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Title

Qualitative Assessment of Wildfire-Induced Radiological Risk at the Los Alamos National Laboratory Interim Internal Status Report - 2003

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Qualitative Assessment of Wildfire-Induced Radiological Risk at the Los Alamos National Laboratory

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Abstract

A new site-wide wildfire accident analysis is needed for the Los Alamos National Laboratory in 2004 as required by the Department of Energy every five years. Sufficient changes have occurred in the parameters originally analyzed in 1999 that they potentially alter the risk calculations of a radiological release resulting from wildfire. This potential change might compromise the National Environmental Policy Act (NEPA) baseline to which many NEPA reviews are compared. For example, one of the new domes used for the Transuranic Waste Inspectable Storage Project at Technical Area 54 has twice the capacity of the domes used in the 1999 analysis. An analysis using the larger capacity dome would likely result in a larger radiological source term and dose portion of the risk equation. Also, the tritium inventory at the Weapons Engineering Tritium Facility (WETF) is expected to increase, but the vulnerability of WETF buildings to wildfire has been reduced. Lastly, the likelihood or chance of a wildfire accident scenario resulting in a radiological release needs to be carried inside the Laboratory boundary to the point of release at Laboratory buildings. The required five-year update of the Site-Wide Environmental Impact Statement is the most appropriate outlet for such an analysis.

Introduction

This assessment was completed as a component of the Cerro Grande Fire Recovery Project. The purpose of this assessment is to evaluate the need, as required by the Department of Energy (DOE), to update the site-wide wildfire accident analysis that was reported in the 1999 Site-Wide Environmental Impact Statement (SWEIS) for the Los Alamos National Laboratory (LANL or the Laboratory). The evaluation was accomplished by qualitatively assessing how much, if any, the key accident parameters have changed since the 1999 analysis. The key contributors to the human radiological exposure assessed in the SWEIS were

- building sources (inventories) of radiological materials and
- soil and vegetation sources of radiological materials.

The key components of the likelihood or chance of occurrence of a site-wide wildfire were

- factors resulting in a wildfire advancing to the LANL boundary,
- fuels providing a pathway across the Laboratory, and
- the combustibility of key nuclear facilities at the Laboratory, which is partly dependent on fuel loads adjacent to those facilities.

The current states of these risk-contributing parameters were compared with the values used in the SWEIS in order to recommend whether or not a quantitative analysis, as done in 1999, was needed in fiscal year 2004, as required by the DOE five years after the completion of the SWEIS.

Background

A wildfire resulting in the exposure of humans to airborne radiation was one of several operational site-wide accident scenarios analyzed and reported in the 1999 SWEIS for LANL (DOE 1999). The health impact of the wildfire accident was 0.34 latent cancer fatalities esulting from an estimated population dose of 675 person-rem. The dose to the maximally exposed individual (MEI) member of the public was <25 rem, and the estimated frequency of occurrence was approximately once every 10 years, or "likely." While the estimated radiological dose consequence of a wildfire accident was small, the high frequency of occurrence resulted in a risk (product of the frequency and consequence) that was surpassed by only one other postulated accident in the SWEIS.

The wildfire accident analysis assumed multiple source releases including radiological inventories from buildings, suspended soils with environmental (very low) levels of contamination, and ash from burnt vegetation (this ash also had very low levels of contamination). Since the analysis in 1999, radiological inventories in buildings have changed, the vulnerability of buildings to ignition by wildfire has changed as a result of tree thinning, more-accurate and more-comprehensive data have been compiled on concentrations of radionuclides in vegetation, vegetation fuel loads have changed, and the frequency of occurrence has possibly changed. In this manuscript the results of qualitatively assessing the change in some of these factors are reported, and recommendations for further analysis are made based on these results.

General Scenario Description

Following the Cerro Grande Fire of 2000, the LANL site and surrounding vicinity are still considered forested areas with high fuel loading in some areas (canyons) and moderate to low fuel loads in areas that have been thinned. Wildfires in the region that includes expansive areas of forest are still common. While the Cerro Grande Fire of 2000 reduced some of the pathways by which fires originating on neighboring lands to the south and west could encroach on LANL, encroachment from Bandelier National Monument lands (Frijoles Canyon), San Ildefonso tribal lands, and parts of unburned Santa Fe National Forest still pose a wildfire risk for the Laboratory. Untreated canyons (e.g., Los Alamos, Pajarito) and beetle-killed trees within LANL pose a fire risk as well. While reductions in fuel loads on LANL have occurred as a result of the Cerro Grande Fire and tree thinning on mesa tops, extensive tree death from drought and an insect epidemic may have countered some of the beneficial effects of the reduced fuel loads. Also, heavy fuel loads remain in canyons. Planned “defensible space” thinning, which includes clear-cutting up to 50 feet around buildings with radiological inventories, is also generally assessed. All totaled, these factors were considered to qualitatively estimate the likelihood of experiencing a radiological exposure event resulting from wildfire.

Wildfire Frequency

A new analysis is needed in 2004 that will consider and quantify the full extent of the scenario culminating in the release of radiological materials. The probability component of the risk equation reported in the 1999 SWEIS only considered the advancement of a large wildfire to the LANL boundary, and then assumed, with no analysis, that the fire necessarily continued on a path through LANL, reaching and igniting LANL buildings, and causing a radiological release.

The frequency of a large fire encroaching on LANL (1 in 10 years) was estimated in 1999 as the joint probability of ignition in the adjacent forests, high to extreme fire danger, failure to promptly extinguish the fire, and fire-favorable weather. The frequency estimate for ignition in the adjacent forests was based on a 21-year period (1976–1996) and it probably has not changed appreciably in the seven years that have passed. Fire ignitions have continued to occur in adjacent forests. Periods of high to extreme fire danger have continued to occur frequently during the summer months, and fire-favorable conditions have continued as well. The estimated likelihood of a fire reaching a LANL boundary did not include the likelihood of a fire advancing across LANL to encroach on buildings containing (appreciable amounts of) radiological materials, the likelihood of buildings igniting, and the likelihood of a release occurring once buildings are assumed to ignite. The likelihood of a fire encroaching on a rad-containing building is dependent on, among other factors, fuel load and continuity of fuel leading up to the space surrounding the buildings. The likelihood of a nuclear facility igniting is dependent on the joint probability of fuel load indices for fuel adjacent to buildings, slope on which the adjacent fuel loads exist, and the combustibility of buildings. This factor was quantified in 1999 and has been updated recently. The likelihood of a release would be related to the damage ratio (likelihood that the material at risk [MAR] was actually impacted by the accident) and the leakpath factor (likelihood that confinement, if any, is breached). While the probability of a large fire encroaching on LANL remains moderate to high, depending on location, probably still on the order of once per 10 years (0.1/yr) or more frequent, the probability of a LANL facility containing a radiological inventory being ignited by a wildfire and releasing some or all of the inventory has been reduced somewhat by the “defensible space” thinning and by the reductions in fuel by the Cerro Grande Fire.

As mentioned above, the likelihood of a nuclear facility igniting was quantified in 1999 and has been updated recently (LANL/FWO 2003). The fuel hazard, slope hazard, and structure hazard of many facilities throughout LANL were quantified and integrated to estimate the wildfire risk of each building. The ratings were “None,” “Very Low,” “Low,” “Moderate,” “High,” and “Extreme.” The SWEIS analysis assumed that buildings with a “Moderate,” “High,” or “Extreme” wildfire vulnerability burned and released their entire content of radiological inventories. A reduction in the wildfire vulnerability of key buildings through reductions in the fuel load around the building could substantially reduce the likelihood of the building igniting and could also reduce the release of radiological materials by lowering the intensity of fire. Since

1999, however, the wildfire vulnerability of only two (Buildings 229 and 230) of several key storage domes at the Transuranic Waste Inspectable Storage Project (TWISP) at Technical Area 54 (TA-54) has been lowered from High to Moderate. The Weapons Engineering Tritium Facility (WETF) wildfire vulnerability has been reduced from Moderate to Very Low.

Since the probability estimate for the SWEIS stopped at the LANL boundary, there is no value for the probability of the fire advancing across the Laboratory to nuclear facilities, igniting buildings, and causing a release. Without this value, an assessment of how this probability might have changed cannot be made. One can conservatively estimate that there's a 50% chance that the three factors just mentioned occur, then interact this probability value (0.5) with the assumed probability for a wildfire reaching the Laboratory boundary (0.1). This results in a conservative estimate of the probability for a release to occur resulting from a wildfire and resulting in radiological exposures of 0.05. This interprets to a 5 in 100 year chance of occurrence, which is about equal to once in 20 years, or 5×10^{-2}/yr. This estimate is in agreement with the draft Documented Safety Analysis for Area G. The fact that the Cerro Grande Fire did not result in the ignition of a LANL nuclear facility is evidence that thinning works and preventative maintenance will keep key facilities safer from wildfire than in the past.

Dose Consequence and Radiological Risk

A new quantitative analysis of dose consequence and population health impact is needed in 2004 because the current capacity for radiological materials at a key facility is double the value used in the 1999 analysis. Particular buildings, mostly storage domes, at the TA-54 TWISP were associated with the large majority (~59%) of radiological dose reported in the 1999 SWEIS. The capacity of a new dome (Bldg. 375) at TA-54 can hold approximately twice the radiological inventory than the value used in the 1999 analysis. Although the 1999 analysis was conservative, this change may result in the case where the SWEIS analysis no longer bounds the current condition.

The wildfire accident analysis of 1999 estimated the radiological dose to the MEI at several locations resulting from releases from three main sources—buildings with radiological inventories that were entirely released, suspended soil that had environmental (very low) levels of contamination, and suspended ash from burnt vegetation that also had very low levels of contamination. The estimated MEI dose was <25 rem, with the highest contribution of 22 rem from TA-54 structures. The highest MEI dose from burning vegetation and suspended soil was

0.21 mrem from EF Site with uranium isotopes as the source. For comparison, Kraig et al. (2001) published an estimated inhalation dose from the Cerro Grande Fire to the MEI as based on air monitoring data during the fire. They estimated a dose of 0.2 mrem with the majority (99.85%) contributed by natural sources of radiation. Although differences exist between the factors involved in the two different estimates, the estimate of 0.2 mrem based on actual measurements is comparable to the sum of soil- and vegetation-contributed dose in the SWEIS—0.21 mrem. Other estimates of very low radiation doses resulting from burning large volumes of conifer tree materials have been made (Gonzales et al. 2001). Below are discussions of changes that have occurred in the three main sources of radiation in the SWEIS estimate.

Building Sources. In the SWEIS estimate, the dose from the release of radionuclides from buildings largely dominated the total dose from all sources. Buildings in six TAs (TA-03, -16, -21, -43, -48, and -54) contributed the majority of the radiological dose from the postulated fire and of the six, one—TA-54—contributed the majority (~59%) of the dose (individual and population). The WETF contributed another 28% of the total population dose. Particular buildings (storage domes) at TA-54 for the TWISP were associated with the large majority of radiological dose. Given that the TWISP and WETF dominated the dose contribution, this evaluation concentrates on assessing the gross change, if any, in MAR at these two facilities. A total of 4,041 ^{239}Pu plutonium-equivalent curies (PE-Ci) of combustible transuranic (TRU) waste and 7,854 PE-Ci of noncombustible TRU waste were used in the SWEIS consequence analysis. This was derived from assuming that the total TWISP TRU waste inventory was split evenly between six domes. The current TRU waste inventory at TWISP is contained in 11 domes. Split evenly, the MAR comparable to the SWEIS values are 3,117 ^{239}Pu PE-Ci of combustible TRU waste and 8,883 PE-Ci of noncombustible TRU waste (LANL/FWO-SWO 2003). Considering both MAR changes—the increase (1,029 PE-Ci) in noncombustible TRU waste and the decrease (924 PE-Ci) in combustible TRU waste—there is a net reduction in the "weighted initial source term" (0.16 PE-Ci; pg. G-191) of approximately 19% (-0.03 PE-Ci) and there is no change in the wind-caused "resuspension source term" (0.74 PE-Ci; pg. G-192). However, one of the new domes (TA-54-375) is approximately double the size of the other 10 domes. If a new analysis were to conservatively assume that this, the largest dome, was the one involved in a site-wide wildfire, the estimated doses and health impact could double those in the SWEIS. Even so, the new dose would be in agreement with estimates proposed in the draft Documented Safety Analysis for Area G.

A total of 1.36 kg of tritium gas (^3H) at the WETF was used in the consequence analysis in the SWEIS. The WETF Technical Safety Requirements currently restrict the tritium inventory at WETF to 1.4 kg of ^3H (LANL 2002), thus the MAR assumed for the WETF in the SWEIS analysis remains unchanged. However, pending the completion of some requirements for containers holding ^3H, the administrative limit will be increased to 2 kg (Tingey 2003). Therefore, the five-year update of the SWEIS in 2004 should use 2 kg as the MAR.

Vegetation and Soil Sources. Suspended ash from vegetation and suspended soil contributed about 7% (~50 person-rem) of the total population radiological dose reported in the SWEIS. Concentrations of radionuclides in vegetation at LANL were largely unavailable when the SWEIS analyses were performed in the late 1990s. Given plant/soil uptake coefficients for some radionuclides in the published literature, concentrations of radionuclides in plants were largely based on concentrations in soil. Since the SWEIS, data have been compiled on concentrations of radionuclides in vegetation at LANL (Gonzales et al. 2003). If comparisons can be made between data used in the SWEIS with other, more recent, data on concentrations of radionuclides in plants, perspective can be gained on the change in vegetation as a radiation source term for wildfire. One concentration used in the SWEIS was 320 μg uranium per g of dry vegetation (μg/g-dry) collected in 1975 (Miera et al. 1980), which was from a sample collected where uranium concentrations in surface soils were 20 to 3,500 times background levels. This compares to <u>maximum</u> concentrations of 0.65 μg/g-dry in the bark of shrubs that were rooted in TRU waste material (Wenzel et al. 1987), 0.073[1] μg/g-dry in understory vegetation collected at one of 12 LANL Environmental Surveillance Program onsite locations in 1998 (Gonzales et al. 2000), 0.066[2] μg/g-dry in overstory vegetation at one of the same 12 locations and same year, 0.05[2] μg/g-dry in pine needles from the TA-16 WETF facility in 1985 (Fresquez and Ennis 1995), 0.72[2] μg/g-dry in overstory vegetation at the Dual-Axis Radiographic Hydronamic Test Facility in 2002 (Nyhan et al. 2003); and 1.5[3] μg/g-dry in piñon tree bark at a firing site in 2001 (Gonzales et al. 2003). Other than for total uranium, the SWEIS does not identify the concentrations used in source term calculations. Ignoring the other radionuclides, and based on the comparison of the total uranium concentration assumed in the SWEIS with other, more

[1] Computed using ash/dry weight ratio of 0.1 from Fresquez and Ferenbaugh (1999).
[2] Computed using ash/dry weight ratio of 0.08 from Fresquez and Ferenbaugh (1999).
[3] Computed by converting radioisotopic data to uranium mass data and using ash/dry weight ratio of 0.029 for bark from Gonzales et al. (2003).

recent, data on concentrations of total uranium in plants, the source term from vegetation used in the SWEIS is still bounding of any that would be calculated using other, more recent, concentration data. Thus, the predicted MEI dose from vegetation and soil in a site-wide fire remains less than one mrem. Although the Cerro Grande Fire burned only about 7,500 acres of forest within LANL, the estimated inhalation dose based on measurements by Kraig et al. (2001) supports our contention that vegetation (and soil) contributes very little radiation dose.

Conclusions

A new wildfire quantitative accident analysis (as described in a proposal by Gonzales et al. 2002) is needed at LANL to update the risk terms as required by DOE every five years. A slight reduction in the vulnerability of key buildings to wildfire as well as other factors leading up to a release of radiological materials from a wildfire resulted in an estimated chance of occurrence of about once in 20 years. The overwhelmingly dominant source of radiological risk from a wildfire at LANL in 1999 was building inventories of radiological materials, particularly inventories of the TWISP at TA-54 and the WETF. Given the same assumption—that it is credible to use a per-dome average inventory of radiological materials for the TWISP in the dose consequence estimates—the analysis in the SWEIS still bounds the current condition. However, a more conservative analysis would be to use the time-averaged inventory of Building 375, a new dome with about twice the capacity of other domes. An analysis using the Building 375 inventory should be conducted as part of the five-year update of the SWEIS. Also, the tritium inventory at the WETF is expected to increase, so the five-year update of the SWEIS in 2004 should use 2 kg as the MAR. Radiological inventories of only two facilities were surveyed for this assessment—inventories may have changed at other facilities and this should be assessed. Changes in fuel loads have possibly changed the pathways of potential fires and, with this, whether or not the continuity of fuels can still support postulated scenarios. The general public's sensitivity to the subject of wildfires at LANL requires that accurate (quantitative) assessments are current. Furthermore, there are other types of risk, beyond radiological, associated with wildfire that take important information from wildfire accident analyses. As such, a scope and plan for a more thorough (quantitative) analysis of wildfire accidents at LANL have been developed.

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