ESHID-600408

LA-UR-13-28608

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Intended for: Internal report
Report

Issued: 2013-11-08

LA-UR-13-xxxxx
October 2013

Comprehensive Air Monitoring Report for Measurements during the Las Conchas Fire at Los Alamos National Laboratory

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Executive Summary

During the Las Conchas Fire, ambient air was monitored for radionuclides and particulate matter at and around Los Alamos National Laboratory (the Laboratory). During the fire, a variety of samplers were deployed, including the radiological air sampling network, high-volume air samplers, Tapered Element Oscillating Microbalances (PM 2.5 and PM 10), and environmental continuous air monitors. These different types of samplers provided real time, more in-depth retrospective information on air quality. In total, roughly 220 air samples were collected, and the results were consistent with other regional fires. Laboratory officials and Los Alamos County used real-time data to make public health risk determinations according to the Air Quality Index. Particulate levels were elevated and exceeded the National Ambient Air Quality Standard during the fire because of smoke. Elevated levels of naturally occurring radon decay products, consistent with all forest fires, were detected. Gross-alpha measurements had an average of range of 400 aCi/m^3 to 13,400 aCi/m^3. Measurements of gross beta during the fire had a range of 34,000 aCi/m^3 to 74,000 aCi/m^3. These values are not statistically different from national or regional averages.

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1.0 INTRODUCTION

Extensive air monitoring data were collected from June 26 to July 7, 2011, during the Las Conchas wildfire at and around Los Alamos National Laboratory (the Laboratory or LANL). Air was monitored for particulate matter (PM) in addition to natural and anthropogenic radionuclides. The purpose of these measurements was to assess if Laboratory-derived radionuclides, which include plutonium, americium, uranium, tritium, and gamma emitters, might have been resuspended from soil during the wildfire. Measurements were performed and analyzed to obtain both rapid turnaround and retrospective information on air-quality parameters and concentrations of radionuclides. The Laboratory employs a radiological air sampling network or AIRNET to measure natural and anthropogenic radionuclides year round, enabling air concentration results collected during the fire to be compared with pre-fire concentrations. This report summarizes the Laboratory's response to the Las Conchas fire and the results of all air monitoring conducted from June 20 to July 7, 2011.

1.1 Site Overview

Los Alamos County has a temperate, semiarid mountain climate and an elevation of 7300 ft; however, the 1000-ft elevation change across the Laboratory site results in significant fluctuations of locally observed temperature and precipitation.

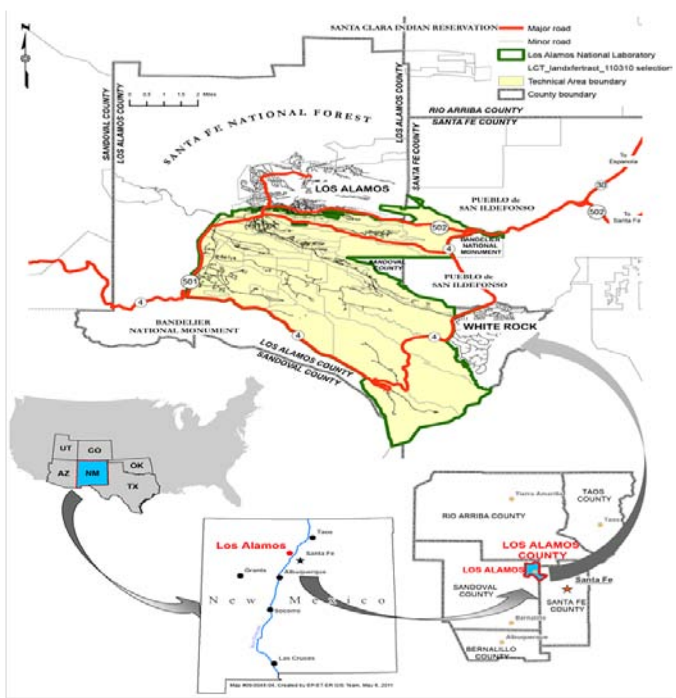


Figure 1 Location of the Laboratory

Four distinct seasons occur in Los Alamos County. Spring is the windiest season. Summer is the rainy season, with occasional afternoon thunderstorms. Autumn typically brings cool, clear weather. Daily temperatures are highly variable, with a 23˚F range on average; historical temperature averages are shown in Figure 2. Precipitation falls as snow from November to March and April. Figure 3 shows historical precipitation averages. New Mexico typically receives less than average precipitation during the winter and spring during a La Niña weather pattern (NWSFO, 2013).

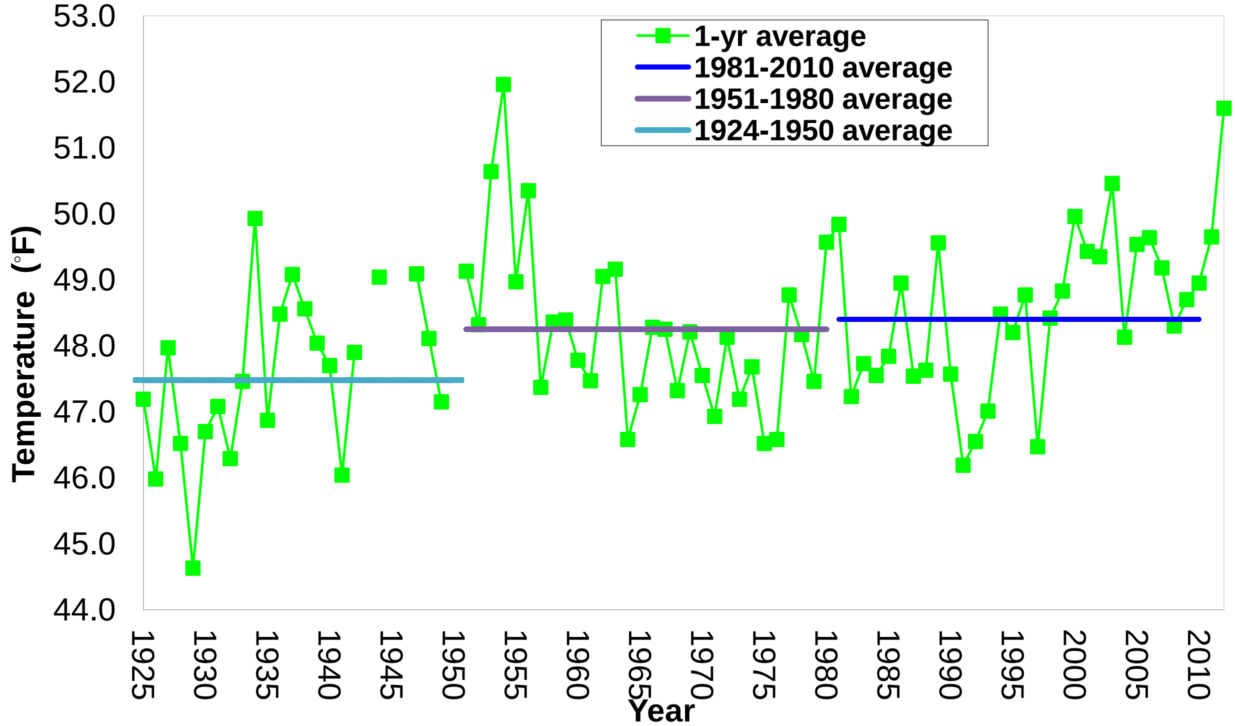


Figure 2 **Historical temperature averages for Los Alamos**

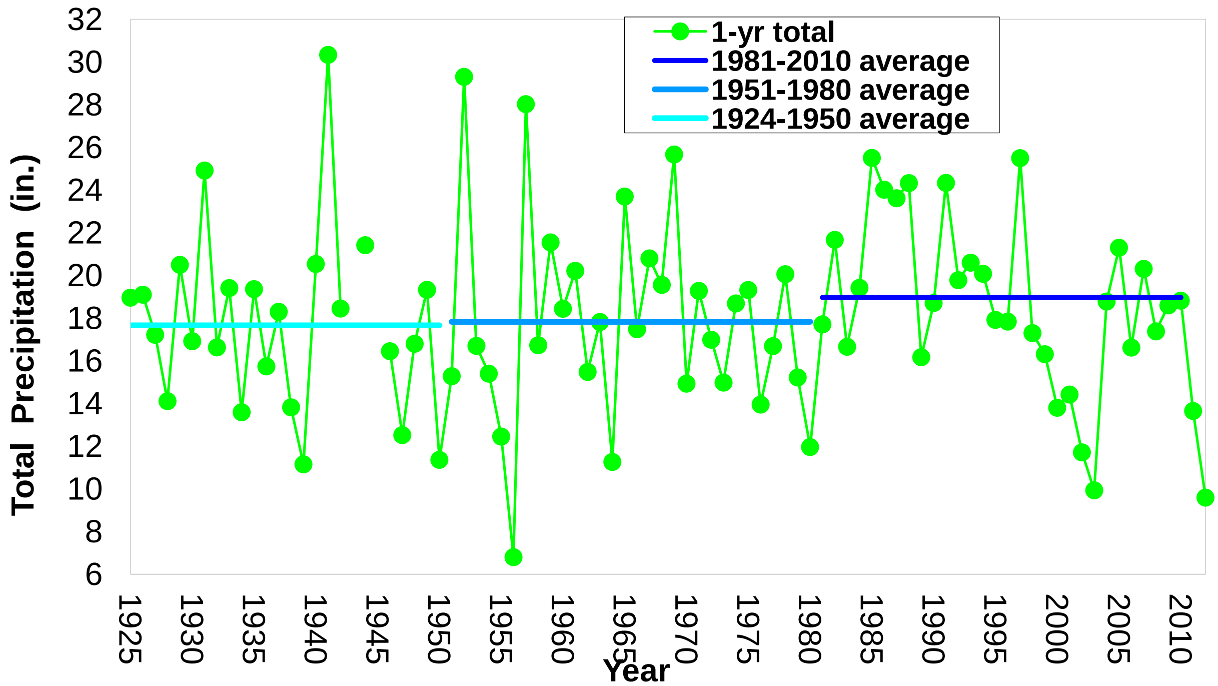


Figure 3 **Historical precipitation averages for Los Alamos**

The complex topography of the Pajarito Plateau and Northern New Mexico also influences local wind patterns. Often a distinct diurnal cycle of winds occurs, with daytime winds coming from the southeast, south, and southwest, and nighttime winds coming from the northwest and northeast. This region is prone to forest fires, as demonstrated by four major wildfires in the region of the Laboratory between 1975 and 2011 (Figure 4) and about 5200 historical fires mapped in the Jemez Mountains from 1900 to 1996 (Craig, 2001). Lightning ignited 75% of the recorded fires in the Jemez Mountains from 1909 to 1996 (Craig, 2001). This type of ignition is frequent and ubiquitous in the Southwest, making climate and fuel conditions the main drivers of fire (Craig, 2001).

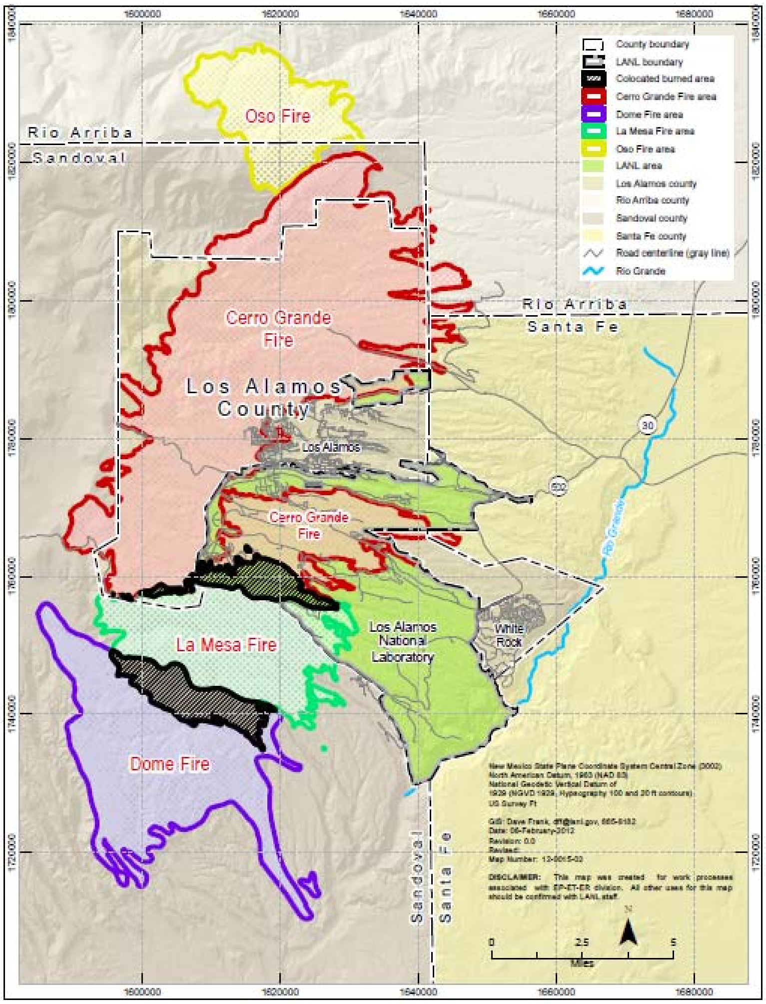
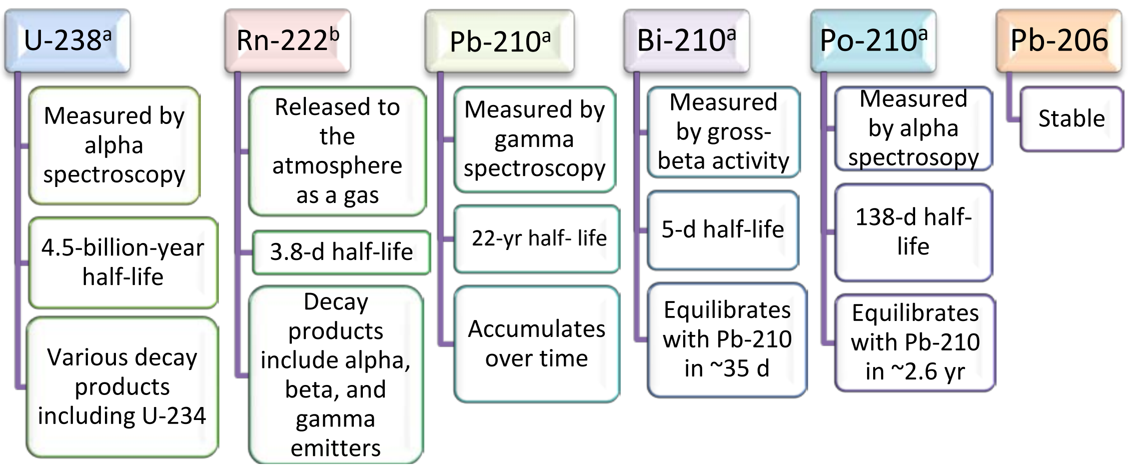


Figure 4 **Map of historical fires: the Cerro Grande fire in 2000, the Oso fire in 1998, the Dome fire in 1997, and the La Mesa fire in 1977.**

1.2 Regional, Global, and LANL Radioactivity

Four sources of radionuclides can be found in the environment in Los Alamos County: global fallout from weapons testing, naturally occurring geologic material, naturally occurring cosmogenic material, and Laboratory-derived materials. Global fallout is present in local soils from historical atmospheric weapons testing performed by multiple countries, including the United States and the former Soviet Union. Since 1945, over 500 atmospheric tests have been conducted resulting in global fallout of long-lived radionuclides such as plutonium-239/240 and fission products cesium-137 and strontium-90 (Beck and Bennett, 2002). Fallout levels of radioactive material at any specific location were affected by the type of device; location of detonation (the Nevada Test Site [NTS], China, the former Soviet Union, etc.); yield; height of the blast; and meteorological conditions.

In the Los Alamos region, plutonium-239/240 background levels in soil from global fallout testing fall between 0.01 pCi/g and 0.07 pCi/g (LANL, 2010). This range of values is based on an average of the top 5 cm of soil and assumes the fallout, which was deposited on the surface, has been mixed to this depth. However, background concentrations can differ 100-fold depending on soil texture, geology, and precipitation (Gallaher et al., 2002). For example, after a fire, the global-fallout materials remain as a thin layer on the surface, and within this thin layer the concentrations are several pCi/g. Regional airborne radioactivity is largely composed of natural radioactive constituents in PM such as uranium and thorium and terrestrial radon and their subsequent decay products. Other natural radionuclides are present in small concentrations that accumulate in and on the surface of plants. Regional and global fallout can be found in the air at low concentrations from resuspension of soil and organic matter within which the radionuclides are mixed (Tables 1 and 2). During a fire, some materials become airborne, especially the more volatile materials, while the refractory materials tend to remain in the ash. After the fire, ash can become airborne or can be mobilized by storm water runoff and flash floods. Physical properties and measurement techniques for the main naturally occurring radionuclides are shown in Figure 5 (Eberhart, 2010).



[a] Radionuclides that are present in PM and accumulate onto other surfaces such as the forest floor, vegetation, and surface soil.

[b] An inert noble gas that is not collected on AIRNET filters.

Figure 5 Uranium-238 decay series (Adapted from Eberhart, 2010)

Natural uranium and uranium decay products are detected by Laboratory air monitoring. Uranium becomes airborne through suspended soil while the uranium gaseous decay product radon becomes airborne through diffusion from soil. Once airborne, radon gas undergoes decay, resulting in other solid radioactive particles. These solid particles can be found in air sample measurements if the air is sampled before these particles settle out onto soil, vegetation, or forest floor litter. Particulate radon decay products may be detected by gross-alpha activity (polonium-210), gross-beta activity (bismuth-210) and gamma-spectroscopic analyses (lead-210). Gross-alpha measurements in this geographic region average between 870 and 930 aCi/m^3. Gross-beta measurements in this region average between 17,300 and 18,700 aCi/m^3, which is similar to the national average 20,000 aCi/m^3 (LANL, 2012). Typical air concentrations of uranium and its decay products are provided in Table 1.

Table 1
Average Background Radionuclide Concentrations in the Regional Atmosphere

Analyte	LANL 2011[a]	Unit
Tritium[b]	1.3	pCi/m^3
Am-241	0.5	aCi/m^3
Pu-238	1.2	aCi/m^4
Pu-239	0.3	aCi/m^5
U-234	16	aCi/m^6
U-235	0.9	aCi/m^7
U-238	16	aCi/m^8

Note: Global reference values for uranium-235 and uranium-238 are estimated to be 1.35 aCi/m^3 and 27 aCi/m^3, respectively (UNSCEAR, 2000).

[a] Regional air sampling stations operated by the Laboratory (locations may vary by year) (LANL, 2012).

[b] Tritium values have been corrected for the tritium lost to bound water in the silica gel.

Additionally, past and current activities at the Laboratory impact ambient air concentrations of radionuclides on-site and around the perimeter of the Laboratory. Historically the Laboratory released radionuclides in liquid effluents into canyons and in air emissions from building exhaust stacks. The Los Alamos Canyon and Mortandad watersheds are the primary areas where the Laboratory released radioactive liquid effluents (Gallaher et al., 1997). Water, soil, and sediment samples have been collected for more than three decades to measure concentrations and to determine the spatial distribution of contaminants in these canyons. These measurements have been used to guide remediation efforts to compare with regulatory limits.

Legacy contamination of plutonium, americium, depleted uranium, and tritium in soils from Laboratory operations can be detected in ambient air measurements. Specifically, plutonium and americium are occasionally measured on-site, primarily near decontamination and decommissioning operations and at the Laboratory's low-level radioactive waste disposal site (Area G). As a result of the resuspension of soils from past Laboratory activities, low concentrations of americium, plutonium, and depleted uranium have also been detected in occasional samples at historical Laboratory sites such as the original technical area (TA) from the Manhattan Project. Measurable concentrations of tritium, which are not discussed in this report, are detected at many on-site locations and at a few nearby off-site locations. Air concentrations for all of these Laboratory-related radionuclides have not exceeded more than a small fraction of the U.S. Environmental Protection Agency (EPA) public dose limit at off-site locations. In 2011, the highest effective dose equivalent (EDE) to any member for the public off-site at a residence, business,or school was 3.53 mrem or 35% of the EPA standard (Fuehne, 2013). This number is higher than in past years because of remediation operations at Material Disposal Area (MDA) B, where legacy waste was removed.

1.3 Air Monitoring at the Laboratory

The Laboratory has a radiological air sampling network designed to measure environmental levels of radionuclides in the air. This network takes regular measurements of radionuclides that may potentially be released by the Laboratory in addition to naturally occurring radionuclides. Additionally, the Laboratory regularly monitors particulate levels in air. The Laboratory's monitoring was maintained for the duration of the fire, and a brief overview of year-round air monitoring is provided below to describe additional measurements taken during the fire.

1.3.1 AIRNET

The Laboratory measures air concentrations of natural and anthropogenic radionuclides with a radiological air sampling network of approximately 60 samplers, referred to as AIRNET (see Figures 6 and 7). Tritium oxide is collected on silica gel while a polypropylene filter collects PM. This network was designed to measure environmental levels of airborne radionuclides released from Laboratory operations, including isotopes of plutonium, americium, and uranium, and tritium. Typically, individual particulate filters are analyzed for target analyte list elements (antimony, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc) as well as for mercury. These filters are changed biweekly and composited across geographically similar sites for sensitive analysis of gamma-emitting radionuclides. Quarterly measurements at each station are made for alpha emitters. In addition, these measurements include natural radionuclides such as beryllium-7 and natural uranium and associated decay products. Natural uranium is usually detected in AIRNET samples because it is present in local soils—the largest source of PM collected on the filters. Gamma-spectroscopy analyses normally detect beryllium-7 produced by spallation of common atmospheric gases by cosmic radiation (http://www.lanl.gov/environment/air/airnet/description. shtml?photo=3). The New Mexico Environment Department (NMED) also operates AIRNET stations to monitor air quality in and around Los Alamos to compare with Laboratory AIRNET data.

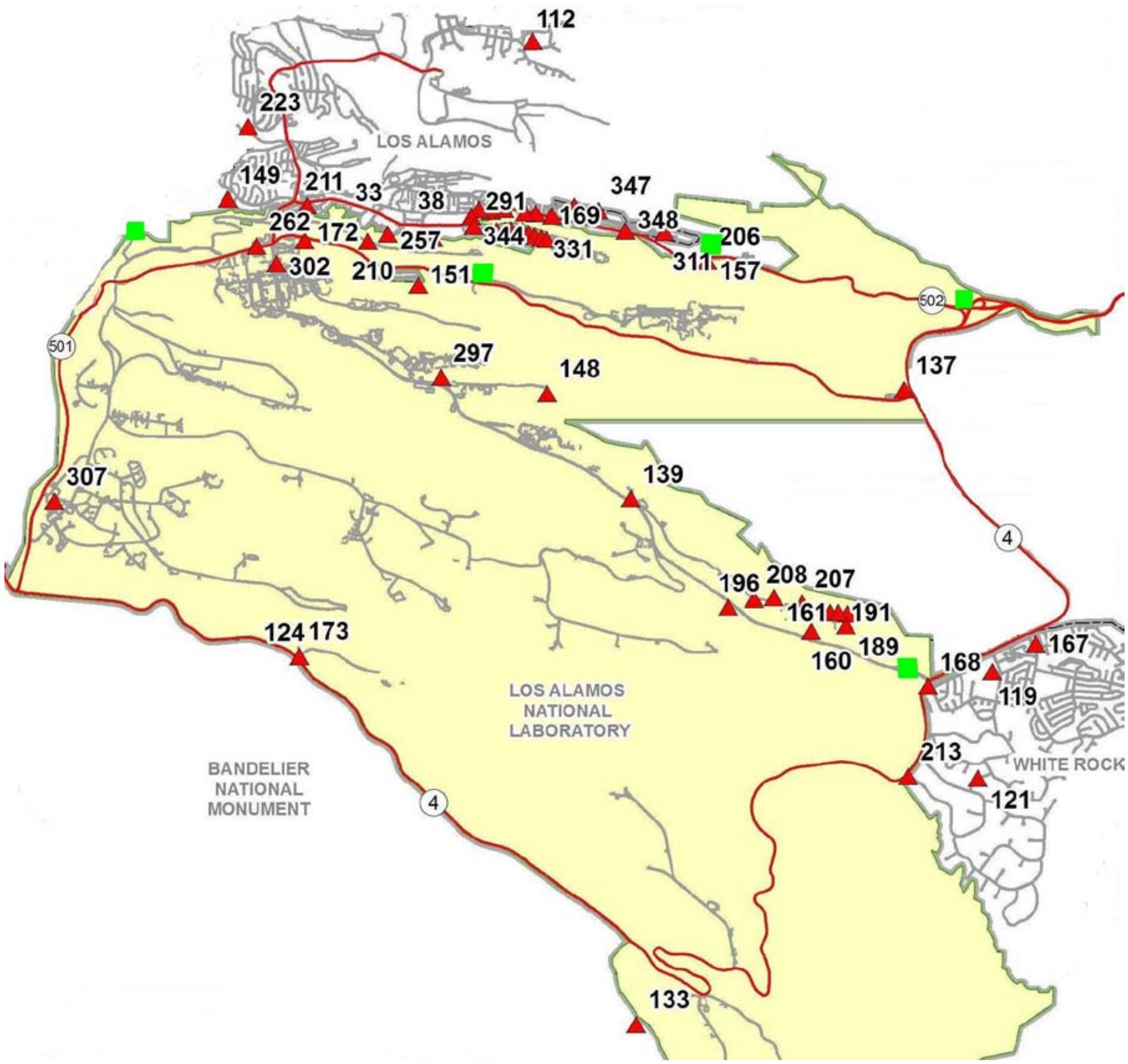


Figure 6 Locations of Laboratory AIRNET stations in Los Alamos County

Figure 7 Locations of regional Laboratory AIRNET stations operated annually are shown in yellow. The locations in red are additional sampling stations that operated during the Las Conchas fire.

1.3.2 Environmental Continuous Air Monitoring

Environmental Continuous Air Monitors (ECAMs) constantly measure alpha-particle emission rates from a filter to calculate air concentrations over short time intervals (240 min) using alpha-energy spectroscopy. The ECAMs used in Los Alamos are solid-state implanted silicon detectors with membrane filters (1.5-µm pore size). An algorithm is used to fit energy peaks and to identify isotopes of concern. Net counts of radionuclides, including plutonium-239 and radon progeny (polonium-218 and polonium-214), in the air are calculated quickly using this algorithm. The results are recorded in an internal data logger and transmitted by cell phone modem to a data storage server every 15 min.

1.3.3 Tapered Element Oscillating Microbalances

Tapered Element Oscillating Microbalances (TEOMs) perform real-time monitoring of the concentration of PM in ambient air. At each sampling location, two TEOM samplers measure the amount of particles 10 µm and smaller and 2.5 µm and smaller, referred to as PM 10 and PM 2.5, respectively. Measurements are taken every 30 min, converted to 24-h rolling averages, and posted to an external Laboratory website (http://environweb.lanl.gov/pm/). Real-time measurements and historical data are available to the public online. The Laboratory monitors particulates in two locations: at the Los Alamos Medical Center and at White Rock near the intersection of Rover and NM 4. The general PM 10 background concentration in Los Alamos before the fire was about 22 ± 15 µg/m^{-3} and the PM 2.5 background was 8 ± 2 µg/m^{-3}.

1.4 Local Conditions Impacting the Fire

During the winter of 2010–2011 and the spring of 2011, Los Alamos experienced weather consistent with a La Niña weather pattern that is caused by the jet stream and storm track shifting poleward, leaving New Mexico under the influence of a stronger than normal high-pressure system (Figure 8).

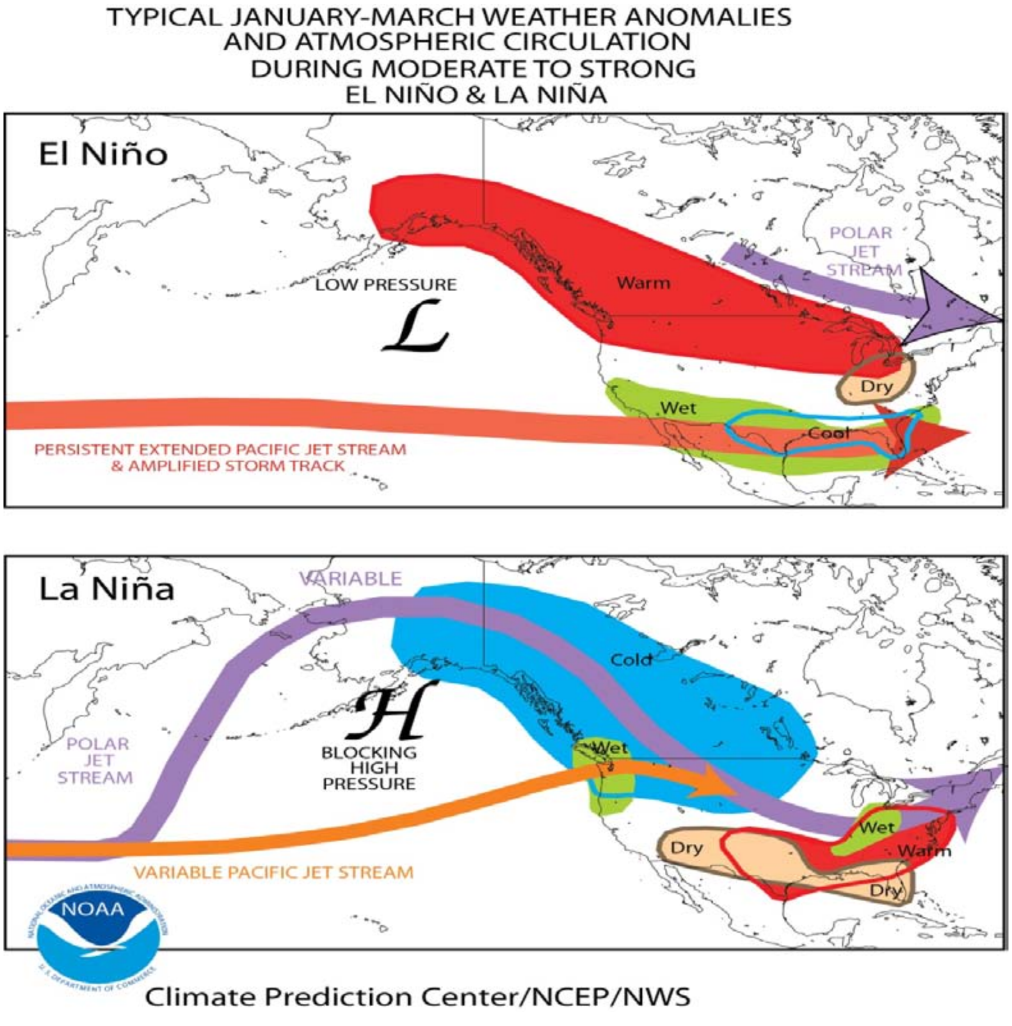


Figure 8 Differences in atmospheric circulation during La Niña and El Niño conditions

Los Alamos received only 33% of normal snowfall during the winter of 2010–2011 (19 in. versus 58 in. average of snow). Dry weather continued during the spring; at the end of June 2011, Los Alamos had received less than half of the precipitation recorded during the first 6 mo of the driest year on record (Figure 9).

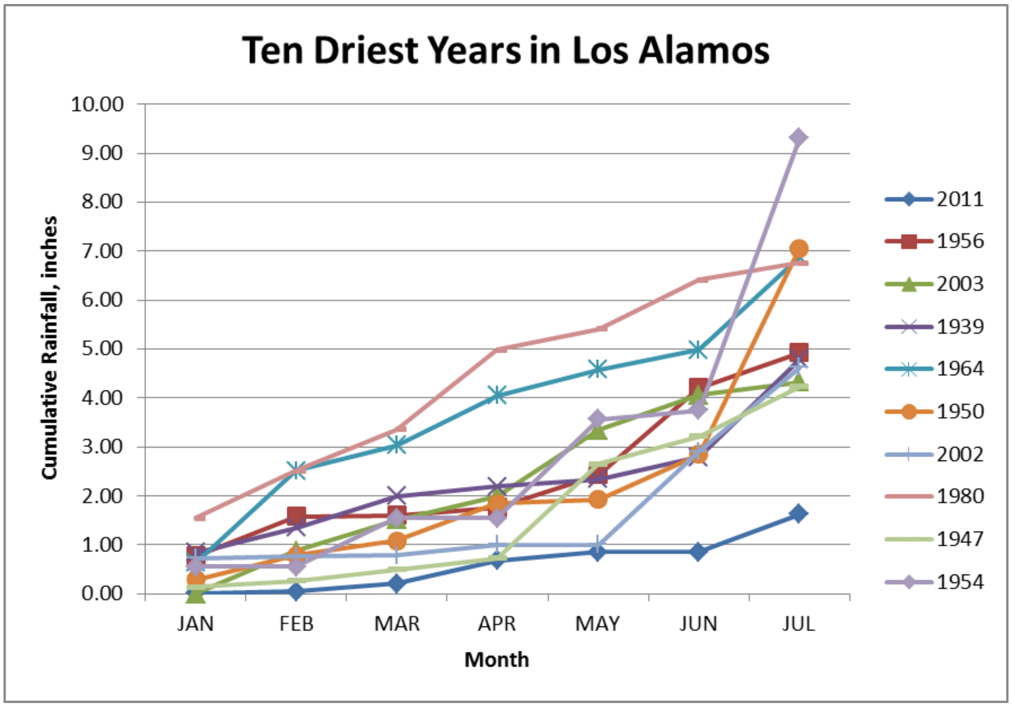


Figure 9 Cumulative rainfall in Los Alamos for the 10 driest years on record

The Laboratory measures the 10-h fuel moisture at the TA-06 meteorological tower to provide one measure of fire potential. Ten-hour fuel moisture refers to the moisture contained in dead twigs and branches between 0.25 and 1 in. in diameter. These fuels, along with 1-h fuels or fuels that are less than 0.25 in. in diameter, are important for predicting the potential for fires to spread. The "10-h" and "1-h" time specification of the measurement refers to the amount of time that fuel (or the dowel in this case) takes to reach two-thirds of the moisture equilibrium with its local environment. The measurement is made using a 0.50-in.-diameter 20-in.-long ponderosa-pine dowel fabricated to U.S. Forest Service (USFS) specifications (Campbell Scientific, 2009). The electronic resistivity of the dowel changes with moisture content. The measurement of the change in resistivity is converted to percent moisture by weight.

Weekly average 10-h fuel moisture (Figure 10) typically ranges between 10% and 15%. In January 2011, 10-h fuel moisture began to fall as winter snows and spring rains did not materialize. At the beginning of June, average weekly 10-h fuel moisture fell below 5%. Single 15-min measurements of 10-h fuel moisture reached 2% to 3% on June 19, 2011 and remained at these low levels until late July when the monsoon rains began.

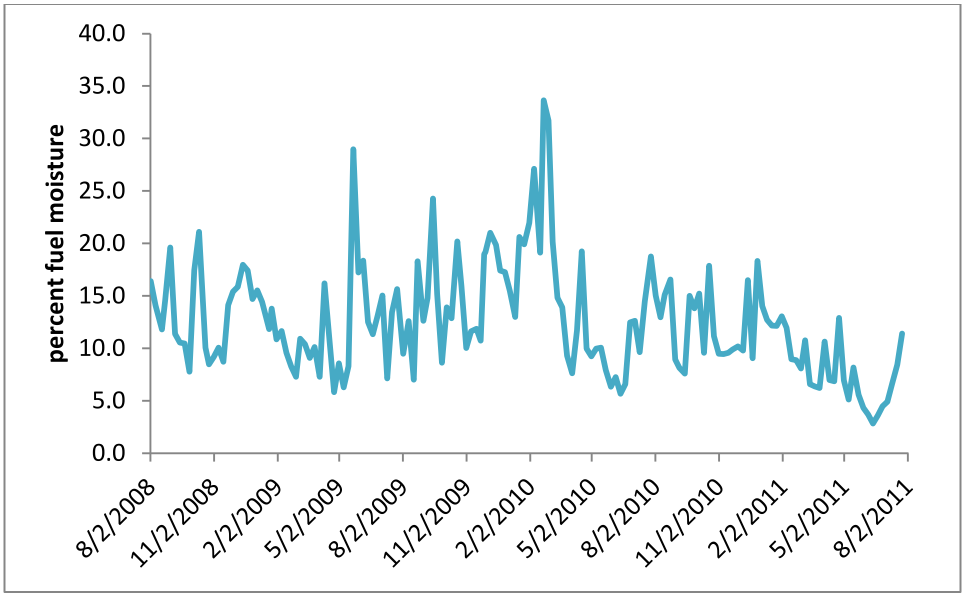


Figure 10 Weekly average 10-hour fuel moisture from 2008 to 2011

In addition to very dry conditions in Los Alamos, the typical windy spring season (March, April, and May) extended through the entire month of June 2011. PM in the atmosphere is caused largely by wind suspension of mineral and organic matter in soil, which increases during dry windy days (Whicker et al., 2006). Daily and seasonal fluctuations in airborne radioactivity concentrations, therefore, may be attributed to meteorological conditions (LANL, 2010). Figure 10 compares the 20-yr long-term average wind speeds at TA-06 Levels 1 and 3 (12- and 46-m height) with the daily average wind speeds recorded during June 2011. The average wind speeds in June 2011 at 12 and 46 m were 28 % and 21% higher, respectively, than long-term average values. These high winds contributed to the massive growth of the Las Conchas fire during its first days.

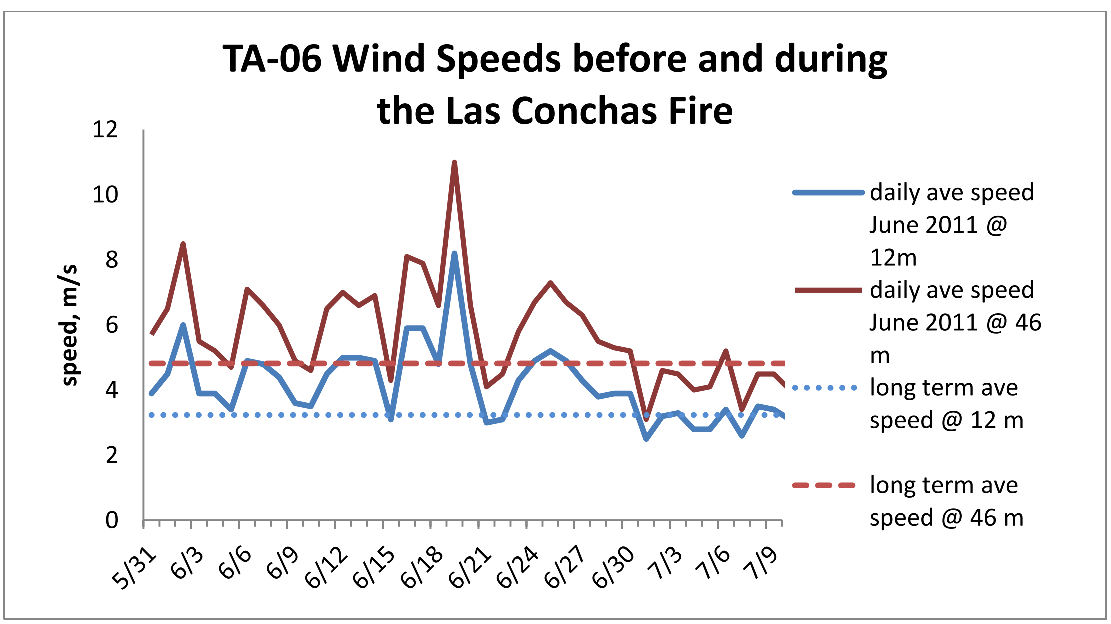


Figure 11 TA-06 daily wind speeds preceding and during the Las Conchas fire

2.0 LAS CONCHAS FIRE

The Las Conchas fire started on Sunday June 26, 2011, in the Santa Fe National Forest, approximately 12 mi southwest of the Laboratory. The fire started when a tree fell on a power line at a campground. The Laboratory's Emergency Operations Center was declared operational at 1700 on Sunday June 26, 2011. Residents were evacuated from Los Alamos townsite between Monday June 27 and Saturday July 3. The Laboratory was closed from June 27 to July 5. The fire ultimately burned about 156,000 acres of public, private, and tribal lands before it was fully contained by August 1, 2011. On Laboratory property, one 2-acre spot fire occurred, and an additional 90 acres of Laboratory property burned during a preventive burn west of NM 501. No additional fire activity occurred on U.S. Department of Energy (DOE)/Laboratory property, and no DOE/Laboratory structures/facilities were damaged by the Las Conchas fire.

The Las Conchas fire was of concern because of its proximity to the Laboratory, potential human exposure to elevated concentrations of PM from smoke, and the potential for Laboratory releases of hazardous materials if the fire began burning on-site. Fires increase concentrations of PM and radioactivity in the ambient air through the burning of vegetation and organic litter on the forest floor. The temperature of the fire and the volatility of the elements or compounds will greatly influence the air concentrations of these elements or compounds, and the dry and windy conditions during the Las Conchas fire may have enhanced the particulate and natural radioactivity load in the air.

The Las Conchas fire affected forests that had not burned for more than 50 yr and had time to accumulate radon decay products. As radon gas decays in the atmosphere, the radioactive decay particles attach to PM and deposit on surfaces such as leaves and needles. These decay products are continuously deposited in forests and have been accumulating for years (for more details see Figure 4 of Eberhart, 2010). Thus, an increase in alpha and beta concentrations from the resuspension of radon decay products, including lead-210, bismuth-210, and polonium-210, was anticipated because of the fire (Nho et al., 1996). Radionuclides can also be taken up and stored in plants. Emissions of gross-alpha and -beta radioactivity from naturally occurring radionuclides and other constituents of interest resulting from fire have been measured in smoke from prescribed burns in Northern New Mexico (Reinhardt et al., 2004) (Table 2). These measurements demonstrate the concentrations of radionuclides and other constituents in air will increase during a fire.

Table 2
Emission Factors from
Prescribed Burns in Northern New Mexico

Analytes	Emission Factor per kg of Fuel Burned
Gross alpha	0.8–5.1 nCi
Gross beta	0–1.4 nCi
210-Po	1.4–10.3 nCi
CO	29–84 g
CO_3	1491–1697 g
CH_4	1.9–11.9 g
TSP	34–47 g
PM_{10}	12.6–43.8 g

Source: Reinhardt et al., 2004.

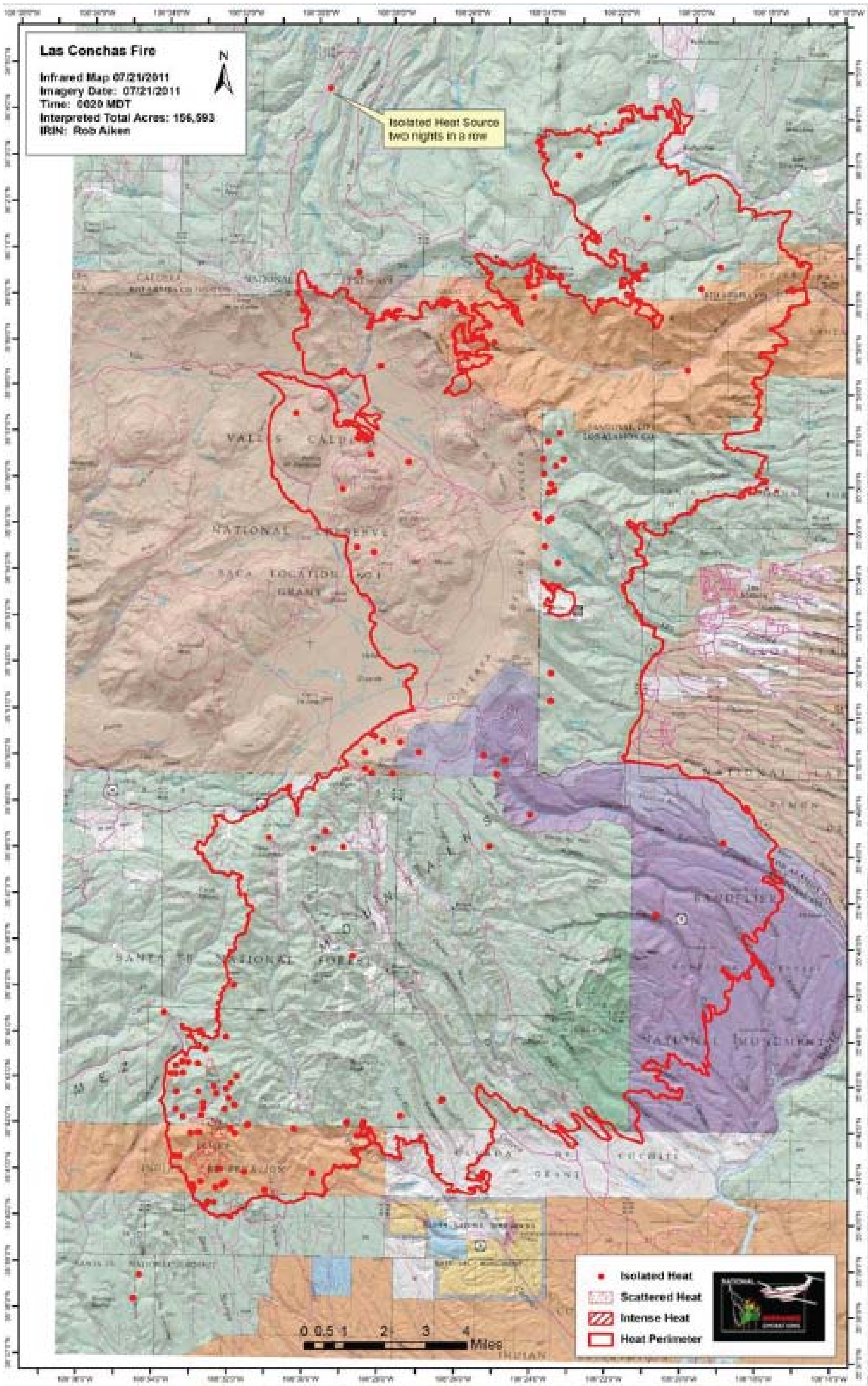


Figure 12 **Map of Las Conchas fire**

3.0 MEASUREMENTS TAKEN IN RESPONSE TO THE LAS CONCHAS FIRE

On June 28, the National Nuclear Security Administration's (NNSA's) Radiological Assistance Program (RAP) team arrived, and a series of targeted preventative burns along the western edge of the Laboratory were started. The Laboratory, DOE, and NMED increased the number of samplers and the frequency of analysis because of the potential for airborne releases of the radioactive and chemical contaminants. During the fire, air samplers were maintained by four groups: the Laboratory's AIRNET Team, NMED, the NNSA RAP team, and the Laboratory Field Monitoring Team (FMT). Sampler types included AIRNET stations, high-volume particulate samplers, TEOMs, ECAMs.

3.1 AIRNET

During the fire, the Laboratory's AIRNET stations were supplemented with five samplers operated by NMED (Figure 13). Individual filters were analyzed for the usual target analyte list elements and mercury. Additionally short-term clumps were analyzed as composites for gamma-emitting radionuclides; no one filter was included in more than one clump. Next-day preliminary sample analysis was performed on-site to quickly reassure the public that no unexpected Laboratory-derived radionuclides or metals were present in the smoke. Additional independent off-site analysis was performed at a commercial analytical laboratory, ALS Environmental, in Colorado to provide radiochemical analysis with greater sensitivity. Measurements of air concentrations reported were not background subtracted. Data were posted and made available on the RACER database at the time of the fire (currently Laboratory data are available at http://www.intellusnmdata.com/). Details about sample collection, sample management, chemical analysis, and data management now are available on the Laboratory website.

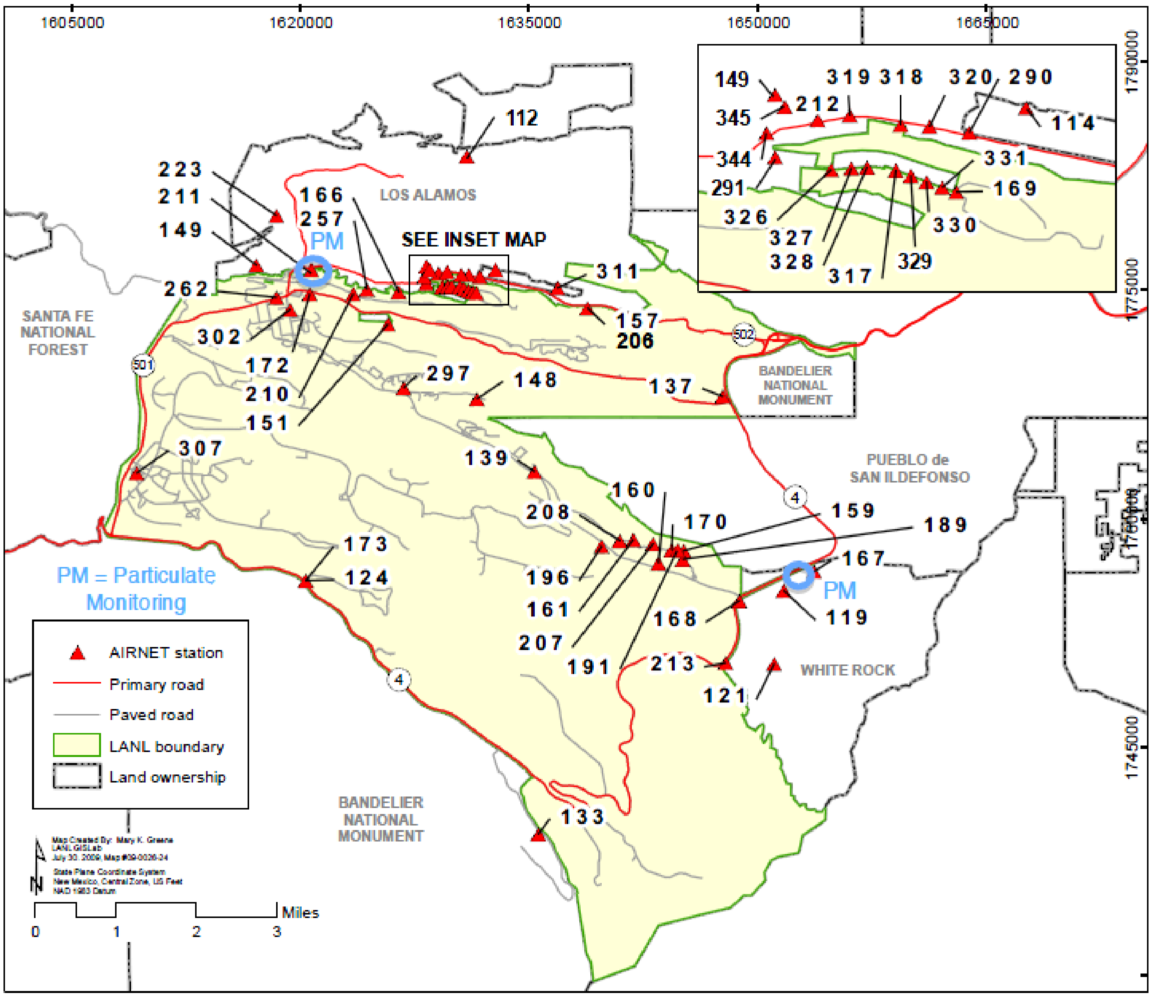
3.2 High-Volume Air Samplers

High-volume air samplers are deployed in strategic locations during emergencies to collect large air samples over a short time period and to monitor air quality. Filters are changed out frequently to prevent clogging with a goal of maintaining air sample flow for the duration of the event. During the Las Conchas fire, 25 of these samplers were deployed by the AIRNET team, FMT and NNSA's RAP team to ensure sufficient data quality and sufficient spatial monitoring.

The Laboratory AIRNET team deployed three high-volume samplers on June 27 and had 11 operational high-volume samplers in the field by June 30. Samplers were located at East Gate (2 samplers), the White Rock fire station, TA-49 replicate station, Los Alamos Medical Center, Crossroads Bible Church, Los Alamos Inn–South, Hedge Row–East Road, DP Road fire station, DP Road–Ace Hardware, DP Road Los Alamos Monitor (Figure 13). Samples were split in two: half the filters used for quick on-site analysis at the Health Physics Analysis Laboratory (HPAL), and the other half was sent for the highly sensitive and independent analysis off-site at ALS in Colorado. A 5- by 5-cm^2 piece was cut from each of the 20-cm by 25-cm high-volume filters and sent to HPAL for a 1-h count on an alpha spectrometer. For each sample, the effective volume sampled was approximately 60 m^3. After background was counted and subtracted, the average activity on each filter was –0.2 pCi ± 1 pCi, and the average concentration was –0.005 pCi ± 0.02 pCi/m^3.

The uncertainty of each measurement, 0.02 pCi/m^3, was a factor of 10 larger than the Clean Air Act (CAA) standard for plutonium-239, 0.002 pCi/m^3. However, the CAA standard applies to the annual average, and during the remainder of the year, the plutonium-239 concentration is close to 0, so these data provide assurance that the annual average is less than the CAA standard.

The FMT also deployed samplers at five location locations in Los Alamos County: the guard station by the Los Alamos Ski Hill, Truck Route by Royal Crest Trailer Park, the guard station on Pajarito Road near White Rock, near the Los Alamos Airport across from the Holiday Inn, and at the bottom of Main Hill Road at the intersection of the NM 502 and NM 4. To reassure the public, RAP samplers were deployed at eight regional locations and performed downwind monitoring at various off-site areas. The samplers were located at Holy Cross Hospital in Taos, the Taos fire station, the Embudo Health Office, the Embudo library, the NMED Las Vegas office, El Valle, Chimayo, and Hondo School. RAP samples were analyzed using the same method as Laboratory samples. Preliminary results were posted to the Laboratory website for public access as they were received.



*Note: Location 157 is the same as station 206. There are no stations 184 and 272.

Figure 13 **Monitoring locations during the Las Conchas fire. The red triangles show AIRNET stations. At AIRNET stations 157, 167, 173, 211, 212, 257, 317, 320, 326, 327, and 328, the Laboratory also operated high-volume samplers.**

3.3 Environmental Continuous Air Monitoring

During the Las Conchas fire, three ECAMs were activated at downwind locations to monitor real-time air for plutonium-239 and other alpha-emitting radionuclides. Four regional ECAMS were also active during the fire.

3.4 Tapered Element Oscillating Microbalances

Laboratory TEOM samplers operated normally throughout the fire. PM 10 and PM 2.5 measurements were taken every 30 min and converted to 24-h rolling averages. In addition, the USFS also monitored PM 2.5 and PM 10 at Cochiti Pueblo, Española, and Abiquiu.

3.5 Other

An ASPECT aircraft from the EPA was deployed to conduct flights over affected areas to look for possible contaminant releases. No elevated levels of contaminants from Laboratory operations were detected. The results of the flights were published on the Laboratory's website. There were also 11 Neighborhood Environmental Watch Network, NEWNET, stations that monitored external gamma radiation levels during the fire. NEWNET uses pressurized ion chambers to measure the gamma radiation. Data are obtained every second and recorded in data loggers, and 15-min averages are reported on a publicly available website, http://environweb.lanl.gov/newnet/.

During stable conditions, the 15-min averages remain relatively constant, and the accuracy of the data is indicated by the standard deviation, which is typically 0.1 micro-R/h. Larger fluctuations in the gamma flux are occasionally observed as a result of changes in the radon concentration or from changes in the water content of the soil. Nevertheless, when averaged over 1 d, NEWNET can typically detect significant fluctuations >0.1 micro-R/h. In Figure 17, the constant value of 17.0 ± 0.1 micro-R/h indicates no unusual changes in the gamma rates occurred during the Las Conchas fire.

4.0 RESULTS

In total, approximately 900 analyses were made on the roughly 220 samples collected by the AIRNET team. The frequency and types of analyses are summarized in Table 3 below (Green et al., 2012).

Table 3
Distribution of Laboratory Radioisotopic and Metal Analyses

Analytes	Number of Analyses
Gross alpha/Gross beta	265
Metals: Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn.	235
Gamma spectroscopy: Be-7, Na-22, K-40, Co-60, I-31, Cs-134, Cs-137, Tl-208, Bi-212, Pb-212, Bi-214, Pb-214, Ac-228, Pa-234m, Th-234, Am-241	136
Alpha spectroscopy: Am-241, Pu-238, Pu-239, U-234, U-235, U-238	235

Sources: Green et al., 2012; LANL, 2012.

4.1 Gross Beta and Gross Alpha

In air samples, gross-alpha and gross-beta data are usually dominated by the decay products of radon-222. Radon-222 decays to polonium-218, lead-214, bismuth-214, and polonium-214, which have a combined half-life of 50 min. Less than 1 d after an air filter is removed from the sampling system, almost all the polonium-214 decays to long-lived lead-210, which has a half-life of 22 yr. Lead-210 emits low-energy betas that are detected with low efficiency because most of them are stopped by the material of the filter and by the dust on the filter. Lead-210 decays to bismuth-210, which has a half-life of 5 d and emits a high-energy beta particle. Bismuth-210 decays to polonium-210, which has a half-life of 138 d and emits alpha particles.

The relative amounts of lead-210, bismuth-210, and polonium-210 are shown in Figure 11 of Eberhart (2010). Because of its longer half-life, polonium-210 grows in more slowly than bismuth-210, so for several months after the air filter is removed, the beta emitters (lead-210 and bismuth-210) have much higher activity than the alpha emitter (polonium-210). Consequently, the gross-beta activity data values are higher than the gross-alpha data.

The filters are generally analyzed at an off-site laboratory a few weeks after they are removed from the AIRNET station, and at this time the gross-beta data are about an order of magnitude greater than the gross-alpha data, as observed with most AIRNET data.

When lead-210 is deposited on the ground, on a tree, or on any surface in a forest, it is likely to remain there for years. During this time, bismuth-210 and polonium-210 come into secular equilibrium, and their activities become equal. The low-energy betas from lead-210 contribute little, so after several years the gross-alpha activity is almost equal to the gross-beta activity. During a fire, these radionuclides become airborne and the ratio of gross alpha to gross beta radioactivity in air samples increases, as observed during the Cerro Grande fire (Eberhart, 2010).

During the fire, gross alpha measurements had a range of 400 aCi/$m^3$to 13,400 aCi/m^3, which is not statistically different from the national or regional average.) Measurements of gross beta during the fire had a range of 34,000 aCi/m^3 to 74,000 aCi/m^3. The large ranges uncertainties are a result of shorter sample counting and collection times.

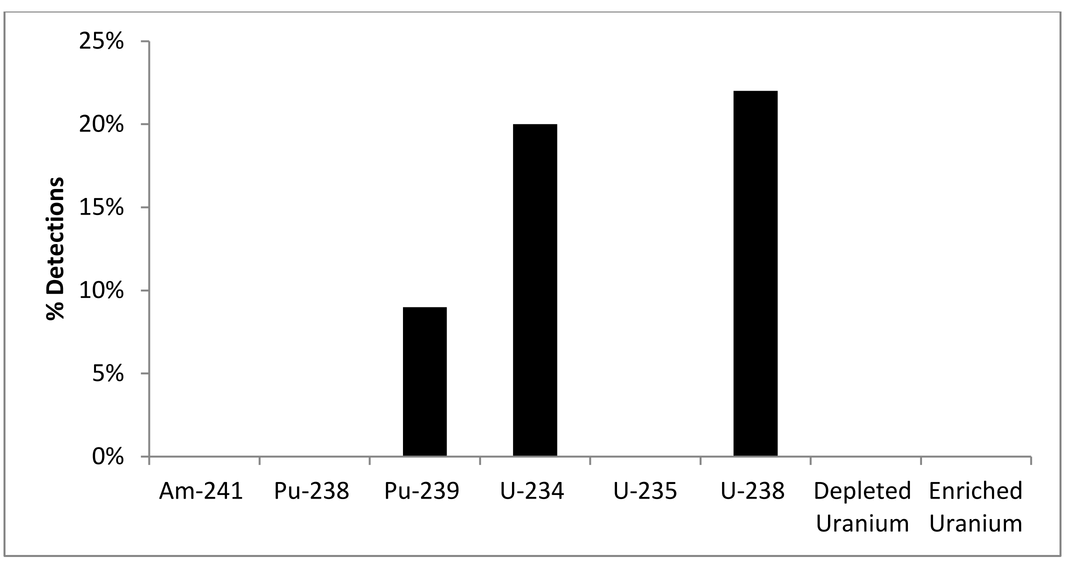


Figure 14 Percentage of alpha detections

Natural uranium from soil and its decay products were identified based on isotope analyses of AIRNET and High Volume samples. The dose from the uranium was negligible: at less than 0.1 mrem (Green et al., 2012). Radon and radon progeny remained fairly consistent before, during, and after the fire.

Plutonium associated with remediation work was measured in samples close to legacy waste sites by TA-01, TA-21, and TA-54. These detections were not associated with the fire because the locations are more than 4 km from the nearest area that burned, and because similar concentrations were detected at these locations before and after the fire. The dose to the maximally exposed individual as a result of this contamination was 0.33 mrem/yr during 2010. During 2011, it was higher (0.9 mrem/yr) because of remediation work at MDA B but was still below the EPA limit of 10 mrem (LANL, 2012). (The ranges of plutonium detected at AIRNET stations are presented in Table 5.) All results are much closer to the long-term observed values than to the federal limits.

Very few counts were seen in the ECAMS results throughout the fire indicating no measurable detection of airborne plutonium (Whicker et al., 2012). High-volume air samplers found no detectable amounts of plutonium-239 and americium-241 (Table 5). Rapid counts were made on portions of the high-volume air sample filters for quick assessment. The results from those assessments were all less than the minimum detectable activity for any contaminants that could have originated from Laboratory operations. This finding is consistent with results found at other wildfires (Reinhardt T., 2004). For corroboration of the preliminary results, an independent laboratory performed the analysis. No elevated levels of contaminants arising from Laboratory operations, and no evidence of manmade radionuclides being released during the fire were detected by RAP. FMT stations did not show any impact from the fire. Tables 7 and 8 show the minimum detectable concentrations and summary statistics for the RAP and FMT air samples, respectively.

Table 4
Details of the Plutonium-239 Detections from June 29 to July 5, 2011

Location	Likely Source	Number of Detections	Individual Doses from Detections (mrem)
South of Los Alamos Lodge	Hillside 137	3	0.10, 0.04, 0.02
Hedge Row, East Road	MDA B	2	0.01, (<0.01)
Ace Hardware, DP Road	MDA B	3	0.02, 0.01, (<0.01)
Los Alamos Monitor, DP Road	MDA B	3	0.03, 0.02, 0.02
West end A-15 tract, DP Road	MDA B	3	1.04, 0.07, 0.06
West center A-15 tract, DP Road	MDA B	1	0.21
East center A-15 tract, DP Road	MDA B	1	0.02
East end A-15 tract, DP Road	MDA B	1	0.02
Los Alamos Airport Hangar	MDA B	1	0.3
NW corner of Area G, TA-54	Area G	1	0.1
Expansion Pit, Area G, TA-54	Area G	1	.28

Sources: LANL 2012; Green et al., 2012.

Table 5
AIRNET High-Volume Results for Americium-241 and Plutonium-239

	Pu-239		**Am-241**	
Location	**MDC (aCi/m^3)**	**Result**	**MDC (aCi/m^3)**	**Result**
East Gate	239	NDA	222.58	NDA
Los Alamos Medical Center	301	NDA	265.56	NDA
White Rock Fire Station	101	NDA	133	NDA
Average	214	NDA	207.05	NDA

Notes: MDC = Minimum detectable concentration; NDA = nondetectable amount.

Table 6
RAP Results for Plutonium-298, Americium-241, and Cesium-137

Location	Pu-239			Am-241			Cs-137		
	Average MDC (aCi/m3)	Range of MDC ($aCi/m^{3)}$	Result	Average MDC (aCi/m3)	Range of MDC (aCi/m^3)	Result	Average MDC (aCi/m^3)	Range of MDC (aCi/m^3)	Result
Chimayo	3.03E+03	5.95E+03	NDA	4.22E+03	8.28E+03	NDA	6.31E+02	1.84E+03	NDA
El Valle	3.02E+03	7.15E+03	NDA	2.17E+03	2.82E+03	NDA	2.25E+02	3.16E+02	NDA
Embudo Health Clinic	1.53E+03	7.15E+03	NDA	1.67E+03	2.80E+03	NDA	1.24E+02	1.87E+02	NDA
Embudo Library	1.43E+03	7.15E+03	NDA	8.67E+02	8.28E+03	NDA	8.66E+01	1.81E+02	NDA
Holy Cross Hospital	1.28E+03	7.15E+03	NDA	1.00E+03	8.28E+03	NDA	6.92E+01	5.34E+01	NDA
Hondo School	1.03E+04	7.15E+03	NDA	8.95E+03	8.28E+03	NDA	5.98E+02	5.18E+02	NDA
Las Vegas NMED	8.38E+03	6.49E+03	NDA	3.95E+03	8.28E+03	NDA	3.53E+02	3.31E+02	NDA
Taos Fire Station 2	8.24E+02	7.15E+03	NDA	9.29E+02	8.28E+03	NDA	6.31E+01	7.85E+01	NDA
Total	2.98E+04	5.53E+04	NDA	2.38E+04	5.53E+04	NDA	2.15E+03	3.51E+03	NDA

Notes: MDC = Minimum detectable concentration; NDA = nondetectable amount.

Table 7
FMT Results for Plutonium and Americium

Location	Average MDC (aCi/m3)	Range of MDC (aCi/m3)	Result	Average MDC (aCi/m3)2	Range of MDC (aCi/m3)3	Results
Across Holiday Inn by Los Alamos Airport	77014	140511	NDA	76054	140202	NDA
Bottom of Main Hill Road by TA-74	25286	12315	NDA	22779	28074	NDA
Guard Station by Ski Hill Rd	135637	510289	NDA	122262	372494	NDA
Guard Station on Pajarito by White Rock Turnoff	36794	75849	NDA	27690	56469	NDA
Truck Route between Royal Crest and TA53 Road	29075	61250	NDA	26897	53399	NDA
Total	303805	800215	NDA	275681	650638	NDA

Notes: MDC = Minimum detectable concentration; NDA = nondetectable amount.

Overall, data from NMED verified Laboratory data and followed trends from the Cerro Grande fire. Results differ slightly because NMED does not correct its data for blanks. This effect was most apparent for the americium-241 measurements because the analytical laboratory added plutonium tracer used to determine percent recovery, which contains small amounts of americium-241. As anticipated both groups found slightly elevated levels of uranium and gross beta, while gross alpha was not elevated. Elevated measurements could be attributed to resuspension of soil, release, and suspension of radon decay products from buried biomass.

4.2 Heavy Metals

Detected metals reflect the local geology and included metals such as aluminum, calcium, copper, iron and manganese, the graph below shows detects for heavy metals. Detections do not contain anthropogenic sources, and many metals were not detected.

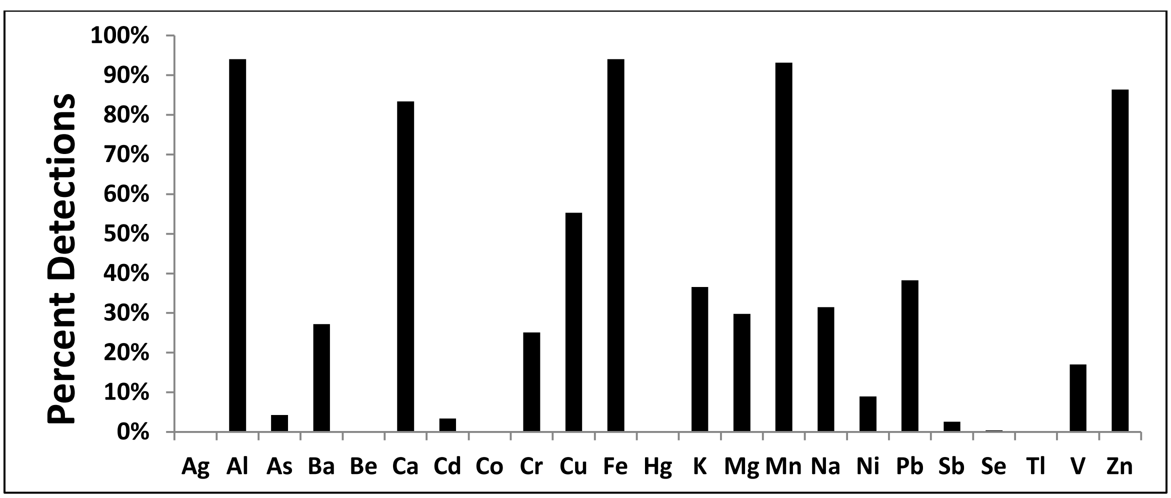


Figure 15 Percentage of heavy metal detections

4.3 Gamma Spectroscopy

No detections were made of anthropogenic gamma emitters (americium-241, cobalt-60, cesium-134, cesium-137, iodine-131, sodium-22), indicating no Laboratory impact. Beryllium-7 was detected from cosmic ray interaction. No statistically significant deviations from the normal gamma rate of 17.0 micro-R/h measured by NEWNET occurred.

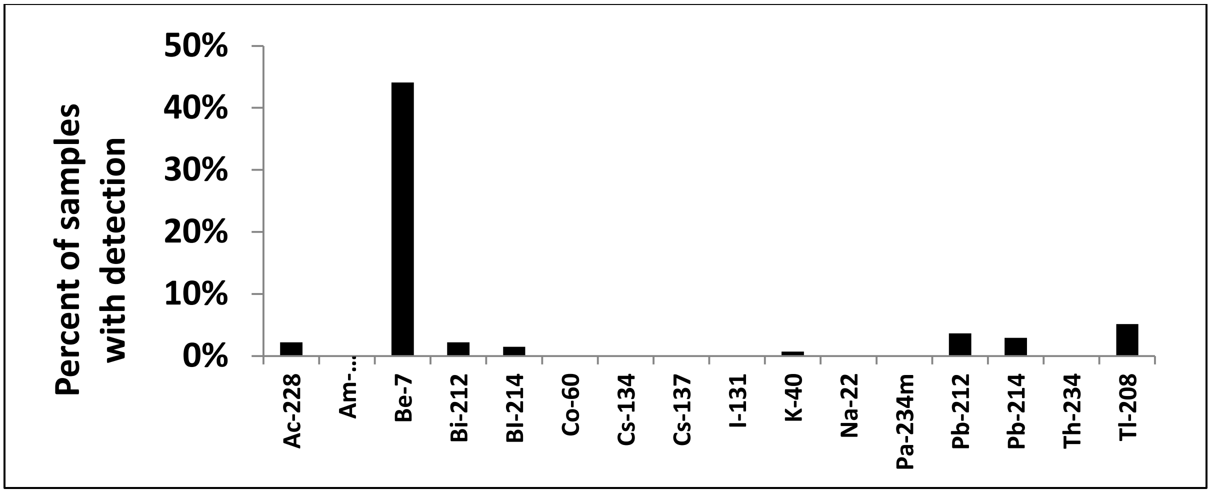


Figure 16 Percentage of gamma-spectroscopy detections

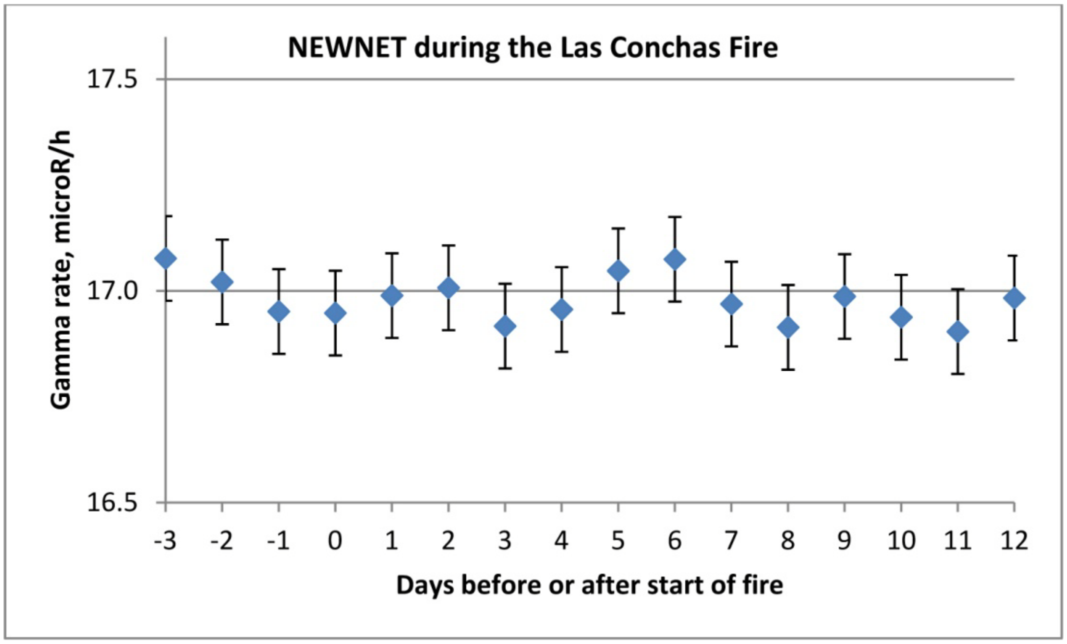


Figure 17 NEWNET data before and during the Las Conchas fire

4.4 Particulate Matter

Results from the fire in Los Alamos and White Rock during the Las Conchas fire show a significant increase in PM, resulting from the fire (Figures 18 through 21). After the fire started, the 30-min averages for PM 10 and PM 2.5 increased to 97 ± 73 µg/m^{-3} and 78 ± 70 µg/m^{-3} in Los Alamos from 22 ± 15 µg/m^{-3} and 8 ± 2 µg/m^{-3} (Whicker et al., 2012*).* Air quality in Los Alamos was unhealthy according to EPA standards for 30-min average PM concentrations, as shown in Figures 18 and 19. During the fire, the ratio of the PM 10 to PM 2.5 average concentrations decreased because of the small particles of smoke. Before the fire, the PM 10 concentration was usually greater than the PM 2.5 concentration, whereas during the fire the PM 2.5 concentration was usually greater than the PM 10 concentration (Whicker et al., 2012*).* The 24-h rolling averages for PM 2.5 and PM 10 are graphed together below to provide a visual representation of the relationship between the two particle sizes. Historical measurements also indicate that smoke is made up of finer particles (Hinds, 1982).

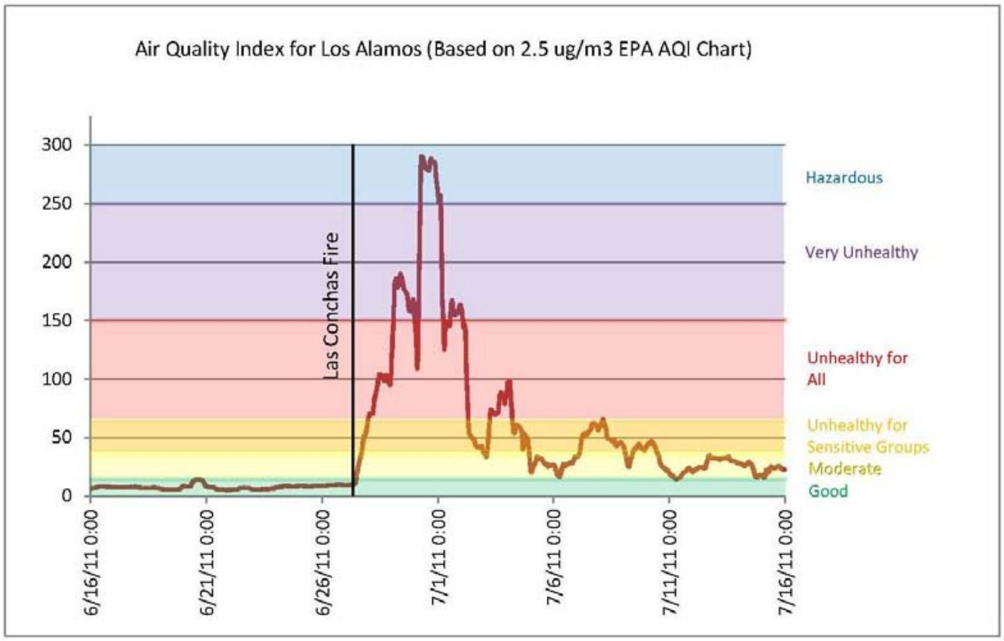


Figure 18 Los Alamos air-quality index

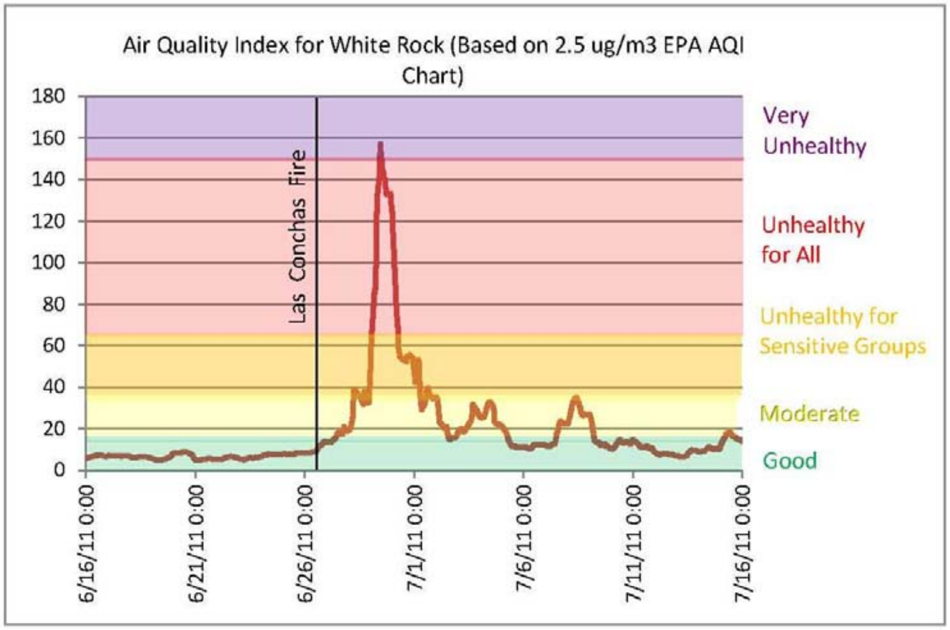


Figure 19 White Rock air-quality index

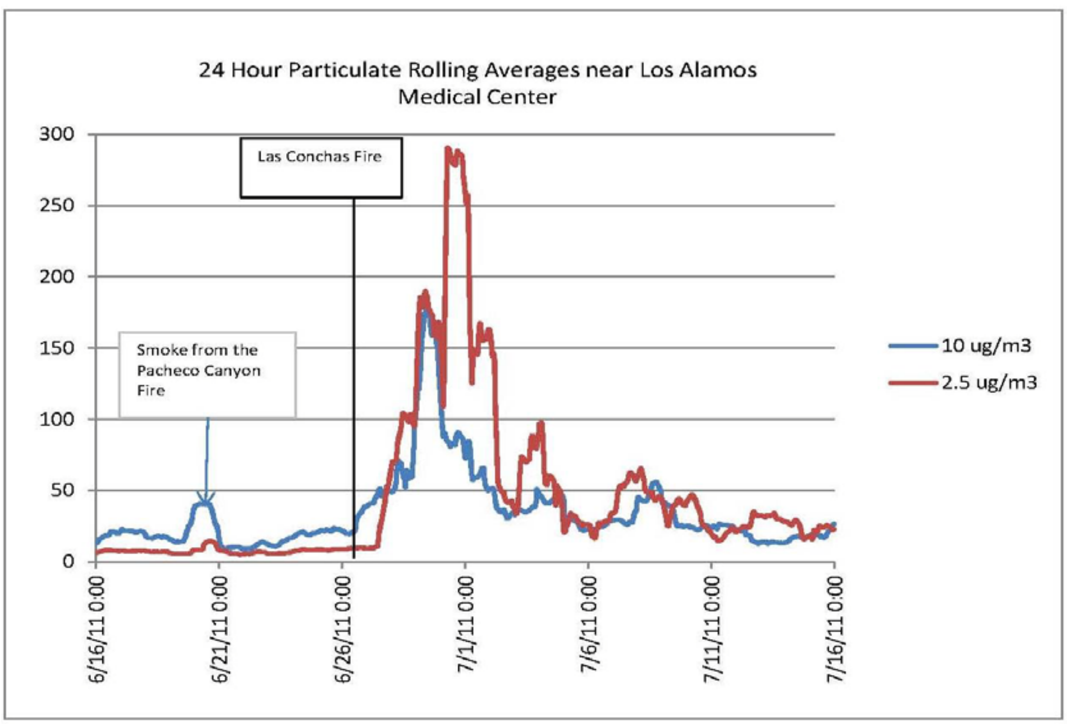


Figure 20 Los Alamos Medical Center TEOM data, rolling 24-h averages

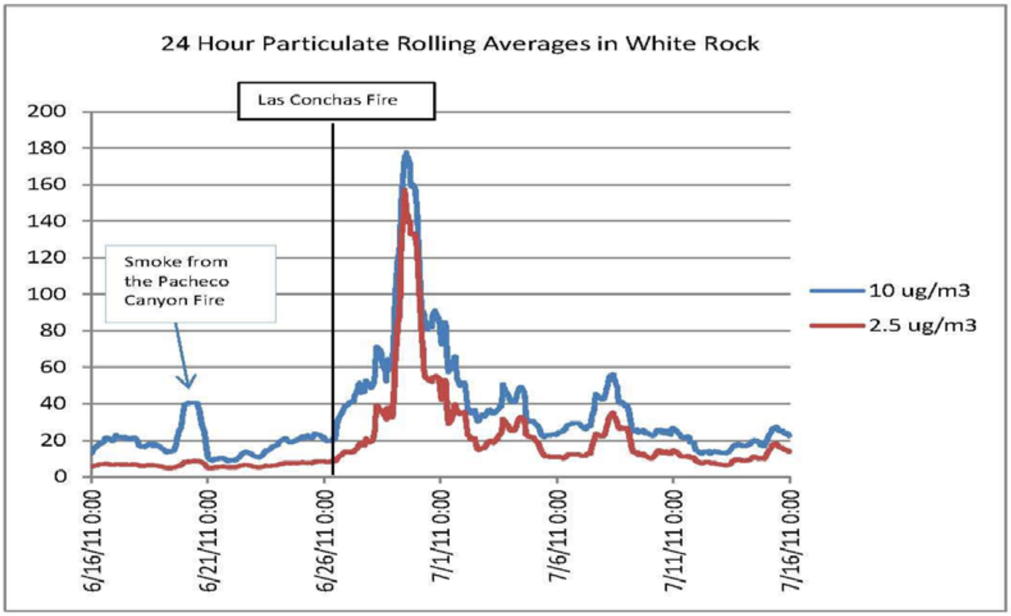


Figure 21 White Rock TEOM data, rolling 24-h averages

5.0 DISCUSSION

The results of air concentration measurements of radionuclides were similar to measurements from the Cerro Grande fire and other fires in the region. Analysis of the data collected during the Las Conchas fire provides the opportunity to compare results from different monitoring equipment and to serve as a learning experience for future emergency response monitoring events.

ECAMs provided valuable real-time information about the air quality for the duration of the fire. The ECAMs performed comparably before and during the fire despite reduced flow rates from smoke particles clogging filter pores during the fire. PM built up on filters but did not diminish the ECAMs's ability to function properly (Whicker et al., 2012).

Constraints to obtaining data of the desired quality in a timely manner include natural radioactivity in air interfering with measurements of isotopes of interest, availability of electrical power, transport of samples to a laboratory, collection of sufficient air volumes, lengthiness of sample preparation, sample count, and data analysis times.

Significant delay in retrospective air sampling analysis techniques, such as AIRNET, limits their value as an emergency response tool. However, such samples do provide additional public assurance after the event and can contribute to a more detailed understanding of the emergency event. TEOMs provided valuable real-time information for Laboratory and Los Alamos County officials to make public health risk determinations and to inform the public of the findings. Air quality was assessed using the EPA guidelines to evaluate public health risk, and the particulate concentrations were updated on a publically available website. Because smoke was the greatest health risk, TEOM data were used to help determine when the evacuation order could be lifted and the Laboratory could resume regular operations.

During an emergency, short-term data are needed to support urgent decisions such as whether to shelter in place or evacuate. There are also enquiries from the news media, from regional authorities, and from the public. Short-term data are less accurate because accurate data require time to sample a large volume of air, time for the short-lived interfering natural radionuclides to decay, time for analytical chemistry work, and time to count the samples.

Both short- and long-term data are important. Long-term data are compared with CAA standards based on annual averages, (Appendix E, Table 2, of 40 CFR 61). Short-term data may be compared with the derived response level (DRL) in the EPA Manual of Protective Action Guides (PAG) (EPA 400R92001). The CAA concentration levels for environmental compliance and PAG DRLs for uranium-238 and plutonium-239 are compared in the following table. They are different because the CAA is based on a year, while the DRLs are based on an hour, and the CAA is based on the regulatory limit of 10 mrem while the DRLs are based on the PAG criterion of 1 rem.

Table 8
CAA Concentration Levels for Environmental Compliance and PAG DRLs for Uranium-238 and Plutonium-239

Radionuclide	CAA	DRL
Units	pCi m^{-3}	nCi m^{-3}
Dose	0.01 rem	1 rem
Time	1 yr	1 h
Uranium-238	0.008	7.0
Plutonium-239	0.002	1.9

6.0 RISKS FROM FIRE

All air-concentration measurements showed no detectable radioactivity from the Laboratory associated with the fire. The greatest public risk hazard was from inhalation of the smoke. The Laboratory TEOM data were used by Laboratory and Los Alamos County officials to communicate and manage public risk.

7.0 REFERENCES

Beck, H., and Bennett, B. Historical Overview of Atmospheric Nuclear Weapons Testing and Estimates of Fallout in the Continental United States. Health Physics Society. 2012.

Campbell Scientific. Campbell Scientific 10-Hour Fuel Temperature/Moisture Sensors. Campbell Scientific. 2009.

Craig A. Water, Watersheds, and Land Use in New Mexico: Impacts of Population Growth on Natural Resources, Santa Fe Region 2001. New Mexico Bureau of Mines and Mineral Resources, Socorro NM. 2001. 239–333.

Eberhart, C. Measurements of Air Contaminants during the Cerro Grande Fire at Los Alamos National Laboratory. Los Alamos National Laboratory, Los Alamos, NM. LA-14160. 2010.*

U.S. Environmental Protection Agency (EPA). Particulate Matter. <http:\\www.epa.gov.mcer.science/pm/>. 2012.

Fuehne, D. 2011 LANL Radionuclide Air Emissions Report. Los Alamos National Laboratory, Los Alamos, NM. LA-14458. 2012.

Gallaher, B; Efurd, D. Plutonium and Uranium from Los Alamos National Laboratory in Sediments of the Northern Rio Grande Valley. Los Alamos National Laboratory, Los Alamos, NM. LA-13974. 2002.

Gallaher, B.M., Efurd, D.W., Rokop, D.J., Benjamin, T.M., & Stoker, A.K. Survey of Plutonium and Uranium Ratios and Activity Levels in Mortandad Canyon. Los Alamos National Laboratory, Los Alamos, NM. LA-13379-MS. 1997.

Green, A., Schleman S.A., Young D.L., Whicker J.J., Eisele W.F., McNaughton M.W., Ahlquist M.E., Stafford D.P., Hoover S.C., Bowman D.R. Ambient Air Monitoring during the 2011 Las Conchas Wildland Fire Near Los Alamos. Los Alamos National Laboratory, Los Alamos, NM. LA-UR-12-24451. 2012.

Hinds, W.C. *Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles.* New York: John Wiley & Sons 1982.

Los Alamos National Laboratory (LANL). Environmental Surveillance Report. Los Alamos National Laboratory, Los Alamos, NM.LA-14445-ENV. 2010.

Los Alamos National Laboratory (LANL). Environmental Surveillance Report. Los Alamos National Laboratory, Los Alamos, NM. LA-UR-14445. 2011.

Los Alamos National Laboratory (LANL). Environmental Surveillance Report. Los Alamos National Laboratory, Los Alamos, NM. LA-UR-13-27065. 2012.

National Weather Service Forecast Office (NWSFO). National Weather Service Forecast Office. 2012.

Nho E.Y., ArdouinM.F., Cloarec L.E., Ramonet M., 1996. Origins of ^{210}Po in the Atmosphere at Lamto, Ivory Coast: Biomass Burning and Saharan Dusts. Atmospheric Environment. 30:22 3705-3714.

Reinhardt T., Wrobel C., and Eberhart C. Factors from Prescribed Burns in Northern New Mexico. Los Alamos National Laboratory, Los Alamos, NM, 2004.

United Nations Scientific Commission on the Effects of Atomic Radiation (UNSCEAR). Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly. 2000.

Whicker, J. J., J.E., P., D.D., B., & C.F, E. (2006). From Dust to Dose: Effects of Forest Disturbance on Increased Inhalation Exposure. *Science of the total Environment*, 519–530.

Whicker J.J., Baltz D., Eisele W., Hart O., McNaughton M., Green, A. Operational Experience of Continuous Air Monitoring of Smoke for 239PU during a Wildfire. *Health Physics Society*. 2012.

*Editorial note: Most printed copies of LA-14250 have the wrong publication number.