U.S. DEPARTMENT OF ENERGY

PNNL-22900

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Solar Powered Radioactive Air Monitoring Stations

JM Barnett
LE Bisping
TL Gervais

October 2013

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <http://www.ntis.gov/about/form.aspx>
Online ordering: http://www.ntis.gov

This document was printed on recycled paper.
(8/2010)

PNNL-22900

Solar Powered Radioactive Air Monitoring Stations

JM Barnett TL Gervais
LE Bisping

October 2013

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Environmental monitoring of ambient air for radioactive material is required as stipulated in the PNNL Site radioactive air license. Sampling ambient air at identified preferred locations could not be initially accomplished because utilities were not readily available. Therefore, solar powered environmental monitoring systems were considered as a possible option. PNNL purchased two 24-V DC solar powered environmental monitoring systems which consisted of solar panels, battery banks, and sampling units. During an approximate four month performance evaluation period, the solar stations operated satisfactorily at an on-site test location. They were subsequently relocated to their preferred locations in June 2012 where they continue to function adequately under the conditions found in Richland, Washington.

Acronyms and Abbreviations

cfm	cubic feet per minute
ft^3	cubic feet
in	inch(es)
m^3	cubic meters
mm	millimeter(s)
PLC	programmable logic controller
PNNL	Pacific Northwest National Laboratory
RAEL	Radioactive Air Emissions License
RPT	Radiation Protection Technologist

Contents

Figures

Table

1.0 Introduction

Pacific Northwest National Laboratory (PNNL) currently owns and operates four ambient radioactive air environmental monitoring stations, two of which are solar powered. These stations are operated to comply with the PNNL Site Radioactive Air Emissions License-05 (RAEL-05), which requires the monitoring of ambient air concentrations to confirm low emissions of radionuclides in air. In 2010, a Data Quality Objectives report[1] that supported radiological air emissions from the PNNL Site located in Richland, WA identified preferred ambient air sampling locations; however, utilities were not readily available at two locations on the site boundary. Therefore, solar powered environmental monitoring systems were considered as a possible option. PNNL purchased two 24-V DC solar powered environmental monitoring stations which consisted of solar panels, battery banks, and sampling units. During an approximate 4-month performance evaluation period, the solar stations operated satisfactorily at an on-site test location. The stations were subsequently relocated to their preferred locations in June 2012, where they continue to function normally.

[1] Barnett, JM, KM Meier, SF Snyder, BG Fritz, TM Poston, and K Rhoads. 2010. "Data Quality Objectives Supporting Radiological Air Emissions Monitoring for the PNNL Site," PNNL-19427. Pacific Northwest National Laboratory, Richland, Washington.

2.0 Test Description

Two 24-V DC solar powered environmental monitoring stations (model CF-5624WR) were procured from HI-Q Environmental Products Company (7386 Trade St, San Diego, CA 92121) and operated to evaluate system performance (Figure 2.1). TEST-B system was configured with a 2-inch (in) sample filter, and the TEST-C system was configured with a 4-in sample filter (refer to Table 2.1 for test configurations). TEST-C was reconfigured and renamed TEST-D later in the test period because the 2-in filter would work for the application. TEST-D is an identical 2-in sample filter arrangement as found in TEST-B. To provide comparative sampling results, an AC sampling system was used that consisted of a small housed station with an air volume totalizer, flow controller, and a vacuum pump. This specific setup was identical to the existing AC monitoring stations placed at the same location (Figure 2.2) and is identified as TEST-A in Table 2.1. These test stations were placed approximately 100 feet west of the Battelle Pacific Northwest ball fields (Figure 2.3) in an area where the solar panels would experience full sun when available.

Figure 2.1. 24-V Monitoring Station

Table 2.1. Test System Configurations

Test Name	Power Source	Filter Dimension (in)
TEST-A	AC (120 V)	2
TEST-B	DC (24 V solar battery array)	2
TEST-C	DC (24 V solar battery array)	4
TEST-D	DC (24 V solar battery array)	2

Figure 2.2. AC Monitoring Station (TEST-A)

Figure 2.3. Battelle Pacific Northwest Ball Field and Test Area

Solar sampler testing began on February 22, 2012. On weekdays, Radiation Protection Technologist (RPT) staff would document system status and record data for each environmental monitoring station (Appendix A). Samples for each station were collected bi-weekly, and collection coincided with the AC

monitoring stations. The 2-in sample filters collected from TEST-A, TEST-B, and TEST-D were submitted for analyses; however, the 4-in filters collected from TEST-C were archived and not analyzed because the filter size is larger than the standard 2 in detector size. The objectives of the testing were to determine if the sampler was able to maintain a nominal sample flow of 1.5 cubic feet per minute (cfm), to demonstrate if the environmental monitoring system would work under all weather conditions, to determine if the power supplied by the solar panels would be adequate, and to determine if the analytical results would be equivalent to the AC powered systems.

Following the test period, the two solar powered monitoring stations were placed in their permanent locations as indicated in Figure 2.4.

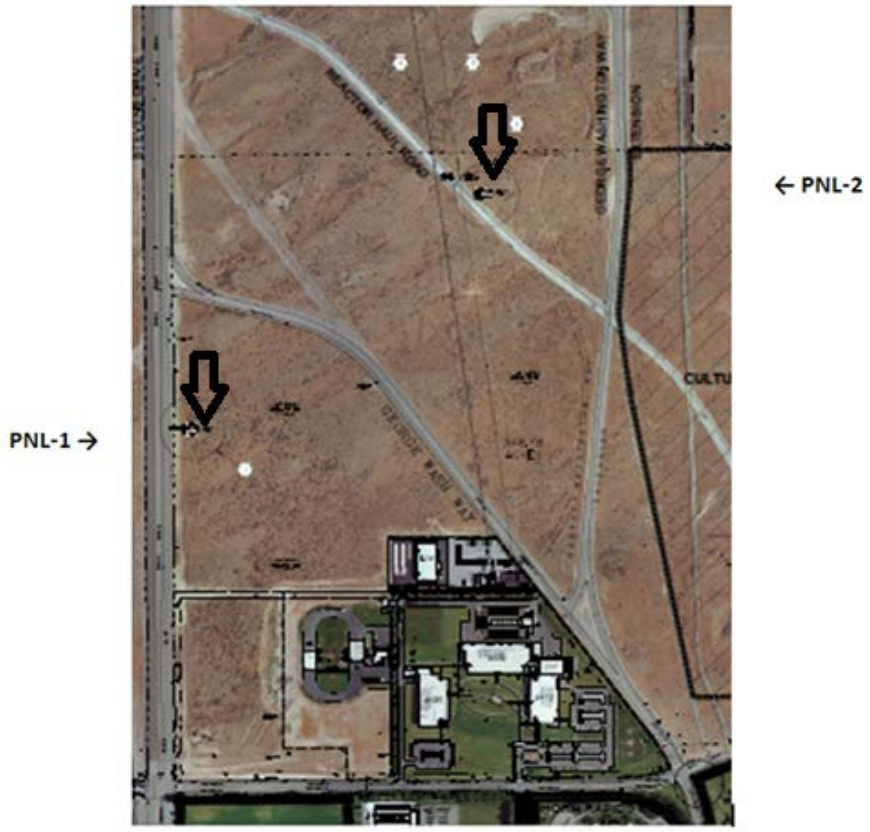

Figure 2.4. Permanent Locations for the Solar Monitoring Stations

3.0 Test Methods and Equipment

The main components of the tested 24-V DC sampling systems included the sampling unit (CF-5624D brushless, automatic flow control, DC-powered, low-volume air sampler), solar panels, and battery banks. If any of these components were inadequate or failed, the system as a whole would not collect the sample as required. The two sample systems tested (referred to as TEST-B and TEST-C) were set up west of the ball fields. TEST-B was set up with the 2-in filter head, and TEST-C was outfitted with the 4-in filter head. Though the 2-in is the standard filter size used for sampling systems, the 4-in filter head was evaluated as an alternative sample method in the event that the 2-in filter could not pull the requisite volume during the 2-week sample period. Midway into the test it was apparent that the 2-in filter could be used and the second solar array was reconfigured as TEST-D with a 2-in filter head.

Figure 3.1 depicts the 2-in filter holder of an environmental monitoring system. The rain cap that would normally be situated over the filter holder and connector was set aside. Air is pulled through the filter head assembly, which contains a 47-millimeter (mm) glass fiber filter, at a desired rate of 1.5 cfm.

Figure 3.1. Solar Environmental Monitoring System with 2-in Sample Holder Exposed

An AC environmental monitoring system identified as TEST-A commenced on January 17, 2012 as a comparative sampler for validating analytical results. TEST-A is an AC system identical to the existing environmental monitoring systems and consists of a small housed station containing an air volume totalizer, vacuum pump, and flow controller.

The solar panels of the environmental monitoring system were positioned to face the south to optimize solar influence. The stations were operated under the same conditions expected to be found in the desired sample locations. The sampling units came pre-calibrated and programmed to a sample rate of 1.5 cfm. A detailed step-by-step explanation of the process and operation of the environmental monitoring systems

can be found in the test plan *Evaluation and Operation of 24 V DC Powered Environmental Monitoring Stations* (EMPT-AIR-001). The solar environmental monitoring system testing began on February 22, 2012. The RPT collected the following data on scheduled workdays (Appendix A):

- date
- time
- flow rate
- total flow
- elapsed time
- battery condition
- environmental conditions.

Issues with monitoring system performance were addressed as soon as practical after the problem was discovered/identified. Sample filter collection was performed bi-weekly. The 2-in sample filters were sent to GEL Laboratories for gross alpha/gross beta analyses. GEL retained the filters for radioisotope specific composite analyses. The 4-in TEST-C filters were not analyzed, but were all archived locally for possible later analyses.

The Test Plan outlined the basic qualification criteria pertaining to the HI-Q system. The specifications necessary for the solar powered environmental monitoring systems to qualify as appropriate for sampling are described in section 4.0.

The AC monitoring system (TEST-A) was operated and sampled using procedure *Air Particulate Sampling and Routine Maintenance of Environmental Monitoring Stations for the PNNL Site* (EPRP-AIR-029). Sample information from both the DC and AC systems is included with current sampling documentation collected by RPT staff.

4.0 Test Results

The solar powered environmental monitoring systems were tested over an approximate 4-month period (February 22, 2012 through June 27, 2012), during which time the environmental conditions were also evaluated. Appendix A provides data collected by RPT staff over the test period and information about the operational feasibility of system usage. Data evaluation was useful in optimizing the system and verifying operational qualification. A detailed discussion about each specification is included in the discussion below.

Specification 1: Sample Flow – Maintain flow through the sample head at 1.5 cfm without variation throughout each 2-week sample period due to diurnal changes or other environmental conditions.

Maintaining a sample flow of 1.5 cfm is important because at this flow rate, the sample volume meets the minimum detection and sample requirements. If the 1.5-cfm flow cannot be sustained, then the required volume of sample required may not be attained resulting in a "no-sample." Information received from daily flow checks showed that instantaneous flow rates fluctuated between 1.4 and 1.5 cfm. The control unit of the system constantly monitors the flow rate and adjusts the sample rate as necessary to maintain the pre-set flow rate of 1.5 cfm, and the system is designed not to exceed the pre-set flow rate value. Sample flow rate averages over the observed 2-week operating periods ranged from 1.489 to 1.497 cfm for the sample periods in which the unit was pre-set to 1.5 cfm. On March 22, 2012, the pre-set flow rate value increased to 1.6 cfm; for this setting, the flow rate averages over the 2-week operating period were between 1.594 and 1.597 cfm.

Specification 2: Blower Operation – The blower on the environmental monitoring system must operate under both hot and cold weather extremes. The blower must have the capacity to continue sampling at 1.5 cfm even if the filter contains an accumulation of dust or ice particles.

Sample collection depends on the ability of the air sampler to operate in adverse weather conditions. Over the time period evaluated (February 22, 2012 through June 27, 2012), the following environmental conditions existed: low-light conditions, temperatures below 32°F and greater than 90°F, overcast conditions, rain, and dust. The environmental conditions experienced did not adversely affect the environmental monitoring systems. Once it was apparent that the 2-in filter system operated normally (e.g., it did not experience sample failure or excessive particulate buildup during the 2-week sample period) the 4-in filter system (TEST-C) was replaced with a 2-in filter system and renamed TEST-D.

Blower/sample unit failure did occur for reasons other than environmental conditions. Both conditions involved equipment failure. TEST-B had a system malfunction which involved a power disruption during low light conditions. On May 18, 2012 and June 4, 2012, the environmental monitoring system shut down due to the lack of power. Troubleshooting showed the power controller inside the battery box overheated causing the controller to operate unpredictably. Corrective action included ordering additional power controllers and replacing the failed power controller.

TEST-C ceased operation on March 21, 2012 and again on April 13, 2012. Both instances involved problems with the programmable logic controller (PLC) on the system. The first time the blower stopped, the issue was resolved by shutting down and re-booting the system. The second time the blower went down, the system would not re-boot, so the unit was returned to the vendor for service. TEST-C operated

normally with the new blower installed. Despite these malfunctions, the system passed the specification because the sample flow rate could be maintained.

Specification 3: Solar Panel Charging Ability and Battery Life – The charging system and battery capacity must be adequate to run the monitoring system as desired for extended periods of low daylight conditions, as overcast and foggy conditions may extend for multiple weeks at a time during the winter.

Low-light conditions experienced during winter months and during heavy overcast weather impacts the ability of the solar powered system to charge the battery array and maintain a steady power source to the environmental monitoring system. To obtain an accurate battery charge reading, RPTs made daily checks before 8:00 am when possible. During the test period, the battery arrays remained charged and functional. The environmental monitoring system ceases operation when the battery array charge drops below 20 V. Overall, the solar charging ability and battery capacity were adequate under the environmental conditions experienced during the test period; 23 V was the lowest battery charge reading

Specification 4: Uniform Analytical Results – Collect analytical samples from the HI-Q systems equivalent to the AC powered systems.

The 2-in particulate sample filters for TEST-A, TEST-B, and TEST-D (TEST-D was started April 18, 2012) were sent off for gross alpha and gross beta analysis after each 2-week sample period. The 2-in sample filters were analyzed at GEL Laboratories (2040 Savage Rd, Charleston, SC 29407) for non-destructive gross alpha and gross beta analysis. Comparative plots of the gross alpha and gross beta analytical results are shown in Figure 4.1 and Figure 4.2 and show a relative degree of similarity. The samples were held and analytical composites for select nuclides were made at the end of June 2012. Data composite results are also similar in that results were below detection limits for most radionuclides for all systems and the few results above detection limits had similar values for all systems (see Appendix B).

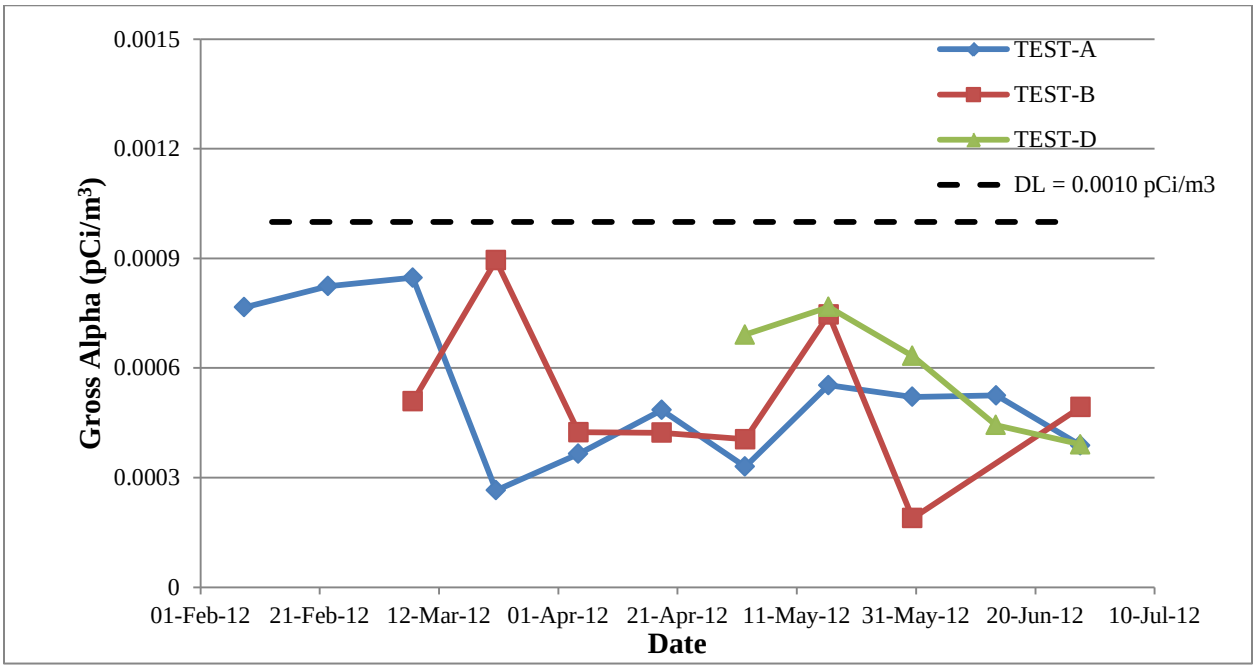

Figure 4.1. Results of Gross Alpha Analysis of Particulate Air Samples (Detection Limit is 0.0010 pCi/m^3)

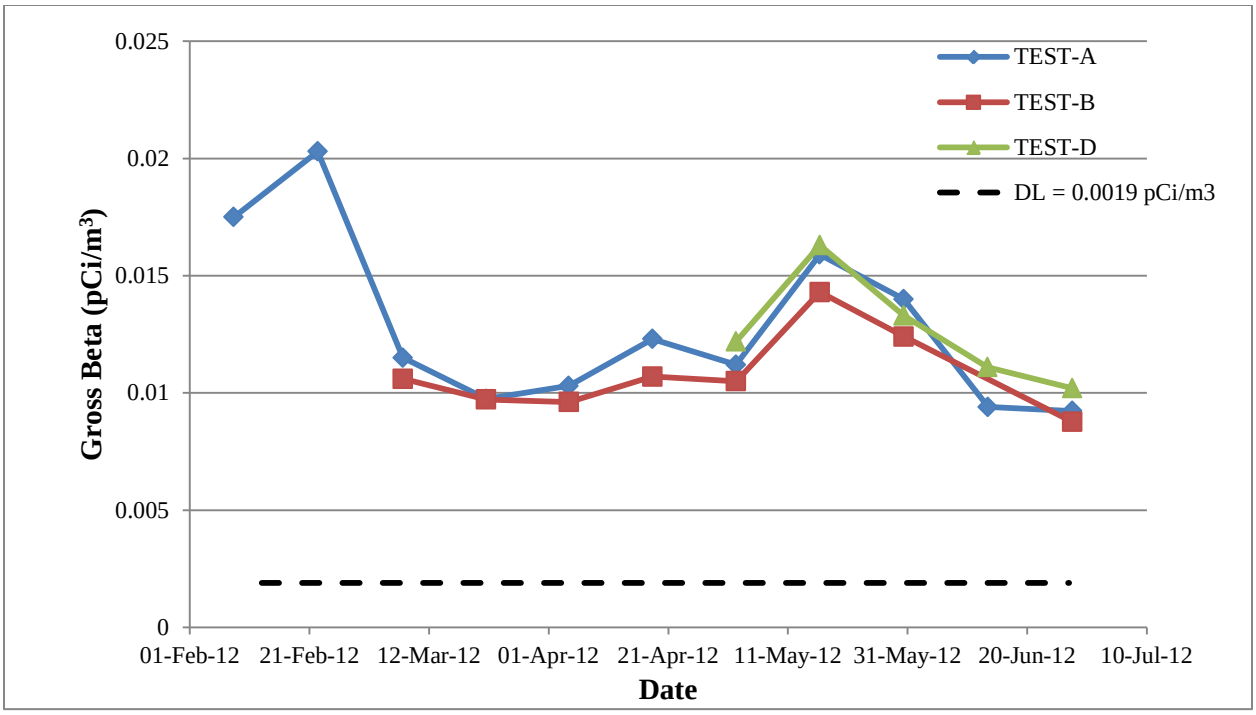

Figure 4.2. Results of Gross Beta Analysis of Particulate Air Samples (Detection Limit is 0.0019 pCi/m^3)

5.0 Conclusions and Recommendations

For the evaluation period, the solar powered monitoring stations meet the established qualification criteria. Results show the solar powered system is a feasible alternative to current AC sampling systems. Sample flows were maintained, and the required air volume sampled was met for each 2-week sample period. The blower operation manages the environmental conditions experienced; however, the solar environmental monitoring stations are more susceptible to failure from the many different components, program software, and electrical connections. Replacement components should be available to maintain the 85% or greater operability factor. The charging ability of the solar panels and battery capacity appear to be sufficient for the power usage required at the 1.6 cfm sample rate. Finally, the test samples analyzed for gross alpha/gross beta indicate similar results.

Based on the tests performed and observations made, the solar powered monitoring stations were deployed to their permanent locations in June 2012 as a viable environmental monitoring method to comply with the PNNL Site RAEL-05.

Appendix A

Daily Monitoring Checklist

Appendix A

Daily Monitoring Checklist Data

Date	Monitoring System	RPT	Time	Flow Rate (cfm)	End Volume (m^3)	Total Flow (ft^3)	Total Flow (ft^3) converted to m^3	Elapsed Time (Hrs)	Battery Condition (V)	Environmental Conditions
	TEST-A	DLM	0915	---(1)	8283	---(1)	---(1)	---(1)	---(1)	(2)
22-Feb-12	TEST-B	DLM	0915	1.5	---	0	0	0	27	(2)
	TEST-C	DLM	0915	1.5	---	0	0	0	27	(2)
	TEST-A	DLM	1345	---	8344	---	---	---	---	(2)
23-Feb-12	TEST-B	DLM	1345	1.4	---	2340	66	26.1	28	(2)
	TEST-C	DLM	1345	1.4	---	2349	66	26.2	28	(2)
	TEST-A	DLM	1015	---	8394	---	---	---	---	(2)
24-Feb-12	TEST-B	DLM	1015	1.4	---	4185	118	46.6	27	(2)
	TEST-C	DLM	1015	1.4	---	4193	119	46.7	26	(2)
	TEST-A	SKM	1310	---	8573	---	---	---	---	(2)
27-Feb-12	TEST-B	SKM	1310	1.5	---	10907	309	121.4	27	(2)
	TEST-C	SKM	1310	1.5	---	10909	309	121.5	27	(2)
	TEST-A	DLM	0930	---	8621	---	---	---	---	(2)
28-Feb-12	TEST-B	DLM	0930	1.4	---	12735	360	141.8	28	(2)
	TEST-C	DLM	0930	1.5	---	12735	360	141.8	27	(2)
	TEST-A	DLM	0855	---	8677	---	---	---	---	(2)
29-Feb-12	TEST-B	DLM	0855	1.5	---	14836	420	165.1	29	(2)
	TEST-C	DLM	0855	1.5	---	14840	420	165.3	27	(2)
	TEST-A	FG	1315	---	8745	---	---	---	---	(2)
1-Mar-12	TEST-B	FG	1315	1.5	---	17371	492	193.3	27	(2)
	TEST-C	FG	1315	1.5	---	17373	492	193.5	27	(2)
	TEST-A	FG	1430	---	8807	---	---	---	---	(2)
2-Mar-12	TEST-B	FG	1430	1.5	---	19649	556	218.7	27	(2)
	TEST-C	FG	1430	1.5	---	19648	556	218.8	27	(2)
	TEST-A	FG	1130	---	8973	---	---	---	---	(2)
5-Mar-12	TEST-B	FG	1130	1.5	---	25849	732	287.6	28	(2)
	TEST-C	FG	1130	1.4	---	25840	731	287.7	27	(2)
	TEST-A	FG	0930	---	9024	---	---	---	---	(2)
6-Mar-12	TEST-B	FG	0930	1.5	---	27802	787	309.4	28	(2)
	TEST-C	FG	0930	1.5	---	27795	787	309.5	27	(2)
	TEST-A	FG	1445	---	9095	---	---	---	---	Sunny
7-Mar-12	TEST-B	FG	1500	1.5	---	30465	862	339	27	Sunny
	TEST-C	FG	1545	1.5	---	30514	864	339.8	27	Sunny
	TEST-A	FG	1300	---	9152	---	---	---	---	Sunny
8-Mar-12	TEST-B	FG	1300	1.5	---	1923	54	21.4	27	Sunny
	TEST-C	FG	1300	1.5	---	1898	54	21.8	27	Sunny
	TEST-A	FG	0915	---	9205	---	---	---	---	Sunny
9-Mar-12	TEST-B	FG	0915	1.5	---	3745	106	41.7	28	Sunny
	TEST-C	FG	0915	1.5	---	3713	105	41.4	27	Sunny

Date	Monitoring System	RPT	Time	Flow Rate (cfm)	End Volume (m^3)	Total Flow (ft^3)	Total Flow (ft^3) converted to m^3	Elapsed Time (Hrs)	Battery Condition (V)	Environmental Conditions
	TEST-A	FG	1400	---	9397	---	---	---	---	Cloudy
12-Mar-12	TEST-B	FG	1400	1.5	---	10552	299	117.4	28	Cloudy
	TEST-C	FG	1400	1.4	---	10510	297	117.1	27	Cloudy
	TEST-A	FG	1400	---	9457	---	---	---	---	Cloudy
13-Mar-12	TEST-B	FG	1400	1.5	---	12695	359	141.4	28	Cloudy
	TEST-C	FG	1400	1.5	---	12668	359	141.1	27	Cloudy
	TEST-A	FG	0800	---	9503	---	---	---	---	Cloudy
14-Mar-12	TEST-B	FG	0800	1.5	---	14303	405	159.3	26	Cloudy
	TEST-C	FG	0800	1.5	---	14273	404	159	26	Cloudy
	TEST-A	FG	1230	---	9574	---	---	---	---	Overcast
15-Mar-12	TEST-B	FG	1230	1.5	---	16835	476	187.8	27	Overcast
	TEST-C	FG	1230	1.5	---	16836	476	187.6	27	Overcast
	TEST-A	FG	1245	---	9636	---	---	---	---	Sunny
16-Mar-12	TEST-B	FG	1245	1.5	---	18969	537	212	27	Sunny
	TEST-C	FG	1245	1.5	---	19005	538	211.7	27	Sunny
	TEST-A	FG	1000	---	9810	---	---	---	---	Sunny
19-Mar-12	TEST-B	FG	1000	1.5	---	25147	712	281.2	28	Sunny
	TEST-C	FG	1000	1.5	---	25217	714	280.9	27	Sunny
	TEST-A	FG	0800	---	9868	---	---	---	---	Partly Overcast
20-Mar-12	TEST-B[(3)]	FG	0800	1.4	---	27104	767	303.2	25	Partly Overcast
	TEST-C[(3)]	FG	0800	1.4	---	27192	770	302.9	25	Partly Overcast
	TEST-A	FG	1315	---	9944	---	---	---	---	Overcast Raining
21-Mar-12	TEST-B	FG	1330	1.5	---	29799	843	332.6	27	Overcast Raining
	TEST-C	FG	1400	1.5	---	29129	824	323.1	27	Overcast Raining
	TEST-A	FG	0745	---	9987	---	---	---	---	Partly Overcast
22-Mar-12	TEST-B	FG	0745	1.5	---	1715	49	18	25	Partly Overcast
	TEST-C	FG	0745	1.5	---	1647	47	17.2	25	Partly Overcast
	TEST-A	FG	0600	---	42	---	---	---	---	Dark
23-Mar-12	TEST-B	FG	0600	1.6	---	3842	109	40.2	25	Dark
	TEST-C	FG	0600	1.6	---	3776	107	39.4	25	Dark
	TEST-A	FG	0830	---	228	---	---	---	---	Overcast
26-Mar-12	TEST-B	FG	0830	1.5	---	10964	310	114.6	26	Overcast
	TEST-C	FG	0830	1.6	---	10898	308	113.8	26	Overcast
	TEST-A	FG	0730	---	285	---	---	---	---	Overcast Raining
27-Mar-12	TEST-B	FG	0730	1.6	---	13150	372	137.5	25	Overcast Raining
	TEST-C	FG	0730	1.6	---	10392	294	136.7	25	Overcast Raining
	TEST-A	FG	0730	---	345	---	---	---	---	Overcast Raining
28-Mar-12	TEST-B	FG	0730	1.6	---	15459	437	161.6	25	Overcast Raining
	TEST-C	FG	0730	1.6	---	15400	436	160.7	25	Overcast Raining
	TEST-A	FG	0830	---	407	---	---	---	---	Partly Cloudy
29-Mar-12	TEST-B	FG	0830	1.5	---	17841	505	186.5	26	Partly Cloudy
	TEST-C	FG	0830	1.5	---	17783	503	185.6	26	Partly Cloudy
	TEST-A	FG	1100	---	473	---	---	---	---	Overcast Raining
30-Mar-12	TEST-B	FG	1100	1.6	---	20392	577	213.2	28	Overcast Raining
	TEST-C	FG	1100	1.5	---	20344	576	212.4	28	Overcast Raining

Date	Monitoring System	RPT	Time	Flow Rate (cfm)	End Volume (m^3)	Total Flow (ft^3)	Total Flow (ft^3) converted to m^3	Elapsed Time (Hrs)	Battery Condition (V)	Environmental Conditions
	TEST-A	SKM	0930	---	651	---	---	---	---	Overcast
2-Apr-12	TEST-B	SKM	0930	1.6	---	27119	767	283.4	28	Overcast
	TEST-C	SKM	0930	1.5	---	27070	766	282.6	28.5	Overcast
	TEST-A	SKM	0900	---	710	---	---	---	---	Partly Cloudy
3-Apr-12	TEST-B	SKM	0900	1.6	---	29368	831	306.9	29	Partly Cloudy
	TEST-C	SKM	0900	1.5	---	29321	830	306.1	28.2	Partly Cloudy
	TEST-A	SKM	0900	---	771	---	---	---	---	Cloudy
4-Apr-12	TEST-B	SKM	0935	1.6	---	31726	898	331.6	27	Cloudy
	TEST-C	SKM	0910	1.6	---	31640	895	330.3	27.5	Cloudy
	TEST-A	SKM	0745	---	830	---	---	---	---	Partly Cloudy
5-Apr-12	TEST-B	SKM	0745	1.6	---	2094	59	21.9	26.5	Partly Cloudy
	TEST-C	SKM	0745	1.6	---	2127	60	22.2	26.5	Partly Cloudy
	TEST-A	SKM	0800	---	894	---	---	---	---	Partly Cloudy
6-Apr-12	TEST-B	SKM	0800	1.6	---	4413	125	46.1	26	Partly Cloudy
	TEST-C	SKM	0800	1.5	---	4453	126	46.5	26	Partly Cloudy
	TEST-A	SKM	0745	---	1083	---	---	---	---	Overcast
9-Apr-12	TEST-B	SKM	0745	1.6	---	11274	319	117.8	26.5	Overcast
	TEST-C	SKM	0745	1.6	---	11314	320	118.2	26.5	Overcast
	TEST-A	SKM	0727	---	1144.3	---	---	---	---	Overcast
10-Apr-12	TEST-B	SKM	0727	1.5	---	13538	383	141.5	25.5	Overcast
	TEST-C	SKM	0727	1.6	---	13583	384	141.9	25.5	Overcast
	TEST-A	SKM	0710	---	1203	---	---	---	---	Overcast
11-Apr-12	TEST-B	SKM	0710	1.6	---	15804	447	165.1	25.5	Overcast
	TEST-C	SKM	0710	1.6	---	15848	448	165.5	25.5	Overcast
	TEST-A	SKM	0730	---	1265	---	---	---	---	Sunny
12-Apr-12	TEST-B	SKM	0730	1.6	---	18136	513	189.5	26	Sunny
	TEST-C	SKM	0730	1.6	---	18181	515	189.9	26	Sunny
	TEST-A	SKM	0745	---	1327	---	---	---	---	Sunny
13-Apr-12	TEST-B	SKM	0745	1.5	---	20467	579	213.9	27	Sunny
	TEST-C	SKM	0745	(4)	---	(4)	(4)	(4)	28	Sunny
	TEST-A	SKM	0750	---	1511	---	---	---	---	Cloudy
16-Apr-12	TEST-B	SKM	0750	1.6	---	27347	774	285.7	25.5	Cloudy
	TEST-C	SKM	0750	(4)	---	(4)	(4)	(4)	28.5	Cloudy
	TEST-A	SKM	0730	---	1572	---	---	---	---	Sunny
17-Apr-12	TEST-B	SKM	0730	1.6	---	29608	838	309.4	26	Sunny
	TEST-C	SKM	0730	(4)	---	(4)	0	(4)	28.5	Sunny
	TEST-A	SKM	0845	---	1637	---	---	---	---	Cloudy
18-Apr-12	TEST-B	SKM	0855	1.6	---	32039	907	334.8	28.5	Cloudy
	TEST-D (4)	SKM	1115	1.6	---	0	0	0	26.5	Cloudy
	TEST-A	SKM	0730	---	1695	---	---	---	---	Sunny
19-Apr-12	TEST-B	SKM	0730	1.6	---	2122	60	22.2	26.5	Sunny
	TEST-D	SKM	0730	1.6	---	1926	55	20.1	26	Sunny
	TEST-A	FG	0730	---	1755	---	---	---	---	Partly Cloudy
20-Apr-12	TEST-B	FG	0730	1.5	---	4408	125	46	26	Partly Cloudy
	TEST-D	FG	0730	1.6	---	4219	119	44	26	Partly Cloudy

Date	Monitoring System	RPT	Time	Flow Rate (cfm)	End Volume (m^3)	Total Flow (ft^3)	Total Flow (ft^3) converted to m^3	Elapsed Time (Hrs)	Battery Condition (V)	Environmental Conditions
	TEST-A	SKM	0745	---	1935	---	---	---	---	Sunny
23-Apr-12	TEST-B	SKM	0745	1.5	---	11324	320	118	26.5	Sunny
	TEST-D	SKM	0745	1.6	---	11144	315	116.3	26	Sunny
	TEST-A	SKM	0730	---	1994	---	---	---	---	Sunny
24-Apr-12	TEST-B	SKM	0730	1.6	---	13609	385	142.2	26.5	Sunny
	TEST-D	SKM	0730	1.6	---	13433	380	140.1	26	Sunny
	TEST-A	SKM	0815	---	2056	---	---	---	---	Cloudy
25-Apr-12	TEST-B	SKM	0815	1.6	---	15977	452	166.9	26.5	Cloudy
	TEST-D	SKM	0815	1.6	---	15806	447	164.9	26.5	Cloudy
	TEST-A	SKM	0800	---	2115	---	---	---	---	Rain
26-Apr-12	TEST-B	SKM	0800	1.6	---	18235	516	190.5	25	Rain
	TEST-D	SKM	0800	1.6	---	18069	511	188.5	25	Rain
	TEST-A	FG	0715	---	2175	---	---	---	---	Sunny
27-Apr-12	TEST-B	FG	0715	1.6	---	20458	579	213.7	26	Sunny
	TEST-D	FG	0715	1.6	---	20298	574	211.7	26	Sunny
	TEST-A	FG	0800	---	2360	---	---	---	---	Sunny
30-Apr-12	TEST-B	FG	0800	1.5	---	27424	776	286.5	27.5	Sunny
	TEST-D	FG	0800	1.6	---	27270	772	284.5	27	Sunny
	TEST-A	DLM	0836	---	2423	---	---	---	---	Sunny
1-May-12	TEST-B	DLM	0836	1.6	---	29769	842	311	28	Sunny
	TEST-D	DLM	0836	1.6	---	29623	838	309	28	Sunny
	TEST-A	SKM	0810	---	2483	---	---	---	---	Sunny
2-May-12	TEST-B	SKM	0840	1.6	---	32058	907	334.9	28.5	Sunny
	TEST-D	SKM	0825	1.6	---	31891	903	332.7	28	Sunny
	TEST-A	DLM	0740	---	2543	---	---	---	---	Overcast
3-May-12	TEST-B	DLM	0740		---	2197	62	23	26	Overcast
	TEST-D	DLM	0740	1.5	---	2221	63	23.2	23.5	Overcast
	TEST-A	DLM	0725	---	2604	---	---	---	---	Overcast
4-May-12	TEST-B	DLM	0725	1.6	---	4469	126	46.7	27	Overcast
	TEST-D	DLM	0725	1.6	---	4496	127	46.9	27	Overcast
	TEST-A	SKM	0740	---	2796	---	---	---	---	Sunny
7-May-12	TEST-B	SKM	0740	1.6	---	11378	322	118.9	27	Sunny
	TEST-D	SKM	0740	1.6	---	11416	323	119.1	26.5	Sunny
	TEST-A	DLM	0740	---	2858	---	---	---	---	Sunny
8-May-12	TEST-B	DLM	0740	1.6	---	13667	387	142.8	27	Sunny
	TEST-D	DLM	0740	1.6	---	13733	389	143.1	27	Sunny
	TEST-A	DLM	0807	---	2921	---	---	---	---	Sunny
9-May-12	TEST-B	DLM	0807	1.6	---	16008	453	167.3	28.5	Sunny
	TEST-D	DLM	0807	1.6	---	16052	454	167.5	27.5	Sunny
	TEST-A	DLM	0800	---	2985	---	---	---	---	Sunny
10-May-12	TEST-B	DLM	0800	1.6	---	18287	518	191.1	28.5	Sunny
	TEST-D	DLM	0800	1.6	---	18335	519	191.3	27	Sunny
	TEST-A	DLM	0730	---	3047	---	---	---	---	Sunny
11-May-12	TEST-B	DLM	0730	1.6	---	20575	582	215	27.5	Sunny
	TEST-D	DLM	0730	1.6	---	20625	584	215.2	26.5	Sunny

Date	Monitoring System	RPT	Time	Flow Rate (cfm)	End Volume (m^3)	Total Flow (ft^3)	Total Flow (ft^3) converted to m^3	Elapsed Time (Hrs)	Battery Condition (V)	Environmental Conditions
	TEST-A	SKM	0745	---	3230	---	---	---	---	Sunny
14-May-12	TEST-B	SKM	0745	1.6	---	27453	777	286.9	24.5	Sunny
	TEST-D	SKM	0745	1.6	---	27515	779	287.1	26.5	Sunny
	TEST-A	DLM	0745	---	3293	---	---	---	---	Sunny
15-May-12	TEST-B	DLM	0745	1.5	---	29740	842	310.8	24.5	Sunny
	TEST-D	DLM	0745	1.5	---	29810	844	311.1	26.5	Sunny
	TEST-A	DLM	0730	---	3353	---	---	---	---	Sunny
16-May-12	TEST-B	DLM	0730	1.6	---	32012	906	334.5	24	Sunny
	TEST-D	DLM	0730	1.6	---	32082	908	334.7	26	Sunny
	TEST-A	DLM	0805	---	3417.2	---	---	---	---	Sunny
17-May-12	TEST-B	DLM	0805	1.6	---	2236	63	23.3	23	Sunny
	TEST-D	DLM	0805	1.6	---	2261	64	23.6	27	Sunny
	TEST-A	DLM	0725	---	3478.1	---	---	---	---	Sunny
18-May-12	TEST-B	DLM	---	(5)	---	(5)	(5)	(5)	23	Sunny
	TEST-D	DLM	0725	1.5	---	4501	127	47	26	Sunny
	TEST-A	SKM	0750	---	3665	---	---	---	---	Cloudy
21-May-12	TEST-B	SKM	0750	1.6	---	10192	288	106.5	25.5	Cloudy
	TEST-D	SKM	0750	1.6	---	11436	324	119.3	26	Cloudy
	TEST-A	DLM	0810	---	3729.7	---	---	---	---	Overcast
22-May-12	TEST-B	DLM	0810	1.5	---	12511	354	130.7	26	Overcast
	TEST-D	DLM	0810	1.6	---	13761	389	143.6	27	Overcast
	TEST-A	DLM	0900	---	3795	---	---	---	---	Thin Overcast
23-May-12	TEST-B	DLM	0900	1.6	---	14894	422	155.6	27.5	Thin Overcast
	TEST-D	DLM	0900	1.6	---	16147	457	168.5	28	Thin Overcast
	TEST-A	SKM	0900	---	3856	---	---	---	---	Sunny
24-May-12	TEST-B	SKM	0900	1.6	---	17198	487	179.7	25	Sunny
	TEST-D	SKM	0900	1.6	---	18451	522	192.5	27.5	Sunny
	TEST-A	SKM	0900	---	3919	---	---	---	---	Sunny
25-May-12	TEST-B	SKM	0900	1.6	---	19495	552	203.7	28	Sunny
	TEST-D	SKM	0900	1.6	---	20751	587	216.5	28	Sunny
	TEST-A	DLM	0810	---	4163	---	---	---	---	Thin Overcast
29-May-12	TEST-B	DLM	0810	1.5	---	28578	809	298.6	25.5	Thin Overcast
	TEST-D	DLM	0810	1.6	---	29853	845	311.5	28	Thin Overcast
	TEST-A	DLM	0855	---	4227	---	---	---	---	Overcast
30-May-12	TEST-B	DLM	0855	1.6	---	30945	876	323.3	24.5	Overcast
	TEST-D	DLM	0855	1.5	---	32219	912	336.2	28	Overcast
	TEST-A	DLM	0825	---	4294	---	---	---	---	Cloudy
31-May-12	TEST-B	DLM	0825	1.6	---	2144	61	22.4	24.5	Cloudy
	TEST-D	DLM	0825	1.6	---	2171	61	22.6	26.5	Cloudy
	TEST-A	DLM	0750	---	4361	---	---	---	---	Cloudy
1-Jun-12	TEST-B	DLM	0750	1.6	---	4386	124	45.8	24	Cloudy
	TEST-D	DLM	0750	1.5	---	4417	125	46.1	27	Cloudy
	TEST-A	SKM	0800	---	4566	---	---	---	---	Cloudy
4-Jun-12	TEST-B	SKM	0800	(6)	---	(6)	(6)	(6)	23	Cloudy
	TEST-D	SKM	0800	1.6	---	11321	320	118.1	26	Cloudy

Date	Monitoring System	RPT	Time	Flow Rate (cfm)	End Volume (m^3)	Total Flow (ft^3)	Total Flow (ft^3) converted to m^3	Elapsed Time (Hrs)	Battery Condition (V)	Environmental Conditions
	TEST-A	FG	0800	---	4634	---	---	---	---	Raining
5-Jun-12	TEST-B	FG	0800	(6)	---	(6)	(6)	(6)	((6)	Raining
	TEST-D	FG	0800	1.6	---	13625	386	142.1	26	Raining
	TEST-A	FG	0830	---	4703	---	---	---	---	Sunny
6-Jun-12	TEST-B	FG	0830	(6)	---	(6)	(6)	(6)	(6)	Sunny
	TEST-D	FG	0830	1.5	---	15969	452	166.6	28	Sunny
	TEST-A	FG	0730	---	4769	---	---	---	---	Cloudy
7-Jun-12	TEST-B	FG	0730	(6)	---	(6)	(6)	(6)	(6)	Cloudy
	TEST-D	FG	0730	1.6	---	18193	515	189.8	27	Cloudy
	TEST-A	DLM	1315	---	4852	---	---	---	---	Partly Cloudy
8-Jun-12	TEST-B	DLM	1315	1.6	---	13399	379	140	28	Partly Cloudy
	TEST-D	DLM	1315	1.6	---	21029	595	219.3	26	Partly Cloudy
	TEST-A	FG	0930	---	5049	---	---	---	---	Partly Cloudy
11-Jun-12	TEST-B	FG	0830	(6)	---	(6)	(6)	(6)	(6)	Partly Cloudy
	TEST-D	FG	0830	(6)	---	(6)	(6)	(6)	(6)	Partly Cloudy
	TEST-A	DLM	1510	---	5130	---	---	---	---	Mostly Cloudy
12-Jun-12	TEST-B	DLM	1330	1.6	---	19866	562	207.6	28	Mostly Cloudy
	TEST-D	DLM	1500	1.5	---	27627	782	288.2	26	Mostly Cloudy
	TEST-A	DLM	1100	---	5187	---	---	---	---	Clear
13-Jun-12	TEST-B	DLM	1000	1.6	---	21824	618	228	28	Clear
	TEST-D	DLM	0910	1.6	---	29364	831	306.3	28	Clear
	TEST-A	DLM	1111	---	5256	---	---	---	---	Sunny
14-Jun-12	TEST-B	DLM	1057	1.6	---	2370	67	24.8	27	Sunny
	TEST-D	DLM	1016	1.6	---	2385	67	24.9	26.5	Sunny
	TEST-A	FG	0830	---	5317	---	---	---	---	Sunny
15-Jun-12	TEST-B	FG	0900	1.6	---	4472	127	46.8	27	Sunny
	TEST-D	FG	0845	1.5	---	4544	129	47.4	28	Sunny
	TEST-A	SKM	0750	---	5520	---	---	---	---	Cloudy
18-Jun-12	TEST-B	SKM	0800	1.6	---	11276	319	117.8	28	Cloudy
	TEST-D	SKM	0755	1.6	---	11361	322	118.5	26.5	Cloudy
	TEST-A	FG	0830	---	5592	---	---	---	---	Cloudy
19-Jun-12	TEST-B	FG	0800	1.5	---	13620	385	142.3	28	Cloudy
	TEST-D	FG	0800	1.6	---	13708	388	143	28	Cloudy
	TEST-A	FG	1300	---	5672	---	---	---	---	Sunny
20-Jun-12	TEST-B	FG	1315	1.6	---	16341	462	170.8	26	Sunny
	TEST-D	FG	1300	1.6	---	16414	465	171.2	26	Sunny
	TEST-A	FG	0800	---	5728	---	---	---	---	Sunny
21-Jun-12	TEST-B	FG	0830	1.6	---	18175	514	189.9	27.5	Sunny
	TEST-D	FG	0815	1.6	---	18257	517	190.5	26.5	Sunny
	TEST-A	DLM	0753	---	5794	---	---	---	---	Overcast
22-Jun-12	TEST-B	DLM	0806	1.5	---	20448	579	213.7	26.5	Overcast
	TEST-D	DLM	0801	1.6	---	20540	581	214.3	26	Overcast
	TEST-A	FG	0915	---	6004	---	---	---	---	Overcast
25-Jun-12	TEST-B	FG	0900	1.5	---	27370	775	266	28	Overcast
	TEST-D	FG	0930	1.6	---	27568	780	287.6	28	Overcast

Date	Monitoring System	RPT	Time	Flow Rate (cfm)	End Volume (m^3)	Total Flow (ft^3)	Total Flow (ft^3) converted to m^3	Elapsed Time (Hrs)	Battery Condition (V)	Environmental Conditions
	TEST-A	FG	1100	---	6079	---	---	---	---	Raining
26-Jun-12	TEST-B	FG	1130	1.6	---	29894	846	312.3	28	Raining
	TEST-D	FG	1115	1.6	---	30081	851	313.8	28	Raining
	TEST-A	FG	1345	---	6155	---	---	---	---	Sunny
27-Jun-12	TEST-B	FG	1430	1.6	---	32335	915	337.8	26	Sunny
	TEST-D	FG	1400	1.6	---	32598	923	340.1	26	Sunny

(1) This data is dependent on the type of monitoring system (120-V versus 24-V) and is not available.
(2) Data not collected.
(3) Increased set flow to 1.6.
(4) System failed and 4-in. filter taken out of service; sent HI-Q blower unit back to vendor for repair. TEST-C was replaced with TEST-D. TEST-C was a 4-in. filter, and TEST-D is a 2-in. filter.
(5) System failed then started unexpectedly after being inoperative for 13 hours.
(6) System power controller failed. System off line.

Appendix B

GEL Laboratories Analytical Results for 2-in Sample Filters

Appendix B

Analytical Results for 2-in Sample Filters

Radionuclide	Monitoring System	Sample On	Sample Off	Lab Qualifier	Value Reported (pCi/m3)	Error/ Standard Deviation (pCi/m3)
ALPHA	TEST-A	17-Jan-12	8-Feb-12		7.66E-04	2.78E-04
		8-Feb-12	22-Feb-12		8.24E-04	4.12E-04
		22-Feb-12	7-Mar-12		8.47E-04	3.75E-04
		7-Mar-12	21-Mar-12	U	2.65E-04	2.45E-04
		21-Mar-12	4-Apr-12	U	3.65E-04	2.99E-04
		4-Apr-12	18-Apr-12		4.85E-04	3.03E-04
		18-Apr-12	2-May-12	U	3.30E-04	2.63E-04
		2-May-12	16-May-12		5.53E-04	2.93E-04
		16-May-12	30-May-12		5.21E-04	2.89E-04
		30-May-12	13-Jun-12		5.25E-04	2.76E-04
		13-Jun-12	27-Jun-12		3.88E-04	2.42E-04
	TEST-B	22-Feb-12	7-Mar-12		5.09E-04	2.93E-04
		7-Mar-12	21-Mar-12		8.95E-04	4.07E-04
		21-Mar-12	4-Apr-12		4.24E-04	2.62E-04
		4-Apr-12	18-Apr-12		4.23E-04	2.70E-04
		18-Apr-12	2-May-12		4.05E-04	2.57E-04
		2-May-12	16-May-12		7.46E-04	3.41E-04
		16-May-12	30-May-12	U	1.89E-04	2.21E-04
		13-Jun-12	27-Jun-12		4.93E-04	2.99E-04
	TEST-D	18-Apr-12	2-May-12		6.91E-04	3.69E-04
		2-May-12	16-May-12		7.67E-04	3.74E-04
		16-May-12	30-May-12		6.33E-04	2.86E-04
		30-May-12	13-Jun-12		4.44E-04	3.26E-04
		13-Jun-12	27-Jun-12		3.91E-04	2.45E-04
BETA	TEST-A	17-Jan-12	8-Feb-12		1.75E-02	1.09E-03
		8-Feb-12	22-Feb-12		2.03E-02	1.46E-03
		22-Feb-12	7-Mar-12		1.15E-02	1.10E-03
		7-Mar-12	21-Mar-12		9.74E-03	9.67E-04
		21-Mar-12	4-Apr-12		1.03E-02	1.01E-03
		4-Apr-12	18-Apr-12		1.23E-02	1.05E-03
		18-Apr-12	2-May-12		1.12E-02	1.01E-03
		2-May-12	16-May-12		1.59E-02	1.22E-03
		16-May-12	30-May-12		1.40E-02	1.14E-03
		30-May-12	13-Jun-12		9.40E-03	8.40E-04
		13-Jun-12	27-Jun-12		9.23E-03	8.28E-04
	TEST-B	22-Feb-12	7-Mar-12		1.06E-02	9.69E-04
		7-Mar-12	21-Mar-12		9.72E-03	9.67E-04
		21-Mar-12	4-Apr-12		9.61E-03	8.68E-04
		4-Apr-12	18-Apr-12		1.07E-02	8.91E-04
		18-Apr-12	2-May-12		1.05E-02	8.82E-04
		2-May-12	16-May-12		1.43E-02	1.09E-03

Radionuclide	Monitoring System	Sample On	Sample Off	Lab Qualifier	Value Reported (pCi/m3)	Error/ Standard Deviation (pCi/m3)
BETA	TEST-B	16-May-12	30-May-12		1.24E-02	1.23E-03
		13-Jun-12	27-Jun-12		8.77E-03	8.68E-04
	TEST-D	18-Apr-12	2-May-12		1.22E-02	9.44E-04
		2-May-12	16-May-12		1.63E-02	1.19E-03
		16-May-12	30-May-12		1.33E-02	1.10E-03
		30-May-12	13-Jun-12		1.11E-02	9.51E-04
		13-Jun-12	27-Jun-12		1.02E-02	8.64E-04
Am-241	TEST-A	17-Jan-12	27-Jun-12	U	1.25E-06	3.70E-06
	TEST-B	22-Feb-12	27-Jun-12	U	-8.96E-08	2.47E-06
	TEST-D	18-Apr-12	27-Jun-12	U	-2.60E-06	5.43E-06
Am-243	TEST-A	17-Jan-12	27-Jun-12	U	2.19E-06	6.64E-06
	TEST-B	22-Feb-12	27-Jun-12	U	-2.08E-06	2.91E-06
	TEST-D	18-Apr-12	27-Jun-12	U	-1.14E-06	3.88E-06
Cm-243/244	TEST-A	17-Jan-12	27-Jun-12	U	-2.08E-06	3.55E-06
	TEST-B	22-Feb-12	27-Jun-12	U	-2.26E-06	2.72E-06
	TEST-D	18-Apr-12	27-Jun-12	U	-5.16E-06	4.95E-06
Co-60	TEST-A	17-Jan-12	4-Apr-12	U	-3.30E-05	6.60E-04
	TEST-A	4-Apr-12	27-Jun-12	U	-3.25E-05	4.99E-04
	TEST-B	22-Feb-12	27-Jun-12	U	-9.54E-05	3.01E-04
	TEST-D	18-Apr-12	27-Jun-12	U	-9.49E-06	6.70E-04
Pu-238	TEST-A	17-Jan-12	27-Jun-12	U	3.85E-07	1.85E-06
	TEST-B	22-Feb-12	27-Jun-12	U	8.36E-07	1.55E-06
	TEST-D	18-Apr-12	27-Jun-12	U	0.00E+00	2.03E-06
Pu-239/240	TEST-A	17-Jan-12	27-Jun-12		4.61E-06	3.12E-06
	TEST-B	22-Feb-12	27-Jun-12	U	1.95E-06	2.32E-06
	TEST-D	18-Apr-12	27-Jun-12		4.16E-06	3.40E-06
U-233/234	TEST-A	17-Jan-12	27-Jun-12		4.82E-05	1.63E-05
	TEST-B	22-Feb-12	27-Jun-12		4.71E-05	1.22E-05
	TEST-D	18-Apr-12	27-Jun-12		4.01E-05	1.55E-05

Appendix C

Daily Monitoring Checklist Sample Form

Appendix C

Daily Monitoring Checklist Sample Form

Daily Monitoring Checklist

	Monitor	RPT Initials	Date	Time	Flow Rate	Total Flow	Elapsed Time	Battery Condition (Voltage)	Environmental Conditions (cloudy, sunny, etc.)
	TEST-A	DM	6-14	11:16	----N/A----	5256	----N/A----	----N/A----	
2	TEST-B			1057	1.6	2370	24.8	27	Sunny
1	TEST-D			10:16	1.6	2385	24.9	26.5	
	TEST-A	TJ	6-15-12	0830	----N/A----	5317	----N/A----	----N/A----	sunny
2	TEST-B	TJ	6-15-12	0900	1.6	4472	46.0	27	
1	TEST-D	TJ	6-15-12	0845	1.5	4544	47.4	28	
	TEST-A	SKm	6-18-12	0750	----N/A----	5520	----N/A----	----N/A----	
2	TEST-B	SKm	6-18-12	0800	1.6	11276	117.8	28	CLOUDY
1	TEST-D	SKm	6-18-12	0755	1.6	11361	118.5	26.5	
	TEST-A	TJ	6-19-12	0830	----N/A----	5592	----N/A----	----N/A----	cloudy
2	TEST-B	TJ	6-19-12	0800	1.5	13620	142.3	28	
1	TEST-D	TJ	6-19-12	0800	1.6	13708	143.0	28	
	TEST-A	TJ	6-20-12	1300	----N/A----	5672	----N/A----	----N/A----	sunny
2	TEST-B	TJ	6-20-12	1315	1.6	16341	170.8	26	
1	TEST-D	TJ	6-20-12	1300	1.6	16414	171.2	26	
	TEST-A				----N/A----		----N/A----	----N/A----	
	TEST-B								
	TEST-D								
	TEST-A				----N/A----		----N/A----	----N/A----	
	TEST-B								
	TEST-D								
	TEST-A				----N/A----		----N/A----	----N/A----	
	TEST-B								
	TEST-D								
	TEST-A				----N/A----		----N/A----	----N/A----	
	TEST-B								
	TEST-D								
	TEST-A				----N/A----		----N/A----	----N/A----	
	TEST-B								
	TEST-D								

Comments on any unusual events from above (reference Location and Date):

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

U.S. DEPARTMENT OF
ENERGY

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)
www.pnnl.gov