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Five-Year ALARA Review of Dosimetry Results, 1 January 2011 through 31 December 2015

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Five-Year ALARA Review of Dosimetry Results 1 January 2011 through 31 December 2015

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Abstract

A review of dosimetry results from 1 January 2011 through 31 December 2015 was conducted to demonstrate that radiation protection methods used are compliant with regulatory limits and conform to the philosophy to keep exposures to radiation As Low As is Reasonably Achievable (ALARA). This included a review and evaluation of personnel dosimetry (external and internal) results at Sandia National Laboratories, New Mexico as well as at Sandia National Laboratories, California. Additionally, results of environmental monitoring efforts at Sandia National Laboratories, New Mexico were reviewed. ALARA is a philosophical approach to radiation protection by managing and controlling radiation exposures (individual and collective) to the work force and to the general public to levels that are As Low As is Reasonably Achievable taking social, technical, economic, practical, and public policy considerations into account. ALARA is not a dose limit but a process which has the objective of attaining doses as far below applicable dose limits As Low As is Reasonably Achievable. In the case of Sandia National Laboratories, a need for formal ALARA goals has not been identified. Collective and individual doses are kept at acceptable through Operational ALARA practices implemented during the development of radiological Technical Work Documents.

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NOMENCLATURE

ACL	Administrative Control Level
AHCF	Auxiliary Hot Cell Facility
ALARA	As Low As is Reasonably Achievable
DOE	Department of Energy
DOELAP	DOE Laboratory Accreditation Program
LLD	Lower Limit of Detection
NCRP	National Council on Radiation Protection and Measurements
RPDP	Radiation Protection Dosimetry Program
SNL	Sandia National Laboratories
SNL/CA	Sandia National Laboratories, California
SNL/NM	Sandia National Laboratories, New Mexico
SPR	Sandia Pulsed Reactor
TED	Total Effective Dose
TLD	Thermoluminescent Dosimeter

1. INTRODUCTION

ALARA is a philosophical approach to radiation protection by managing and controlling radiation exposures (individual and collective) to the work force and to the general public to levels that are As Low As is Reasonably Achievable taking social, technical, economic, practical, and public policy considerations into account. ALARA is not a dose limit but a process which has the objective of attaining doses as far below applicable dose limits as low as is reasonably achievable [10 CFR 835.2].

This report documents a review of personnel dosimetry (external and internal) for the five-year period starting 1 January 2011 through 31 December 2015 performed at Sandia National Laboratories, New Mexico (SNL/NM) as well as Sandia National Laboratories, California (SNL/CA) and environmental monitoring results for the same period at SNL/NM by the Radiation Protection Safety Committee, ALARA Subcommittee. Dosimetry results demonstrate that SNL radiation protection methods are compliant with regulatory limits and consistent with the ALARA philosophy.

1.1. Methods and Materials

The occupational dosimetry program is administered by the Radiation Protection Dosimetry Program (RPDP, Department 04128-3) using procedures maintained by RPDP. The dosimetry program is accredited by the DOE Laboratory Accreditation Program (DOELAP). Dose (i.e., internal dose and external dose) measurements reported for the period starting 1 January 2011 and ending 31 December 2015were reviewed and data were reduced using MS Excel[1] spreadsheets to generate summary descriptive statistics (i.e., mean or arithmetic average, median, standard deviation, minimum and maximum Total Effective Dose (TED) measured). Individual measurements in excess of the Lower Limit of Detection (LLD) for the monitoring system were subjected to statistical evaluation. Measurements that were less than the LLD (i.e., 0.010 rem) were treated as a "zero" measurement. Measurements were compared to applicable regulatory limits and SNL-specific Administrative Control Levels (ACLs). Also, data were plotted with respect to time to identify potential adverse trends.

Environmental Safety and Testing (Department 06234) conducts environmental monitoring at SNL/NM. Environmental radiation exposures are measured using Thermoluminescent Dosimeters (TLDs) placed at locations on and around property controlled by SNL/NM and readily accessible to individuals with access to SNL/NM. TLDs were placed for approximately 90-days (i.e., a calendar quarter) and measured radiation exposure for the entire time that the TLD is deployed (i.e., 8,760 hours per year). Data reduction was performed using MS Excel spreadsheets to generate summary descriptive statistics (i.e., mean or arithmetic average, median, standard deviation, minimum effective dose and maximum effective dose measured) for the period between 1 January 2011 and 31 December 2015. Monitoring data were plotted over time

[1] Microsoft® Excel® 2010 (version 14.0.6112.5000), Part of Microsoft Office Professional Plus 2010, copyright 2010

using a MS Excel spreadsheet for the period 1 January 1995 through 31 December 2015 to provide historical perspective. Data were reviewed to ensure that radiation doses measured at generally accessible locations on SNL-controlled property in and surrounding areas were not in excess of public limits.

2. RESULTS AND DISCUSSION

From 1 January 2011 through 31 December 2015, 10,599 individuals participated in the radiation dosimetry monitoring program. The majority of the TED measurements were reported as "zero" corresponding to less than or equal to the detection capability associated with the measurement technique (i.e., 0.010 rem) with 495 individuals with annual reportable TED measurements. Fourteen annual measurements exceeded 0.250 rem, but all measurements were less than 0.500 rem. No one exceeded his or her applicable Administrative Control Level.

Summary descriptive statistics for the same measurements are shown for the period between 1 January 2011 and 31 December 2015 in **Table 1**. To provide perspective, collective TED measurements (in person-rem) for the same period of time are included. The collective doses reported include only those measurements that exceeded 0.010 rem TED to an individual during a calendar quarter.

Table 1 Summary Descriptive Statistics for SNL Personnel Dosimetry Reported Results for Calendar Years 2011 through 2015

	2011	2012	2013	2014	2015	Five-Year
Average (in rem):	0.059	0.032	0.037	0.070	0.057	0.050
Median (in rem):	0.024	0.016	0.017	0.022	0.026	0.021
Standard Deviation (in rem):	0.081	0.035	0.047	0.104	0.063	0.070
Maximum (in rem):	0.377	0.194	0.256	0.497	0.285	0.497
# of Individuals with Measureable Dose [a]:	114 (4.5%) [b]	93 (4.0%) [b]	115 (6.0%) [b]	81 (4.3%) [b]	92 (4.7%) [b]	495 (4.7%) [b]
# of Individuals Participating in Program:	2,536	2,313	1,932	1,864	1,954	10,599
Collective Total Effective Dose (in person-rem):	6.700	2.970	4.254	5.651	5.263	24.838

[a] TED in excess of 0.010 rem
[b] Percentage of individuals participating in the program with measureable dose

Data from the past ten years (i.e., 2006 through 2015) are plotted as a function of time with a trend line generated using MS Excel (**Figure 1**). The plot suggests (a weak) decrease in the average individual TED and a significant decrease in the collective dose. The correlation coefficient ($R^2 = 0.0019$) for individual TED measurements indicates that the trend is inconclusive. The decrease in collective dose is consistent with the change in mission at SNL/NM associated with the Sandia Pulsed Reactor (SPR) in 2006 and the process of dismantling and decommissioning of SPR in 2007 and 2008. Elevated collective dose observed in 2011 is attributable to activities at the Auxiliary Hot Cell Facility (AHCF).

A histogram showing the distribution of reported doses (TED) during the monitoring period is shown in **Figure 2**.

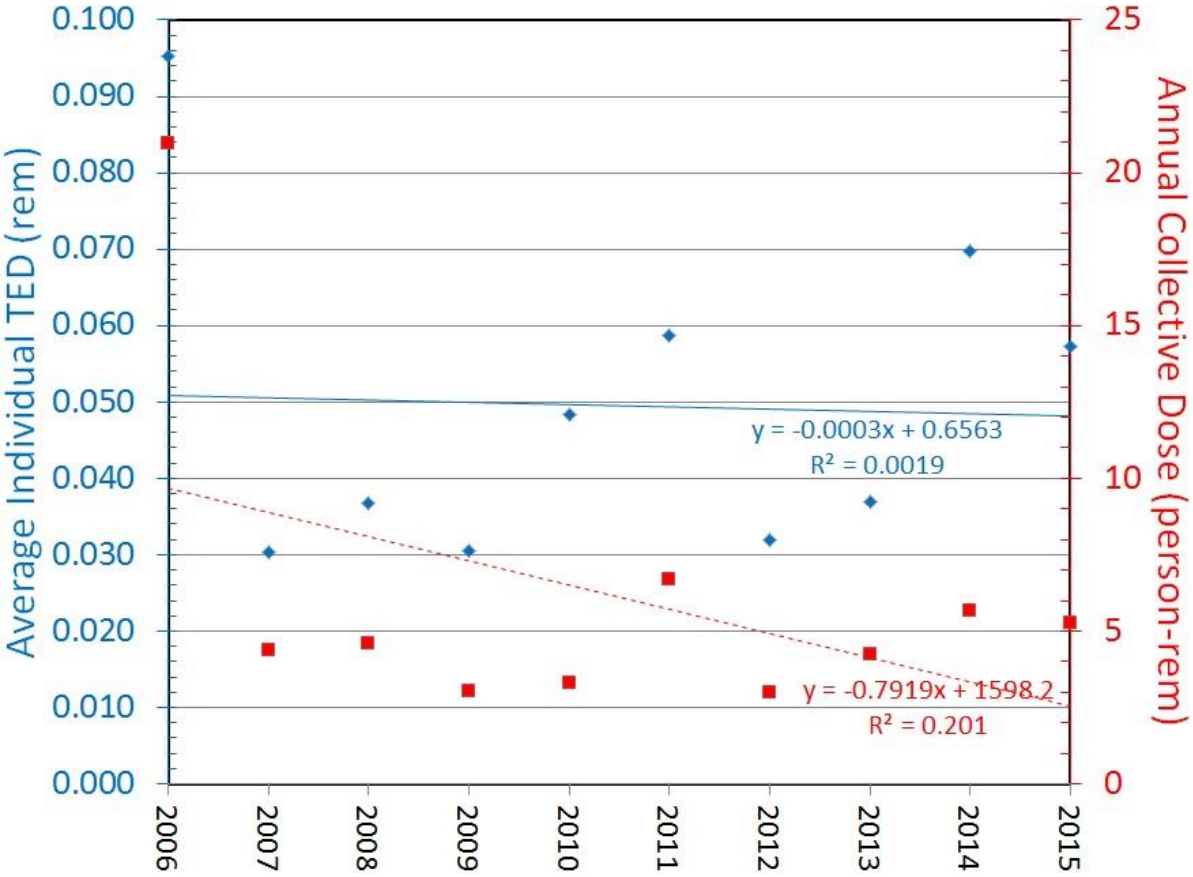

Figure 1. Ten-year trend of average individual Total Effective Dose (TED) measurements (i.e., ≥0.010 rem) and collective TED. Average individual TED measurements are in red (values on left vertical axis) and collective TED in blue (values on right vertical axis). Trend lines with corresponding equations for the line and correlation coefficients are shown in blue for individual TED measurements and in red for collective TED measurements.

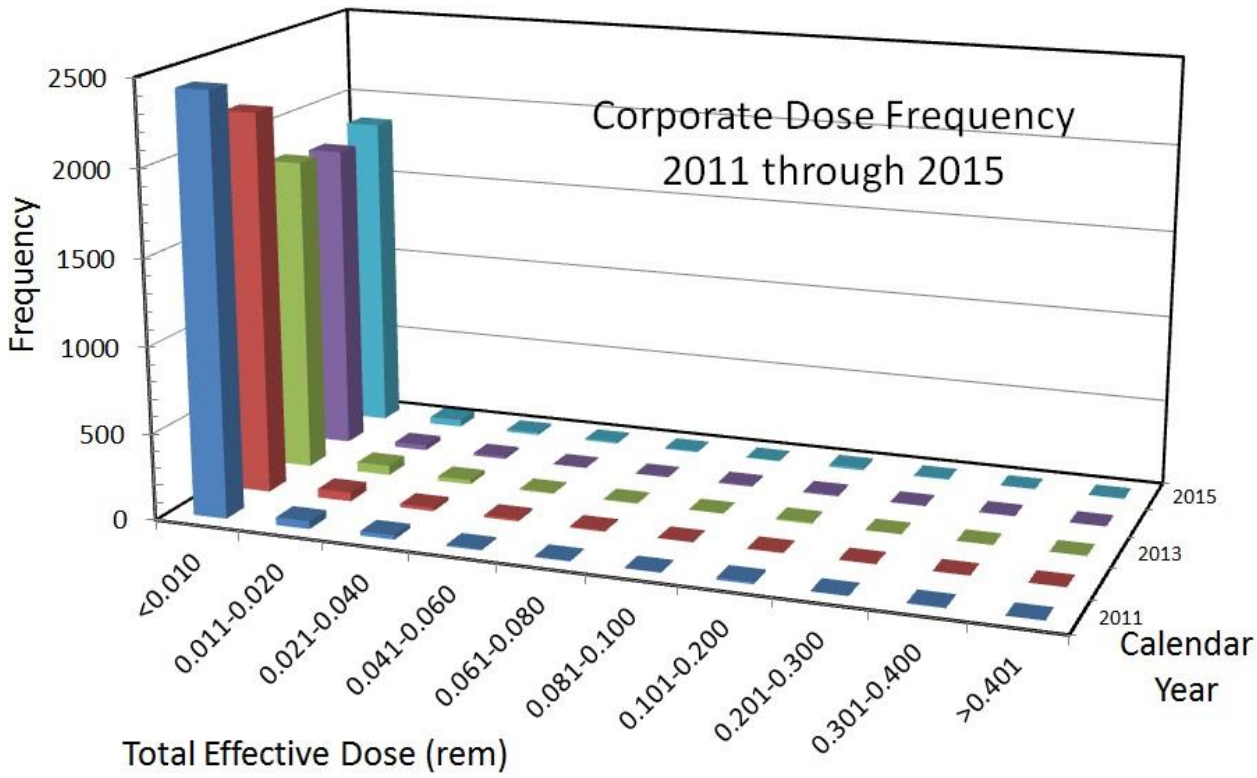

Figure 2. Histogram of Individual Total Effective Dose Measurements at SNL/NM for the monitoring period starting 1 January 2011 and ending 31 December 2015.

One aspect of ALARA is to minimize dose to the individual as well as minimizing overall dose received by Members of the Workforce (i.e., collective dose). As such, a distribution of the number of individuals participating in the SNL dosimetry program as well as the collective TED measurements are shown as a function of SNL Division in **Table 2**. As shown, nearly two-thirds (63.6%) of the individuals monitored during the 2015 calendar year were with Divisions 1000 and 4000. It may be worth noting that the majority (85.5%) of the collective dose was received by Division 1000 and 4000 during the five-year period ending December 2015.

Table 2 – Distribution of Personnel Participating in the Dosimetry Program at Sandia National Laboratories as well as Collective Dose as a Function of Division during the 2015 Calendar Year

	Participants	Collective TED (person-rem)
Division 0000	10 (0.5%) [a]	0.011 (0.2%) [b]
Division 1000	570 (29.2%) [a]	2.941 (54.8%) [b]
Division 2000	184 (9.4%) [a]	0.220 (4.1%) [b]
Division 3000	25 (1.3%) [a]	0.139 (2.6%) [b]
Division 4000	673 (34.4%) [a]	1.649 (30.7%) [b]
Division 5000	195 (10.0%) [a]	0.054 (1.0%) [b]
Division 6000	61 (3.1%) [a]	0.177 (3.3%) [b]
Division 8000	116 (5.9%) [a]	0.143 (2.7%) [b]
Division 9000	10 (0.5%) [a]	0.000 (0.0%) [b]
Division 10000	109 (5.6%) [a]	0.036 (0.7%) [b]
Division 11000	1 (0.1%) [a]	0.036 (0.7%) [b]

[a] Percent of number of individuals participating in the dosimetry program at SNL.
[b] Percent of corporate collective dose

The public dose limit (0.100 rem per year) is in excess to dose received from natural background and/or medical exposures. An expected natural background from cosmic and terrestrial radiation sources for Albuquerque, New Mexico is 0.089 rem·year^{-1} (Mauro and Briggs, 2005). Using this published background value, the gross environmental dosimetry measurement at publicly accessible locations should not exceed 0.189 rem to demonstrate compliance with 10CFR835.208 (i.e., Public Limit = 0.089 + 0.100 = 0.189 rem).

For perspective, the National Council on Radiation Protection and Measurements (NCRP) published an average dose of 0.620 rem per year from natural and medical sources of ionizing radiation (including radon) to the population of the United States in NCRP Report 160 (NCRP 2009). Environmental TLD measurements at SNL New Mexico are well below that value.

Descriptive summary statistics of environmental TLD measurements collected during the monitoring period 1 January 2011 through 31 December 2015 are shown in **Table 3**. During this monitoring period, no environmental TLD measurements exceeded the public dose limit.

Table 3 – Descriptive Statistics of Annual Environmental TLD Measurements Obtained on and around Sandia National Laboratories, New Mexico from 1 January 2011 through 31 December 2015

	2011	2012	2013	2014	2015
Average (in rem)	0.106	0.099	0.112	0.106	0.090
Median (in rem)	0.104	0.100	0.111	0.106	0.089
Standard Deviation (in rem)	0.011	0.010	0.007	0.008	0.007
Minimum (in rem)	0.087	0.071	0.098	0.085	0.077
Maximum (in rem)	0.146	0.118	0.131	0.124	0.113
# of Locations Monitored	38	38	36	36	34

To provide a historical perspective, average annual environmental dosimetry results from 1 January 1992 through 31 December 2015 were plotted to help identify qualitative trends in radiation exposures at environmental monitoring locations (**Figure 3**). A trend line was generated using MS Excel with the equation for the trend line and correlation coefficient (R^2 = 0.1182). The trend line has a very slight positive slope (0.0003) indicating a very slight increase in measured dose. The slope is almost "zero" with a weak correlation coefficient suggesting no significant change in dose to the public or environment over the period extending from 1 January 1992 through 31 December 2015.

Two monitoring locations were dropped in 2013 and another two monitoring locations were dropped in 2015. The two locations dropped at the end of calendar year 2012 were at off-site locations (Albuquerque Fire Station 2 in the Southeast Heights and Albuquerque Fire Station 7 on the Southwest Mesa) which may be responsible for the apparent decrease in average exposure from 2012 to 2013. The two locations dropped at the end of calendar year 2014 were at on-site locations (Building 869 in the limited area of Tech Area I) which may have been slightly elevated due to calibration activities involving high-strength gamma radiation sources in Building 818 resulting in an apparent decrease in average exposure from 2014 to 2015.

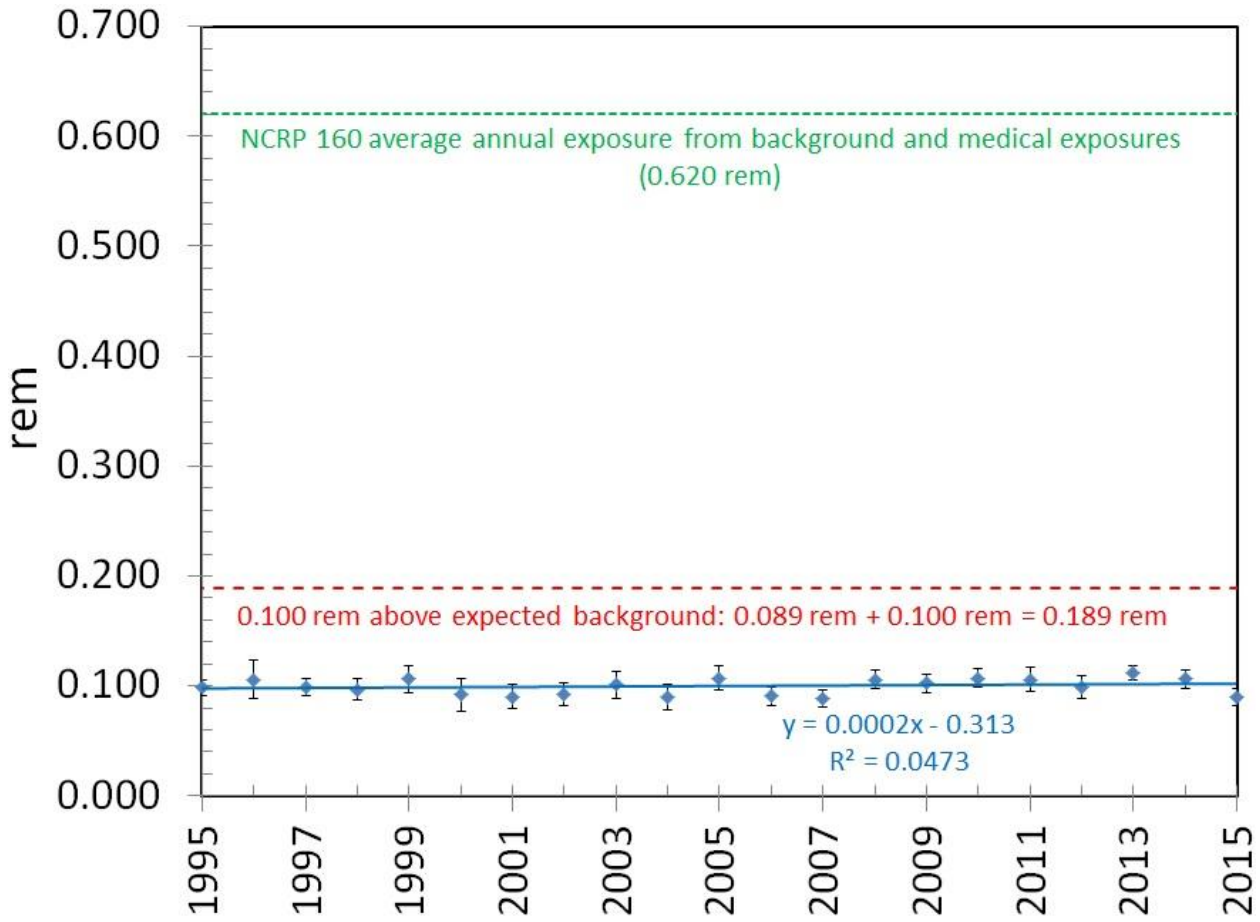

Figure 3. Average annual environmental TLD measurement for the monitoring period starting 1 January 1995 and ending 31 December 2015. Error bars represent the 1-sigma sample standard deviation of measurements collected. The red dotted line represents the sum of the 0.100 rem public dose limit and 0.089 rem from cosmic and terrestrial sources (Mauro and Briggs, 2005). The green dotted line represents the expected annual exposure from background and medical exposures (NCRP 160, 2009).

3. CONCLUSION

The ALARA philosophy uses justification, optimization, and dose limitation as the means to keep exposures to ionizing radiation As Low As is Reasonably Achievable. In accordance with DOE policy (DOE P 441.1, 1996), SNL/NM has maintained radiation exposures to workers below regulatory limits with deliberate efforts to keep exposures and releases ALARA. Based upon this evaluation it appears that SNL/NM maintains a level of dose control for radiological operations commensurate with the radiological risks involved and in the spirit of the ALARA philosophy. That is, radiation protection methods used at SNL/NM are compliant with regulatory limits and conform to the ALARA philosophy

There is no clear indication that average measured occupational TED measurements or collective TED measurements have changed over the five-year period evaluated. However, it may be worth noting that the majority (85.5%) of collective TED received by SNL personnel was received by Divisions 1000 and 4000. This is consistent with historical evaluations and attributable to the radiological operations conducted by Division 1000 which were supported by Division 4000 personnel (i.e., Organizations 04128 (Radiation Protection) and 04144 (Waste Management & Pollution Prevention)).

Dose to a member of the public exposed to radiation and/or radioactive material did not exceed the applicable dose limit in the monitoring period from 1 January 2010 to 31 December 2015. Environmental monitoring data demonstrate that environmental exposures are protective of public health. Since 1 January 1995, no annual environmental TLD dose measurements exceeded 0.189 rem.

4. REFERENCES

1. Title 10 of the Code of Federal Regulations Part 835, 10 CFR 835, *Occupational Radiation Protection*, 1 January 2011 Edition.

2. J. Mauro and N. M. Briggs, *Assessment of Variations in Radiation Exposure in the United States*, Prepared for US Environmental Protection Agency Office of Radiation and Indoor Air, Contract Number EP-D-05-002, Work Assignment Number 1-03, 15 July 2005.

3. National Council on Radiation Protection and Measurements (NCRP), *Ionizing Radiation Exposure of the Population of the United States, NCRP Report 160*, 2009.

4. U.S. Department of Energy Policy, *Department of Energy Radiological Health and Safety Policy*, DOE P 441.1, 26 April 1996.

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