/14	162000		50	2.44	B	1	2.07	B	1	10.3		3	1720		30	3.3	U	3.3	6.82	B	2	30600		110
199-N-19	B2WVT9	6/17/14	98100		50	6.78		1	1	U	1	3	U	3	209		30	3.3	U	3.3	4.98	B	2	20300		110
199-N-3	B2WVV2	6/17/14	146000		50	4.34	B	1	1	U	1	3	U	3	43.7	B	30	3.3	U	3.3	2	U	2	26100		110
199-N-56	B2WVV5	6/17/14	157000		50	3.52	B	1	1	U	1	3	U	3	30	U	30	3.3	U	3.3	5.51	B	2	27500		110
199-N-96A	B2WVV8	6/17/14	19200		50	4.42	B	1	1	U	1	3	U	3	30	U	30	3.3	U	3.3	2	U	2	4360		110
C6132	B2WVW1	6/11/14	15700		50	3.28	B	1	1	U	1	3	U	3	86.9	B	30	3.3	U	3.3	2	U	2	3040		110
N116mArray-0A	B2WVW4	6/11/14	14600		50	1	U	1	1	U	1	3	U	3	142		30	3.3	U	3.3	2	U	2	4510		110

Table 4-6. Groundwater Sample Results for Metals (June 2014)

Well Name	Sample Number	Date	Manganese			Molybdenum			Nickel			Phosphorus			Potassium			Selenium			Silicon			Silver		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2WVR1	6/17/14	395		2	2.36	B	2	2.43	B	1.5	63.4	B	60	5940		50	9.87	B	6	15500		25	2.63	B	1
199-N-169	B2WVR4	6/17/14	1620		2	2.11	B	2	3.22	B	1.5	105	B	60	5870		50	6	U	6	12700		25	3.32	B	1
199-N-171	B2WVR7	6/17/14	4660		2	2	U	2	2.42	B	1.5	298		60	5050		50	11.3	B	6	16000		25	2.74	B	1
199-N-172	B2WVT0	6/17/14	2460		2	4.68	B	2	3.9	B	1.5	68.7	B	60	5890		50	12.5	B	6	14100		25	5.81		1
199-N-173	B2WVT3	6/17/14	618		2	2	U	2	3.73	B	1.5	60	U	60	3540		50	6	U	6	16700		25	1.07	B	1
199-N-183	B2WVT6	6/17/14	3180		2	4.36	B	2	2.83	B	1.5	60	U	60	4810		50	6	U	6	13600		25	2.6	B	1
199-N-19	B2WVT9	6/17/14	12.5		2	2	U	2	1.5	U	1.5	65.7	B	60	5890		50	19.4	B	6	11800		25	1	U	1
199-N-3	B2WVV2	6/17/14	22.3		2	2	U	2	1.5	U	1.5	70.6	B	60	4160		50	6	U	6	9900		25	1.49	B	1
199-N-56	B2WVV5	6/17/14	2	U	2	2	U	2	1.5	U	1.5	69.6	B	60	5050		50	14.7	B	6	12000		25	1.34	B	1
199-N-96A	B2WVV8	6/17/14	2	U	2	2	U	2	1.5	U	1.5	2890		60	1040		50	6	U	6	6430		25	1	U	1
C6132	B2WVW1	6/11/14	3.25	B	2	2	U	2	1.5	U	1.5	60	U	60	1850		50	10.2	B	6	6390		25	1	U	1
N116mArray-0A	B2WVW4	6/11/14	32		2	2	U	2	1.5	U	1.5	60	U	60	942		50	6.55	B	6	4700		25	1	U	1

Well Name	Sample Number	Date	Sodium			Strontium			Thallium			Tin			Uranium			Vanadium			Zinc		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2WVR1	6/17/14	46400		100	528		1	5	U	5	125	DNU	125	72.9		10	5.01		1	3.3	U	3.3
199-N-169	B2WVR4	6/17/14	39600		100	597		1	5	U	5	125	DNU	125	62.6		10	2.69	B	1	3.3	U	3.3
199-N-171	B2WVR7	6/17/14	34400		100	706		1	5	U	5	125	DNU	125	40.5	B	10	9.23		1	3.3	U	3.3
199-N-172	B2WVT0	6/17/14	69500		100	1020		1	5	U	5	250	DNU	250	81.9		10	1.73	B	1	3.3	U	3.3
199-N-173	B2WVT3	6/17/14	21400		100	383		1	5	U	5	125	DNU	125	45.1	B	10	1.26	B	1	3.3	U	3.3
199-N-183	B2WVT6	6/17/14	36000		100	693		1	5	U	5	125	DNU	125	62.5		10	1	U	1	3.3	U	3.3
199-N-19	B2WVT9	6/17/14	64700		100	418		1	5	U	5	50	DNU	50	10.6	B	10	3.55	B	1	3.3	U	3.3
199-N-3	B2WVV2	6/17/14	22100		100	590		1	5	U	5	50	DNU	50	11.3	B	10	2.4	B	1	8.08	B	3.3
199-N-56	B2WVV5	6/17/14	33400		100	652		1	5	U	5	50	DNU	50	10	U	10	1.41	B	1	3.3	U	3.3
199-N-96A	B2WVV8	6/17/14	11900		100	84.6		1	5	U	5	50	DNU	50	17.5	B	10	2.31	B	1	3.3	U	3.3
C6132	B2WVW1	6/11/14	9570		100	67.7		1	5	U	5	25	DU	25	21.1	B	10	3.2	B	1	3.3	U	3.3
N116mArray-0A	B2WVW4	6/11/14	2550		100	60		1	5	U	5	25	DU	25	25.3	B	10	1	U	1	3.3	U	3.3

Table 4-7. Groundwater Sample Results for Metals (January 2015)

Well Name	Sample Number	Date	Aluminum			Antimony			Arsenic			Barium			Beryllium			Bismuth			Boron			Cadmium		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2Y640	1/21/15	159		15	1	U	1	8.5	U	8.5	133		0.6	0.2	U	0.2	Not analyzed			29.2	B	15	0.433	B	0.11
199-N-169	B2Y643	1/20/15	66.5		15	1	U	1	8.5	U	8.5	108		0.6	0.2	U	0.2				24.4	B	15	0.216	B	0.11
199-N-171	B2Y646	1/20/15	46.2		15	1	U	1	8.5	U	8.5	194		0.6	0.2	U	0.2				24	B	15	0.165	B	0.11
199-N-172	B2Y649	1/21/15	83.4		15	1	U	1	8.5	U	8.5	97.4		0.6	0.2	U	0.2				28.3	B	15	0.11	U	0.11
199-N-173	B2Y652	1/21/15	104		15	1	U	1	8.5	U	8.5	192		0.6	0.2	U	0.2				28.3	B	15	0.11	U	0.11
199-N-183	B2Y655	1/20/15	15	U	15	1	U	1	1.7	U	1.7	177		0.6	0.2	U	0.2				17.8		4	0.11	U	0.11
199-N-19	B2Y658	1/21/15	81.3		15	1	U	1	1.7	U	1.7	69.4		0.6	0.2	U	0.2				28.4		4	0.11	U	0.11
199-N-3	B2Y661	1/21/15	15	U	15	1	U	1	1.7	U	1.7	124		0.6	0.2	U	0.2				27.1		4	0.11	U	0.11
199-N-56	B2Y664	1/20/15	15	U	15	1	U	1	1.7	U	1.7	129		0.6	0.2	U	0.2				43.7		4	0.11	U	0.11
199-N-96A	B2Y667	1/21/15	93.3		15	1	U	1	8.5	U	8.5	21.7		0.6	0.2	U	0.2				15	U	15	0.11	U	0.11
C6132	B2Y670	1/21/15	295		15	1	U	1	1.7	U	1.7	13.4		0.6	0.2	U	0.2				9.59	B	4	0.11	U	0.11

Well Name	Sample Number	Date	Calcium			Chromium			Cobalt			Copper			Iron			Lead			Lithium			Magnesium		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2Y640	1/21/15	154000		50	2	U	2	1.61	B	0.1	2.55	B	0.35	312		30	0.5	U	0.5	Not analyzed			28100		110
199-N-169	B2Y643	1/20/15	137000		50	2	U	2	2.25	B	0.1	3.92	B	0.35	122		30	0.703	B	0.5				25300		110
199-N-171	B2Y646	1/20/15	181000		50	2	U	2	0.176	B	0.1	5.76	B	0.35	1050		30	1.66	B	0.5				33500		110
199-N-172	B2Y649	1/21/15	201000		50	2	U	2	0.189	B	0.1	2.7	B	0.35	803		30	0.721	B	0.5				40700		110
199-N-173	B2Y652	1/21/15	162000		50	2	U	2	0.26	B	0.1	1.73	B	0.35	30	U	30	0.5	U	0.5				29100		110
199-N-183	B2Y655	1/20/15	154000		50	2	U	2	2.11	B	0.1	1.26	B	0.35	2650		30	0.5	U	0.5				30100		110
199-N-19	B2Y658	1/21/15	95000		50	10.1		2	0.211	B	0.1	0.539	B	0.35	213		30	0.5	U	0.5				19700		110
199-N-3	B2Y661	1/21/15	124000		50	9.85		2	0.108	B	0.1	0.461	B	0.35	141		30	0.5	U	0.5				21600		110
199-N-56	B2Y664	1/20/15	157000		50	15.4		2	0.438	B	0.1	1.61	B	0.35	74.6	B	30	0.5	U	0.5				26800		110
199-N-96A	B2Y667	1/21/15	17600		50	36.1		2	0.158	B	0.1	4.24	B	0.35	126		30	0.5	U	0.5				4120		110
C6132	B2Y670	1/21/15	14100		50	4.6		2	0.153	B	0.1	0.899	B	0.35	312		30	0.5	U	0.5				2870		110

Table 4-7. Groundwater Sample Results for Metals (January 2015)

Well Name	Sample Number	Date	Manganese			Molybdenum			Nickel			Phosphorus			Potassium			Selenium			Silicon			Silver		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2Y640	1/21/15	533		5	2.16	B	0.17	2.35		0.5	60	U	60	6980		50	7.5	U	7.5	16300		25	0.2	U	0.2
199-N-169	B2Y643	1/20/15	735		5	1.61	B	0.17	3.23		0.5	60	U	60	6290		50	7.5	U	7.5	14300		25	0.2	U	0.2
199-N-171	B2Y646	1/20/15	3240		5	0.932	B	0.17	1.35	B	0.5	91.8	B	60	5610		50	7.5	U	7.5	14300		25	0.2	U	0.2
199-N-172	B2Y649	1/21/15	1590		5	0.634	B	0.17	1.02	B	0.5	131	B	60	6530		50	7.5	U	7.5	17200		25	0.2	U	0.2
199-N-173	B2Y652	1/21/15	1200		5	0.652	B	0.17	1.32	B	0.5	60	U	60	6640		50	7.5	U	7.5	14800		25	0.2	U	0.2
199-N-183	B2Y655	1/20/15	3310	D	10	3.42	B	0.17	2.08		0.5	70.3	B	60	5150		50	1.5	U	1.5	14100		25	0.2	U	0.2
199-N-19	B2Y658	1/21/15	22.2		1	1.3	BC	0.17	3.89		0.5	88.6	B	60	6070		50	1.5	U	1.5	12000		25	0.2	U	0.2
199-N-3	B2Y661	1/21/15	3.43	B	1	0.478	BC	0.17	4.09		0.5	69.9	B	60	3740		50	1.5	U	1.5	9890		25	0.2	U	0.2
199-N-56	B2Y664	1/20/15	1.55	B	1	0.361	B	0.17	9.89		0.5	108	B	60	5780		50	1.5	U	1.5	12700		25	0.2	U	0.2
199-N-96A	B2Y667	1/21/15	41		5	1.24	B	0.17	1.43	B	0.5	3560		60	1320		50	7.5	U	7.5	8320		25	0.2	U	0.2
C6132	B2Y670	1/21/15	10.8		1	1.51	B	0.17	0.64	B	0.5	60	U	60	1820		50	1.5	U	1.5	7540		25	0.2	U	0.2

Well Name	Sample Number	Date	Sodium			Strontium			Thallium			Tin			Uranium			Vanadium			Zinc		
			ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
199-N-167	B2Y640	1/21/15	50400		100	682		2	0.45	U	0.45	1	U	1	3.3		0.07	4.71	B	1	15.9		3.5
199-N-169	B2Y643	1/20/15	43300		100	615		2	0.45	U	0.45	1	U	1	3.32		0.07	3.7	B	1	5.35	B	3.5
199-N-171	B2Y646	1/20/15	38500		100	856		2	0.45	U	0.45	1	U	1	1.97		0.07	1.62	B	1	17.2		3.5
199-N-172	B2Y649	1/21/15	62100		100	901		2	0.45	U	0.45	1.85	B	1	2.02		0.07	1.42	B	1	17.5		3.5
199-N-173	B2Y652	1/21/15	54700		100	854		2	0.45	U	0.45	1	U	1	4.42		0.07	1.24	B	1	13.5		3.5
199-N-183	B2Y655	1/20/15	37000		100	736		2	0.45	U	0.45	1	U	1	2.04		0.07	1	U	1	3.5	U	3.5
199-N-19	B2Y658	1/21/15	68300		100	469		2	0.45	U	0.45	1	U	1	5.7		0.07	4.44	B	1	5.19	B	3.5
199-N-3	B2Y661	1/21/15	21400		100	548		2	0.45	U	0.45	1	U	1	5.07		0.07	2.09	B	1	10.5		3.5
199-N-56	B2Y664	1/20/15	50600		100	872		2	0.45	U	0.45	1	U	1	7.9		0.07	2.12	B	1	6.96	B	3.5
199-N-96A	B2Y667	1/21/15	17300		100	71.6		2	0.45	U	0.45	1	U	1	0.117	B	0.07	4.48	B	1	3.91	B	3.5
C6132	B2Y670	1/21/15	20000		100	68.9		2	0.45	U	0.45	1	U	1	0.561		0.07	3.64	B	1	3.5	U	3.5

Table 4-8. Groundwater Sample Results for Organics (June 2014)

Sample Number	B2WVR1			B2WVR4			B2WVR7			B2WVT0			B2WVT3			B2WVT6		
Well Name	199-N-167			199-N-169			199-N-171			199-N-172			199-N-173			199-N-183		
CONSTITUENT	6/17/14			6/17/14			6/17/14			6/17/14			6/17/14			6/17/14		
	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Acenaphthene	0.143	U	0.143	0.147	U	0.147	0.76		0.136	0.696		0.146	0.147	U	0.147	0.143	U	0.143
Acenaphthylene	0.143	U	0.143	0.147	U	0.147	0.156	J	0.136	0.465	J	0.146	0.147	U	0.147	0.143	U	0.143
Anthracene	0.143	U	0.143	0.147	U	0.147	0.136	U	0.136	0.146	U	0.146	0.147	U	0.147	0.143	U	0.143
Benzo(a)anthracene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Benzo(a)pyrene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Benzo(b)fluoranthene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Benzo(ghi)perylene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Benzo(k)fluoranthene	0.00762	U	0.00762	0.00784	U	0.00784	0.00727	U	0.00727	0.00777	U	0.00777	0.00784	U	0.00784	0.00762	U	0.00762
Chrysene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Dibenz[a,h]anthracene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Fluoranthene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Fluorene	0.143	U	0.143	0.147	U	0.147	1.95		0.136	1.2		0.146	0.147	U	0.147	0.143	U	0.143
Indeno(1,2,3-cd)pyrene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Naphthalene	0.143	U	0.143	0.147	U	0.147	0.136	U	0.136	0.146	U	0.146	0.147	U	0.147	0.143	U	0.143
Phenanthrene	0.173	U	0.173	0.178	U	0.178	0.165	U	0.165	0.177	U	0.177	0.178	U	0.178	0.173	U	0.173
Pyrene	0.0152	U	0.0152	0.0157	U	0.0157	0.0145	U	0.0145	0.0155	U	0.0155	0.0157	U	0.0157	0.0152	U	0.0152
Volatile Organic Constituents																		
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
2-Butanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
4-Methyl-2-Pentanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
Acetone	3	U	3	3	U	3	10.8	J	3	9.15	J	3	3	U	3	3	U	3
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Carbon tetrachloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chloroform	1.89	J	0.3	1.11	J	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Ethylbenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Methylenechloride	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Tetrachloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Toluene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Xylenes (total)	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3

Table 4-8. Groundwater Sample Results for Organics (June 2014)

Sample Number	B2WVT9			B2WVV2			B2WVV5			B2WVV8			B2WVW1			B2WVW4		
Well Name	199-N-19			199-N-3			199-N-56			199-N-96A			C6132			N116mArray-0A		
CONSTITUENT	6/17/14			6/17/14			6/17/14			6/17/14			6/11/14			6/11/14		
	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																		
Acenaphthene	0.144	U	0.144	0.134	U	0.134	0.147	U	0.147	0.147	U	0.147	0.143	U	0.143	0.142	U	0.142
Acenaphthylene	0.144	U	0.144	0.134	U	0.134	0.147	U	0.147	0.147	U	0.147	0.143	U	0.143	0.142	U	0.142
Anthracene	0.144	U	0.144	0.134	U	0.134	0.147	U	0.147	0.147	U	0.147	0.143	U	0.143	0.142	U	0.142
Benzo(a)anthracene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Benzo(a)pyrene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Benzo(b)fluoranthene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Benzo(ghi)perylene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Benzo(k)fluoranthene	0.00769	U	0.00769	0.00714	U	0.00714	0.00784	U	0.00784	0.00784	U	0.00784	0.00762	U	0.00762	0.00755	U	0.00755
Chrysene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Dibenz[a,h]anthracene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Fluoranthene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Fluorene	0.144	U	0.144	0.134	U	0.134	0.147	U	0.147	0.147	U	0.147	0.143	U	0.143	0.142	U	0.142
Indeno(1,2,3-cd)pyrene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Naphthalene	0.144	U	0.144	0.134	U	0.134	0.147	U	0.147	0.147	U	0.147	0.143	U	0.143	0.142	U	0.142
Phenanthrene	0.175	U	0.175	0.163	U	0.163	0.178	U	0.178	0.178	U	0.178	0.173	U	0.173	0.172	U	0.172
Pyrene	0.0154	U	0.0154	0.0143	U	0.0143	0.0157	U	0.0157	0.0157	U	0.0157	0.0152	U	0.0152	0.0151	U	0.0151
Volatile Organic Constituents																		
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
2-Butanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
4-Methyl-2-Pentanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
Acetone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Carbon tetrachloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chloroform	1.61	J	0.3	1.04	J	0.3	0.8	J	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Ethylbenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Methylenechloride	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Tetrachloroethene	0.3	U	0.3	0.38	J	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Toluene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Xylenes (total)	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3

Table 4-9. Groundwater Sample Results for Organics (January 2015)

Sample Number	B2Y640			B2Y643			B2Y646			B2Y649			B2Y652			B2Y655			B2Y658		
Well Name	199-N-167			199-N-169			199-N-171			199-N-172			199-N-173			199-N-183			199-N-19		
CONSTITUENT	1/21/15			1/21/15			1/21/15			1/21/15			1/20/15			1/21/15			1/20/15		
	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
Polycyclic Aromatic Hydrocarbons																					
Acenaphthene	0.1	U	0.1	0.104	U	0.104	0.574	J	0.106	0.298	J	0.106	0.104	U	0.104	0.183	J	0.0481	0.044	U	0.044
Acenaphthylene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Anthracene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Benzo(a)anthracene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Benzo(a)pyrene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Benzo(b)fluoranthene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Benzo(ghi)perylene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	BJ	0.044
Benzo(k)fluoranthene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Chrysene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Dibenz[a,h]anthracene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	BJ	0.044
Fluoranthene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Fluorene	0.1	U	0.1	0.104	U	0.104	1.43	J	0.106	0.809	J	0.106	0.104	U	0.104	0.173	J	0.0481	0.044	U	0.044
Indeno(1,2,3-cd)pyrene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Naphthalene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Phenanthrene	0.13	J	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Pyrene	0.1	U	0.1	0.104	U	0.104	0.106	U	0.106	0.106	U	0.106	0.104	U	0.104	0.0481	U	0.0481	0.044	U	0.044
Volatile Organic Constituents																					
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
2-Butanone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
4-Methyl-2-Pentanone	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3	3	U	3
Acetone	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3	3	TU	3
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Carbon tetrachloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chloroform	0.92	J	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	1.55	J	0.3
Ethylbenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Methylenechloride	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Tetrachloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Toluene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Xylenes (total)	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3

Table 4-9. Groundwater Sample Results for Organics (January 2015)

Sample Number	B2Y661			B2Y664			B2Y667			B2Y670		
Well Name	199-N-3			199-N-56			199-N-96A			C6132		
CONSTITUENT	1/20/15			1/21/15			1/20/15			1/21/15		
	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL	ug/L	Q	PQL
yclic Aromatic Hydrocarbons												
Acenaphthene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Acenaphthylene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Anthracene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Benzo(a)anthracene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Benzo(a)pyrene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Benzo(b)fluoranthene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Benzo(ghi)perylene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Benzo(k)fluoranthene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Chrysene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Dibenz[a,h]anthracene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Fluoranthene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Fluorene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Indeno(1,2,3-cd)pyrene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Naphthalene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Phenanthrene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
Pyrene	0.047	U	0.047	0.05	U	0.05	0.102	U	0.102	0.048	U	0.048
latile Organic Constituents												
1,1,1-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1,2-Trichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,1-Dichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
1,2-Dichloroethane	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
2-Butanone	3	TU	3	3	TU	3	3	TU	3	3	TU	3
4-Methyl-2-Pentanone	3	U	3	3	U	3	3	U	3	3	U	3
Acetone	3.06	JT	3	3	TU	3	3	TU	3	3	TU	3
Benzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Carbon disulfide	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Carbon tetrachloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chlorobenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Chloroform	1.45	J	0.3	0.92	J	0.3	0.3	U	0.3	0.3	U	0.3
Ethylbenzene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Methylenechloride	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6	1.6	U	1.6
Tetrachloroethene	0.35	J	0.3	0.33	J	0.3	0.3	U	0.3	0.3	U	0.3
Toluene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Trichloroethene	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Vinyl chloride	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3	0.3	U	0.3
Xylenes (total)				0.3	U	0.3	0.3	U	0.3	0.3	U	0.3

Table 4-10. Groundwater Elevations during Sampling Events

Well Name	June 2014 Elevation (m)	January 2015 Elevation (m)	Delta (m/ft)
199-N-167	119.40	118.86	0.55/1.80
199-N-169	119.40	118.86	0.54/1.77
199-N-171	119.36	118.84	0.52/1.72
199-N-172	119.28	118.83	0.45/1.49
199-N-173	119.58	118.98	0.60/1.97
199-N-183	119.32	118.86	0.47/1.53
199-N-19	119.29	118.83	0.46/1.50
199-N-3	119.37	118.85	0.52/1.70
199-N-56	119.42	118.77	0.65/2.13
199-N-96A	119.64	118.93	0.71/2.34

In general, if dissolved oxygen is present in groundwater above 0.5 mg/L, then aerobic biodegradation of petroleum hydrocarbons is the dominant process. If dissolved oxygen concentrations are less than 5 mg/L but nitrate concentrations exceed 1.0 mg/L, then denitrification dominates. Because nitrite is an unstable intermediate product of denitrification, the presence of measurable nitrite concentrations is indicative of nitrate reduction. If groundwater is deprived of dissolved oxygen, nitrate, and nitrite, but concentrations of ferrous iron are greater than 0.5 mg/L, then iron reduction will be the dominant biodegradation process. If groundwater is depleted in ferrous iron but contains concentrations of sulfate above 1.0 mg/L and hydrogen sulfide above 0.05 mg/L, then sulfate reduction will be the dominant process. Finally, if the groundwater is depleted in all the electron acceptors and byproducts, with the exception of methane greater than 0.2 mg/L, then methanogenesis is the predominant process degrading petroleum hydrocarbons. When applied at a field scale, this differentiation of microbial zones commonly encounters uncertainties, as many of the byproducts of microbial metabolism (e.g., ferric iron, hydrogen sulfide, and methane) are readily transported downgradient.

The spatial distribution of electron acceptors measured during the June 2014 and January 2015 sampling events are shown in Figures 4-1 and 4-2, respectively. Nitrate and sulfate concentrations are generally higher upgradient of the petroleum plume compared to concentrations within the plume.

The concentration of oxidation byproducts (iron and manganese) was higher within the plume compared to upgradient and downgradient conditions. This increased concentration of these dissolved-phase products indicates iron and manganese reduction of dissolved-phase petroleum hydrocarbons.

4.1.2 Groundwater Concentrations

Tables 4-2 through 4-9 present the groundwater sample results for June 2014 and January 2015. Monitoring Well 199-N-171 continues to exhibit the highest concentrations of petroleum, consisting of approximately 70 to 80 percent diesel-range (C10-C20) petroleum and 20 to 30 percent motor-oil-range (C20-C36) petroleum. Diesel-range petroleum is also relatively higher than motor-oil-range petroleum in

samples collected from Wells 199-N-172 and 199-N-183. These wells are all located in the center of the petroleum plume. Diesel-range concentrations are generally similar, or lower than, motor-oil-range concentrations at the boundaries of the petroleum plume. Gasoline-range petroleum was detected in groundwater samples collected from Well 199-N-171. Petroleum concentrations are generally higher in the June 2014 sample results collected at higher groundwater elevation than in the January 2015 sample results collected at lower groundwater elevation. Wells 199-N-171, 199-N-172, 199-N-173, and 199-N-183 are located along the axis of the groundwater plume and have the highest concentrations at low and high groundwater elevation.

During the June 2014 sampling, an oily sheen was observed in groundwater sampled from Wells 199-N-169 and 199-N-171. Groundwater sampled on January 21, 2015 from Well 199-N-171 was noted to have a yellow tint, a strong sulfur odor, and an oily sheen.

September 2014 sampling performed for another 100-N Area groundwater monitoring program included sampling of Wells 199-N-173 and 199-N-183. Diesel odors were noted during sampling of Well 199-N-173. The groundwater sample collected from Well 199-N-183 was observed to have a large amount of air in the sample, likely due to injection of air into the nearby Well 199-N-172 since the bioventing system was operating during this sampling event. Figures 4-3 and 4-4 depict the petroleum contamination plume distribution in groundwater for the 100-NR-2 OU for high and low groundwater periods, respectively.

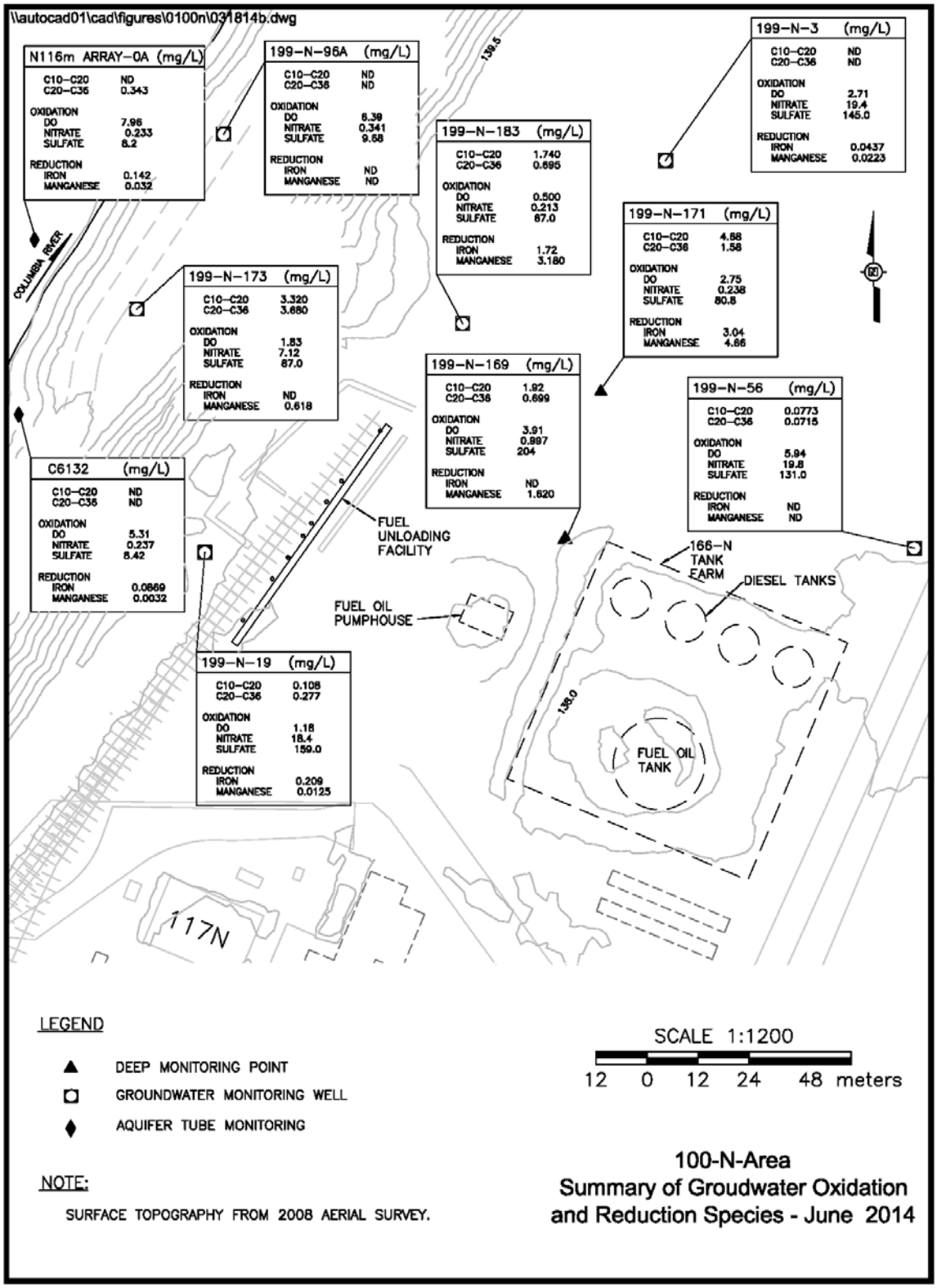


Figure 4-1. Summary of Groundwater Oxidation and Reduction Species, June 2014

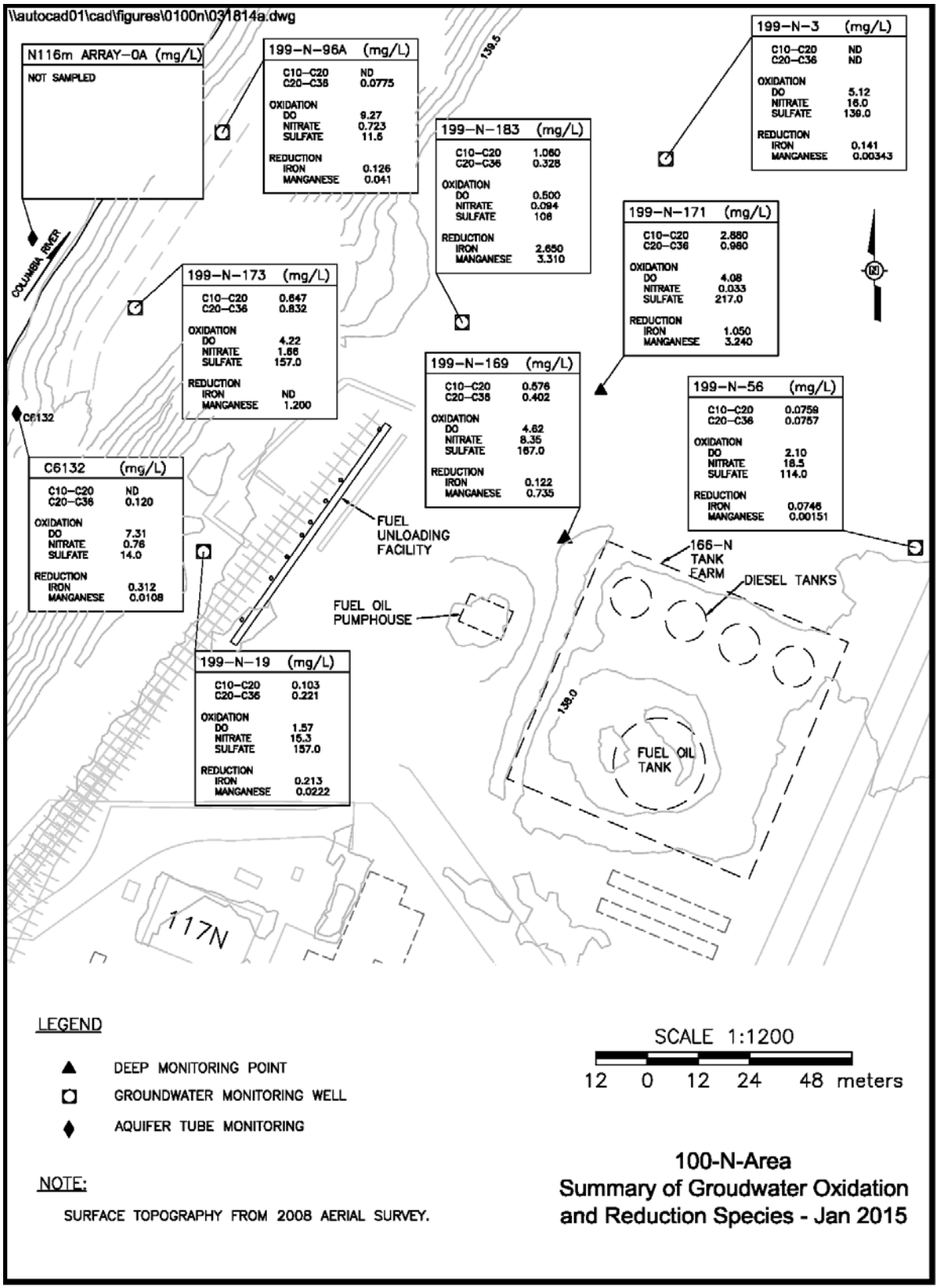


Figure 4-2. Summary of Groundwater Oxidation and Reduction Species, January 2015

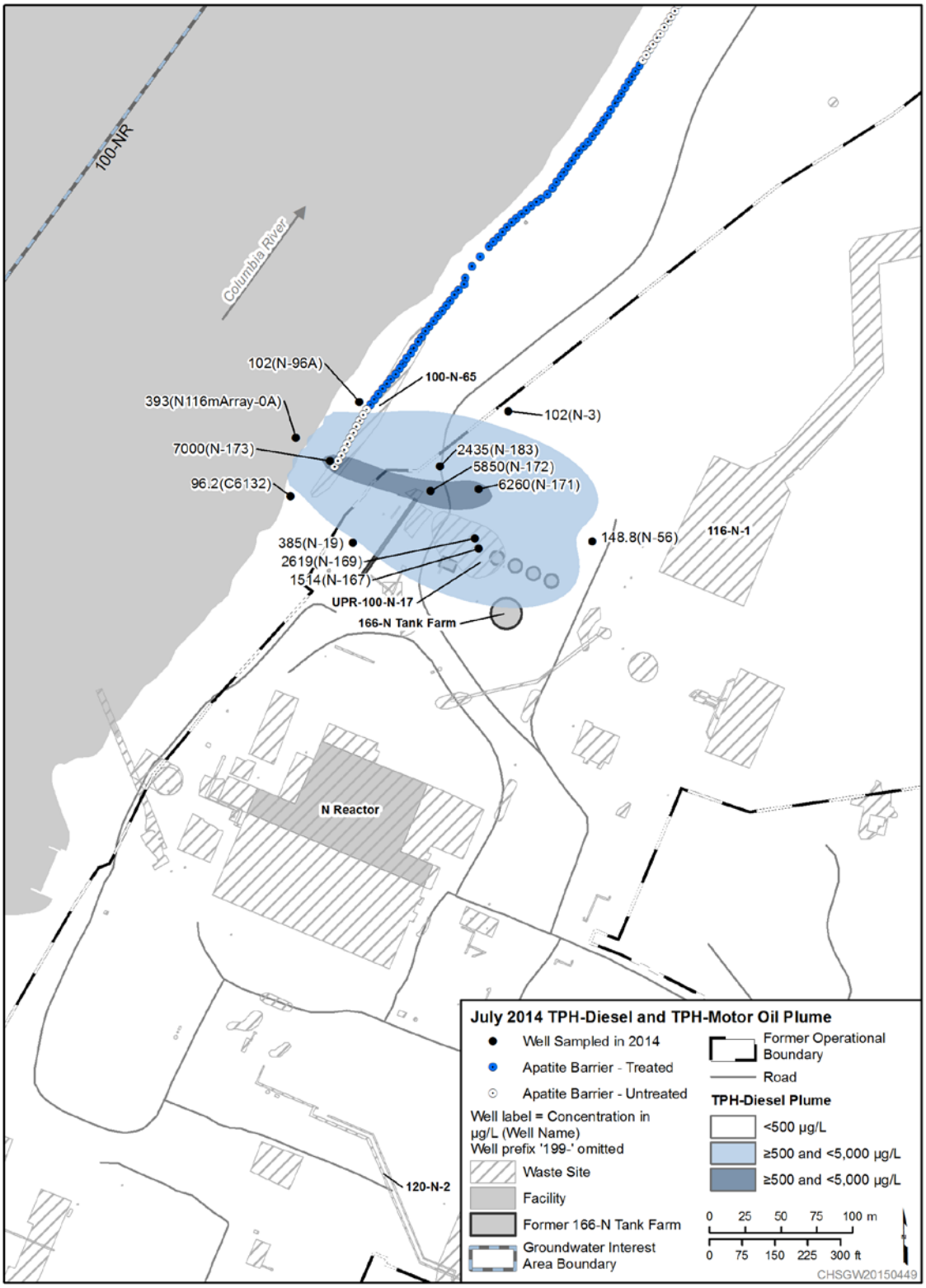


Figure 4-3. Petroleum Plume Distribution in Groundwater at the 100-NR-2 OU, July 2014

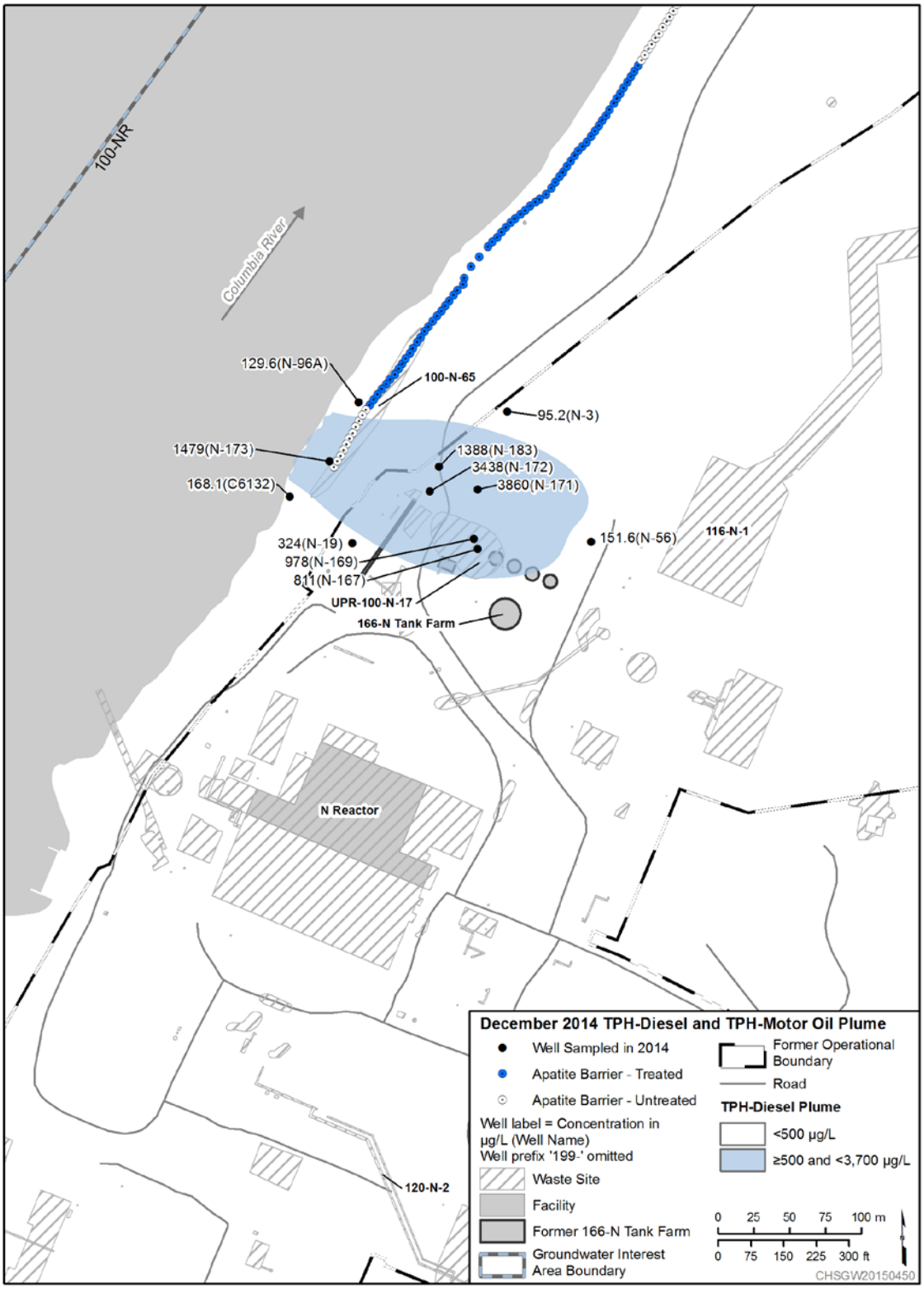


Figure 4-4. Petroleum Plume Distribution in Groundwater at the 100-NR-2 OU, December 2014

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5 Supplementary Information

In January 2014, three petroleum-contaminated soil samples collected in 2009 from the deep vadose zone were submitted for laboratory analysis of extractable petroleum hydrocarbon (EPH). The three samples were collected during drilling of the bioventing wells and were archived at the CHPRC geotechnical library. At the time of drilling, the EPH method was not available and only gasoline-, diesel-, and motor-oil-range petroleum analysis or total petroleum hydrocarbon (TPH) analysis were performed. The results of the 2009 testing are provided in WCH-370.

The EPH method provides detailed quantification of aromatic and aliphatic carbon fraction range hydrocarbons. This testing was performed for informational purposes and to support an evaluation of the laboratory's performance of the method in support of the investigation (WCH-604). Figure 5-1 shows the location of the samples, and Table 5-1 provides a summary of the results of the testing compared to the 2009 TPH results. Even though the samples were archived for 6 years, petroleum contamination is present in the samples. The data indicate that the majority of petroleum consists of the heavier fractions (C12 through C34) and predominantly the aliphatic hydrocarbons. This data may be useful in the future for evaluating partitioning of petroleum hydrocarbon fractions between soil and groundwater.

Table 5-1. Summary of Extractable Petroleum Hydrocarbon Results for Archived Soil Samples

Borehole	Depth (ft bgs)	2009 TPH (mg/kg)	Aliphatic Hydrocarbons (mg/kg)					Aromatic Hydrocarbons (mg/kg)				
			C8-C10	>C10-C12	>C12-C16	>C16-C21	>C21-C34	C8-C10	>C10-C12	>C12-C16	>C16-C21	>C21-C34
199-N-167	70	3200	0.978	ND	283	539	590	ND	ND	19.5	203	27.1
199-N-172	75	4100	4.52	108	1070	933	ND	ND	1.52	125	474	38
199-N-171	70	2200	1.02	ND	120	268	41.8	ND	ND	17.3	113	15

bgs = below ground surface
ND = not detected
TPH = total petroleum hydrocarbon

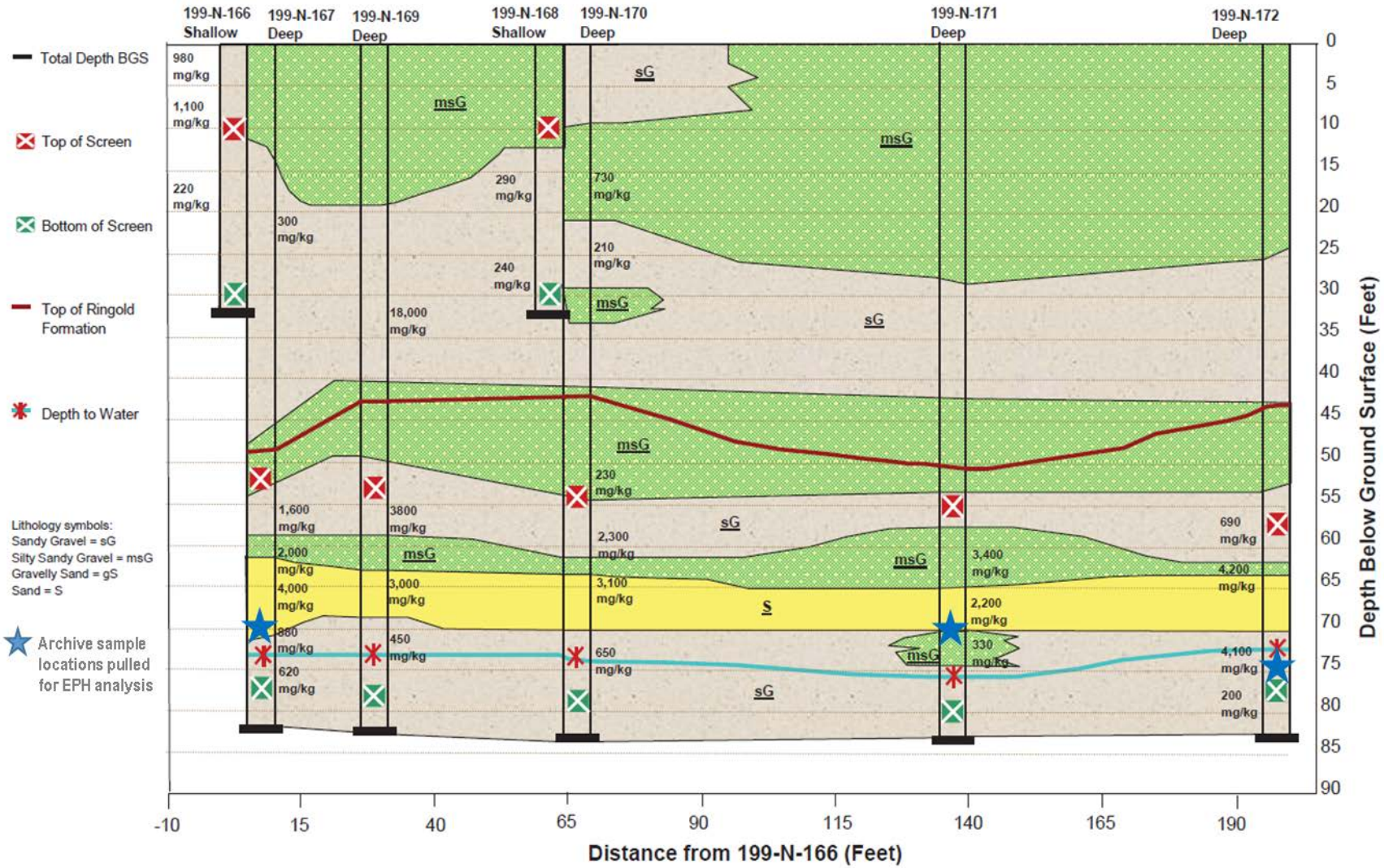

Figure 5-1. Locations of Samples Collected and Archived in 2009 and Submitted for Extractable Petroleum Hydrocarbon Analysis

6 Conclusions and Recommendations

As noted by Amec Foster Wheeler (Appendix A), the respirometry rates from the 2014 and January 2015 testing events are generally below the literature values for recommending bioventing as a viable option. However, there is clear evidence that oxygen is a limiting factor for microbial degradation of petroleum hydrocarbons in the deep vadose zone and that bioventing will help maintain this degradation, albeit at a somewhat low rate. Since groundwater remains locally impacted at the site and appears to act as an ongoing hydrocarbon source in the smear zone, bioventing will continue to be beneficial as a remedial action approach.

The following recommendations are made regarding system operations and performance monitoring for 2015:

- Pulse the bioventing system on a predetermined schedule (e.g., one week on, three weeks off). This operational protocol is expected to be sufficient to maintain oxygen levels in the subsurface while substantially reducing costs for power consumption. This suggested “on/off” regimen could be adjusted to match other scheduled field events, thereby keeping site visits to a minimum.
- Continue semi-annual respirometry testing to evaluate remediation progress and the effect of seasonal variability on the measured biodegradation rates.
- Coordinate semi-annual respirometry testing during high and low groundwater periods. Because of the relatively low respirometry rates measured in the most recent tests, future testing should be conducted over a period of four to six weeks.
- Coordinate groundwater sampling in the area of the plume to measure petroleum hydrocarbon concentrations.
- Consider the evaluation of soil samples at the site to verify achievement of cleanup criteria with respect to hydrocarbons in soil.
- Consider the collection of soil samples to the southwest of Wells 199-N-167, 199-N-169, and 199-N-171 to evaluate whether significant petroleum mass is located along the fringe of the system influence. A new well (199-N-377) is planned to be drilled in this area to provide a new groundwater monitoring location and define a lateral upriver boundary of the groundwater TPH plume. The sampling plan for this well includes analysis for TPH, EPH and polycyclic aromatic hydrocarbons (PAHs) from soil samples collected during drilling to characterize residual petroleum contamination remaining in the deep vadose zone beneath the remediated 100-N-84:2 pipeline excavation.
- Consider the use of an alternate treatment technology (e.g., sparging) to treat hydrocarbon-impacted groundwater and saturated zone soils in order to accelerate the overall cleanup time frame. Converting the bioventing system to a combined bioventing/biosparging system is feasible and would be expected to maintain elevated oxygen concentrations in both the saturated and vadose zones. Testing of such a system would be necessary to determine how large the radius of influence would be within the saturated zone.

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Appendix A

June – July 2014 Respirometry Testing

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Project Engineer/STR

8-7-14

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WCH-DE-032 (02/13/2014)

Technical Memorandum

To: Wendy Thompson, WCH
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Project Number: 361M12034
Cc: Ernest Biebrich, WCH
Abby Bazin, AMEC
Craig Weber, AMEC
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Date: July 28, 2014

Subject: Summary of June to July 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

AMEC Environment & Infrastructure, Inc. (AMEC) has prepared this technical memorandum for Washington Closure Hanford (WCH) to summarize the results of the June to July 2014 in-situ respiration test performed at the subsurface bioventing remediation system located at the 100-N Hanford DOE Site in Benton County, Washington. Since startup in November 2012, the bioventing system has been configured to supply bioventing air to two injection wells: 199-N-167 and 199-N-172. Approximately 250 cubic feet per minute (cfm) of air is routed to each well through a custom fitted wellhead. Based on previous studies, it is predicted that the radius of influence (ROI) for each injection well is at least 200 feet. The system has been in operation continuously since startup, except for periodic short-term shutdowns for maintenance and respirometry test events.

Testing was conducted in accordance with the procedures detailed in the Revised Subsurface Respirometry Test Plan dated May 21, 2014 and revised June 4, 2014, with exceptions as noted below. Respiration testing was initiated by turning off the bioventing system blower on June 3, 2014, at 8:00 am. Gas composition samples were then collected periodically, starting immediately after shut down and continuing through test completion on July 8, 2014. Prior to restarting the system on July 8, 2014, AMEC performed an annual inspection of the bioventing system. The annual Operations & Maintenance (O & M) inspection documentation is provided as Attachment 1 to this memorandum. When the bioventing system was restarted following the inspection, only two of the three blowers were powered back on. The system was designed to run three blowers to three injection wells. Running all three of the blowers at the same time into only two wells could increase the back pressure and generate more heat in the CONEX building, potentially causing the system to shut down. AMEC recommends that the system be run with one blower powered on for each well receiving injected air in order to alleviate this issue and to comply with the original scoping for the bioventing system.

During the respiration resting, soil gas samples were collected and analyzed for oxygen, carbon dioxide, methane, and total volatile hydrocarbons (TVH) from six monitoring locations:

- 199-N-167,
- 199-N-169,
- 199-N-171,
- 199-N-172,
- 199-N-183, and
- 199-N-18.

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Sixteen samples were collected from each of the six monitoring locations on a predetermined schedule over a period of approximately 840 hours (5 weeks). Readings were collected frequently for the first 48 hours (at approximately 0, 1.5, 3, 4, 6, 8, 10, 24, 36, and 48 hours) and daily through 144 hours (at approximately 72, 96, 120, and 144 hours). The 144 hour readings at each well had stabilized to less than 1% change since the previous reading; therefore, daily readings were discontinued at that time. The bioventing system then remained off, and a follow-up sampling event occurred at 481 hours. Although not proposed in the test plan, the bioventing system was allowed to remain off for an additional two weeks, to confirm the trends of oxygen utilization and degradation rates as ambient conditions were re-established. A final follow-up sampling event occurred at 840 hours (approximately 15 days after the 481 hours readings; and approximately 35 days after the initial system shutdown). Daily field reports and field measurements are included as Attachment 2, and instrument calibration sheets are included as Attachment 3.

Purge times required to achieve the minimum of one casing volume of air to be extracted prior to monitoring were calculated in the field by the technician, using the pump curve for the purge pump to estimate the actual rate of purging. Primary samples were collected by attaching Tedlar bags to the discharge of the vacuum pump, and then readings were collected by attaching the direct reading instrument to the Tedlar Bag sample port. For quality assurance (QA) purposes, direct readings were also taken during selected events by attaching the direct reading instruments to the discharge of the vacuum pump. Direct read values were generally similar to readings collected using the Tedlar bags. Readings in 199-N-171 exhibited more frequent disparity, and the largest differences were noted during the final sampling round. Only the readings collected using the Tedlar bags were utilized in the oxygen utilization and biodegradation rate calculations for this report.

The AFCEE (2004) guidance document was followed for interpretation of results and calculating oxygen utilization and biodegradation rates. Oxygen utilization rates for each monitoring point were determined from the slope of the line obtained by plotting the measured oxygen concentration verses time for each monitoring point. Oxygen utilization rates are presented in Table 1, and supporting data, calculations, and graphs of the data are included as Attachment 4.

Biodegradation rates were calculated using the following equation:

$$\boxed{K_b = \frac{-k_o\ \theta_a\ \rho_{O2}\ C \times 0.01}{\rho_k}}$$

Where (calculated or assumed values for the Site follow each description):

- K_b: biodegradation rate calculated in mg hydrocarbon consumed per kg of soil per day
- k_o: oxygen utilization rate calculated for each monitoring point in $\%O_2$ consumed per day
- θ_a: gas-filled pore space (volumetric content at the vapor phase) = 0.19 cm^3 gas/cm^3 soil (based on measured value)
- ρ_{O2}: density of oxygen; assumed soil temp of 50F = 1,378 mg/L (AFCEE 2004)

- C: mass ratio of hydrocarbons to oxygen required for mineralization (calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20}$+ $15O_2$ => $10CO_2$ + $10H_2O$) = 0.29
- ρ_k: soil bulk density; measured value = 1.736 g/cm^3 (measured value)
- θ: total porosity (where $\theta = 1 - \rho_k/\rho_T$) = 0.22 cm^3/cm^3 (based on measured value)
- θ_w: water filled porosity (where $\theta_w = M*\rho_k/\rho_T$) = 0.04 cm^3/cm^3 (based on measured value)
- ρ_T: soil mineral density; assumed value = 2.65 g/cm^3
- M: moisture content; 3.13% (measured value) = 0.0313 g moisture per g soil

The values for soil bulk density (1.736 g/cm^3) and moisture content (3.13%) are based on the average of two representative soil samples collected from well 199-N-183 at depth intervals of 53-55 feet and 63-65 feet below ground surface (bgs), as presented in Attachment 4 and described in detail in AMEC (2014). Calculations prior to January 2014 were made using the bulk density (2.063 g/cm^3) measured from a single soil sample collected from 58-60 feet bgs in 199-N-183. The updated soil bulk density value of 1.736 g/cm^3 is considered more representative of the overall site lithology. The values for θ_a, θ, and θ_w from all of the monitoring events were adjusted using the updated bulk density value.

Calculated biodegradation rates and baseline measurements of oxygen are presented in Table 1. During the respiration test, methane and TVH were detected throughout the test at all the monitoring points at low level concentrations. The highest concentrations of both constituents, TVH at 8.3 parts per million (ppm) and methane at 26.51 ppm, were detected in 199-N-171; these results exhibit a decrease in maximum values detected as compared to concentrations from the January 2014 test.

Table 1: Soil Gas Monitoring Results, Oxygen Utilization and Biodegradation Rates Calculated from In-Situ Respiration Testing

Monitoring Point	Baseline Oxygen (%)	Oxygen Utilization (%/day)	Biodegradation Rate (mg/kg-day)
199-N-167	20.9	0.08	-0.06
199-N-169	20.9	0.12	-0.09
199-N-171	20.7	0.12	-0.09
199-N-172	21.1	0.03	-0.02
199-N-183	21.1	0.02	-0.01
199-N-18	21.1	0.01	-0.01

Baseline oxygen concentrations were near atmospheric levels in all six monitoring locations. The oxygen consumption rates are very low at all six wells tested, with the highest consumption rates being observed at the southeast monitoring wells (199-N-167, 199-N-169, and 199-N-171) and the lowest consumption rates being observed in the northwest monitoring wells (199-N-172, 199-N-183, and 199-N-18). Higher oxygen utilization values are commonly recorded in soils with higher levels of hydrocarbon contamination which support larger populations of bacteria. Comparing oxygen utilization rates in wells across the site indicates that if significant residual vadose zone contamination remains at the site, the likely location would be nearer to monitoring wells 199-N-167, 199-N-169, and 199-N-171 (the more southeastern wells), rather than near monitoring wells 199-N-172, 199-N-183, and 199-N-18.

It has been observed during prior excavation and test-pitting activities at the site that petroleum contamination remains beneath the base of an excavation located approximately 100 feet to the southwest of 199-N-167 and 199-N-169. Test Pit #4, completed in this area, was found to contain diesel and motor oil range petroleum hydrocarbons to a depth of at least 31 feet below ground surface (Thompson, 2014). While the increased biodegradation activity observed in the southeastern wells (primarily 199-N-167 and 199-N-169) does not indicate that hydrocarbon mass is present further to the south/southwest, the existence of a hydrocarbon mass beneath the Test Pit #4 area would be consistent with the increased biological activity detected in the nearest monitoring wells.

Table 2 presents a comparison of the 2010 (pilot test) (AMEC, 2010), December 2012 (AMEC 2012), January 2014 (AMEC, 2014), and June to July 2014 testing data. Data from March 2010 and December 2012 were recalculated using a soil bulk density of 1.736 g/cm^3 and a moisture content of 3.13% for comparison to the 2014 biodegradation rate calculations. The biodegradation rates continue to show a significant decline from the initial rates measured in 2010.

The summer (June to July 2014) respirometry test was completed during seasonally high groundwater levels. Water level data (provided to AMEC by WCH; collected on June 17, 2014) ranged from 69.86 to 71.47 feet below the measuring point for all wells in this test program, with the exception of 199-N-18 which was not gauged. As compared to the winter (January 2014) test, biodegradation rates are slightly higher on average during the summer test event, indicating that seasonal fluctuations may be affecting biodegradation at the site. The January 2014 sampling event was conducted over a period of one week, in comparison to the five week test performed during June to July 2014. The extended test program provides more robust trends, and the June to July 2014 data generally exhibited higher R-squared values, a measure of goodness-of-fit of linear regression. The data from the extended sampling program provides more reliable biodegradation rate calculations. Groundwater sampling at the site indicates that elevations of impacted groundwater vary significantly over time, resulting in a smear zone that is likely to be several feet thick. Bioventing will be most effective when groundwater elevations are low and this smear zone is exposed.

Table 2: Comparison of Biodegradation Rates over Time Calculated from In-Situ Respiration Testing

Monitoring Point	Biodegradation Rate (mg/kg-day)			
	Jul. 2014	Jan. 2014	Dec. 2012	Mar. 2010
199-N-167	-0.06	-0.01	-0.15	-0.99
199-N-169	-0.09	-0.07	-0.28	-0.97
199-N-171	-0.09	-0.05	-9.82	-0.37
199-N-172	-0.02	-0.01	-0.14	-0.54
199-N-183	-0.01	-0.09	not tested	not tested
199-N-18	-0.01	-0.01	not tested	not tested

A number of variables could be responsible for the decrease in biodegradation indicated, the most obvious being that the bio-available hydrocarbon food source in the treatment zone has been reduced to levels that no longer support significant biological activity. The availability of hydrocarbons in vadose zone soils can only be determined by soil sampling. Changes in subsurface conditions such as temperature, moisture, and/or nutrient availability may also have impacted the rates shown, though one would expect only minor fluctuations in temperature and

moisture at these depths. High groundwater table elevations may also be contributing to low biodegradation rates because less of the smear zone is exposed to be treated by bioventing.

Oxygen utilization results observed in well 199-N-18 were extremely low for both respirometry tests during which it was used as a monitoring well. The well construction information indicates that the eight-inch carbon steel casing has perforations from 12 to 78 feet deep, with a telescoping six-inch stainless steel 10 slot screen installed from 58.5 to 79. Since the well casing has perforations beginning at 12 feet deep, the gas composition samples collected from this well are likely heavily influenced by the shallow subsurface and not representative of deeper vadose zone activity.

Estimating Time-frame for Site Closure

This section presents an update to the estimated time-frame for site closure as discussed in AMEC, 2014. The exercise to estimate a time-frame necessary to achieve regulatory closure of the site is straightforward, though it relies on specified assumptions regarding the level of contamination present, the cleanup goal, and the biodegradation rate to apply to the affected area. The most recent information on the level of total petroleum hydrocarbon (TPH) contamination is from subsurface samples collected in early 2009 when wells 199-N-166, -167, -168, -169, -170, -171, and -172 were drilled (Gamon, 2009). As shown in Figure 5 of Gamon (2009), the bulk of the hydrocarbon contamination was present from 60 feet bgs to 72 feet bgs in the five deep borings. One sample from well 199-N-169 at 35 feet bgs reported a TPH result of 18,000 mg/kg; however, the report identified this as a probable erroneous result. Excluding that sample result, the next highest concentration detected was 4,400 mg/kg at 65 feet bgs in 199-N-167. The average concentration of the samples collected within the smear zone interval (55 to 72 feet bgs) was approximately 3,000 mg/kg.

The cleanup standard for TPH in soil at the Hanford site is currently set at 200 mg/kg per the 1999 Interim Action Record of Decision (ROD). Current Washington State regulations allow TPH cleanup standards of 2,000 mg/kg unless modified to address the potential for NAPL to migrate to groundwater.

Finally, the rates of biodegradation provided in Table 2 above, range from a high of 9.82 mg/kg-day (199-N-171 Dec. 2012) to a low of 0.01 mg/kg-day in several wells recently tested. The rates have clearly declined since 2010, when the average of the four wells tested was 0.72 mg/kg-day. The average biodegradation rate during the June to July 2014 testing (excluding well 199-N-18) was 0.05 mg/kg-day. In the following table, the time to achieve cleanup at the site is presented for several scenarios.

Table 3. Various Scenarios for Estimating Time-frame to Reach Cleanup Standards

Scenario ID	Assumed concentration of TPH in Soil Throughout Treatment Zone (mg/kg)	Cleanup Std. for TPH (mg/kg)	Concentration Reduction to Meet Std. (mg/kg)	Biodegradation Rate (mg/kg-day)	Time to Achieve Cleanup (yrs)
1	3,000	200	2,800	-9.82	0.78
2	3,000	200	2,800	-0.72	10.6
3	3,000	200	2,800	-0.05	153
4	3,000	2,000	1,000	-9.82	0.3
5	3,000	2,000	1,000	-0.72	3.8
6	3,000	2,000	1,000	-0.05	55

As shown in Table 3, there is wide variation in the estimated time to reach cleanup at the 100-N site depending upon the variables chosen for the calculation. The slight increase in average biodegradation rate for the June to July 2014 test (0.05 mg/kg-day) as compared to the January 2014 test (0.04 mg/kg-day) results in a slight decrease in the time to achieve cleanup for Scenario 3 (153 years as compared to 190 years) and Scenario 6 (55 years as compared to 68 years). The significant decline in degradation rates found in the 2014 test events suggest that the mass of hydrocarbons available for microbial degradation have decreased substantially since the initial round of biovent testing in 2010, and that the estimated timeframe for cleanup lies on the low end of the possible scenarios. The most likely scenario is that biodegradation rates were high in the early stages of the bioventing process and hydrocarbon concentrations declined significantly during this time. Biodegradation rates are decreasing over time; however, hydrocarbon concentrations have also declined as a result of biodegradation, resulting in a shorter time to achieve cleanup than the most conservative scenario shown. The actual time to achieve cleanup is likely to fall within the ranges listed. This estimate does have some additional uncertainty, due to the fact that it is not currently known if a reservoir of petroleum exists along the southern fringe of influence of the bioventing system. If such a reservoir exists, it could be influencing testing results.

Summary and Recommendations

The results from the 2014 testing would generally not support the continuation of bioventing as a remedial alternative. However, groundwater remains impacted at the site and is likely to act as an ongoing hydrocarbon source in the smear zone. In order to address the ongoing impacts to the smear zone and potentially speed groundwater cleanup, AMEC is recommending the following actions in 2014 at the site:

- Pulse the bioventing system on a predetermined schedule, such as one week on, three weeks off. This operational protocol is expected to be sufficient to maintain oxygen levels in the subsurface, while substantially reducing costs for power consumption. This suggested on/off regimen could be adjusted to match other scheduled field events, thereby keeping site visit costs to a minimum.

- Conduct an additional respirometry test in the fall of 2014 to continue to evaluate the effect of seasonal variability on the degradation rates measured – specifically as they relate to the river stage and its impacts on the groundwater elevation at the site.

- During future respirometry tests, allow the bioventing system to remain “off” for a minimum of two weeks and up to four weeks after the initial week of testing concludes, and perform additional gas composition sampling rounds every two weeks. This procedure provides confirmation of the low degradation rates as ambient conditions are re-established.

- Consider excluding 199-N-18 from future respirometry testing due to the shallow casing perforations in the well. Consider sampling an alternate monitoring well with a more appropriate well design for testing of the deeper vadose zone.

- Consider the collection of soil samples at the site to verify achievement of cleanup criteria with respect to hydrocarbons in soil.

7

- Consider the collection of soil samples to the southwest of 199-N-167, 199-N-169, and 199-N-171 to evaluate whether significant petroleum mass is located along the fringe of system influence.

Attachments:

Attachment 1 – Annual O & M Inspection
Attachment 2 – Daily Field Reports and Field Measurements
Attachment 3 – Instrument Calibration Sheets
Attachment 4 – Design Worksheet for Oxygen Utilization and Biodegradation Rates

References

Air Force Center for Environmental Excellence (AFCEE). 2004. Procedures for Conducting Bioventing Pilot Tests and Long-Term Monitoring of Bioventing Systems. May.

AMEC Environment & Infrastructure, Inc. (E&I). 2014. Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site. February 7.

AMEC E&I. 2012. Technical Memorandum, Summary of Respiration Testing Results for the Startup of the Bioremediation System at the N100 Bioremediation Site. December 12.

AMEC Geomatrix. 2010. Technical Memorandum, Results Summary of In-situ Respiration Testing at the N100 Bioremediation Pilot Test Site. March 22.

Gamon, D. A. 2009. Bioremediation Well Borehole Soil Sampling and Data Analysis Summary Report for the 100-N Area Bioremediation Project (UPR-100-N-17). WCH-370, Rev. 0, Washington Closure Hanford, Richland, Washington. September.

Thompson, W.S. 2014. Work Instruction for Verification Sampling of the 100-N-84:2, 100-N Area Fuel and Foam Pipelines Waste Site, 0100N-WI-G0083, Rev. 0, Washington Closure Hanford, Richland, Washington. Appendix A, Test Pit Investigation Results. May.

ATTACHMENT 1
Annual O & M Inspection

Hanford Bioventing System

Annual Inspection

Technician(s): Paul Stull / Jason Gardner Date: July 8, 2014 Arrival Time: 07:30 Departure Time: 12:50

System Status (Operations and Alarms) Upon Arrival at Site: System was entirely off-line – controls set all blowers to "Off" Mode

CONEX Temperature: 108F inside 104F outside

BRS Operating Data

	Blower A	Blower B	Blower C	Blower D	Comments
Running on arrival?	Y (N)	Y (N)	Y (N)	Y N —	Blower D is future
Blower Mode (circle one):	(On) Off Hand	(On) Off Hand	On (Off) Hand	On Off Hand	Mode at departure
Control Panel Reading-- Back Pressure (in. WC):	56	57	0	—	Blowers A/B in Auto Mode
Gauge Reading-- Back Pressure (in. WC):	57	59	0	—	
If Greater than 60, was filter inspected?	Y N	Y N	Y N	Y N	N/A - See below
Running at Departure?	(Y) N	(Y) N	Y (N)	Y N —	

	Well 1	Well 2	Well 3	Well 4
Air Flow (cfm)	200 - 270	Closed	Closed	200 - 270

Maintenance needed on future visit: 1) Replace Sensaphone 2000 NiCad batteries during Oct 2014 visit, as necessary

Monthly Inspection Performed?	Yes/No (Circle One)
Inspection of Pipe Fittings / Couplers / Power Cable / Etc (Interior and Exterior)	(Y)/N
Inspection/Replacement of Blower Filters	(Y)/N
Monitoring/Adjustments of System Pressures	(Y)/N
Monitoring / Switching Blowers	(Y)/N

Quarterly Inspection Performed?	Yes/No (Circle One)
Inspection of Wells	(Y)/N
Inspection of CONEX Box Outlets, Lights, Fan, Alarms	(Y)/N
Replace Sensaphone Batteries at Least Annually	**Replaced? Yes/(No)**

Note Any Maintenance Issues Encountered

Notes:

1) Discussed gate valve replacement with cam-lock plug to alleviate well dead head issue with Art.
2) Exterior hoses are functional but showing signs of UV impact. Replacement hose is inside CONEX.
3) Interior lights all working.
4) Inspected all air filters (A/B/C) for all three blowers. Recommend replacing filters at Oct. or Dec. 2014 inspection events, unless needed earlier.
5) Pre-bleed gauge = 57" WC
   Post-mainfold gauge = 57" WC
6) Well #1 – 199-N-167
   Well #4 – 199-N-172
7) CONEX fan thermostat set to 75°F - working

ATTACHMENT 2
Daily Field Reports and Field Measurements

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/2/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:
6/1/2014	- Prep and travel to Richland
6/2/2014	
06:00	- Travel to Fermi bldg to get badged and for Tyler to take Hanford training
08:00	- Testing and badging done for Tyler. Travel to Hanford Bio vent system.
09:00	- Performed JSHA and Pre-Ev meeting with Bio-vent crew and management.
10:30	- Finished preop meeting then did preop job walk. Then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	361M12034.001.01	Date:	6/3/2014
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial):	jg	AMEC Project Manager (Initials):	JK
Weather Conditions:			

FIELD REPORT NOTES

Time:	Field Notes:
6/3/2014	
07:00	- Pre ev meeting then set up for resp test start.
08:00	- Bio-vent blowers off, started test.
08:27	- Site vac pump over heated due to high amp draw. Replaced with spare unit.
19:02	- Finished first day testing. Picked up equipment then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/4/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

6/4/2014 Morning readings

07:30 - Pre ev meeting then set up for resp test start with Mike Self, Nick Holland, Tyler Marley and myself.
08:00 - Started test at 199-N-167.
09:00 - Finished test at 199-N-18 after testing 6 points.
10:00 - Demobed equipment signed out then off site. Tyler off site to Portland.

6/4/2014 Evening readings

19:30 - Met on site for pre ev and system set up.
19:56 - Started test on 199-N-167.
21:11 - Finished test at 199-N-18 after testing 6 points.
21:30 - Demobed equipment signed out then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/5/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

6/5/2014 Morning readings

07:30 - Pre ev meeting no longer needed then set up for resp test start with Mike Self, Nick Holland and myself.
08:00 - Started test at 199-N-167.
09:36 - Finished test at 199-N-18 after testing 6 points.
10:20 - Demobed equipment signed out then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/6/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

6/6/2014 Morning readings

07:30 - On site then set up for resp test start with Mike Self, Nick Holland and myself.
08:00 - Started test at 199-N-167.
09:19 - Finished test at 199-N-18 after testing 6 points.
09:30 - Demobed equipment signed out then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/7/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

6/7/2014 Morning readings

07:45 - On site then set up for resp test start with Richard Mattson, Nick Holland and myself.
08:00 - Started test at 199-N-167.
09:19 - Finished test at 199-N-18 after testing 6 points.
09:30 - Demobed equipment signed out then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/8/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

6/8/2014 Morning readings

07:30 - On site then set up for resp test start with Mike Self, Jerry and myself.
08:00 - Started test at 199-N-167.
09:19 - Finished test at 199-N-18 after testing 6 points.
09:30 - Demobed equipment signed out then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/9/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

6/9/2014 Morning readings

07:30 - On site then set up for resp test start with Mike Self, Jerry and myself.
08:00 - Started test at 199-N-167.
09:38 - Finished test at 199-N-18 after testing 6 points. We got the ok to terminate test from John Kuiper today or tomorrow dependant on the availability of a rad tech. If one wasn't available until tomorrow we will collect one more round of readings.
10:00 - Rich was able to acquire a rad tech for today so today's readings will be the last until the 23rd event.
10:20 - Rad tech on site. Mike Self conducted a "pre-ev" work meeting, then both wells (183 and 18) were scanned and cleared then manifolds were removed.
10:38 - Rad tech off site. Nick and I then cleaned up the bio-vent box and Mike performed an inventory for the system turn over.
12:15 - Bio-vent box cleaned out. Signed out then off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 6/23/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

6/23/2014 Morning readings

06:00 - Paul Stull and myself pick up badges at FERMI bldg.
07:20 - I am badged and off to 100N area. Paul has to retake on line course.
07:55 - On site. Began setup.
08:30 - Mike Self held pre-ev meeting prior to installing manifolds and have wells 183 and 18 and having them cleared by nuke tech.
09:00 - Paul Stull on site and finished set up.
09:02 - Started test on well 169.
09:24 - Vac pump over heated at the end of the test on well 171. Swapped out for other unit. New piump operates at a flow rate of 1.7 cu ft/min.
11:35 - Finished well gas sampling. Buttoned up wells and stored equipment in Bio-vent box.
12:30 - Off site.

g

Contractor's Rep. (Initials): N/A

Continued: N/A

DAILY FIELD REPORT

amec
Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 7/8/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial): jg	AMEC Project Manager (Initials): JK
Weather Conditions:	

FIELD REPORT NOTES

Time:	Field Notes:

7/08/2014 Morning readings

06:00 - Paul Stull and myself pick up badges at FERMI bldg.
07:10 - On site and signed in.
07:30 - At Bio-vent area and began setup. Did initial work scope meeting with Mike Self and Tracey, then got MW-18 and MW-183 collection headers ready for installation. Rad tech on site.
09:00 - Envircon personel Mike Oswald on site. Held pre-ev meeting prior to installing manifolds and have wells 183 and 18 and having them cleared by rad tech. Wells were screened for VOCs and rad and cleared for access. Installed manifolds.
09:15 - Attempted startup but inrush current popped gfci pigtail, reset and and started again. It popped once more. Following Hanford gfci guidelines unit was removed form use and another was dispatched to site by Rich Mattson.
10:00 - Rich on site with replacement gfci. Removed all airflow restrictions on vac pump and started unit without issues. Began extracting air from well 183.
12:16 - Finished well gas sampling. Buttoned up wells and stored equipment in Bio-vent box.
12:30 - Performed annual O and M on Bio-vent system.
13:15 - Off site.

Contractor's Rep. (Initials): N/A

Continued: N/A

ATTACHMENT 3
Instrument Calibration Sheets

Gas Detector Calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 361M120340.0001.01

Events: June 2-9, June 22, and July 7 2014 Completed By: Jason Gardner

Instrument name(s): GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Time	Warm up time	Gas	FID/PID readings	O2/CO2 Readings	Corrected readings
GEM O2	6/2/2014	20:00	30 min	zero air	n/a	20.80%	21.50%
GEM CO2	6/2/2014	20:00	30 min	15% CO2	n/a	14%	15%
TVA 1000	6/2/2014	20:00	30 min	zero air	0.36 ppm / 0.41 ppm	n/a	n/a
TVA 1000	6/2/2014	20:00	30 min	100 ppm Isob.	99.1 ppm (PID)	n/a	100 ppm
TVA 1000	6/2/2014	20:00	30 min	100 ppm Methane	99.7 ppm (FID)	n/a	100 ppm
GEM O2	6/4/2014	6:00	30 min	zero air	n/a	21.10%	22.00%
GEM CO2	6/4/2014	6:00	30 min	15% CO2	n/a	15%	15%
TVA 1000	6/4/2014	6:00	30 min	zero air	-0.01 ppm / -0.12 ppm	n/a	n/a
TVA 1000	6/4/2014	6:00	30 min	100 ppm Isob.	96.4 ppm (PID)	n/a	100 ppm
TVA 1000	6/4/2014	6:00	30 min	100 ppm Methane	97.6 ppm (FID)	n/a	99.7 ppm
GEM O2	6/5/2014	6:00	30 min	zero air	n/a	21.40%	21.70%
GEM CO2	6/5/2014	6:00	30 min	15% CO2	n/a	15%	15%
TVA 1000	6/5/2014	6:00	30 min	zero air	-0.22 ppm / 0.48 ppm	n/a	n/a
TVA 1000	6/5/2014	6:00	30 min	100 ppm Isob.	99.9 ppm (PID)	n/a	99.8 ppm
TVA 1000	6/5/2014	6:00	30 min	100 ppm Methane	99.2 ppm (FID)	n/a	100 ppm
GEM O2	6/6/2014	6:00	30 min	zero air	n/a	21.50%	21.90%
GEM CO2	6/6/2014	6:00	30 min	15% CO2	n/a	15%	15%
TVA 1000	6/6/2014	6:00	30 min	zero air	0.42 ppm / 0.16 ppm	n/a	n/a
TVA 1000	6/6/2014	6:00	30 min	100 ppm Isob.	99.6 ppm (PID)	n/a	100 ppm
TVA 1000	6/6/2014	6:00	30 min	100 ppm Methane	99.7 ppm (FID)	n/a	101 ppm
GEM O2	6/7/2014	6:00	30 min	zero air	n/a	20.90%	21.80%
GEM CO2	6/7/2014	6:00	30 min	15% CO2	n/a	15%	15%
TVA 1000	6/7/2014	6:00	30 min	zero air	-0.05 ppm / -0.15 ppm	n/a	n/a
TVA 1000	6/7/2014	6:00	30 min	100 ppm Isob.	104 ppm (PID)	n/a	100 ppm
TVA 1000	6/7/2014	6:00	30 min	100 ppm Methane	99.4 ppm (FID)	n/a	99.9 ppm

Gas Detector Calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 361M120340.0001.01

Events: June 2-9, June 22, and July 7 2014 Completed By: Jason Gardner

Instrument name(s): GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Time	Warm up time	Gas	FID/PID readings	O2/CO2 Readings	Corrected readings
GEM O2	6/8/2014	6:00	30 min	zero air	n/a	21.60%	21.80%
GEM CO2	6/8/2014	6:00	30 min	15% CO2	n/a	15%	15%
TVA 1000	6/8/2014	6:00	30 min	zero air	-1.49 ppm / -0.98 ppm	n/a	n/a
TVA 1000	6/8/2014	6:00	30 min	100 ppm Isob.	99.2 ppm (PID)	n/a	99.9 ppm
TVA 1000	6/8/2014	6:00	30 min	100 ppm Methane	99.7 ppm (FID)	n/a	103 ppm
GEM O2	6/9/2014	6:00	30 min	zero air	n/a	21.20%	21.90%
GEM CO2	6/9/2014	6:00	30 min	15% CO2	n/a	15%	15%
TVA 1000	6/9/2014	6:00	30 min	zero air	-0.55 ppm / -0.34 ppm	n/a	n/a
TVA 1000	6/9/2014	6:00	30 min	100 ppm Isob.	98.3 ppm (PID)	n/a	99.8 ppm
TVA 1000	6/9/2014	6:00	30 min	100 ppm Methane	99.2 ppm (FID)	n/a	99.6 ppm
GEM O2	6/22/2014	22:00	30 min	zero air	n/a	20.90%	21.90%
GEM CO2	6/22/2014	22:00	30 min	15% CO2	n/a	15%	15%
TVA 1000	6/22/2014	22:00	30 min	zero air	-3.46 ppm / -1.79 ppm	n/a	n/a
TVA 1000	6/22/2014	22:00	30 min	100 ppm Isob.	99.2 ppm (PID)	n/a	100 ppm
TVA 1000	6/22/2014	22:00	30 min	100 ppm Methane	99.7 ppm (FID)	n/a	99.8 ppm
GEM O2	7/7/2014	21:30	30 min	zero air	n/a	20.90%	21.90%
GEM CO2	7/7/2014	21:30	30 min	15% CO2	n/a	13%	15%
TVA 1000	7/7/2014	21:30	30 min	zero air	-0.63 ppm / 0.93 ppm	n/a	n/a
TVA 1000	7/7/2014	21:30	30 min	100 ppm Isob.	99.6 ppm (PID)	n/a	100 ppm
TVA 1000	7/7/2014	21:30	30 min	100 ppm Methane	99.7 ppm (FID)	n/a	101 ppm

ATTACHMENT 4
Design Worksheet for Oxygen Utilization and Biodegradation Rates

DESIGN WORKSHEET

Client: WCH
Project: Hanford 100-N Biovent
Data For: June to July 2014 Respiration Test

Date: 16-Jul-14
Project Number: 361m12034
Prepared by: K. Diller
Reviewed by: C. Weber

An in-situ respiration test was conducted at the Hanford Site 100-N from June to July 2014. Data collected from the field test is used to calculate oxygen utilization (k_o) and biodegradation rates (K_b). Calculations and results are presented below.

OXYGEN UTILIZATION RATE CALCULATION

Oxygen utilization rates (%/hour) are derived from the slope of the linear portion of the line when percent oxygen (y-axis) measured in the soil is plotted against time in hours (x-axis). See attached for data plots.

Location	O_2 Utilization (%/hour)	k_o O_2 Utilization (%/day)	R^2 value for linear curve fit
199-N-167	0.0035	0.08	0.957
199-N-169	0.0052	0.12	0.990
199-N-171	0.005	0.12	0.903
199-N-172	0.0012	0.03	0.174
199-N-183	0.0007	0.02	0.434
199-N-18	0.0005	0.01	0.139

BIODEGRADATION RATE CALCULATION

Biodegradation rates (K_b) are calculated for each of the monitoring points.

The Kb values below are calculated using updated site-specific soil bulk density and moisture content soil parameters, based on measured values from samples collected in the screen interval of 199-N-183. The biodegradation calculations for the 2010 and 2012 respiration test data have also been updated with these site-specific soil parameters.

Equation for biodegradation rate calculation:

$$K_b = \frac{-k_o \, \theta_a \, \rho_{o2} \, C \times 0.01}{\rho_k}$$

Parameters using site-specific measured values from 199-N-183 soil samples

θ_a =	0.32	cm^3 gas/cm^3 soil	Gas-filled pore space (volumetric content at the vapor phase); where $\theta_a = \theta - \theta_w$
ρ_{O2} =	1,378	mg/L	Density of oxygen; assuming 10°C (50°F) soil temperature reference value from AFCEE, 2004
C =	0.29	---	Mass ratio of hydrocarbons to oxygen required for mineralization; calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20} + 15O_2 \Rightarrow 10CO_2 + 10H_2O$
ρ_k =	1.736	g/cm^3	Soil bulk density; measured value from 199-N-183, average of bulk densities from samples 212 and 215
θ =	0.34	cm^3/cm^3	Total porosity; where $\theta = 1 - \rho_k/\rho_T$
θ_w =	0.02	cm^3/cm^3	Water filled porosity; where $\theta_w = M*\rho_k/\rho_T$
ρ_T =	2.65	g/cm^3	Soil mineral density; assumed value
M =	0.0313	g moisture /g soil	3.13% moisture content; measured value from 199-N-183, average of percent moisture from samples 212, 214, and 215

Note: Subsurface soil temperature is assumed to be constant year-round and temperature adjustments of oxygen utilization rates were not conducted. If temperatures are warmer in the summer months then oxygen utilization rates are expected to increase. Temperature changes are extremely unlikely for the deep well locations.

Location	Parameter	Jul-14	Jan-14	Dec-12	Mar-10	Units	Notes
199-N-167	K_o =	0.08	0.01	0.20	1.32	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.06**	**-0.01**	**-0.15**	**-0.99**	mg/Kg-day	Biodegradation rate; calculated value
199-N-169	K_o =	0.12	0.09	0.37	1.29	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.09**	**-0.07**	**-0.28**	**-0.97**	mg/Kg-day	Biodegradation rate; calculated value

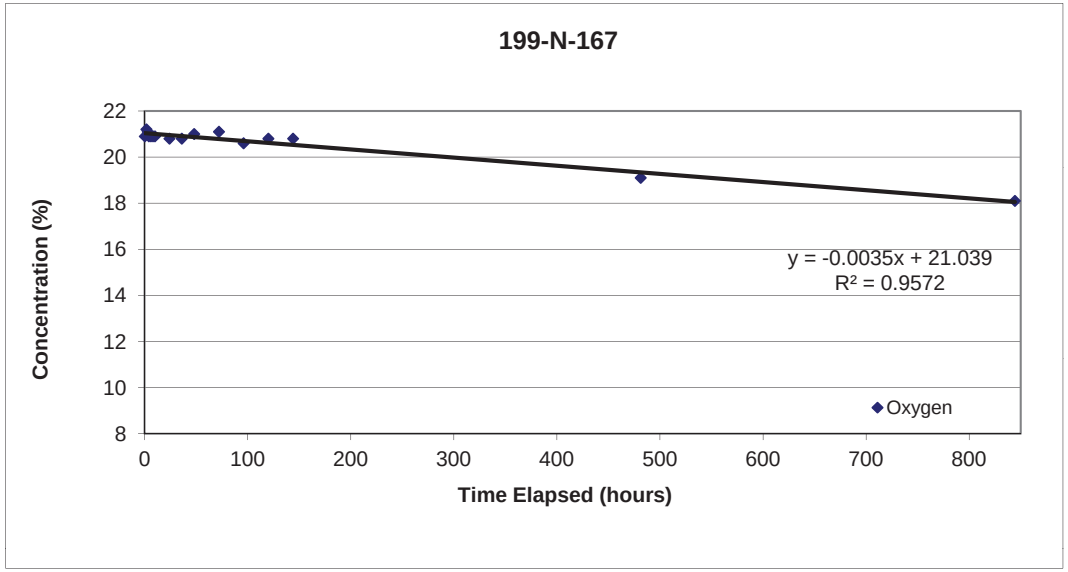
DESIGN WORKSHEET

Client: WCH
Project: Hanford 100-N Biovent
Data For: June to July 2014 Respiration Test

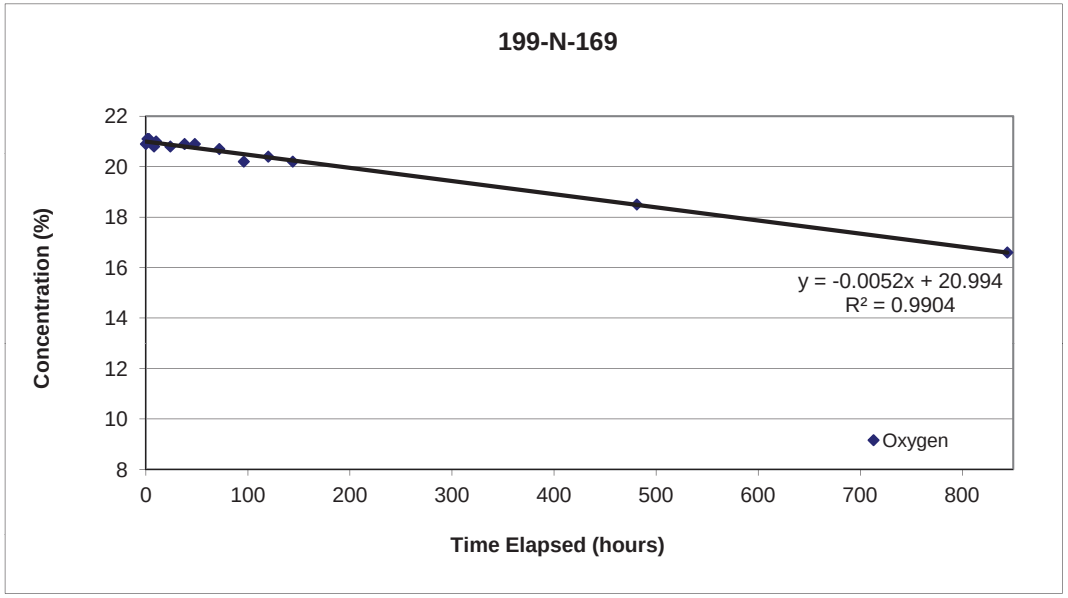
Date: 16-Jul-14
Project Number: 361m12034
Prepared by: K. Diller
Reviewed by: C. Weber

Location	Parameter	Jul-14	Jan-14	Dec-12	Mar-10	Units	Notes
199-N-171	K_o =	0.12	0.07	13.07	0.49	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.09**	**-0.05**	**-9.82**	**-0.37**	mg/Kg-day	Biodegradation rate; calculated value
199-N-172	K_o =	0.03	0.02	0.18	0.71	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.02**	**-0.01**	**-0.14**	**-0.54**	mg/Kg-day	Biodegradation rate; calculated value
199-N-183	K_o =	0.02	0.12	not tested	not tested	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.01**	**-0.09**	not tested	not tested	mg/Kg-day	Biodegradation rate; calculated value
199-N-18	K_o =	0.01	0.02	not tested	not tested	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.01**	**-0.01**	not tested	not tested	mg/Kg-day	Biodegradation rate; calculated value

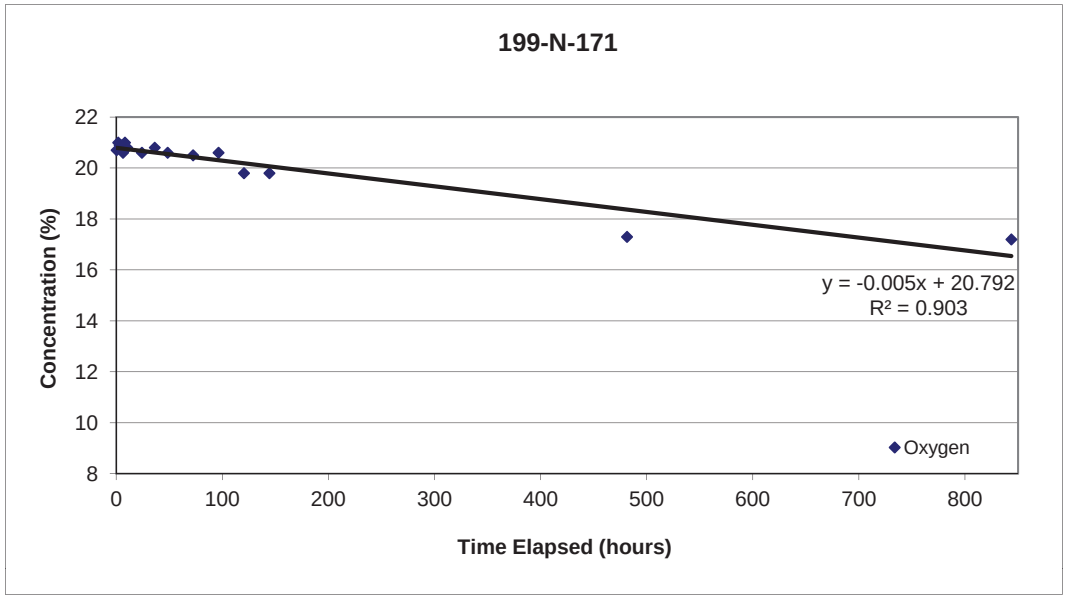
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	199-N-167 Oxygen %
6/3/14	8:00	blower off	--	--
6/3/14	8:11	0:11:00	0.18	20.9
6/3/14	9:44	1:44:00	1.73	21.2
6/3/14	11:01	3:01:00	3.02	21.1
6/3/14	12:07	4:07:00	4.12	20.9
6/3/14	14:07	6:07:00	6.12	20.9
6/3/14	16:06	8:06:00	8.10	20.9
6/3/14	18:05	10:05:00	10.08	20.9
6/4/14	8:04	24:04:00	24.07	20.8
6/4/14	20:01	36:01:00	36.02	20.8
6/5/14	8:06	48:06:00	48.10	21.0
6/6/14	8:09	72:09:00	72.15	21.1
6/7/14	8:04	96:04:00	96.07	20.6
6/8/14	8:03	120:03:00	120.05	20.8
6/9/14	8:02	144:02:00	144.03	20.8
6/23/14	9:15	481:15:00	481.25	19.1
7/8/14	12:14	844:14:00	844.23	18.1



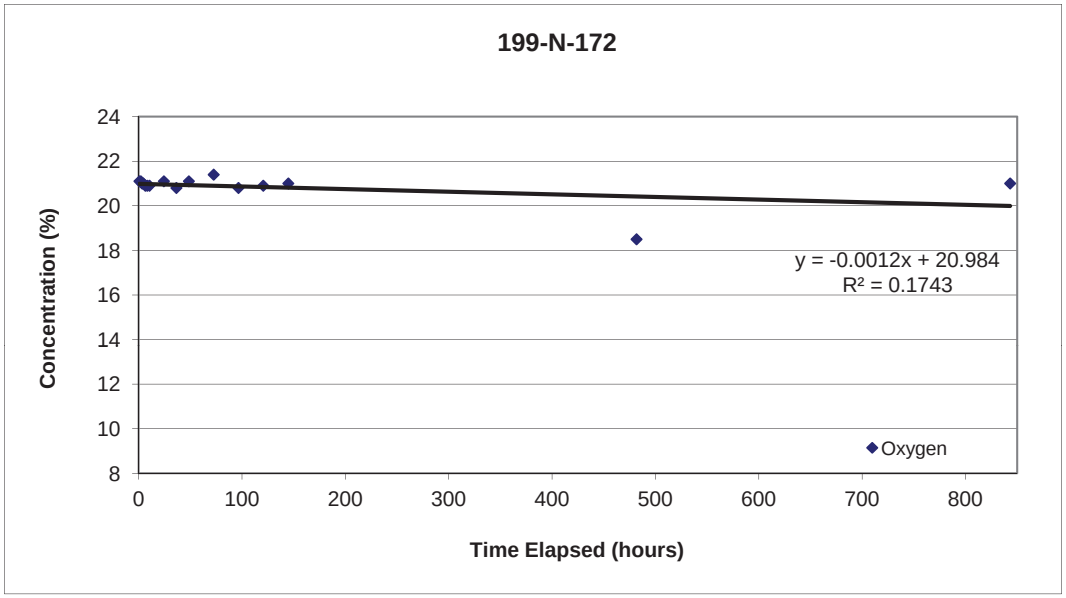
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	199-N-169 Oxygen %
6/3/14	8:00	blower off	--	--
6/3/14	8:00	0:00:00	0.00	20.9
6/3/14	9:34	1:34:00	1.57	21.1
6/3/14	10:55	2:55:00	2.92	21.1
6/3/14	12:03	4:03:00	4.05	21.0
6/3/14	14:01	6:01:00	6.02	20.9
6/3/14	16:00	8:00:00	8.00	20.8
6/3/14	18:00	10:00:00	10.00	21.0
6/4/14	8:00	24:00:00	24.00	20.8
6/4/14	21:56	37:56:00	37.93	20.9
6/5/14	8:00	48:00:00	48.00	20.9
6/6/14	7:57	71:57:00	71.95	20.7
6/7/14	7:57	95:57:00	95.95	20.2
6/8/14	7:56	119:56:00	119.93	20.4
6/9/14	7:56	143:56:00	143.93	20.2
6/23/14	9:02	481:02:00	481.03	18.5
7/8/14	12:06	844:06:00	844.10	16.6



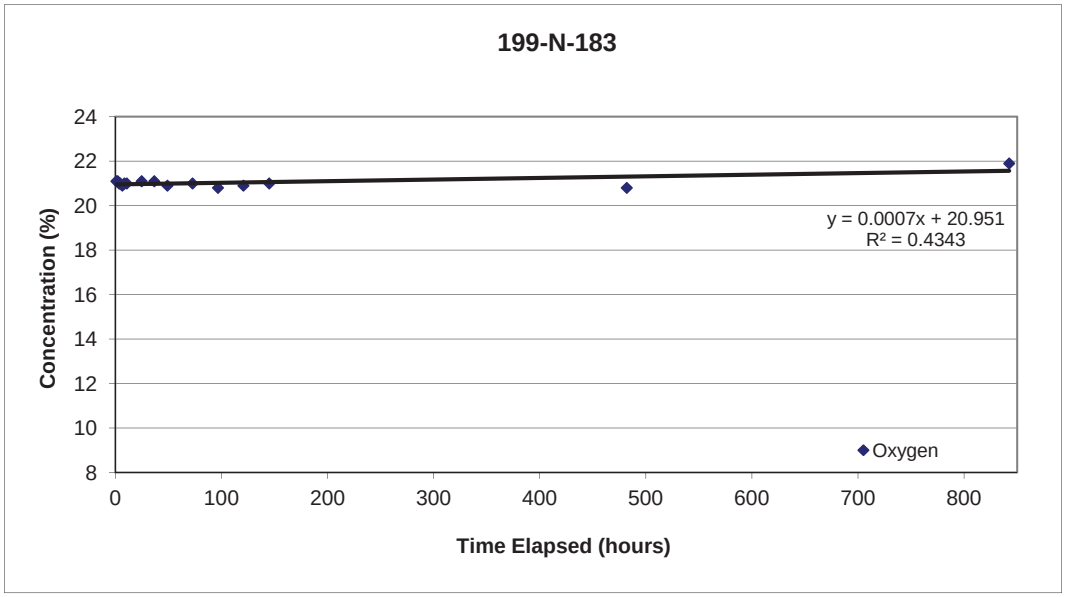
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	199-N-171 Oxygen %
6/3/14	8:00	blower off	--	--
6/3/14	8:22	0:22:00	0.37	20.7
6/3/14	9:52	1:52:00	1.87	21.0
6/3/14	11:11	3:11:00	3.18	20.9
6/3/14	12:14	4:14:00	4.23	20.9
6/3/14	14:18	6:18:00	6.30	20.6
6/3/14	16:12	8:12:00	8.20	21.0
6/3/14	18:13	10:13:00	10.22	20.8
6/4/14	8:12	24:12:00	24.20	20.6
6/4/14	20:17	36:17:00	36.28	20.8
6/5/14	8:22	48:22:00	48.37	20.6
6/6/14	8:22	72:22:00	72.37	20.5
6/7/14	8:23	96:23:00	96.38	20.6
6/8/14	8:19	120:19:00	120.32	19.8
6/9/14	8:20	144:20:00	144.33	19.8
6/23/14	9:24	481:24:00	481.40	17.3
7/8/14	11:40	843:40:00	843.67	17.2



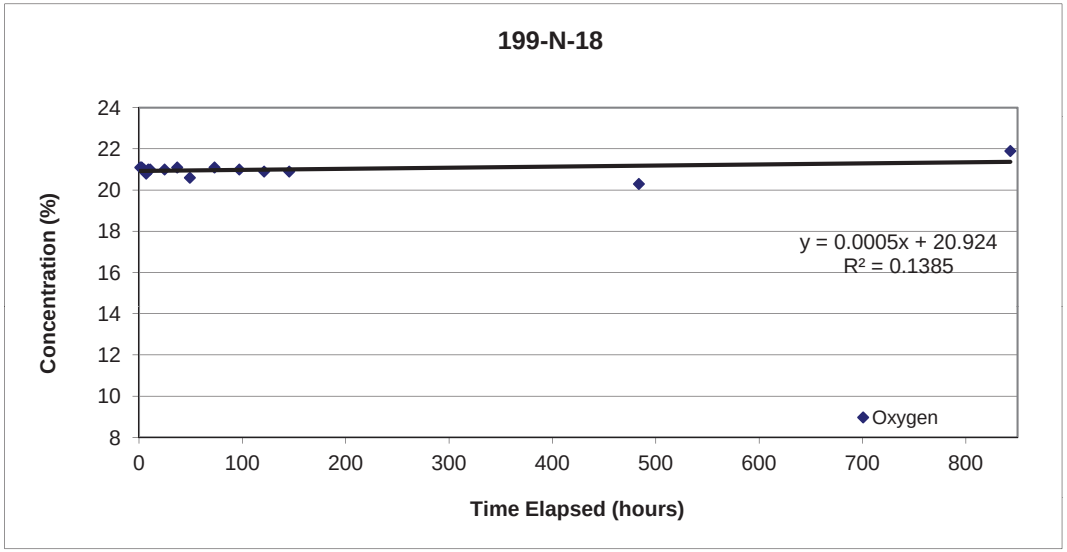
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	199-N-172 Oxygen %
6/3/14	8:00	blower off	--	--
6/3/14	8:40	0:40:00	0.67	21.1
6/3/14	10:01	2:01:00	2.02	21.1
6/3/14	11:19	3:19:00	3.32	21.0
6/3/14	12:20	4:20:00	4.33	21.0
6/3/14	14:27	6:27:00	6.45	20.9
6/3/14	16:20	8:20:00	8.33	20.9
6/3/14	18:22	10:22:00	10.37	20.9
6/4/14	8:20	24:20:00	24.33	21.1
6/4/14	20:28	36:28:00	36.47	20.8
6/5/14	8:32	48:32:00	48.53	21.1
6/6/14	8:33	72:33:00	72.55	21.4
6/7/14	8:30	96:30:00	96.50	20.8
6/8/14	8:30	120:30:00	120.50	20.9
6/9/14	8:44	144:44:00	144.73	21.0
6/23/14	9:40	481:40:00	481.67	18.5
7/8/14	11:08	843:08:00	843.13	21.0



Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	199-N-183 Oxygen %
6/3/14	8:00	blower off	--	--
6/3/14	8:54	0:54:00	0.90	21.1
6/3/14	10:08	2:08:00	2.13	21.1
6/3/14	11:25	3:25:00	3.42	21.0
6/3/14	12:25	4:25:00	4.42	21.0
6/3/14	14:33	6:33:00	6.55	20.9
6/3/14	16:25	8:25:00	8.42	21.0
6/3/14	18:40	10:40:00	10.67	21.0
6/4/14	8:41	24:41:00	24.68	21.1
6/4/14	20:36	36:36:00	36.60	21.1
6/5/14	8:59	48:59:00	48.98	20.9
6/6/14	8:41	72:41:00	72.68	21.0
6/7/14	8:38	96:38:00	96.63	20.8
6/8/14	8:36	120:36:00	120.60	20.9
6/9/14	9:00	145:00:00	145.00	21.0
6/23/14	9:56	481:56:00	481.93	20.8
7/8/14	10:25	842:25:00	842.42	21.9



Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	199-N-18 Oxygen %
6/3/14	8:00	blower off	--	--
6/3/14	9:10	1:10:00	1.17	21.1
6/3/14	10:30	2:30:00	2.50	21.1
6/3/14	11:40	3:40:00	3.67	21.0
6/3/14	12:40	4:40:00	4.67	21.0
6/3/14	14:51	6:51:00	6.85	20.8
6/3/14	16:55	8:55:00	8.92	21.0
6/3/14	18:42	10:42:00	10.70	21.0
6/4/14	8:40	24:40:00	24.67	21.0
6/4/14	20:51	36:51:00	36.85	21.1
6/5/14	9:07	49:07:00	49.12	20.6
6/6/14	8:59	72:59:00	72.98	21.1
6/7/14	8:57	96:57:00	96.95	21.0
6/8/14	9:00	121:00:00	121.00	20.9
6/9/14	9:14	145:14:00	145.23	20.9
6/23/14	11:35	483:35:00	483.58	20.3
7/8/14	11:00	843:00:00	843.00	21.9



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Appendix B

December 2014 – January 2015 Respirometry Testing

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Memorandum

To	Art Lee, CH2M HILL Plateau Remediation Company	File no	4-61M-120342.2.1
		cc	Craig Weber, PE, Amec Foster Wheeler
From	Kristi Diller, PG, Amec Foster Wheeler		John Kuiper, RG, Amec Foster Wheeler
Date	March 3, 2015		

Subject **Summary of December 2014 to January 2015 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site**

INTRODUCTION

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), has prepared this technical memorandum for CH2M HILL Plateau Remediation Company (CHPRC) to summarize the results of the December 2014 to January 2015 in-situ respiration test performed at the subsurface bioventing remediation system located at the 100-N Hanford DOE Site in Benton County, Washington. Operation and monitoring activities for the bioventing remediation system are conducted in accordance with DOE/RL-2005-93, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*, Appendix H, *Phase II Testing/Performance Monitoring Plan for the UPR-100-N-17 Bioremediation*." Since startup in November 2012, the bioventing system has been configured to supply air to the subsurface via two injection wells: 199-N-167 and 199-N-172. Approximately 250 cubic feet per minute (cfm) of air is routed to each well through a custom fitted wellhead. Based on previous studies, it is predicted that the radius of influence (ROI) for each injection well is at least 200 feet. The system was in continuous operation since startup through September 30, 2014, except for periodic short-term shutdowns for maintenance and respirometry test events. The operation and maintenance (O&M) of the system transitioned from Washington Closure Hanford (WCH) to CHPRC, and the system was shut down at the end of September 2014 while CHPRC performed system modifications to replace injection manifold PVC piping with cast steel and developed their procedures for O&M. The system resumed operation on December 3, 2014. Testing was conducted in accordance

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with the procedures detailed in the Revised Subsurface Respirometry Test Plan (Test Plan) dated October 22, 2014, with exceptions as noted below.

TESTING PROCEDURES

Immediately prior to the system restart on December 3, 2014, subsurface gas composition samples were collected by Amec Foster Wheeler and CHPRC field staff from the six wells in the monitoring program (shown on the attached figure):

- 199-N-167 (air injection well),
- 199-N-169 (monitoring well),
- 199-N-171 (monitoring well),
- 199-N-172 (air injection well),
- 199-N-183 (monitoring well), and
- 199-N-18 (monitoring well).

The samples were collected and analyzed to evaluate soil gas concentrations of oxygen, carbon dioxide, methane, and total volatile hydrocarbons (TVH) at the end of the system shutdown period. The bioventing system was then restarted on December 3, 2014 and in continuous operation for 12 days prior to starting the respirometry test.

Prior to blower shutdown on December 15, 2014, baseline readings were collected from the four monitoring wells (199-N-169, 199-N-171, 199-N-183, and 199-N-18), while the air injection wells were still in operation. Respiration testing was initiated by turning off the bioventing system blowers on December 15, 2014, at 9:15 am. Gas composition samples were then collected periodically, starting immediately after shut down and continuing through January 26, 2015. During the respiration testing, soil gas samples were collected and analyzed for oxygen, carbon dioxide, methane, and TVH from the four monitoring wells and two bioventing injection wells.

Seventeen samples were collected from each of the six monitoring locations on a predetermined schedule over a period of approximately 1008 hours (6 weeks). Readings were collected frequently for the first two days (at approximately 0, 1.5, 3, 4, 6, 8, 10, 24, 36, and 48 hours) and then daily for the remainder of the first week (at approximately 72, 96, 120, 144, and 168 hours). The bioventing system then remained off for five additional weeks during which three additional sampling events occurred at approximately 504, 744, and 1008 hours.

Purge times required to achieve the minimum of one casing volume of air extracted prior to monitoring were calculated in the field by the technician, using the pump curve for the purge pump to estimate the actual rate of purging. The Test Plan proposed collecting samples by attaching Tedlar bags to the discharge of the vacuum pump and taking readings by attaching the direct reading instrument to the Tedlar Bag sample port. CHPRC supervisors made the field

decision to use alternate sampling procedures which involved attaching the direct reading instruments to the discharge of the vacuum pump, eliminating the need for Tedlar bags.

Daily field reports and field measurements are included as Attachment 1, and instrument calibration sheets are included as Attachment 2.

BIODEGRADATION RATE RESULTS

The 2004 AFCEE guidance document[1] was followed for interpretation of results and calculating oxygen utilization and biodegradation rates. Oxygen utilization rates for each monitoring point were determined from the slope of the line obtained by plotting the measured oxygen concentration verses time for each monitoring point. Oxygen utilization rates are presented in Tables 1 and 2, and supporting data, calculations, and graphs of the data are included as Attachment 3.

Biodegradation rates were calculated using the following equation:

$$K_b = \frac{-k_o\ \theta_a\ \rho_{o2}\ C \times 0.01}{\rho_k}$$

Where (calculated or assumed values for the site follow each description):

- K_b: biodegradation rate calculated in mg hydrocarbon consumed per kg of soil per day
- k_o: oxygen utilization rate calculated for each monitoring point in $\%O_2$ consumed per day
- θ_a: gas-filled pore space (volumetric content at the vapor phase) = 0.19 cm^3 gas/cm^3 soil (based on measured value)
- ρ_{O2}: density of oxygen; assumed soil temp of 50F = 1,378 mg/L (AFCEE, 2004)
- C: mass ratio of hydrocarbons to oxygen required for mineralization (calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20} + 15O_2 \Rightarrow 10CO_2 + 10H_2O$) = 0.29
- ρ_k: soil bulk density; measured value = 1.736 g/cm^3 (measured value)
- θ: total porosity (where $\theta = 1 - \rho_k/\rho_T$) = 0.22 cm^3/cm^3 (based on measured value)
- θ_w: water filled porosity (where $\theta_w = M^*\rho_k/\rho_T$) = 0.04 cm^3/cm^3 (based on measured value)
- ρ_T: soil mineral density; assumed value = 2.65 g/cm^3
- M: moisture content; 3.13% (measured value) = 0.0313 g moisture per g soil

The values for soil bulk density (1.736 g/cm^3) and moisture content (3.13%) are based on the average of two representative soil samples collected from well 199-N-183 at depth intervals of

[1] Air Force Center for Environmental Excellence (AFCEE), 2004, Procedures for Conducting Bioventing Pilot Tests and Long-Term Monitoring of Bioventing Systems, May.

53 to 55 feet and 63 to 65 feet below ground surface (bgs), as presented in Attachment 3 and described in detail in AMEC (2014[2]). Calculations prior to January 2014 were made using the bulk density (2.063 g/cm^3) measured from a single soil sample collected from 58-60 feet bgs in 199-N-183. The updated soil bulk density value of 1.736 g/cm^3 is considered more representative of the overall site lithology. The values for θ_a, θ, and θ_w from all of the monitoring events were adjusted using the updated bulk density value.

Qualitative information regarding biodegradation rates was also derived from the nine-week bioventing system shut down period between September 30, 2014 and December 3, 2014. Although no baseline readings were collected on September 30, 2014, prior to the system shut down, it can be assumed that all monitoring points were at an atmospheric oxygen concentration of 20.9%. On December 3, 2014, oxygen readings were collected before system operation was resumed. From that single data point and the assumed initial oxygen concentration of 20.9%, an oxygen utilization rate and biodegradation rate were calculated. Results are reported in Table 1.

Table 1: Soil Gas Monitoring Results, Oxygen Utilization, and Biodegradation Rates Calculated from System Shut Down Period

Monitoring Point	Assumed Initial Oxygen Concentration on Sep. 30, 2014 (%)	Measured Oxygen Concentration on Dec. 3, 2014 (%)	Oxygen Utilization (%/day)	Biodegradation Rate (mg/kg-day)
199-N-167	20.9	14.9	0.09	-0.07
199-N-169	20.9	20.8	NA	NA
199-N-171	20.9	7.3	0.21	-0.16
199-N-172	20.9	18.7	0.03	-0.03
199-N-183	20.9	21.2	NA	NA
199-N-18	20.9	20.8	NA	NA

NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.

Insignificant oxygen consumption was observed in wells 199-N-169, 199-N-183, and 199-N-18. The lack of biodegradation occurring in 199-N-183 and 199-N-18 is consistent with previous tests; however, 199-N-169 had previously shown notable oxygen depletion within three weeks. The highest biodegradation rate was observed at 199-N-171, with lower rates observed at 199-N-167 and 199-N-172.

For the 6-week in-situ respirometry test initiated on December 15, 2014, calculated biodegradation rates and baseline measurements of oxygen are presented in Table 2. During the respiration test, methane and TVH were detected at all the monitoring points at low level

[2] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, February 7.

concentrations. The highest concentrations of both constituents, TVH at 29.2 parts per million (ppm) and methane at 26.57 ppm, were detected in 199-N-171; these results exhibit a slight decrease in maximum values detected as compared to concentrations from the January 2014 test.

Table 2: Soil Gas Monitoring Results, Oxygen Utilization and Biodegradation Rates Calculated from In-Situ Respiration Testing

Monitoring Point	Baseline Oxygen (%)	Oxygen Utilization (%/day)	Biodegradation Rate (mg/kg-day)
199-N-167	21.0	0.07	-0.05
199-N-169	21.0	0.30	-0.23
199-N-171	20.9	0.30	-0.23
199-N-172	20.6	0.07	-0.05
199-N-183	20.8	NA	NA
199-N-18	20.7	NA	NA

NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.

Baseline or initial oxygen concentrations were near atmospheric levels in all six monitoring locations. Oxygen concentrations in monitoring wells 199-N-183 and 199-N-18 remained above 20% throughout the test and exhibited insignificant oxygen depletion; therefore, a biodegradation rate was not calculated for those wells. The results for these two wells are consistent with previously conducted respirometry test results as shown in Table 3 below and Attachment 3. Well construction information for 199-N-18 indicates that the eight-inch carbon steel casing has perforations from 12 to 78 feet deep, with a telescoping six-inch stainless steel 10-slot screen installed from 58.5 to 79. Since the well casing has perforations beginning at 12 feet deep, the gas composition samples collected from this well are likely heavily influenced by the shallow subsurface and not representative of deeper vadose zone activity

The oxygen consumption rates are relatively low at all six wells tested, with the highest utilization calculated for monitoring wells 199-N-169 and 199-N-171. The highest oxygen utilization values would be expected in soil zones with greater levels of hydrocarbon “food” that would tend to support a higher mass of microbes. Note that a hydrocarbon sheen was observed in wells 199-N-169 and 199-N-171 during groundwater sampling in June 2014. A sheen was also observed in well 199-N-171 during groundwater sampling in January 2015. The presence of a sheen is evidence that this area is associated with elevated concentrations of hydrocarbons in the vadose and smear zones above the groundwater surface. Comparing oxygen utilization rates in wells across the affected area indicates that the most significant residual petroleum contamination is likely co-located with monitoring wells 199-N-169 and 199-N-171.

COMPARISON OF BIODEGRADATION RATES OVER TIME

Table 3 presents a comparison of the 2010 pilot test[3], December 2012[4], January 2014[5], June to July 2014[6], and December 2014 to January 2015 respirometry testing data. Data from March 2010 and December 2012 were recalculated using a soil bulk density of 1.736 g/cm^3 and a moisture content of 3.13% for comparison to the most recent biodegradation rate calculations.

Table 3: Comparison of Biodegradation Rates over Time Calculated from In-Situ Respiration Testing

Monitoring Point	Biodegradation Rate (mg/kg-day)				
	Jan. 2015	Jul. 2014	Jan. 2014	Dec. 2012	Mar. 2010
199-N-167	-0.05	-0.06	-0.01	-0.15	-0.99
199-N-169	-0.23	-0.09	-0.07	-0.28	-0.97
199-N-171	-0.23	-0.09	-0.05	-9.82	-0.37
199-N-172	-0.05	-0.02	-0.01	-0.14	-0.54
199-N-183	NA	NA	-0.09	not tested	not tested
199-N-18	NA	NA	NA	not tested	not tested

NA = Not applicable; oxygen depletion insignificant and biodegradation rate not calculated.

The biodegradation rates exhibit a declining trend from the initial rates measured in 2010. A number of variables could be responsible for the decrease in biodegradation indicated, the most obvious being that the bio-available hydrocarbon food source in the treatment zone has been reduced to levels that no longer support significant biological activity. The concentration of hydrocarbons in vadose zone soils can most accurately be determined by direct soil sampling. Changes in subsurface conditions such as temperature, moisture, and/or nutrient availability may also have impacted the rates shown, though one would expect only minor fluctuations in temperature and moisture at these depths.

One goal of the recent respirometry tests is to evaluate the effect of seasonal variability on the degradation rates measured, specifically as they relate to the groundwater elevation and temperature at the site. An obvious difference is observed in the biodegradation rates from January 2014 as compared to January 2015, with higher degradation rates calculated for the January 2015 data. This difference may be at least partially related to testing methodology. The

[3] AMEC Geomatrix, 2010, Technical Memorandum, Results Summary of In-situ Respiration Testing at the N100 Bioremediation Pilot Test Site, March 22.
[4] AMEC Environment & Infrastructure, Inc., 2012, Technical Memorandum, Summary of Respiration Testing Results for the Startup of the Bioremediation System at the N100 Bioremediation Site, December 12.
[5] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of January 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, February 7.
[6] AMEC Environment & Infrastructure, Inc., 2014, Technical Memorandum, Summary of June to July 2014 Respirometry Test Results for the Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site, July 28.

respirometry test in January 2014 was completed over a time period of one week, instead of the six week period of the January 2015 test. If the January 2015 test event had been halted after one week, the biodegradation rate calculations would have yielded lower values for all of the monitoring points. The July 2014 and January 2015 test events were carried out for five and six weeks, respectively, providing more time for ambient conditions to become re-established. The longer test events provided a more robust trend of oxygen utilization, with the data generally exhibiting higher R-squared values, a measure of goodness-of-fit of linear regression.

There also is an obvious difference observed in the biodegradation rates from January 2015 compared with July 2014, with the higher degradation rate calculated for the January 2015 data. Groundwater sampling at the site indicates that elevations of impacted groundwater vary significantly over time, resulting in a smear zone that is likely to be several feet thick. Bioventing will be most effective when groundwater elevations are low and this smear zone is exposed. The summer (July 2014) respirometry test was completed during seasonally high groundwater levels; whereas the current test was completed during seasonally low groundwater levels. Water level measurements taken while collecting groundwater samples during the two test periods indicate groundwater levels were lower by an average of 1.8 feet during the current test compared to the July 2014 water levels. As compared to the summer test, current biodegradation rates are more than twice as high for wells 199-N-169, 199-N-171, and 199-N-172, which correlates well with the concept that bioventing will be most effective during seasonally low groundwater periods. Groundwater at the site has been recorded as 2 to 4 degrees Celsius colder in some winters than the summer months. Although the lower groundwater temperatures would be correlated to lower biodegradation rates, the higher biodegradation rates associated with the seasonally low water level likely outweigh the effects of lower temperatures.

ESTIMATING TIME-FRAME FOR SITE CLOSURE

This section presents an update to the estimated time-frame for site closure as discussed in the previous respirometry testing memorandums. The exercise to estimate a time-frame necessary to achieve regulatory closure of the site is straightforward, though it relies on specified assumptions regarding the level of contamination present, the cleanup goal, and the biodegradation rate to apply to the affected area. The most recent information on the level of total petroleum hydrocarbon (TPH) contamination is from subsurface samples collected in early 2009 when wells 199-N-166, -167, -168, -169, -170, -171, and -172 were drilled (Gamon, 2009[7]). As shown in Figure 5 of Gamon (2009), the bulk of the hydrocarbon contamination was present from 60 feet bgs to 72 feet bgs in the five deep borings. One sample from well 199-N-169 at 35 feet bgs reported a TPH result of 18,000 mg/kg; however, the report identified this as a probable erroneous result. Excluding that sample result, the next highest concentration detected was

[7] Gamon, D.A., 2009, Bioremediation Wells Borehole Soil Sampling and Data Analysis Summary Report for 100-N Area Bioremediation, Project (UPR-100-N-17), Washington Closure Hanford, Richland, Washington, September.

4,400 mg/kg at 65 feet bgs in 199-N-167. The average concentration of the samples collected within the smear zone interval (55 to 72 feet bgs) was approximately 3,000 mg/kg.

The cleanup standard for TPH in soil at the Hanford site is currently set at 200 mg/kg per the 1999 Interim Action Record of Decision (ROD). Current Washington State regulations allow TPH cleanup standards of 2,000 mg/kg unless modified to address the potential for NAPL to migrate to groundwater.

Estimated time-frames to reach TPH cleanup standards are calculated in the next two paragraphs using well 199-N-169 as an example case. Biodegradation rates at 199-N-169 were initially measured at 0.97 mg/kg-day during the pilot test. Today, after approximately two years of bioventing system operation, biodegradation rates were measured at 0.23 mg/kg-day in that well. In order to estimate the amount of hydrocarbon removal that has occurred at that well during the course of the two-year operation (730 days) of the bioventing system, the average of those two biodegradation rates (0.6 mg/kg-day) is used. Over two years, the bioventing system has removed approximately 438 mg/kg of TPH from the petroleum-impacted soils near well 199-N-169.

In order to meet a TPH cleanup standard of 200 mg/kg, an additional 2,362 mg/kg of TPH remains to be removed from the petroleum-impacted soils near 199-N-169. At the current rate of biodegradation at that well (0.23 mg/kg-day), the cleanup standard would be achieved in 28 years. Alternatively, if the TPH cleanup standard was 2,000 mg/kg, an additional 562 mg/kg of TPH would need to be removed from the petroleum-impacted soils near 199-N-169. At the current rate of biodegradation at that well (0.23 mg/kg-day), the cleanup standard would be achieved in less than 7 years.

The estimate contains uncertainties related to current soil TPH concentrations and changes in biodegradation rates over time. There is additional uncertainty due to the fact that it is not currently known if a reservoir of petroleum exists along the southern fringe of influence of the bioventing system. It has been observed during prior excavation and test-pitting activities at the site that petroleum contamination remains beneath the base of an excavation located approximately 100 feet to the southwest of 199-N-167 and 199-N-169. Test Pit #4, completed in this area, was found to contain diesel and motor oil range petroleum hydrocarbons to a depth of at least 31 feet below ground surface (Thompson, 2014[8]). If such a reservoir exists, it could be influencing testing results. In addition, there is inherent difficulty in making this prediction when dissolved petroleum in groundwater has the potential to re-impact remediated soils each time the water table fluctuates. The use of another remedial technology (e.g., sparging) to treat the groundwater and saturated zone soils may accelerate the overall cleanup timeframe.

[8] Thompson, W.S. 2014. Work Instruction for Verification Sampling of the 100-N-84:2, 100-N Area Fuel and Foam Pipelines Waste Site, 0100N-WI-G0083, Rev. 0, Washington Closure Hanford, Richland, Washington. Appendix A, Test Pit Investigation Results. May

SUMMARY AND RECOMMENDATIONS

The respirometry rates from the 2014 and January 2015 testing events are generally below literature values for recommending bioventing as a viable remedial option. However, there is clear evidence that oxygen is a limiting factor for microbial degradation in the area of monitoring wells 199-N-169 and -171 and that bioventing will help maintain this biodegradation, even if the rate is somewhat low. The fact that groundwater remains locally impacted at the site and may act as an ongoing hydrocarbon source in the smear zone indicates bioventing will continue to be beneficial as a remedial approach. Amec Foster Wheeler is recommending the following actions in 2015 at the site:

- Pulse the bioventing system on a predetermined schedule, such as one week on, three weeks off. This operational protocol is expected to be sufficient to maintain oxygen levels in the subsurface, while substantially reducing costs for power consumption. This suggested on/off regimen could be adjusted to match other scheduled field events, thereby keeping site visit costs to a minimum.
- Conduct an additional respirometry test in the spring of 2015 to continue to evaluate the effect of seasonal variability on the biodegradation rates measured. Coordinate this testing window with groundwater level gauging and sampling of the groundwater for petroleum hydrocarbon concentrations in the area of the bioventing wells.
- Because of the relatively low respirometry rates measured in the most recent tests, future testing should be conducted over a period of at least 4 weeks.
- Consider the collection of soil samples at the site to verify achievement of cleanup criteria with respect to hydrocarbons in soil.
- Consider the collection of soil samples to the southwest of 199-N-167, 199-N-169, and 199-N-171 to evaluate whether significant petroleum mass is located along the fringe of system influence.
- Consider the use of an alternate treatment technology (e.g. sparging) to treat the hydrocarbon-impacted groundwater and saturated zone soils, in order to accelerate the overall cleanup timeframe. Converting the bioventing system to a combined bioventing/biosparging system is feasible and would be expected to maintain elevated oxygen concentrations in both the saturated and vadose zones. Testing of such a system would be necessary to determine how large the radius of influence would be within the saturated zone.

Figure:
Figure – Wells Planned for Biovent Respirometry Testing

Attachments:
Attachment 1 – Daily Field Reports and Field Measurements
Attachment 2 – Instrument Calibration Sheets
Attachment 3 – Design Worksheet for Oxygen Utilization and Biodegradation Rates

FIGURE

Columbia River
Columbia River
N Reactor
0 50 100 m
199-N-183
199-N-18
199-N-172
199-N-171
199-N-169
199-N-167
Wells Planned for Biovent Respirometry Testing
Respirometry Monitoring Location
Injection Well and Respirometry Monitoring Location
Biovent Hose (Above Ground)
Biovent Blower Shed
0 5 10 15 20 25 m
0 25 50 75 100 ft
N
CHSGW20150123
Image Source: 2012 Benton County

ATTACHMENT 1

Daily Field Reports and Field Measurements

DAILY FIELD REPORT

amec
Earth & Environmental, Inc.
7376 SW Durham Road
Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 361M12034.001.01	Date: 12/2/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

12/2/2014 Morning readings

08:00 - On site with Art Lee and CHPRC sampling crew. Did sampling walk through then discussed procedures.

09:20 - Off site. Calbrated units and got equipment ready off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	361M12034.001.01	Date:	12/3/2014
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	jg	AMEC Project Manager (Initials)	JK
Weater Conditions			

Earth & Environmental, Inc.

7376 SW Durham Road
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Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

12/03/2014 Morning readings

07:30 - On site and got equipment ready for days sampling.
08:00 - CH PRC on site. Performed tailgate meeting and did a job review.

It was decided per Art Lee and CH PRC sampling crew (Kevin and Barb) and their supervisor that since all sampling was going to be done within a sampling cargo van that we could change the procedures so that we could go to a direct read sample collection from sample port on vac pump and do away with the Tedlar bags. I agree'd that this makes better since and gives us a better data set.

08:30 - Set up on well 167 and started purge.
11:05 - Finished well gas sampling. Buttoned up wells and turned over both vac pumps to CH PRC. Length of time spent on this sampling event was due to ironing out our team working procedures and making sure everyone was on the same page.
11:20 - Off site. Art said that operations crew would turn system on and collect start up readings later in the afternoon.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M12034.02.01	Date:	12/14/2014
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	jg	AMEC Project Manager (Initials)	JK
Weater Conditions			

Earth & Environmental, Inc.

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FIELD REPORT NOTES

Time:	Field Notes:

12/14/2014

Travel to Richland.

Calibrate instruments and complete manifold.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	461M12034.02.01	Date:	12/15/2014
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	jg	AMEC Project Manager (Initials)	JK
Weater Conditions			

amec
Earth & Environmental, Inc.
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Fax: 503-620-7892

FIELD REPORT NOTES

Time:	Field Notes:

12/15/2014 Monday test readings

06:00 - Load equipment and then mobe to site.
07:15 - On site and got equipment ready for days sampling. Tyler is doing his Hanford training to get badged.
07:30 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling trucks.
08:30 - Set up on well 171 and started purge.
09:15 - Blowers off.
14:30 - Art looked at blower flow charts and and based on our high vacuum changed our purge times I concurred with this plan.
19:30 - Finished well gas sampling. Buttoned up .
19:40 - Off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

amec
Earth & Environmental, Inc.
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Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M12034.02.01	Date: 12/16/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

12/16/2014 Tuesday test readings. The 24th and 36th hr test intervals.

05:30 - Calibrated instruments and loaded equipment, then mobe to site.
07:15 - On site and got equipment ready for days sampling with Tyler.
07:30 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling trucks.
08:00 - Set up on well 171 and started purge.
09:00 - 24 interval complete. Demobed equipment and then Tyler off site to Portland.
10:00 - Data review and logging. Reports.
15:00 - Calibrated instruments.
17:30 - Art looked at blower flow charts and and based on our high vacuum changed our purge times to further compensate for vacuum, I concurred with this plan.
18:00 - Mobed to site.
18:40 - On site . Set up for 36 interval sampling.
19:00 - Started test.
20:15 - Finished well gas sampling. Buttoned up .
20:30 - Off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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Phone: 503-639-3400
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PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M12034.02.01	Date: 12/17/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

12/17/2014 Wednesday test readings. The 48th hr interval.

05:30 - Calibrated instruments and loaded equipment, then mobe to site.
07:15 - On site and got equipment ready for days sampling.
07:30 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling trucks.
07:41 - Set up on well 171 and started purge.
09:00 - 48 interval complete. Demobed equipment and then off site.
10:00 - Data review and logging. Reports.
14:00 - Calibrated instruments.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M12034.02.01	Date: 12/18/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

12/18/2014 Thursday test readings. The 72nd hr interval.

06:00 - Loaded equipment, then mobeto site.
07:15 - On site and got equipment ready for days sampling.
07:30 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling truck.
07:41 - Set up on well 171 and started purge.
09:00 - 72nd interval complete. Demobed equipment and then off site.
11:00 - Data review and logging. Reports.
12:00 - Bill arrived and started testing at Central badging.
13:00 - Calibrated instruments.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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Portland, Oregon 97224
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PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M12034.02.01	Date: 12/19/2014
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

12/19/2014 Friday test readings. The 84th hr interval.

06:00 - Loaded equipment, then mobeto site.
07:15 - On site with Bill Mcfarland and got equipment ready for days sampling.
07:30 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling truck.
07:41 - Set up on well 171 and started purge.
09:00 - 72nd interval complete. Demobed equipment and then off site.
11:00 - Data review and logging. Reports.
13:00 - Calibrated instruments with Bill Mcfarland.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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Fax: 503-620-7892

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	361M12034.001.01	Date:	12/20/2014
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	WJM	AMEC Project Manager (Initials)	JK
Weater Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

12/20/2014 Saturday test readings

05:30 - Calibrate Equipment(see cal data sheet)
06:00 - Load equipment and then mob to site.
07:15 - On site and got equipment ready for days sampling.
07:50 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Set up inside sampling trucks.
08:09 - Set up on Well 171 and started purge.
09:26 - Testing completed for today. (see data spread sheet)
09:45 - Off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	361M12034.001.01	Date:	12/21/2014
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	WJM	AMEC Project Manager (Initials)	JK
Weater Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

12/21/2014 Sunday test readings. Hour 144

05:30 - Calibrate Equipment(see cal data sheet)
06:20 - Load equipment and then mob to site.
07:10 - On site and got equipment ready for days sampling.
07:35 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Set up inside sampling trucks.
08:09 - Set up on Well 171 and started purge.
09:10 - Testing completed for today. (see data spread sheet)
09:20 - Off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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Earth & Environmental, Inc.
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PROJECT NAME:	HANFORD BIO VENT PROJECT		
Project No:	361M12034.001.01	Date:	12/22/2014
Field Report No:		Page:	1
Arrival:		Departure:	
AMEC Field Rep. (Initial)	WJM	AMEC Project Manager (Initials)	JK
Weater Conditions			

FIELD REPORT NOTES

Time:	Field Notes:

12/22/2014 Sunday test readings. Hour 168

05:30 - Calibrate Equipment(see cal data sheet)
06:20 - Load equipment and then mob to site.
07:10 - On site and got equipment ready for days sampling.
07:35 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Set up inside sampling trucks.
07:44 - Set up on Well 171 and started purge.
08:59 - Testing completed for today. (see data spread sheet)
09:20 - Off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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Earth & Environmental, Inc.
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Portland, Oregon 97224
Phone: 503-639-3400
Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M12034.02.01	Date: 1/5/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

1/4/2015 Sunday calibration.

18:00 - Calibrated units.

1/5/2015 Monday test readings

06:30 - Load equipment and then mobe to site.
07:15 - On site and got equipment ready for days sampling.
08:00 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling trucks.
08:15 - Set up on well 171 and started purge.
10:00 - Finished sampling. Demobed equipment then off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

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PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M12034.02.01	Date: 1/15/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:

1/14/2015 Wednesday calibration.

22:00 - Calibrated units.

1/15/2015 Thursday test readings

06:30 - Load equipment and then mobe to site.
07:15 - On site and got equipment ready for days sampling.
08:00 - CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling trucks.
08:15 - Set up on well 171 and started purge.
10:00 - Finished sampling. Demobed equipment then off site.

Contractor's Rep. (Initials) N/A

Continued N/A

DAILY FIELD REPORT

amec
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7376 SW Durham Road
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Fax: 503-620-7892

PROJECT NAME: HANFORD BIO VENT PROJECT	
Project No: 461M12034.02.01	Date: 1/26/2015
Field Report No:	Page: 1
Arrival:	Departure:
AMEC Field Rep. (Initial) jg	AMEC Project Manager (Initials) JK
Weater Conditions	

FIELD REPORT NOTES

Time:	Field Notes:
1/25/2015	Sunday calibration.
10:00	- Calibrated units.
1/26/2015	Monday test readings
06:30	- Load equipment and then mobe to site.
07:15	- On site and got equipment ready for days sampling.
09:00	- CH PRC, and DOE samplers on site. Performed tailgate meeting and did a job review. Did set up inside sampling trucks. Late start due to all hands meeting.
09:18	- Set up on well 171 and started purge.
10:50	- Finished sampling. Demobed equipment then off site.

Contractor's Rep. (Initials) N/A

Continued N/A

Field Measurements
December 2014 to January 2015 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
167	12/3/2014	8:58	-286	0	4 min	14.9	1.7	0.77	12.87	Purge rate at ~5 cu ft/sec. Direct read collection was used for sampling.
167	12/15/2014	9:19	-302	0	3 min	21	0	0	0	System off at 9:15. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/15/2014	10:20	-304	0	3 min	21.2	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/15/2014	11:12	-304	0	3 min	21.3	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/15/2014	13:16	-303	0	3 min	21.4	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/15/2014	15:21	-302	0	*4 min	21.3	0	0	0	* Purge time increased to 4 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/15/2014	17:15	-304	0	4 min	21.4	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/15/2014	19:18	-304	0	4 min	21.5	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/16/2014	8:57	-272	0	4 min	21	0	1.1	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/16/2014	20:10	-282	0	*6 min	20.3	0.1	0.5	0	* Purge time increased to 6 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/17/2014	8:49	-280	0	6 min	20.5	0.1	1	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/18/2014	9:02	-283	0	6 min	21.1	0.1	0.9	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/19/2014	8:57	na	0	6 min	21.5	0.1	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/20/2014	9:26	-283	0	6 min	21.5	0	0.9	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/21/2014	8:55	-283	0	6 min	21.5	0	1.3	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	12/22/2014	8:53	-282	0	6 min	21.9	0	0.7	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/5/2015	9:38	-281	0	6 min	20.5	0.2	1.9	5.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/15/2015	8:56	-295	0	6 min	18.3	0.6	1.4	1.6	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
167	1/26/2015	10:30	-281	0	6 min	18.7	0.7	0.3	1.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

Field Measurements
December 2014 to January 2015 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
169	12/3/2014	9:10	-253	0	3 min	20.8	0.1	0.28	0	Purge rate at ~5 cu ft/sec. Direct read collection was used for sampling.
169	12/15/2014	9:10	-290	0	3 min	21	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/15/2014	10:15	-293	0	3 min	21.1	0	0	0	System off at 9:15. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/15/2014	11:07	-286	0	3 min	21.2	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/15/2014	13:08	-284	0	3 min	21.3	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/15/2014	15:16	-289	0	3 min	21.2	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/15/2014	17:15	-288	0	3 min	21.2	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/15/2014	19:12	-289	0	3 min	21.3	0	0	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/16/2014	8:51	-248	0	3 min	20.9	0.1	1.2	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/16/2014	20:15	-253	0	*4 min	20.1	0.2	0.9	0	* Purge time increased to 6 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/17/2014	8:55	-250	0	4 min	20.1	0.2	1.2	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/18/2014	9:07	-251	0	4 min	20.6	0.2	0.9	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/19/2014	9:03	na	0	4 min	20.6	0.3	0.3	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/20/2014	9:19	-247	0	4 min	20.1	0.3	1.1	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/21/2014	9:01	-246	0	4 min	20.3	0.3	0.5	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	12/22/2014	8:59	-249	0	4 min	20.7	0.3	0.9	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/5/2015	9:32	-244	0	4 min	15.7	1.6	2.6	4.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/15/2015	9:01	-274	0	4 min	12.3	2.9	2.5	3.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
169	1/26/2015	10:36	-244	0	4 min	7.9	5.2	1.1	0	* O2 to low to keep instrument on sample line. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

Field Measurements
December 2014 to January 2015 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
171	12/3/2014	11:04	-247	0	3 min	7.3	6.9	0.13	0	Purge rate at ~5 cu ft/sec. Direct read collection was used for sampling.
171	12/15/2014	8:39	-300	0	3 min	20.9	0.2	0.4	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/15/2014	9:38	-288	0	3 min	19.8	1	7.05	23.8	System off at 9:15. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/15/2014	10:38	-293	0	3 min	19.6	0.9	7.7	21.77	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/15/2014	12:38	-292	0	3 min	19.6	1	3.47	1.56	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/15/2014	14:39	-291	0	3 min	19.8	1	3.04	5.29	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/15/2014	16:38	-292	0	3 min	19.5	1	7.1	24.37	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/15/2014	18:38	-293	0	3 min	19.5	1.1	7.5	26.57	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/16/2014	8:12	-276	0	3 min	20.1	1	4.7	4.8	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/16/2014	19:07	-292	0	*5 min	18.7	1.5	8.2	10.5	* Purge time increased to 5 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/17/2014	7:44	-303	0	5 min	18.4	1.8	7.7	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/18/2014	7:44	-296	0	5 min	18.8	1.8	6.3	14.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/19/2014	7:52	na	0	5 min	18.7	1.9	7	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/20/2014	8:13	-298	0	5 min	17.5	2.3	18.9	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/21/2014	7:50	-293	0	5 min	18.5	1.9	13.3	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	12/22/2014	7:48	-300	0	5 min	18.5	2	10.2	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/5/2015	8:19	-275	0	5 min	16.8	5.1	16.8	22.6	GEM is drifting and shutting down. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/5/2015	9:22	-284	0	5 min	13.7	4.3	12	16.7	Put backup GEM in service and resampled point, Use this data set. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/15/2015	7:50	-298	0	5 min	7.3	8.5	29.2	27.9 *	* O2 too low to keep instrument on sample line. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
171	1/26/2015	9:24	-288	0	6 min	8.9	7.8	1.7	7	* O2 too low to keep instrument on sample line. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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Field Measurements
December 2014 to January 2015 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
172	12/3/2014	10:53	-271	0	3 min	18.7	0.6	0.62	12.91	Purge rate at ~5 cu ft/sec. Direct read collection was used for sampling.
172	12/15/2014	9:25	-284	0	3 min	20.6	0.2	0.27	0	System off at 9:15. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/15/2014	10:05	-274	0	3 min	20.8	0.1	2.03	4.07	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/15/2014	11:00	-277	0	3 min	20.7	0.1	2.48	5.97	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/15/2014	13:00	-276	0	3 min	20.6	0	1.77	0.11	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/15/2014	15:11	-275	0	*4 min	20.7	0	1.33	0.27	* Purge time increased to 4 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/15/2014	17:10	-273	0	4 min	20.8	0	2.17	5.8	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/15/2014	19:08	-272	0	4 min	20.7	0	2.03	5.27	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/16/2014	8:43	-264	0	4 min	21.2	0	1.3	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/16/2014	19:28	-278	0	*5 min	20.2	0.1	2	0.6	* Purge time increased to 5 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/17/2014	8:37	-273	0	5 min	20.5	0.1	1.1	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/18/2014	8:49	-273	0	5 min	21	0.1	1.1	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/19/2014	8:43	na	0	5 min	21.2	0.1	0.8	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/20/2014	9:07	-274	0	5 min	21.3	0	1.1	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/21/2014	8:43	-272	0	5 min	21.5	0	0.5	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	12/22/2014	8:42	-275	0	5 min	21.9	0	0.7	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/5/2015	9:16	-266	0	5 min	18.6	0.4	0.8	4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/15/2015	8:45	-294	0	5 min	19.1	0.3	2.2	4.4	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
172	1/26/2015	8:18	-295	0	7 min	17.8	0.5	0.8	2.8	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

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Field Measurements
December 2014 to January 2015 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
183	12/3/2014	10:21	-330	0	16 min	21.2	0	0.24	0	Purge rate at ~5 cu ft/sec. Direct read collection was used for sampling.
183	12/15/2014	8:49	-341	0	3 min	20.8	0.2	0.92	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/15/2014	9:46	-340	0	3 min	20.8	0.1	3.62	8.11	System off at 9:15. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/15/2014	10:46	-348	0	3 min	20.7	0.1	4.2	8.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/15/2014	12:46	-351	0	3 min	20.6	0.1	2.32	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/15/2014	14:55	-350	0	*14 min	20.7	0.1	1.91	1.9	* Purge time increased to 4 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/15/2014	16:53	-345	0	14 min	20.6	0.1	3.04	7.5	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/15/2014	18:53	-346	0	14 min	20.7	0.1	2.93	6.81	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/16/2014	8:15	-334	0	14 min	20.6	0.1	1.4	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/16/2014	19:59	-351	0	*30 min	20.2	0.1	1.2	0	* Purge time increased to 30 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/17/2014	8:17	-353	0	30 min	20.1	0.2	2.5	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/18/2014	8:27	-358	0	30 min	20.9	0.1	1.5	1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/19/2014	8:23	na	0	30 min	21	0.1	0.3	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/20/2014	8:46	-361	0	30 min	21.4	0.1	1.1	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/21/2014	8:22	-355	0	30 min	21.3	0.1	1.2	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	12/22/2014	8:34	-347	0	30 min	22	0	0	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/5/2015	8:52	-343	0	30 min	21.1	0.2	1	6.9	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/15/2015	8:24	-361	0	30 min	21.2	0.1	1.8	6.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
183	1/26/2015	9:56	-352	0	30 min	20.9	0.2	0.5	5.7	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
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Field Measurements
December 2014 to January 2015 Respirometry Test
Subsurface Bioventing Remediation System at the 100-N Hanford DOE Site

Monitoring Location	Date	Time	Vac During Extraction (inches H_2O)	Pre-Extraction Pressure/Vac	Purge Time	Oxygen (%)	Carbon Dioxide (%)	TVH (ppm)	Methane (ppm)	Notes
18	12/3/2014	9:52	-223	0	12 min	20.8	0.2	0.2	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/15/2014	8:58	-281	0	7 min	20.7	0.1	0.96	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/15/2014	9:59	-252	0	7 min	20.8	0.1	1.73	4.75	System off at 9:15. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/15/2014	10:55	-248	0	7 min	20.6	0.1	2.89	5.77	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/15/2014	12:55	-273	0	7 min	20.5	0.1	1.82	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/15/2014	15:06	-266	0	*8 min	20.6	0	1.77	1.77	* Purge time increased to 8 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/15/2014	17:04	-263	0	8 min	20.7	0.1	2.28	5.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/15/2014	19:02	-267	0	8 min	20.5	0.1	2.2	4.67	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/16/2014	8:38	-272	0	8 min	21.1	0.1	1	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/16/2014	19:21	-351	0	*12 min	20.1	0.2	2.1	0.3	* Purge time increased to 30 min due to high vac. Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/17/2014	8:30	-353	0	12 min	20.3	0.1	1.1	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/18/2014	8:41	-296	0	12 min	21	0.1	1.2	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/19/2014	8:37	na	0	12 min	21.3	0.1	0.6	0	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/20/2014	9:00	-278	0	12 min	21.3	0.1	0.3	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/21/2014	8:36	-274	0	12 min	21.2	0.1	1.2	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	12/22/2014	8:03	-282	0	12 min	21.4	0.1	0.5	0.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/5/2015	9:08	-281	0	12 min	21.1	0.2	0.6	4.1	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/15/2015	8:37	-271	0	12 min	20.9	0.3	1.9	4.3	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.
18	1/26/2015	10:10	-276	0	12 min	20.6	0.2	0.6	2.2	Purge rate at <5 cu ft/sec. Direct read collection was used for sampling.

cu ft/sec = cubic feet per second
ppm = parts per million
TVH = total volatile hydrocarbons

ATTACHMENT 2

Instrument Calibration Sheets

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 361M120340.0001.01

Date / Time: 12/2/2014 12:30:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/2/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/2/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/2/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/2/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/2/2014	30 min	zero air	-0.29 ppm / 0.44 ppm	n/a	n/a
TVA 1000 (8810682)	12/2/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	101 ppm
TVA 1000 (8810682)	12/2/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/2/2014	30 min	zero air	-0.87 ppm / 0.62 ppm	n/a	n/a
TVA 2020 (202001408040)	12/2/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	101 ppm
TVA 2020 (202001408040)	12/2/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	98 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/14/2014 9:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/14/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/14/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/14/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/14/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/14/2014	30 min	zero air	-0.13 ppm / 0.20 ppm	n/a	n/a
TVA 1000 (8810682)	12/14/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/14/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/14/2014	30 min	zero air	-0.28 ppm / 0.14 ppm	n/a	n/a
TVA 2020 (202001408040)	12/14/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	101 ppm
TVA 2020 (202001408040)	12/14/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	99 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/16/2014 5:30:00 AM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/16/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/16/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/16/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/16/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/16/2014	30 min	zero air	-0.63 ppm / 0.02 ppm	n/a	n/a
TVA 1000 (8810682)	12/16/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/16/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/16/2014	30 min	zero air	-0.19 ppm / 0.03 ppm	n/a	n/a
TVA 2020 (202001408040)	12/16/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	101 ppm
TVA 2020 (202001408040)	12/16/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	99 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/16/2014 3:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/16/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/16/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/16/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/16/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/16/2014	30 min	zero air	-1.28 ppm / 0.09 ppm	n/a	n/a
TVA 1000 (8810682)	12/16/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/16/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/16/2014	30 min	zero air	-0.21 ppm / 0.14 ppm	n/a	n/a
TVA 2020 (202001408040)	12/16/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	12/16/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	98 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/17/2014 5:30:00 AM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/17/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/17/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/17/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/17/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/17/2014	30 min	zero air	-0.97 ppm / 0.32 ppm	n/a	n/a
TVA 1000 (8810682)	12/17/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/17/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/17/2014	30 min	zero air	-0.12 ppm / 0.14 ppm	n/a	n/a
TVA 2020 (202001408040)	12/17/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	12/17/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/18/2014 2:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/18/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/18/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/18/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/18/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/18/2014	30 min	zero air	-0.21 ppm / 0.01 ppm	n/a	n/a
TVA 1000 (8810682)	12/18/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/18/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	101 ppm
TVA 2020 (202001408040)	12/18/2014	30 min	zero air	-0.28 ppm / 0.12 ppm	n/a	n/a
TVA 2020 (202001408040)	12/18/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	12/18/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/19/2014 2:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/18/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/18/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/18/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/18/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/18/2014	30 min	zero air	0.16 ppm / 0.1 ppm	n/a	n/a
TVA 1000 (8810682)	12/18/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	102 ppm
TVA 1000 (8810682)	12/18/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/18/2014	30 min	zero air	0.31 ppm / 0.1 ppm	n/a	n/a
TVA 2020 (202001408040)	12/18/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	103 ppm
TVA 2020 (202001408040)	12/18/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	101

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/20/2014 5:30:00 AM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/20/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/20/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/20/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/20/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/20/2014	30 min	zero air	-0.97 ppm / 0.32 ppm	n/a	n/a
TVA 1000 (8810682)	12/20/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/20/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/20/2014	30 min	zero air	-0.12 ppm / 0.14 ppm	n/a	n/a
TVA 2020 (202001408040)	12/20/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	12/20/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/21/2014 5:30:00 AM Completed By: WJ McFarland

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/21/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/21/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/21/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/21/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/21/2014	30 min	zero air	-0.93 ppm / 0.44 ppm	n/a	n/a
TVA 1000 (8810682)	12/21/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/21/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/21/2014	30 min	zero air	-0.23 ppm / 0.17 ppm	n/a	n/a
TVA 2020 (202001408040)	12/21/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	12/21/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 12/22/2014 5:30:00 AM Completed By: WJ McFarland

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	12/22/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	12/22/2014	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	12/22/2014	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	12/22/2014	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	12/22/2014	30 min	zero air	-0.45 ppm / 0.49 ppm	n/a	n/a
TVA 1000 (8810682)	12/22/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	12/22/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	12/22/2014	30 min	zero air	0.13 ppm / 0.26 ppm	n/a	n/a
TVA 2020 (202001408040)	12/22/2014	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	12/22/2014	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 1/4/2015 6:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	1/4/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	1/4/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	1/4/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	1/4/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	1/4/2015	30 min	zero air	0.11 ppm / 0.21 ppm	n/a	n/a
TVA 1000 (8810682)	1/4/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	101 ppm
TVA 1000 (8810682)	1/4/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	1/4/2015	30 min	zero air	0.05 ppm / 0.17 ppm	n/a	n/a
TVA 2020 (202001408040)	1/4/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	1/4/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 1/14/2015 10:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	1/14/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	1/14/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	1/14/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	1/14/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	1/14/2015	30 min	zero air	0.49 ppm / 0.28 ppm	n/a	n/a
TVA 1000 (8810682)	1/14/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	101 ppm
TVA 1000 (8810682)	1/14/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	1/14/2015	30 min	zero air	-0.16 ppm / 0.23 ppm	n/a	n/a
TVA 2020 (202001408040)	1/14/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	1/14/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:

Gas detector calibration

Project Name: **Hanford 100N Bio-Vent** Project Number: 461M120340.02.01

Date / Time: 1/25/2015 10:00:00 PM Completed By: Jason Gardner

Instrument name(s) GEM O2/CO2 meter and TVA 1000 FID/PID

Calibration Method: Zero gas (ambient air) readings and then span gases

Equipment owner: ARGUS / HAZCO

Span gas flow control: 0.5 L/min

Instrument	Date	Warm up time	Gas	FID/PID readings	Span Readings	Final readings
GEM GM12695	1/25/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12695	1/25/2015	30 min	15% CO2	n/a	15%	15%
GEM GM12075/09	1/25/2015	30 min	zero air	n/a	0.00%	0.00%
GEM GM12075/09	1/25/2015	30 min	15% CO2	n/a	15%	15%
TVA 1000 (8810682)	1/25/2015	30 min	zero air	0.21 ppm / -0.12 ppm	n/a	n/a
TVA 1000 (8810682)	1/25/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 1000 (8810682)	1/25/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100 ppm
TVA 2020 (202001408040)	1/25/2015	30 min	zero air	-0.06 ppm / -0.21 ppm	n/a	n/a
TVA 2020 (202001408040)	1/25/2015	30 min	100 ppm Isob.	100 ppm (PID)	n/a	100 ppm
TVA 2020 (202001408040)	1/25/2015	30 min	100 ppm Methane	100 ppm (FID)	n/a	100

Notes:

ATTACHMENT 3

Design Worksheet for Oxygen Utilization and Biodegradation Rates

DESIGN WORKSHEET

Date: 11-Feb-15
Client: CHPRC
Project Number: 461M120342
Project: Hanford 100-N Biovent
Prepared by: K. Diller
Data For: System Shut Down Sep. 2014 to Dec. 2014
Reviewed by: C. Weber

Bioventing system management transitioned from Washington Closure Hanford (WCH) to CHPRC, and the system was shut down at the end of September 2014 while CHPRC developed their procedures for operations and maintenance of the system. Qualitative information regarding biodegradation rates were also derived from the nine week bioventing system shut down period between September 30, 2014 and December 3, 2014. Although no baseline readings were collected on September 30, 2014, prior to the system shut down, it can be assumed that all monitoring points were at an atmospheric oxygen concentration of 20.9%. On December 3, 2014, oxygen readings were collected before system operation was resumed. From that single data point and the assumed initial oxygen concentration of 20.9%, an oxygen utilization rate (k_o) and biodegradation rate (K_b) were calculated. Calculations and results are presented below.

OXYGEN UTILIZATION RATE CALCULATION

Oxygen utilization rates (%/hour) are derived from the slope of the linear portion of the line when percent oxygen (y-axis) measured in the soil is plotted against time in hours (x-axis). See attached for data plots.

Location	O_2 Utilization (%/hour)	k_o O_2 Utilization (%/day)	R^2 value for linear curve fit
199-N-167	0.0039	0.09	NA
199-N-169	--	--	--
199-N-171	0.0089	0.21	NA
199-N-172	0.0014	0.03	NA
199-N-183	--	--	--
199-N-18	--	--	--

Oxygen readings between 19 and 22% represent essentially atmospheric conditions and amount to insignificant oxygen depletion. Biodegradation rates are only calculated for wells with significant oxygen depletion (below 19%); others are marked as --.

BIODEGRADATION RATE CALCULATION

Biodegradation rates (K_b) are calculated for each of the monitoring points with oxygen utilization results.

The Kb values below are calculated using updated site-specific soil bulk density and moisture content soil parameters, based on measured values from samples collected in the screen interval of 199-N-183. The biodegradation calculations for the 2010 and 2012 respiration test data have also been updated with these site-specific soil parameters.

Equation for biodegradation rate calculation:

$$K_b = \frac{-k_o \, \theta_a \, \rho_{o2} \, C \times 0.01}{\rho_k}$$

Parameters using site-specific measured values from 199-N-183 soil samples

θ_a =	0.32	cm^3 gas/cm^3 soil	Gas-filled pore space (volumetric content at the vapor phase); where $\theta_a = \theta - \theta_w$
ρ_{O2} =	1,378	mg/L	Density of oxygen; assuming 10°C (50°F) soil temperature reference value from AFCEE, 2004
C =	0.29	---	Mass ratio of hydrocarbons to oxygen required for mineralization; calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20} + 15O_2 \Rightarrow 10CO_2 + 10H_2O$
ρ_k =	1.736	g/cm^3	Soil bulk density; measured value from 199-N-183, average of bulk densities from samples 212 and 215
θ =	0.34	cm^3/cm^3	Total porosity; where $\theta = 1 - \rho_k/\rho_T$
θ_w =	0.02	cm^3/cm^3	Water filled porosity; where $\theta_w = M^*\rho_k/\rho_T$
ρ_T =	2.65	g/cm^3	Soil mineral density; assumed value
M =	0.0313	g moisture /g soil	3.13% moisture content; measured value from 199-N-183, average of percent moisture from samples 212, 214, and 215

DESIGN WORKSHEET

Client: CHPRC
Project: Hanford 100-N Biovent
Data For: System Shut Down Sep. 2014 to Dec. 2014

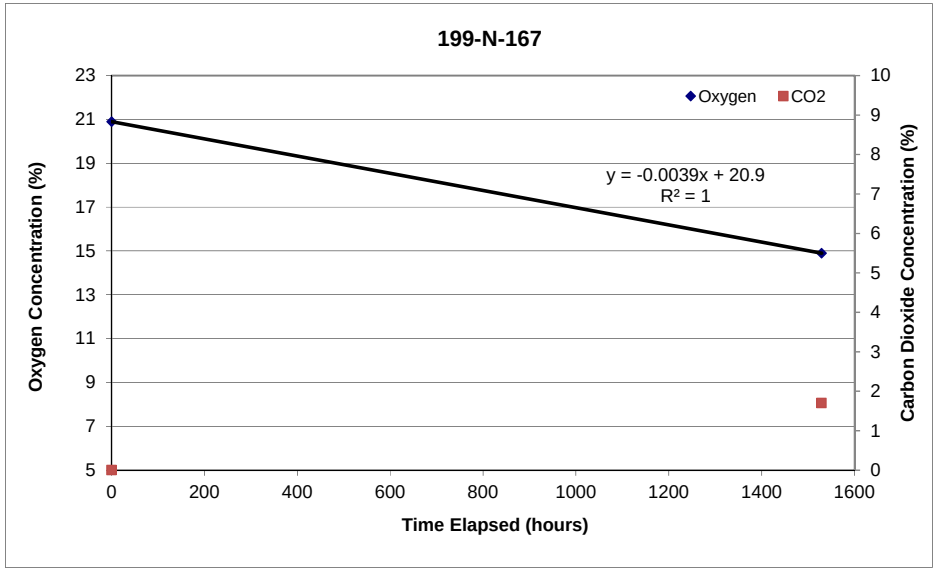
Date: 11-Feb-15
Project Number: 461M120342
Prepared by: K. Diller
Reviewed by: C. Weber

Location	Parameter	Shut Down Period (Dec 2014)	Units	Notes
199-N-167	K_o =	0.09	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.07**	mg/Kg-day	Biodegradation rate; calculated value
199-N-171	K_o =	0.21	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.16**	mg/Kg-day	Biodegradation rate; calculated value
199-N-172	K_o =	0.03	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.03**	mg/Kg-day	Biodegradation rate; calculated value

Sheet 2 of 2

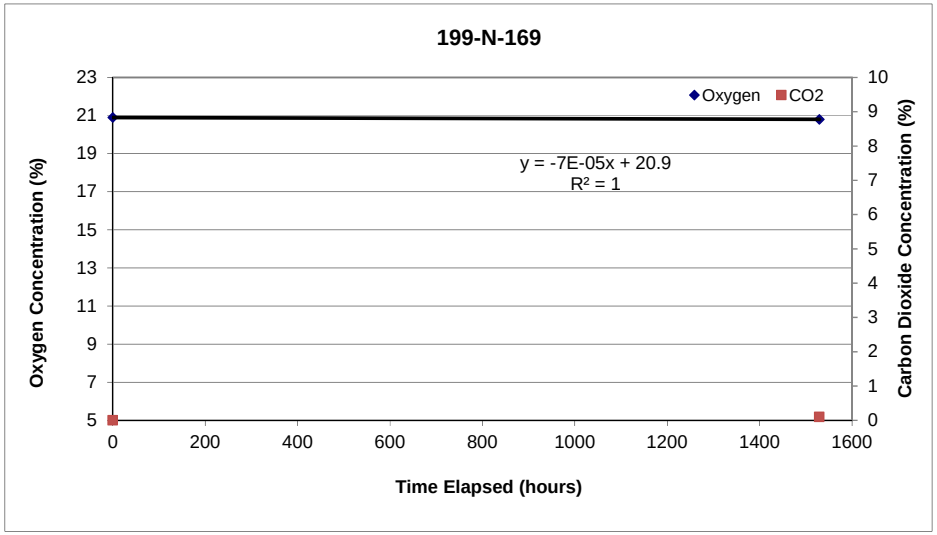
Oxygen Utilization Generation Plots
Period During System Shut Down
September 30, 2014 to December 3, 2014

199-N-167						
Date	Time	Comment	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
9/30/2014	16:00	system shutdown	0:00:00	0.00	20.9	0
12/3/2014	8:58	before system restart	1528:58:00	1528.97	14.9	1.7



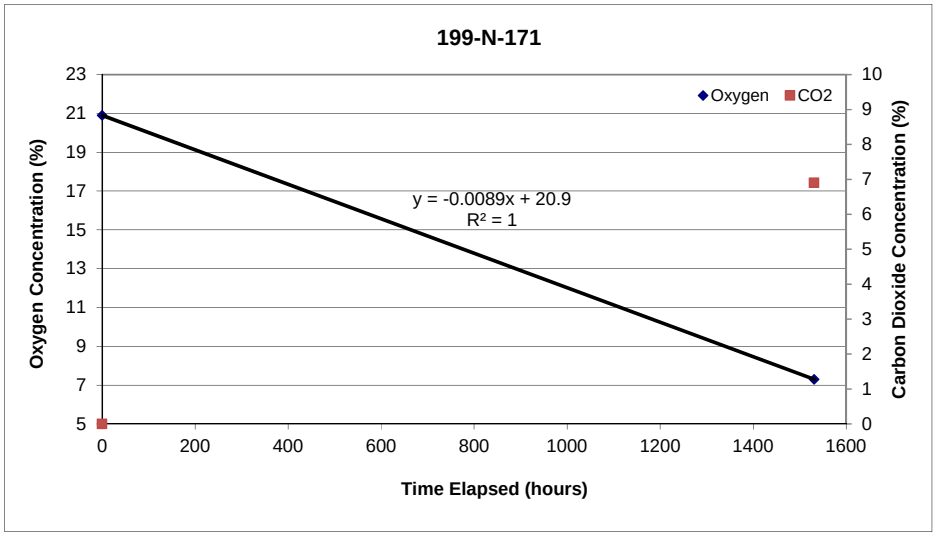
199-N-169						
Date	Time	Comment	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
9/30/2014	16:00	system shutdown	0:00:00	0.00	20.9	0
12/3/2014	9:10	before system restart *	1529:10:00	1529.17	20.8	0.1

* This data point is considered anomalous, as it appears ambient air affected the reading.

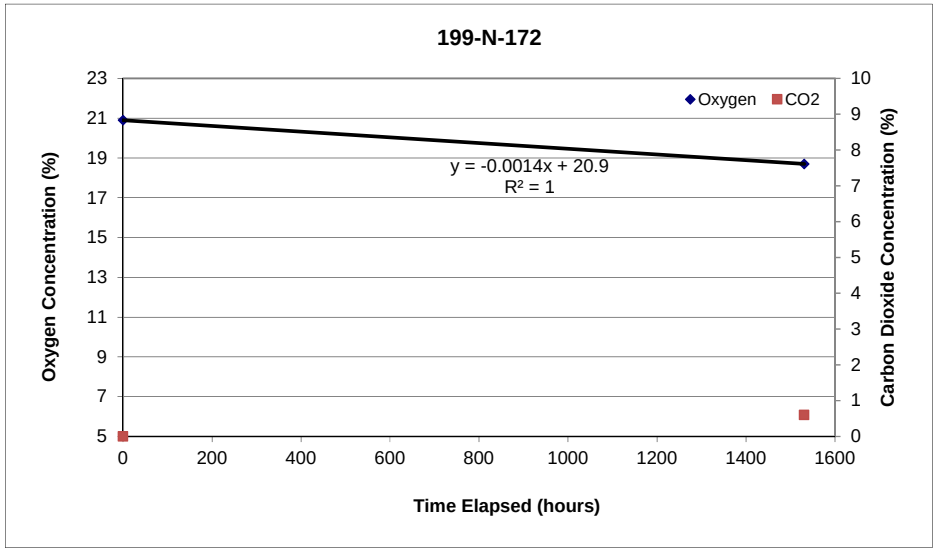


Oxygen Utilization Generation Plots
Period During System Shut Down
September 30, 2014 to December 3, 2014

199-N-171						
Date	Time	Comment	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
9/30/2014	16:00	system shutdown	0:00:00	0.00	20.9	0
12/3/2014	11:04	before system restart	1531:04:00	1531.07	7.3	6.9



199-N-172						
Date	Time	Comment	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
					%	%
9/30/2014	16:00	system shutdown	0:00:00	0.00	20.9	0
12/3/2014	10:53	before system restart	1530:53:00	1530.88	18.7	0.6



**Calculations not performed for 199-N-183 and 199-N-18 due to their high readings at system restart.

DESIGN WORKSHEET

Client:	CHPRC	Date:	11-Feb-15
Project:	Hanford 100-N Biovent	Project Number:	461M120342
Data For:	Dec. 2014 to Jan. 2015 Respiration Test	Prepared by:	K. Diller
		Reviewed by:	C. Weber

An in-situ respiration test was conducted at the Hanford Site 100-N from December 2014 to January 2015. Data collected from the field test is used to calculate oxygen utilization (k_o) and biodegradation rates (K_b). Calculations and results are presented below.

OXYGEN UTILIZATION RATE CALCULATION

Oxygen utilization rates (%/hour) are derived from the slope of the linear portion of the line when percent oxygen (y-axis) measured in the soil is plotted against time in hours (x-axis). See attached for data plots.

Location	O_2 Utilization (%/hour)	k_o O_2 Utilization (%/day)	R^2 value for linear curve fit
199-N-167	0.0028	0.07	0.698
199-N-169	0.0126	0.30	0.977
199-N-171	0.0127	0.30	0.929
199-N-172	0.003	0.07	0.680
199-N-183	--	--	--
199-N-18	--	--	--

Oxygen readings between 19 and 22% represent essentially atmospheric conditions and amount to insignificant oxygen depletion. Biodegradation rates are only calculated for wells with significant oxygen depletion (below 19%); others are marked as --.

BIODEGRADATION RATE CALCULATION

Biodegradation rates (K_b) are calculated for each of the monitoring points.

The Kb values below are calculated using updated site-specific soil bulk density and moisture content soil parameters, based on measured values from samples collected in the screen interval of 199-N-183. The biodegradation calculations for the 2010 and 2012 respiration test data have also been updated with these site-specific soil parameters.

Equation for biodegradation rate calculation:

$$K_b = \frac{-k_o \, \theta_a \, \rho_{o2} \, C \times 0.01}{\rho_k}$$

Parameters using site-specific measured values from 199-N-183 soil samples

θ_a =	0.32	cm^3 gas/cm^3 soil	Gas-filled pore space (volumetric content at the vapor phase); where $\theta_a = \theta - \theta_w$
ρ_{O2} =	1,378	mg/L	Density of oxygen; assuming 10°C (50°F) soil temperature reference value from AFCEE, 2004
C =	0.29	---	Mass ratio of hydrocarbons to oxygen required for mineralization; calculated assuming diesel as $C_{10}H_{20}$ and stoichiometric relationship of $C_{10}H_{20} + 15O_2 \Rightarrow 10CO_2 + 10H_2O$
ρ_k =	1.736	g/cm^3	Soil bulk density; measured value from 199-N-183, average of bulk densities from samples 212 and 215
θ =	0.34	cm^3/cm^3	Total porosity; where $\theta = 1 - \rho_k/\rho_T$
θ_w =	0.02	cm^3/cm^3	Water filled porosity; where $\theta_w = M^*\rho_k/\rho_T$
ρ_T =	2.65	g/cm^3	Soil mineral density; assumed value
M =	0.0313	g moisture /g soil	3.13% moisture content; measured value from 199-N-183, average of percent moisture from samples 212, 214, and 215

Note: Subsurface soil temperature is assumed to be constant year-round and temperature adjustments of oxygen utilization rates were not conducted. If temperatures are warmer in the summer months then oxygen utilization rates are expected to increase. Temperature changes are extremely unlikely for the deep well locations.

DESIGN WORKSHEET

Client: CHPRC
Project: Hanford 100-N Biovent
Data For: Dec. 2014 to Jan. 2015 Respiration Test

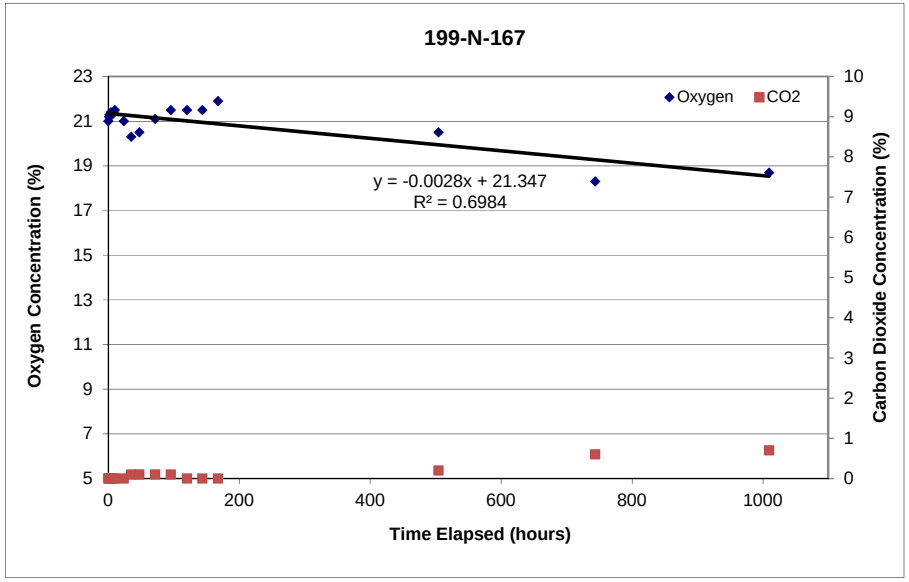
Date: 11-Feb-15
Project Number: 461M120342
Prepared by: K. Diller
Reviewed by: C. Weber

Location	Parameter	Jan-15	Jul-14	Jan-14	Dec-12	Mar-10	Units	Notes
199-N-167	K_o =	0.07	0.08	0.01	0.20	1.32	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.05**	**-0.06**	**-0.01**	**-0.15**	**-0.99**	mg/Kg-day	Biodegradation rate; calculated value
199-N-169	K_o =	0.3	0.12	0.09	0.37	1.29	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.23**	**-0.09**	**-0.07**	**-0.28**	**-0.97**	mg/Kg-day	Biodegradation rate; calculated value
199-N-171	K_o =	0.3	0.12	0.07	13.07	0.49	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.23**	**-0.09**	**-0.05**	**-9.82**	**-0.37**	mg/Kg-day	Biodegradation rate; calculated value
199-N-172	K_o =	0.07	0.03	0.02	0.18	0.71	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**-0.05**	**-0.02**	**-0.01**	**-0.14**	**-0.54**	mg/Kg-day	Biodegradation rate; calculated value
199-N-183	K_o =	--	--*	0.12	not tested	not tested	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**--**	**--***	**-0.09**	not tested	not tested	mg/Kg-day	Biodegradation rate; calculated value
199-N-18	K_o =	--	--*	--*	not tested	not tested	%/day	Oxygen utilization rate; calculated value from respiration test
	K_b =	**--**	**--***	**--***	not tested	not tested	mg/Kg-day	Biodegradation rate; calculated value

* Biodegradation rates were previously calculated based on respirometry data, but upon further review, insignficant oxygen depletion was recorded in the wells and biodegradation should have been reported as insignificant.

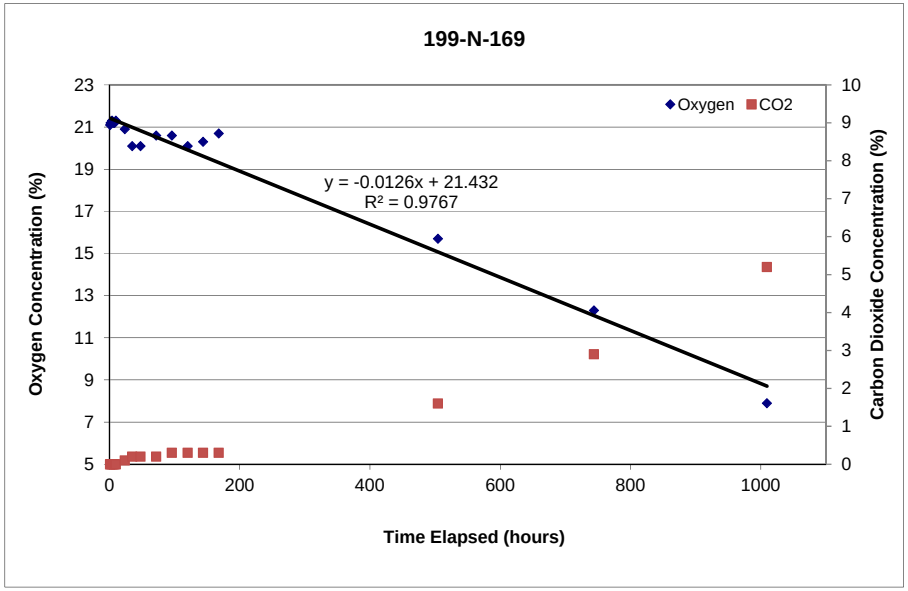
Oxygen Utilization Generation Plots
December 2014 to January 2015 Respirometry Test

199-N-167					
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
				%	%
12/3/2014	8:58	before system restart	--	14.9	1.7
12/15/2014	9:15	blower off	0	--	--
12/15/2014	9:19	0:04:00	0.07	21	0
12/15/2014	10:20	1:05:00	1.08	21.2	0
12/15/2014	11:12	1:57:00	1.95	21.3	0
12/15/2014	13:16	4:01:00	4.02	21.4	0
12/15/2014	15:21	6:06:00	6.10	21.3	0
12/15/2014	17:15	8:00:00	8.00	21.4	0
12/15/2014	19:18	10:03:00	10.05	21.5	0
12/16/2014	8:57	23:42:00	23.70	21	0
12/16/2014	20:10	34:55:00	34.92	20.3	0.1
12/17/2014	8:49	47:34:00	47.57	20.5	0.1
12/18/2014	9:02	71:47:00	71.78	21.1	0.1
12/19/2014	8:57	95:42:00	95.70	21.5	0.1
12/20/2014	9:26	120:11:00	120.18	21.5	0
12/21/2014	8:55	143:40:00	143.67	21.5	0
12/22/2014	8:53	167:38:00	167.63	21.9	0
1/5/2015	9:38	504:23:00	504.38	20.5	0.2
1/15/2015	8:56	743:41:00	743.68	18.3	0.6
1/26/2015	10:30	1009:15:00	1009.25	18.7	0.7



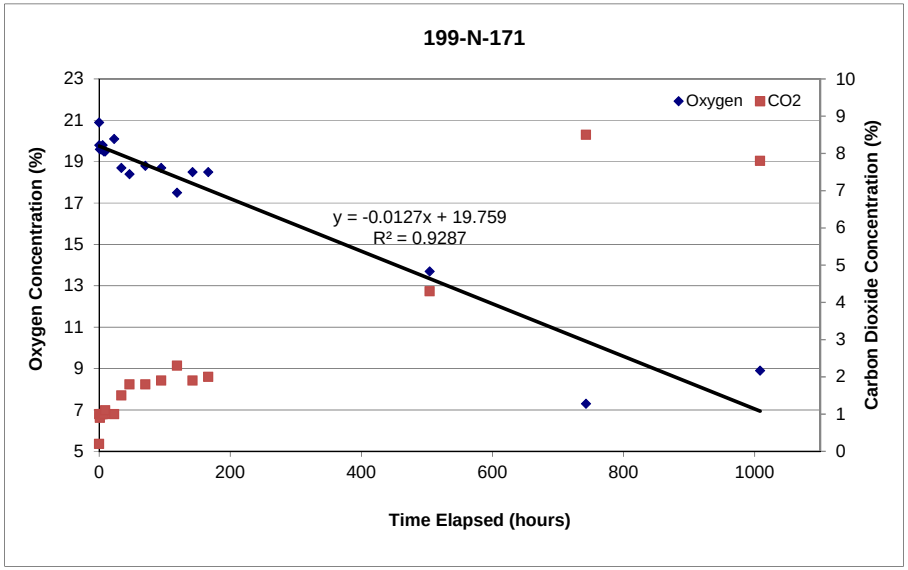
199-N-169					
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
				%	%
12/3/2014	9:10	before system restart	--	20.8*	0.1
12/15/2014	9:10	baseline reading	--	21	0
12/15/2014	9:15	blower off	0	--	--
12/15/2014	10:15	1:00:00	1.00	21.1	0
12/15/2014	11:07	1:52:00	1.87	21.2	0
12/15/2014	13:08	3:53:00	3.88	21.3	0
12/15/2014	15:16	6:01:00	6.02	21.2	0
12/15/2014	17:15	8:00:00	8.00	21.2	0
12/15/2014	19:12	9:57:00	9.95	21.3	0
12/16/2014	8:51	23:36:00	23.60	20.9	0.1
12/16/2014	20:15	35:00:00	35.00	20.1	0.2
12/17/2014	8:55	47:40:00	47.67	20.1	0.2
12/18/2014	9:07	71:52:00	71.87	20.6	0.2
12/19/2014	9:03	95:48:00	95.80	20.6	0.3
12/20/2014	9:19	120:04:00	120.07	20.1	0.3
12/21/2014	9:01	143:46:00	143.77	20.3	0.3
12/22/2014	8:59	167:44:00	167.73	20.7	0.3
1/5/2015	9:32	504:17:00	504.28	15.7	1.6
1/15/2015	9:01	743:46:00	743.77	12.3	2.9
nt is consider	10:36	1009:21:00	1009.35	7.9	5.2

* This data point is considered anomalous, as it appears ambient air affected the reading.

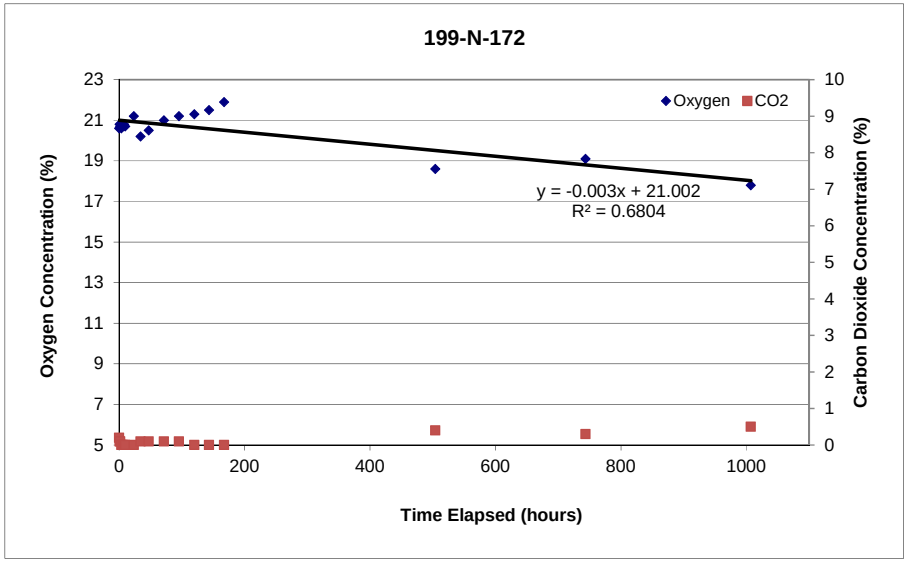


Oxygen Utilization Generation Plots
December 2014 to January 2015 Respirometry Test

199-N-171					
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
				%	%
12/3/2014	11:04	before system restart	--	7.3	6.9
12/15/2014	8:39	baseline	--	20.9	0.2
12/15/2014	9:15	blower off	0	--	--
12/15/2014	9:38	0:23:00	0.38	19.8	1
12/15/2014	10:38	1:23:00	1.38	19.6	0.9
12/15/2014	12:38	3:23:00	3.38	19.6	1
12/15/2014	14:39	5:24:00	5.40	19.8	1
12/15/2014	16:38	7:23:00	7.38	19.5	1
12/15/2014	18:38	9:23:00	9.38	19.5	1.1
12/16/2014	8:12	22:57:00	22.95	20.1	1
12/16/2014	19:07	33:52:00	33.87	18.7	1.5
12/17/2014	7:44	46:29:00	46.48	18.4	1.8
12/18/2014	7:44	70:29:00	70.48	18.8	1.8
12/19/2014	7:52	94:37:00	94.62	18.7	1.9
12/20/2014	8:13	118:58:00	118.97	17.5	2.3
12/21/2014	7:50	142:35:00	142.58	18.5	1.9
12/22/2014	7:48	166:33:00	166.55	18.5	2
1/5/2015	9:22	504:07:00	504.12	13.7	4.3
1/15/2015	7:50	742:35:00	742.58	7.3	8.5
1/26/2015	9:24	1008:09:00	1008.15	8.9	7.8

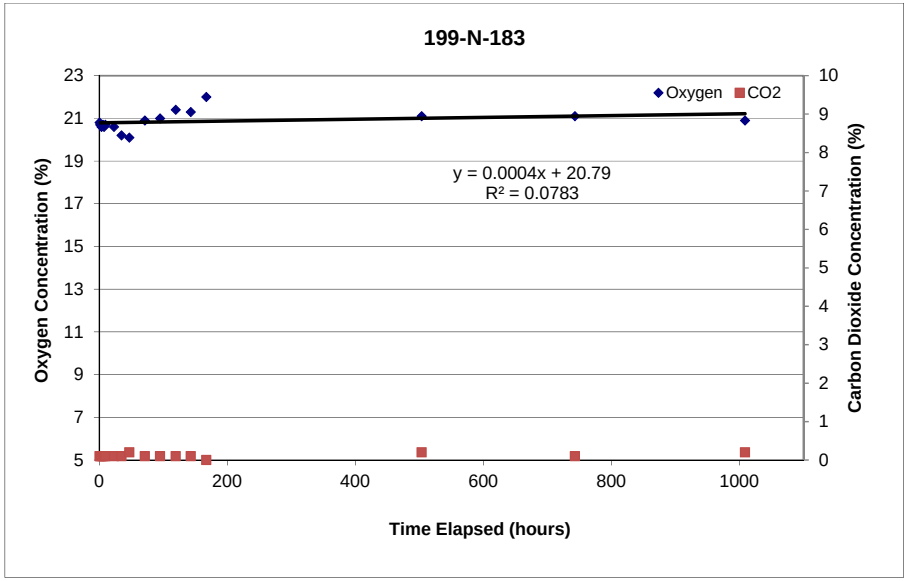
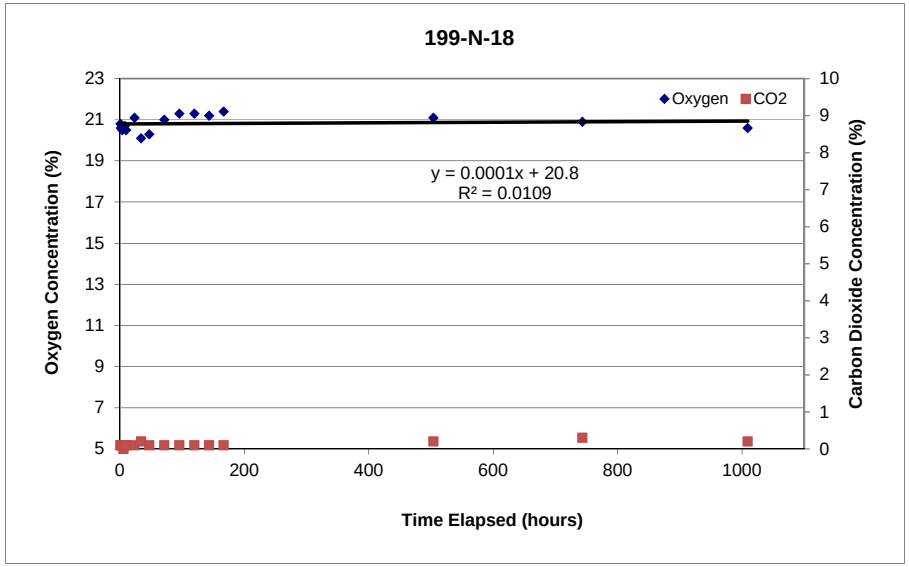


199-N-172					
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
				%	%
12/3/2014	10:53	before system restart	--	18.7	0.6
12/15/2014	9:15	blower off	0	--	--
12/15/2014	9:25	0:10:00	0.17	20.6	0.2
12/15/2014	10:05	0:50:00	0.83	20.8	0.1
12/15/2014	11:00	1:45:00	1.75	20.7	0.1
12/15/2014	13:00	3:45:00	3.75	20.6	0
12/15/2014	15:11	5:56:00	5.93	20.7	0
12/15/2014	17:10	7:55:00	7.92	20.8	0
12/15/2014	19:08	9:53:00	9.88	20.7	0
12/16/2014	8:43	23:28:00	23.47	21.2	0
12/16/2014	19:28	34:13:00	34.22	20.2	0.1
12/17/2014	8:37	47:22:00	47.37	20.5	0.1
12/18/2014	8:49	71:34:00	71.57	21	0.1
12/19/2014	8:43	95:28:00	95.47	21.2	0.1
12/20/2014	9:07	119:52:00	119.87	21.3	0
12/21/2014	8:43	143:28:00	143.47	21.5	0
12/22/2014	8:42	167:27:00	167.45	21.9	0
1/5/2015	9:16	504:01:00	504.02	18.6	0.4
1/15/2015	8:45	743:30:00	743.50	19.1	0.3
1/26/2015	8:18	1007:03:00	1007.05	17.8	0.5



Oxygen Utilization Generation Plots
December 2014 to January 2015 Respirometry Test

199-N-183					
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
				%	%
12/3/2014	10:21	before system restart	--	21.2	0
12/15/2014	8:49	baseline reading	--	20.8	0.2
12/15/2014	9:15	blower off	0	--	--
12/15/2014	9:46	0:31:00	0.52	20.8	0.1
12/15/2014	10:46	1:31:00	1.52	20.7	0.1
12/15/2014	12:46	3:31:00	3.52	20.6	0.1
12/15/2014	14:55	5:40:00	5.67	20.7	0.1
12/15/2014	16:53	7:38:00	7.63	20.6	0.1
12/15/2014	18:53	9:38:00	9.63	20.7	0.1
12/16/2014	8:15	23:00:00	23.00	20.6	0.1
12/16/2014	19:59	34:44:00	34.73	20.2	0.1
12/17/2014	8:17	47:02:00	47.03	20.1	0.2
12/18/2014	8:27	71:12:00	71.20	20.9	0.1
12/19/2014	8:23	95:08:00	95.13	21	0.1
12/20/2014	8:46	119:31:00	119.52	21.4	0.1
12/21/2014	8:22	143:07:00	143.12	21.3	0.1
12/22/2014	8:34	167:19:00	167.32	22	0
1/5/2015	8:52	503:37:00	503.62	21.1	0.2
1/15/2015	8:24	743:09:00	743.15	21.1	0.1
1/26/2015	9:56	1008:41:00	1008.68	20.9	0.2



199-N-18					
Date	Time	Elapsed Time (hr:min:sec)	Elapsed Time (hours)	Oxygen	CO_2
				%	%
12/3/2014	9:52	before system restart	--	20.8	0.2
12/15/2014	8:58	baseline reading	--	20.7	0.1
12/15/2014	9:15	blower off	0	--	--
12/15/2014	9:59	0:44:00	0.73	20.8	0.1
12/15/2014	10:55	1:40:00	1.67	20.6	0.1
12/15/2014	12:55	3:40:00	3.67	20.5	0.1
12/15/2014	15:06	5:51:00	5.85	20.6	0
12/15/2014	17:04	7:49:00	7.82	20.7	0.1
12/15/2014	19:02	9:47:00	9.78	20.5	0.1
12/16/2014	8:38	23:23:00	23.38	21.1	0.1
12/16/2014	19:21	34:06:00	34.10	20.1	0.2
12/17/2014	8:30	47:15:00	47.25	20.3	0.1
12/18/2014	8:41	71:26:00	71.43	21	0.1
12/19/2014	8:37	95:22:00	95.37	21.3	0.1
12/20/2014	9:00	119:45:00	119.75	21.3	0.1
12/21/2014	8:36	143:21:00	143.35	21.2	0.1
12/22/2014	8:03	166:48:00	166.80	21.4	0.1
1/5/2015	9:08	503:53:00	503.88	21.1	0.2
1/15/2015	8:37	743:22:00	743.37	20.9	0.3
1/26/2015	10:10	1008:55:00	1008.92	20.6	0.2