LA-UR-14-27684

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Title:	Analysis of Wildland Fire Hazard to the TWF at Los Alamos National Labs
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Intended for:	2014 Safety Analyst Workshop, 2014-10-11/2014-10-17 (Pleasanton, California, United States)
Issued:	2014-10-02

Analysis of Wildland Fire Hazard to the TWF at Los Alamos National Labs

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Project: TWF DSA R0
Objective: To provide quantitative data for Wildland Fire Accident Analysis and Control Selection/Designation by updating LA-UR-13-24529 for site specific information to the TWF

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Acronyms

AA	Accident Analysis
CMR	Chemistry and Metallurgy Research
DOE	Department of Energy
FHA	Fire Hazard Analysis
FPP	Fire Protection Program
HA	Hazard Analysis
LANL	Los Alamos National Laboratory
MAR	Material – At – Risk
NPH	Natural Phenomena Hazard
PE-Ci	Plutonium Equivalent Curies
TA	Technical Area
TRU	Transuranic
TWF	Transuranic Waste Facility
UL	Underwriters Laboratory
WIPP	Waste Isolation Pilot Plant

1 Overview

Wildfires represent an Anticipated Natural Phenomena Hazard for LANL and the surrounding area. The TWF facility is located in a cleared area and is surrounded on three sides by roadway pavement. Therefore, direct propagation of flames to the facility is not considered the most credible means of ignition. Rather, fires started by airborne transport of burning brands constitute the most significant wildland fire threat to the TWF.

The TWF is located at TA-63 along Pajarito Road, as seen in Figure 1. It is surrounded on all sides by technical areas and neighbors TA-55. It is designated as a Hazard Category 2 nuclear facility and stores Transuranic Waste drums preparing to be shipped to WIPP. As designed and operated, full facility fire would involve 20,200 PE-Ci of MAR in the form of combustible, dispersible material.

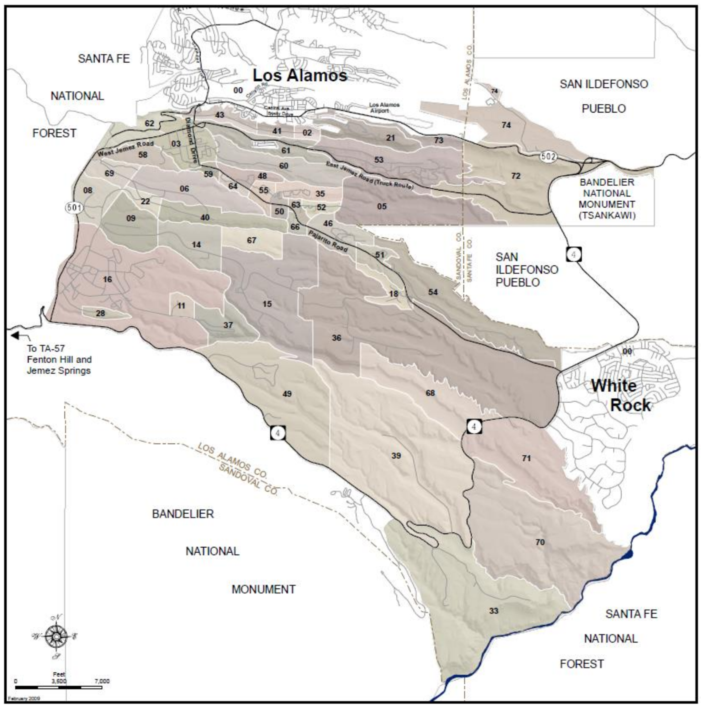

Figure 1 - Map of LANL Technical Areas

The purpose of this document is to update LA-UR-13-24529, *Airborne Projection of Burning Embers – Planning and Controls for Los Alamos National Laboratory Facilities*, to be specific to the TWF site and operations.

Minimizing the risk posed by wildland fires requires effective preventive and mitigative measures. For a fire to propagate, three conditions must be satisfied: sufficient ignition energy, sufficient fuel, and oxygen. It is impossible to eliminate oxygen from this system and so prevention and mitigation efforts must focus on reducing ignition and fuel sources as well as emergency preparedness and response programs.

2 Historical Fires

LANL facilities have been threatened by two large scale fires within the last 15 years. The Cerro Grande Fire in 2000 was considered a *severe* fire type and challenged a number of laboratory facilities, burning more than 7,500 acres of Laboratory land. Many laboratory facilities were in close enough proximity to expose buildings and structures to direct flame impingement and lofted brands. However, no major buildings were significantly damaged and no facilities with a nuclear hazard classification were affected [1].

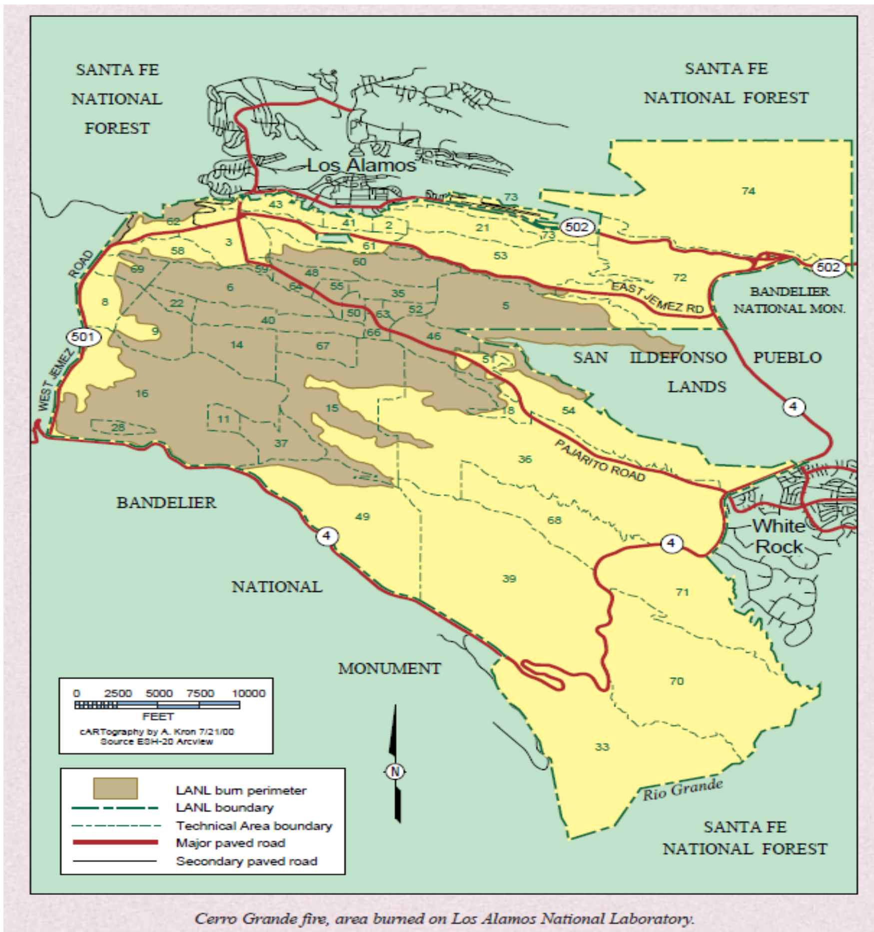

Figure 2 - Map of LANL showing the 2000 Cerro Grande Fire Extent on Laboratory Property [2]

As is evident in Figure 2, TA-63 was not impacted by direct flames but was within range for burning embers. Damage from this fire was mitigated largely because of LANL facility requirements, fire department response efforts, preparations performed as a part of the LANL Fire Protection Program (FPP), and the LANL emergency response programs.

The 2011 Las Conchas Fire did not encroach on Laboratory land, as seen in Figure 3, but was within range to drop burning brands. The Las Conchas fire did not get close enough to pose a *severe* challenge to LANL facilities due to successful firefighting efforts and favorable wind directions.

Figure 3 - Map of the 2011 Las Conchas Fire Extent and its' vicinity to Laboratory Property [3]

Figure 4 - An image of TA-3 during the 2011 Las Conchas Fire [4]

3 Direct Flame Impingement

The risk of direct flame impingement due to wildland fires is directly related to wildland separation distances to facility structures. As a general rule, flame height is between three to five times the height of the fuel that is burning [5]. So, if one foot of grass is burning, then the height of the flame could be up to five feet high, in ideal fire growth conditions. The flame height for a burning tree has been shown to be up to 3 times the height of the tree, often referred to as the fire's crown, demonstrated in Figure 4.

The vegetation surrounding the TWF is typical of the region and consists of sparse tree cover and desert grassland. The facility is not within the Ponderosa forests that surround the region. The trees represented in the wildlands surrounding the TWF consist of Bristlecone Pine (approximately 15 feet in height), Gamble Oak (approximately 20 feet in height), and Piñon Pines (approximately 20 feet in height) as well as grasses consisting of Arizona Fescue, Mutton Grass, and Kentucky Bluegrass, all of which grow to a height less than 3 feet in an unmaintained state [6].

Assuming a maximum flame height from the wildland trees, a minimum defensible space of 60 feet is required to prevent direct flame impingement to structures located at the TWF.

Figure 5 - Image of the TWF Site Boundary with selected distances to neighboring wildlands

Figure 5 shows the distances from the site boundary to existing wildland areas. The minimum existing distance is 115 ft, which is almost a factor of two larger than the minimum separation distance required to prevent a fire by direct flame impingement.

Administratively, the wildland separation distance is controlled to 75 feet, providing an additional 15 feet of conservatism toward protecting against direct impingement.

4 Burning Embers

The transport distances associated with burning embers is the subject of considerable research and modeling. The threat posed by burning embers is directly related to the thermal size of the fire, wind speed and direction, vegetation density, and the physical dimensions of the lofted brand. In a recent study of Wildland Fire Hazard to the CMR facility, a facility located approximately 1.8 miles from the TWF site, a large fire was defined as one exceeding 40 MW. Such a fire was found to have a maximum ember loft radius of 558 ft which corresponds to a 2 mm burning leaf-shaped ember. The meteorological and vegetation assumptions of this study are outlined in SB-DO:CALC-11-015 and are directly applicable to the TWF facility. The computations carried out in SB-DO:CALC-11-015 are based on a 2006 study of fires associated with high winds[7], comparable to the high winds experienced by fire fighters when combatting the Cerro Grande Fire, thereby providing a realistically conservative meteorological assumption. The study concluded that, in addition to the large scale fire information analyzed by the calculation, small scale fires from burning brush or over-grown grass have the potential to loft embers a maximum distance of 148 ft.

The wildland separation distances for the TWF are shown in Figure 5. The shortest distance between the facility boundary and wildland is 115 ft, well within the 558 ft maximum ember loft for large fires and within the margin of error for the 148 ft maximum ember travel distance for small scale fires.

Administratively, the protected distance between the facility structures and wildland is 75 ft. At this distance, embers as large as 20 mm could impact the facility with temperatures of approximately 580^{o}C [8]. This temperature is sufficient to ignite combustible surfaces, as wooden roofs have been demonstrated to ignite with as little as 250^{o}C ember temperature.

Both the calculation and the study assume buoyancy for the large fire study, which is the primary contributor to the travel distance. In the absence of buoyancy, consistent with the assumptions of the TWF HA, the maximum travel distance of embers in a small scale fire, 148 ft, are appropriate. When combined with the size and temperature of potential embers, the wildland separation distance is insufficient in eliminating the hazard posed by burning brands.

5 Roof Assemblies

The TWF's primary vulnerability in a wildland fire is due to 20 mm burning embers landing on a roof structure and igniting the facility. Many studies have been conducted on the effectiveness of fire resistant roofing in preventing building ignition due to embers.

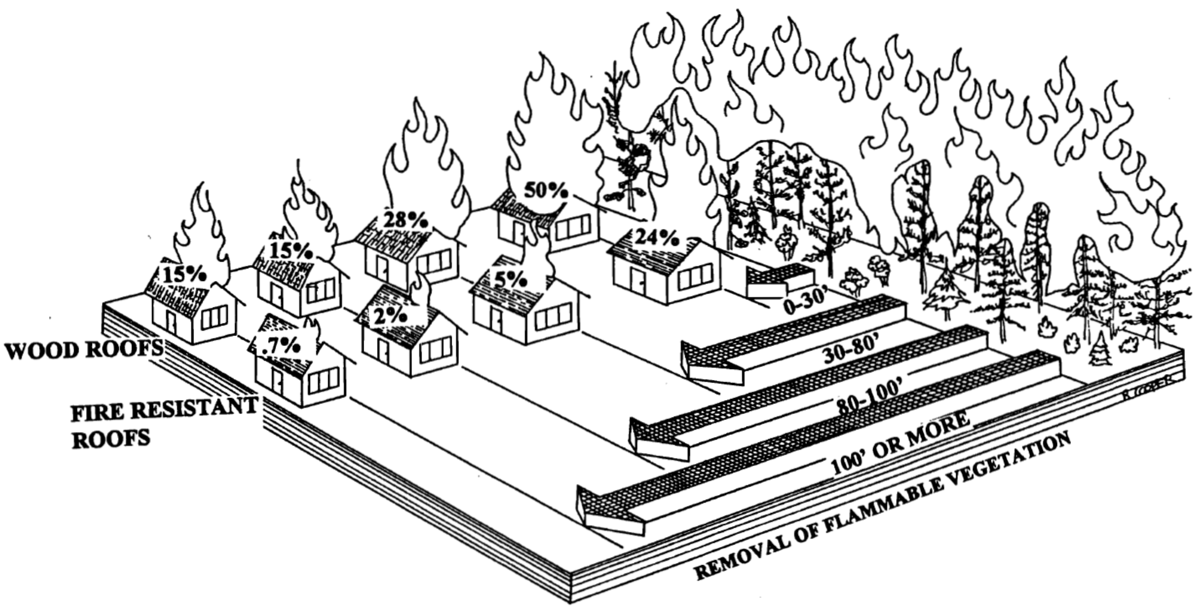

Figure 6 - Wildland separation distance effectiveness comparing combustible and non-combustible roofing structures [9]

The probability that a roof will catch fire decreases with distance according to the following relations:

$$P(x) = 0.0064 + 0.234\, e^{\left(-x/30\right)} \quad \text{Non} - \text{Combustible roofing}$$
$$P(x) = 0.0881 + 0.412\, e^{\left(-x/30\right)} \quad \text{Combustible roofing}$$

Where *x* is the distance of the structure from the fire.

At a stand-off of 75 ft, approximately 12% of structures with combustible roofing will ignite. Therefore, in the absence of other controls, the Separation distance offers an order of magnitude reduction in frequency as a preventer (10^{-1} reduction to likelihood).

In contrast, a fire resistant roof in combination with the stand-off distance reduces the likelihood of roof ignition by two orders of magnitude (10^{-2} reduction to likelihood). The aggregate risk reduction is sufficient to credit a frequency bin reduction in Accident Analysis, though it is important to note that the assumption of a non-combustible roof does not designate the roofing type.

ASTM E-108, UL-790 and UBC 15-2 define Non-Combustible roofing types in the following three categories [10]:

- CLASS A – “includes roof coverings which are effective against *severe* fire exposures”
- CLASS B – “includes roof coverings which are effective against *moderate* fire exposures”
- CLASS C – “includes roof coverings which are effective against *light* fire exposures”

These classifications apply to the roofing assemblies and NOT the metal roofing panel alone. A roofing panel that is classified as part of a Class A assembly may not qualify as part of a Class A assembly if changes are made within the insulated or non-insulated construction.

The terms *severe*, *moderate*, and *light* fire exposures are largely qualitative and defined as follows [11]:

- *Severe* – a fire resulting in flames beating directly against the fire retardant exposed, for longer than a five minutes at a time, with sufficient heat to cause wired glass to soften and sag out.
- *Moderate* – a fire such that the fire retardant is subjected to intense radiant heat and occasional licking of flames, but not continuous flame impact, with sufficient heat to ignite wood.
- *Light* – a fire of sufficient heat to blister paint, but insufficient heat to ignite wood.

Due to the anticipated frequency (10^{-1}/year) of *severe* wildland fires with the potential to challenge facility structures, all TWF nuclear operations structures are designed to meet UL Class A standards for roofing structures. Both Underwriters Laboratories Inc. and ASTM International publish standards for test methods for fire tests of roof coverings [12][13].The test methods are nearly identical. The class A roof classification is defined in UL 790 as follows:

- *Class A roof coverings are effective against severe fire test exposures. Under such exposures, roof covering of this class afford a high degree of fire protection to the roof deck, do not slip from position, and are not expected to produce flying brands.*

The tests for these classes include intermittent-flame, spread-of-flame, burning-brand, and flying-brand tests. This consists of exposing the roof structure to flames of 888 ± 28^{o}C for five minutes over a 12 inch by 12 inch area in the most vulnerable location of the roof. [14]

6 LANL Fire Protection Program

The FPP is administered by the LANL Fire Protection Division. This program has been identified as an important mitigation factor in both of the large scale fires that have threatened the laboratory within the last 15 years. The complete list of responsibilities is included in PD1220 and includes programmatic, management, and implementation responsibilities. The FPP Manual consists of about 80 sections and is available from the Fire Protection Division website. Introductory material from the wildland fire module includes the following statement [15]:

> *The Laboratory addresses the risk of starting wildland fires through the use of the Fire Danger Matrix and the concurrent Fire Danger Rating… and through procedures for controlling spark – or flame – producing operations. Damage from wildland fires is mitigated by performing regular wildland fire risk assessments, establishing clear structure ignition zones and/or defensible space, and taking additional measures in areas of higher risk.*

As part of the FPP, the Fire Protection Division also performs Fire Hazard Analyses (FHAs) for laboratory facilities. For facilities at risk of wildfire, these FHAs include a Wildfire Hazard Analysis typically based on NFPA 1144, *Standard for Reducing Structure Ignition Hazards from Wild land Fire* [16] or the techniques contained within the *International Wildland-Urban Interface Code* [17].

Facilities are expected to maintain a minimum 30 ft defensible (cleared of combustibles) space around buildings. Additional mitigation has been performed where needed in “Structural Ignition Zones” of up to 200 ft from facilities.

In the case of TWF, the defensible space is set at 75 ft.

7 Summary

Burning brands from forest fires are a credible risk at LANL. All TWF Nuclear Operations buildings are designed with UL Class A roofs. Waste at the TWF is stored in fire resistant containers. The laboratory has a comprehensive Fire Protection Program, which includes assessing wildland fire risk and mitigating fuels. This program is managed through the Fire Protection Division. Vegetation is cut-back to at least national consensus standards on a regular basis around nuclear facilities. Fire Department services are provided by Los Alamos County through an agreement with the Department of Energy. The interface between the Fire Department and LANL during emergencies is the Emergency Operations Division.

The ability of LANL facilities to withstand a wildland fire was tested by the Cerro Grande fire in 2000. No nuclear or high-hazard facilities were damaged even though the fire burned around a number of them. Since them, the laboratory has strengthened programs to protect against wildland fires.

The following summarizes the results of this literature study in regards to impact on the TWF HA/AA:

- The wildland separation distance prevents direct impingement fires from impacting the TWF
- The wildland separation distance reduces the brand size to 20 mm and a temperature of 580^{o}C at 75 feet.
- The wildland separation distance in combination with a non-combustible roof reduces the frequency bin from Anticipated to Unlikely (a 10^{-2} reduction in frequency)
- The Class A roof prevents ignition from brands < 305 mm in length and at a temperature of 888^{o}C.
- The Class A roof in combination with the wildland separation distance prevents the ignition of buildings due to burning embers
    - The Utility Building, Operations Center, and Characterization Trailers are assumed to have combustible roofs.

8 Acknowledgements

This works was performed with a heavy reliance on the work carried out by Donald Siebe in LA-UR-13-24529, *Airborne Projection of Burning Embers – Planning and Controls for Los Alamos National Laboratory Nuclear Facilities* which was adapted specifically to the TWF.

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