Los Alamos
NATIONAL LABORATORY
EST. 1943

Associate Director for ESH
Environment, Safety, and Health
P.O. Box 1663, MS K491
Los Alamos, New Mexico 87545
505-667-4218/Fax 505-665-3811

Environmental Management
Los Alamos Field Office
1900 Diamond Drive, MS M984
Los Alamos, New Mexico 87544
(505) 665-5658/FAX (505) 606-2132

Date: JUL 13 2016
Refer To: ADESH-16-096
LAUR: 16-24628
Locates Action No.: n/a

John Kieling, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

Subject: Submittal of the Work Plan for a Tracer Test at Material Disposal Area L, Technical Area 54

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Work Plan for a Tracer Test at Material Disposal Area L, Technical Area 54. The work plan describes activities proposed to be conducted to further characterize subsurface properties of the Cerros del Rio basalts at Material Disposal Area (MDA) L. The tracer test will provide fundamental gas flow and transport information under field conditions that would be difficult to obtain otherwise. The results will be used to better understand the long-term transport of vapors downward through the basalt towards the regional water table in support of future remedial actions at MDA L.

If you have any questions, please contact Kent Rich at (505) 665-4272 (krich@lanl.gov) or Ramoncita Massey at (505) 665-7771 (ramoncita.massey@em.doe.gov).

Sincerely,

Bruce Robinson, Program Director
Environmental Remediation Program
Los Alamos National Laboratory

Sincerely,

David S. Rhodes, Director
Office of Quality and Regulatory Compliance
Environmental Management
Los Alamos Field Office

JM/DR/BR/KR:sm

Enclosure: Two hard copies with electronic files – Work Plan for a Tracer Test at Material Disposal Area L, Technical Area 54 (EP2016-0098)

Cy: (w/enc.)
Ramoncita Massey, DOE-EM-LA
Kent Rich, ADEM ER Program

Cy: (w/electronic enc.)
Laurie King, EPA Region 6, Dallas, TX
emla.docs@em.doe.gov
Steve Yanicak, NMED-DOE-OB
Public Reading Room (EPRR)
ADESH Records
PRS Database

Cy: (w/o enc./date-stamped letter emailed)
lasomailbox@nnsa.doe.gov
Peter Maggiore, DOE-NA-LA
Kimberly Davis Lebak, DOE-NA-LA
David Rhodes, DOE-EM-LA
Bruce Robinson, ADEM ER Program
Randy Erickson, ADEM
Jocelyn Buckley, ADESH-EPC-CP
Mike Saladen, ADESH-EPC-CP
John McCann, ADESH-EPC-DO
Michael Brandt, ADESH
William Mairson, PADOPS
Craig Leasure, PADOPS

LA-UR-16-24628
July 2016
EP2016-0098

Work Plan for a Tracer Test at Material Disposal Area L, Technical Area 54

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Associate Directorate for Environmental Management

EP2016-0098

Work Plan for a Tracer Test at Material Disposal Area L, Technical Area 54

July 2016

Responsible project manager:

Kent Rich		Project Manager	Environmental Remediation Program	7/7/16
Printed Name	Signature	Title	Organization	Date

Responsible LANS representative:

Randall Erickson		Associate Director	Associate Directorate for Environmental Management	7/11/16
Printed Name	Signature	Title	Organization	Date

Responsible DOE-EM-LA representative:

David S. Rhodes		Office Director	Quality and Regulatory Compliance	7-11-2016
Printed Name	Signature	Title	Organization	Date

CONTENTS

Figures

Table

1.0 INTRODUCTION

This work plan describes activities proposed to be conducted by Los Alamos National Laboratory (LANL or the Laboratory) to further characterize subsurface properties of the Cerros del Rio basalts at Material Disposal Area (MDA) L. The work presented in this plan follows from the "Interim Measures Work Plan for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54, Revision 1," submitted to the New Mexico Environment Department (NMED) in September 2014 (LANL 2014, 261843). Remediation of the vapor plume by soil-vapor extraction (SVE) is recommended as part of the final remedy in the "Corrective Measures Evaluation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54, Revision 2" to meet a remedial action objective of preventing groundwater from being impacted above a regulatory standard by the transport of volatile organic compounds (VOCs) to groundwater through soil vapor (LANL 2011, 205756). The depth to regional groundwater beneath MDA L is on the order of 285 m (935 ft), whereas the vapor plume is predominantly within the Bandelier Tuff in the upper 90 m (300 ft) of the surface. The tuff units beneath the surface at MDA L are underlain by a thick (nearly 150-m [500-ft]) sequence of Cerros del Rio basalts. There is uncertainty regarding the long-term transport of vapors downward through the basalt towards the water table.

2.0 BACKGROUND

To further characterize subsurface properties in the Cerros del Rio basalt, the Laboratory proposes gas tracer testing that will help to determine diffusivity in the fractured basalt that makes up nearly half the thickness of the unsaturated rock column between the MDA L disposal area and the regional water table. The tracer testing will provide fundamental gas flow and transport information under field conditions that would be difficult to obtain otherwise. In particular, an objective of the tracer test is to investigate the effects of changes in atmospheric pressure on the mobility of belowground gaseous contaminants, a phenomenon known as barometric (or atmospheric) pumping.

Theoretical and numerical reasoning combined with field observations has led to the conclusion that barometric pumping in the Cerros del Rio basalt will likely lead to 1–2-kPa variations in subsurface pressure (Neeper 2002, 098639). Such pressure variations will induce oscillatory flow and create an effective diffusivity that could be orders of magnitude larger than pure gas diffusion (Auer et al. 1996, 069793). Field measurements have shown that the pressure variations in the basalt are in phase with the atmospheric pressure variations, despite the fact that pressure variations in the overlying tuff units lag behind the atmospheric condition. This finding indicates that the basalt is extremely conductive to air flow from as far away as the outcrops in White Rock Canyon, some 3.8 km (2.4 mi) to the east of MDA L.

To demonstrate this process of barometric pumping, a numerical model representing a 90-ft section of uncased borehole located at the center of a two-dimensional radial domain was developed. The model is built within FEHM (Finite Element Heat and Mass) porous-flow simulator, developed at the Laboratory that has been used successfully to simulate barometrically pumped contaminant transport in fractured rock (Neeper and Stauffer 2012, 601587; Neeper and Stauffer 2012, 601588). The domain includes layers of both vesicular and massive basalt extending from the top of the basalt at 118 m (388 ft) below ground surface (bgs) to a depth of approximately 290 m (950 ft) bgs based on borehole geophysical logs for well 54-24399 (Figure 2.0-1). Vesicular basalt and massive basalt are assigned porosity values of 35% and 0.1%, respectively. Permeability of these units is based on the work of Neeper (2002, 098639), where a best fit to amplitude and phase-shift data from boreholes 54-1015 and 54-1016 yielded permeability/porosity ratio of 2.2×10^{-8} m^2. The domain is initialized with an average mesa pressure of 80 kPa, and a barometric pressure wave obtained from August 2015 Technical Area 54 atmospheric data is applied to the outer boundary at a radius of 1.5 km (0.9 mi) based on Neeper (2002, 098639). The numerical model assumes a packer will isolate pressure within a 27-m (90-ft) section of uncased borehole. An initial tracer concentration of 200 ppmv is applied to the simulated borehole nodes, which corresponds to an initial tracer mass of approximately 0.5 g of SF_6 (Figure 2.0-1).

Figure 2.0-2 shows concentration versus time within the open borehole for a simulation of gas tracer transport for a case with an initial low in the barometric pressure applied at the outer boundary of the radial domain compared with a simulation with diffusion only. For the diffusion-only case, the tracer mass initially located in the open borehole moves radially outward along a concentration gradient. Concentrations within the borehole are well behaved and monotonically decrease with time. This curve is an end-member of possible behavior if the permeability in the basalt were not connected to the atmosphere. For the case where the basalt permeability is well connected to the atmosphere, the results are dramatically different. The initial low pressure in the atmospheric-pressure wave causes the tracer mass (0.5 g of SF_6) in the open borehole to move rapidly radially out of the borehole into the formation, thereby reducing concentrations at very early times. However, because atmospheric pressure soon increases to values above average, flow is reversed and the tracer is pushed back into the open borehole. Simultaneously, the tracer mixes with pore gas, leading to rapid dilution and a decrease in the concentration measurable in the open borehole. These two curves represent potential extremes of the system behavior, and data from the proposed tracer test will allow the Laboratory to make the first in situ estimates of barometrically enhanced diffusion in the Cerros del Rio basalts.

3.0 INVESTIGATION APPROACH

3.1 Tracer Gas

Preliminary activities include planning, permitting, and analysis of existing data. The tracer test will include one or more injections of gas tracer (SF_6) into borehole 54-24399 through a packer system and subsequent monitoring of concentration decay as the tracer spreads into the subsurface. SF_6 is an inorganic, colorless, odorless, nonflammable gas that is poorly soluble in water.

Borehole 54-24399 is cased from ground surface to a depth of 565 ft, followed by an uncased section of approximately 28 m (92 ft). This bore was selected because it is the only borehole at MDA L that has an uncased section open in the Cerros del Rio basalt. The proposed SF_6 mass to be injected into the uncased section of borehole is 0.5 g per test injection, based on maintaining a total tracer mass fraction of less than 0.1% to ensure no density-driven flow. The uncased section of borehole has a drilled diameter of 14 cm (5.5 in.) and is approximately 28 m (92 ft) long, leading to a volume of 0.43 m^3. The mass of air in the open interval is approximately 0.43 kg ([0.9 lb] assuming 1 kg/m^3 air density). At 0.1% by mass, this yields 0.43 g of SF_6. Given the large voids in some sections of the open borehole, this value has been rounded to 0.5 g for simplicity.

3.2 Background Data Collection

The Laboratory has collected and analyzed samples from borehole 54-24399 using data from both a field-deployed INNOVA Photoacoustic Gas Monitor and Tedlar sampling bags (hereafter, INNOVA). These data will be used to determine background SF_6 readings for both sampling methods (e.g., field and analytical laboratory). The Laboratory will further collect background samples for SF_6 analysis from boreholes 54-01015 and 54-01016. Tedlar samples will be collected from ports in these two boreholes that lie within the basalt and submitted for laboratory analysis.

3.3 Injection Tracer Tests

For each individual injection, a single-injection of SF_6 will be conducted in borehole 54-24399 via a dual-port packer system (Figure 3.3-1). An aliquot of the tracer SF_6 will be injected in the open borehole (0.5 g SF_6) through the injection/return flow tubing shown schematically in Figure 3.3-1. After injection, measurement of SF_6 concentration below the packer will commence, and the concentration of the tracer in the packed off open borehole will be monitored. After the tracer is introduced to the system, the INNOVA will be connected in a continuous loop with the exhaust from the unit returning through the tracer injection tubing. The continuous loop ensures no excess pressure is introduced to the borehole and will minimize the possibility of advective flow. The injection tubing will be located approximately 6 m (20 ft) above the sample collection tubing to provide mixing within the packed off open section of the borehole.

Modeled concentrations of SF_6 under the influence of barometric pumping are expected to be highly variable as a result of daily changes in atmospheric pressure and potential mesoscale meteorological phenomenon (Figure 2.0-1). Therefore, in the early stages after injection, the Laboratory will continuously monitor data on concentrations in the packed-off open borehole using the data logging capabilities of INNOVA (the manufacturer's reported detection limit of 0.006 ppmv). Because the modeled concentrations fall off quickly to levels that can be below INNOVA's detection limit, the Laboratory will also take grab samples of borehole air from the circulating air stream for subsequent high precision (sub-ppbv) gas chromatographic (GC) SF_6 analysis. These samples will be collected hourly in U.S. Environmental Protection Agency–recommended Tedlar sampling bags during initial stages after injection. Photoacoustic and hourly grab sampling will be collected during working hours of the first 2 to 3 d after injection. The duration of this sampling will be determined based on initial results of days 1 and 2. Additional sampling will be carried out at a lower frequency of up to 10 to 12 d after injection, depending on how quickly tracer concentrations in the packed-off open borehole drop. Table 3.3-1 summarizes the proposed sampling locations, depths, and analytical method.

3.4 Well Pressure Data

Sampling beneath the packer with a high-resolution (+100-Pa) pressure transducer will provide data to further constrain both conceptual and numerical models of tracer migration. With real time data of the barometric wave within the packed off borehole, models will have an additional calibration target, thus increasing confidence in the results of the data/model calibration. The pressure transducer will be placed to allow measurement of pressure changes below the backer in the uncased section of borehole 54-24399, with a dedicated wire running to the surface where it will be connected to an electronic data logger. Data will be collected with a minimum resolution of 15 min while the packer system is inflated for the tracer test.

3.5 Sampling at Secondary Wells

Sampling will also be performed at ports in boreholes 54-01015 and 54-01016 to validate model performance and provide additional data to better quantify the influence of the barometric pumping effect. These two angled boreholes have ports in the basalt approximately 30–76 m (100–250 ft) laterally from borehole 54-24399 and are the only boreholes with dedicated sampling ports that penetrate the basalt. Sampling at these boreholes will be performed exclusively by grab sampling with Tedlar bags and analyzed by GC in the laboratory because expected concentrations at these distances from the injection point will be in the low- to sub-ppbv levels.

3.6 Repetition of Injection

The tracer test described in section 3.3 will be repeated several times with the goal of generating data during a range of barometric conditions. For example, if the initial test is performed during falling barometric pressure, a second test will be performed to target a rising barometric signal. Another region of interest is a relatively flat barometric phase, such as when a high-pressure system persists for several days. The exact timing of these barometric conditions is impossible to predict months in advance but will be fairly predictable within a few days to 1 wk of final test implementation.

3.7 Analysis of Data

Levels of SF_6 determined by photoacoustic analysis (INNOVA) will be compared with high-precision GC analysis. GC and INNOVA data will be used together to create concentration-versus-time graphs such as those shown in Figure 2.0-1. These data will be compared with modeling of barometric pumping effects to determine the character of the permeable pathway from the open borehole to the atmospheric connection. Using the best estimates of the connected pathway, an effective diffusion coefficient will be determined for the Cerros del Rio basalt using a high-resolution numerical model (Neeper 2003, 098640; Stauffer et al. 2007, 097871).

4.0 SCHEDULE

Tracer tests are anticipated to begin in late August or early September 2016, after the August quarterly round of subsurface vapor sampling at MDA L has been completed. NMED has determined that tracer (SF_6) is not of concern to groundwater and no notice of intent to discharge will be required for this test. Information on tracer breakthroughs will be reported in the 2017 interim measures progress report.

5.0 REFERENCES

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID or ESH ID. This information is also included in text citations. ER IDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESH IDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the ESH Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Auer, L.H., N.D. Rosenberg, K.H. Birdsell, and E.M. Whitney, November 1996. "The Effects of Barometric Pumping on Contaminant Transport," *Journal of Contaminant Hydrology,* Vol. 24, No. 2, pp. 145–166. (Auer et al. 1996, 069793)

LANL (Los Alamos National Laboratory), September 2011. "Corrective Measures Evaluation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54, Revision 2," Los Alamos National Laboratory document LA-UR-11-4798, Los Alamos, New Mexico. (LANL 2011, 205756)

LANL (Los Alamos National Laboratory), September 2014. "Interim Measures Work Plan for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54, Revision 1," Los Alamos National Laboratory document LA-UR-14-26472, Los Alamos, New Mexico. (LANL 2014, 261843)

Neeper, D.A., 2002. "Investigation of the Vadose Zone Using Barometric Pressure Cycles," *Journal of Contaminant Hydrology,* Vol. 54, pp. 59-80. (Neeper 2002, 098639)

Neeper, D.A., 2003. "Harmonic Analysis of Flow in Open Boreholes Due to Barometric Pressure Cycles," *Journal of Contaminant Hydrology,* Vol. 60, pp. 135-162. (Neeper 2003, 098640)

Neeper, D.A., and P.H. Stauffer, May 2012. "Transport by Oscillatory Flow in Soils with Rate-Limited Mass Transfer: 1. Theory," *Vadose Zone Journal,* Vol. 11, No. 2. (Neeper and Stauffer 2012, 601587)

Neeper, D.A., and P.H. Stauffer, May 2012. "Transport by Oscillatory Flow in Soils with Rate-Limited Mass Transfer: 2. Field Experiment," *Vadose Zone Journal,* Vol. 11, No. 2. (Neeper and Stauffer 2012, 601588)

Stauffer, P.H., J.K. Hopkins, T. Anderson, and J. Vrugt, July 11, 2007. "Soil Vapor Extraction Pilot Test at Technical Area 54, Material Disposal Area L: Numerical Modeling in Support of Decision Analysis," Los Alamos National Laboratory document LA-UR-07-4890, Los Alamos, New Mexico. (Stauffer et al. 2007, 097871)

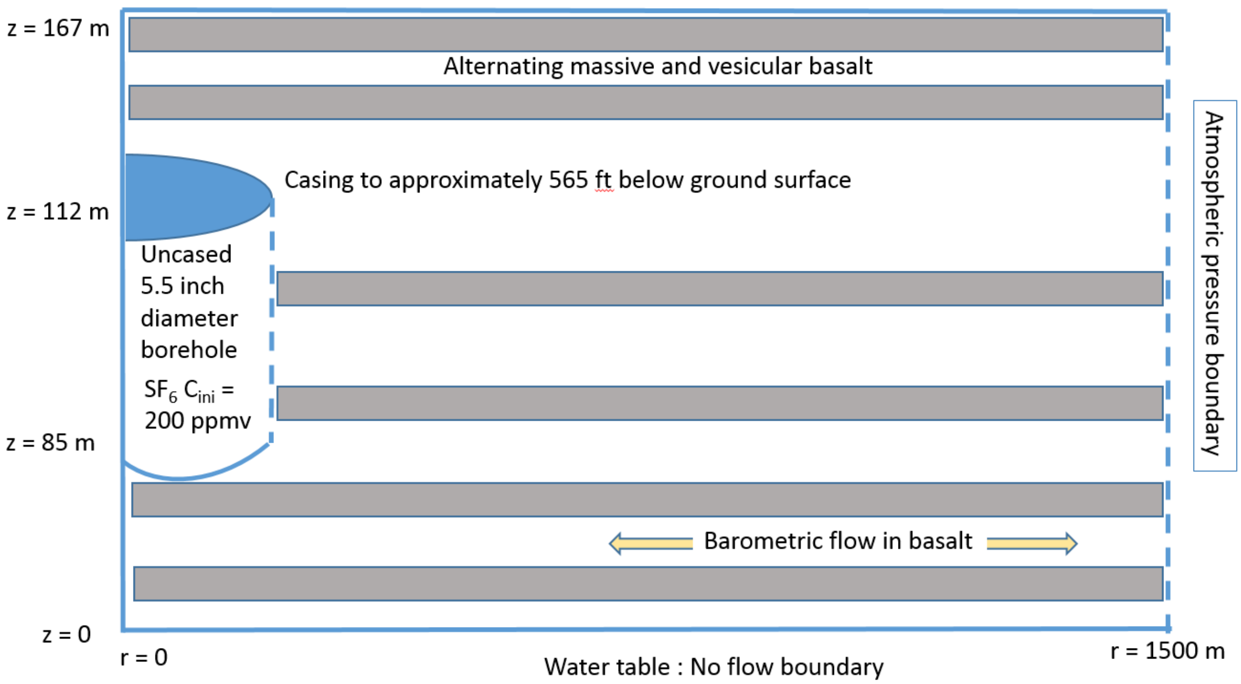

Figure 2.0-1 Numerical domain for tracer test simulations

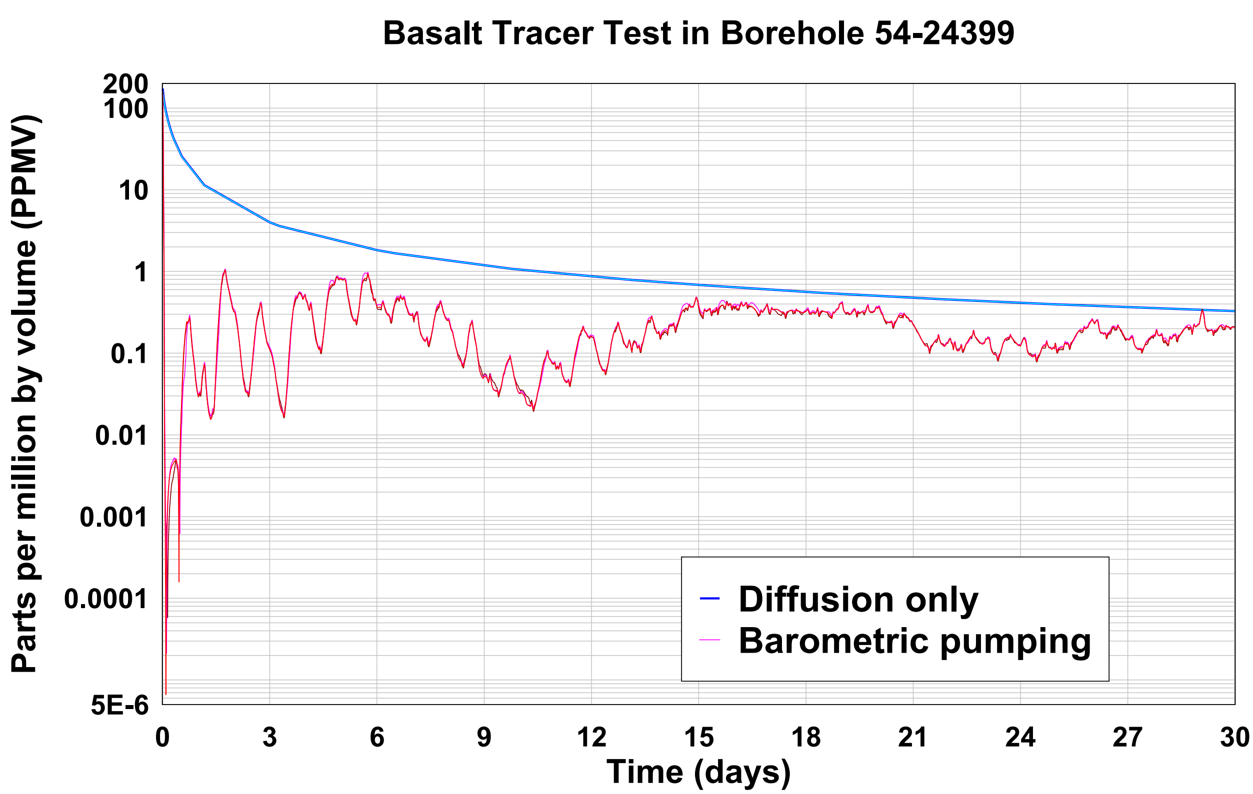

Figure 2.0-2 Model-predicted concentration in the open borehole (54-24399) versus time for diffusion only and barometrically pumped dispersion

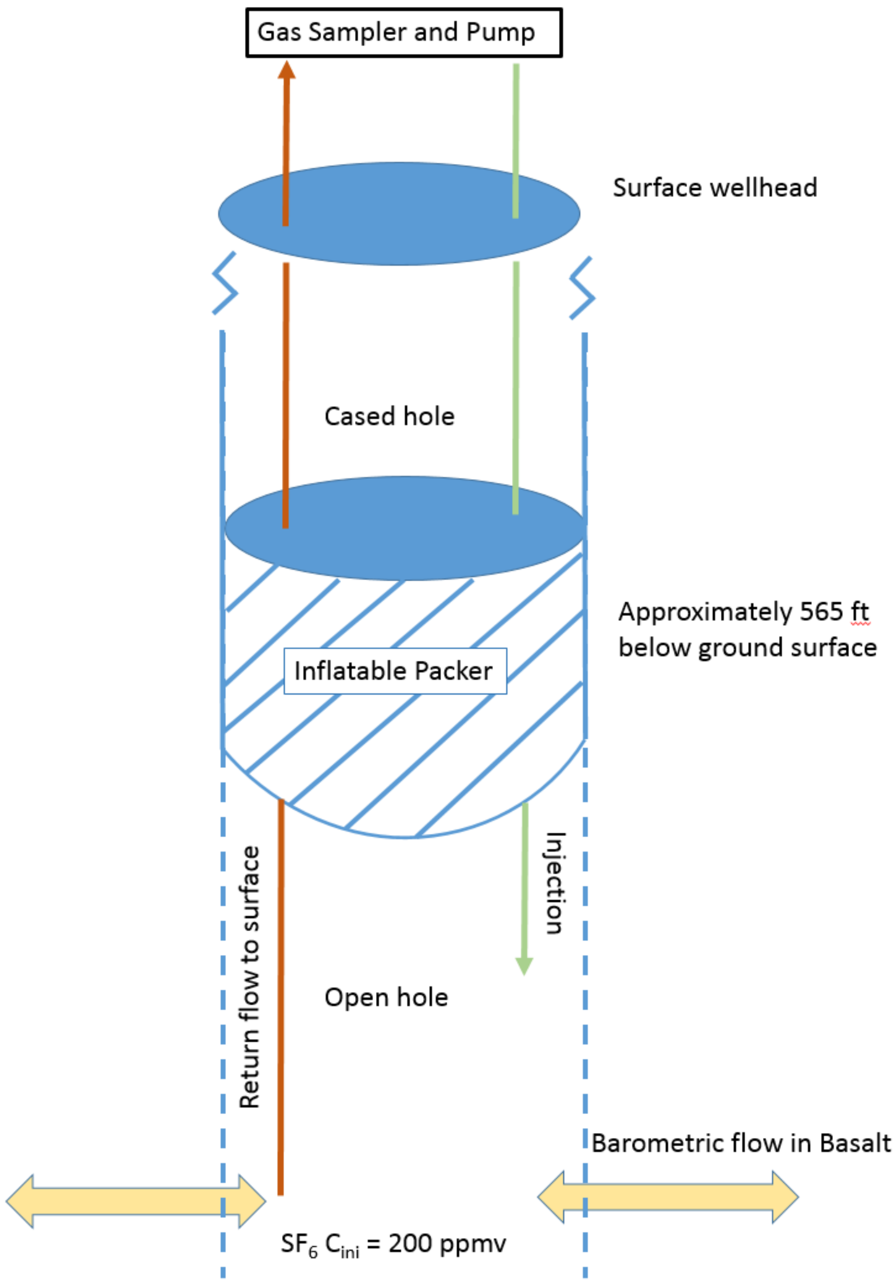

Figure 3.1-1 Schematic of the inflatable packer with injection and sample-collection port penetrations shown

Table 3.3-1
Proposed Tracer Test Sampling at MDA L

Sampling Objective	Location Number	Location	Sample Interval	INNOVA	GC (SF_6)
Continuous SF_6 monitoring during tracer test	54-24399	20 ft below packer in open borehole	585.5–608 ft bgs	X[a]	—[b]
Hourly sample collection after tracer injection (day 1 and day 2)	54-24399	20 ft below packer in open borehole	585.5–608 ft bgs	—	X
Additional sampling up to 10 to 12 d after injection	54-24399	20 ft below packer in open borehole	585.5–608 ft bgs	—	X
Twice daily on day 1 and day 2. Daily up to 10 to 12 d after injection.	54-01015[c]	Sample ports in Cerros del Rio basalts	425–435 ft bgs	—	X
			480–490 ft bgs	—	X
			520–530 ft bgs	—	X
Twice daily on day 1 and day 2. Daily up to 10 to 12 d after injection.	54-01016[c]	Sample ports in Cerros del Rio basalts	473–483 ft bgs	—	X
			530–540 ft bgs	—	X
			592–602 ft bgs	—	X

[a] X = Analysis will be performed.

[b] — = Sampling not proposed.

[c] Vapor-monitoring borehole angled. Sample interval is length along borehole.