

SANDIA REPORT

SAND2014-17100

Unlimited Release

August 2014

Five-Year ALARA Review of Dosimetry Results, 1 January 2009 through 31 December 2013

Luke R. Paulus

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.



Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represent that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@adonis.osti.gov
Online ordering: <http://www.osti.gov/bridge>

Available to the public from

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd.
Springfield, VA 22161

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.fedworld.gov
Online order: <http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online>



SAND2014-17100
Unlimited Release
Printed August 2014

Five-Year ALARA Review of Dosimetry Results 1 January 2009 through 31 December 2013

Luke R. Paulus
Radiation Protection Department (Organization 04128-1)
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS0870

Abstract

A review of dosimetry results from 1 January 2009 through 31 December 2013 was conducted to demonstrate that radiation protection methods used are compliant with regulatory limits and conform to the ALARA philosophy. 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.

ACKNOWLEDGMENTS

Sandia National Laboratories' Radiation Protection Safety Committee ALARA Subcommittee:

Hazel Barclay, Subcommittee Chairman

Todd Culp

Mike Moore

Mark Miller

Ross Miller

Robert P. Miltenberger

Ted Simmons

Michael T. Spoerner

Katie Moore

Sandia National Laboratories' Radiation Protection Dosimetry Program:

Sarah Goke

Nathan Elliott

David Farrar

CONTENTS

1. Introduction.....	8
1.1. Methods and Materials	8
2. Results and Discussion	10
3. Conclusion	16
4. References.....	18
Distribution.....	20

FIGURES

Figure 1. Five-year trend of average individual Total Effective Dose (TED) measurements (i.e., ≥ 0.010 rem) and collective TED. Average individual TED measurements are in blue and collective TED in green. Trend lines with corresponding equations for the line and correlation coefficients are shown in blue and green for individual TED measurements and collective TED measurements, respectively.	13
Figure 2. Histogram of Individual Total Effective Dose Measurements at SNL/NM for the monitoring period starting 1 January 2009 and ending 31 December 2013.	14
Figure 3. Average Annual Environmental TLD measurement for the monitoring period starting 1 January 1991 and ending 31 December 2013. Error bars represent the 1-sigma sample standard deviation of measurements collected. The red dotted line represents the 0.100 rem public dose limit and the green dotted line represents the expected annual exposure from background and medical exposures (NCRP 160).	17

TABLES

Table 1 Summary Descriptive Statistics for SNL Personnel Dosimetry Reported Results for Calendar Years 2009 through 2013	12
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 2013 Calendar Year	15
Table 3 – Descriptive Statistics of Annual Environmental TLD Measurements Obtained on and around Sandia National Laboratories, New Mexico from 1 January 2009 through 31 December 2013	16

NOMENCLATURE

ACL	Administrative Control Level
ALARA	As Low As is Reasonably Achievable
DOE	Department of Energy
DOELAP	DOE Laboratory Accreditation Program
NCRP	National Council on Radiation Protection and Measurements
RPDP	Radiation Protection Dosimetry Program
SNL	Sandia National Laboratories
SNL/NM	Sandia National Laboratories, New Mexico
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 2009 through 31 December 2013 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. Results demonstrate that radiation protection methods used at SNL are compliant with regulatory limits and the ALARA philosophy.

1.1. Methods and Materials

The dosimetry program at SNL/NM 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 2009 and ending 31 December 2013 were reviewed and data were reduced using MS Excel¹ 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 Programs (Department 04143) 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 2009 and 31 December 2013. Monitoring data were plotted over time using a MS Excel spreadsheet for the period 1 January 1991 through 31 December 2013 to provide

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

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 2009 through 31 December 2013, 11,538 individuals participated in the SNL/NM 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 505 individuals with annual reportable TED measurements. Eleven 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 2009 and 31 December 2013 in **Table 1**. To provide perspective, collective TED measurements (in person-rem) for the same period of time are included.

Table 1 Summary Descriptive Statistics for SNL Personnel Dosimetry Reported Results for Calendar Years 2009 through 2013

	2009	2010	2011	2012	2013	Five-Year
Average (in rem):	0.030	0.047	0.058	0.032	0.037	0.041
Median (in rem):	0.014	0.020	0.023	0.016	0.017	0.017
Standard Deviation (in rem):	0.053	0.076	0.081	0.035	0.047	0.061
Maximum (in rem):	0.454	0.477	0.377	0.194	0.256	0.477
# of Individuals with Measureable Dose ^a:	101 (4.4%) ^b	70 (2.8%) ^b	116 (4.6%) ^b	102 (4.4%) ^b	116 (6.0%) ^b	505 (4.4%) ^b
# of Individuals Participating in Program:	2,292	2,463	2,536	2,313	1,934	11,538
Collective Total Effective Dose (in person-rem):	3.106	3.426	6.666	3.911	4.306	21.415
^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., 2004 through 2013) are plotted as a function of time with a trend line generated using MS Excel (**Figure 1**). The plot suggests (a weak) increase in the average individual TED and a significant decrease in the collective dose. The correlation coefficient ($R^2 = 0.004$) 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**.

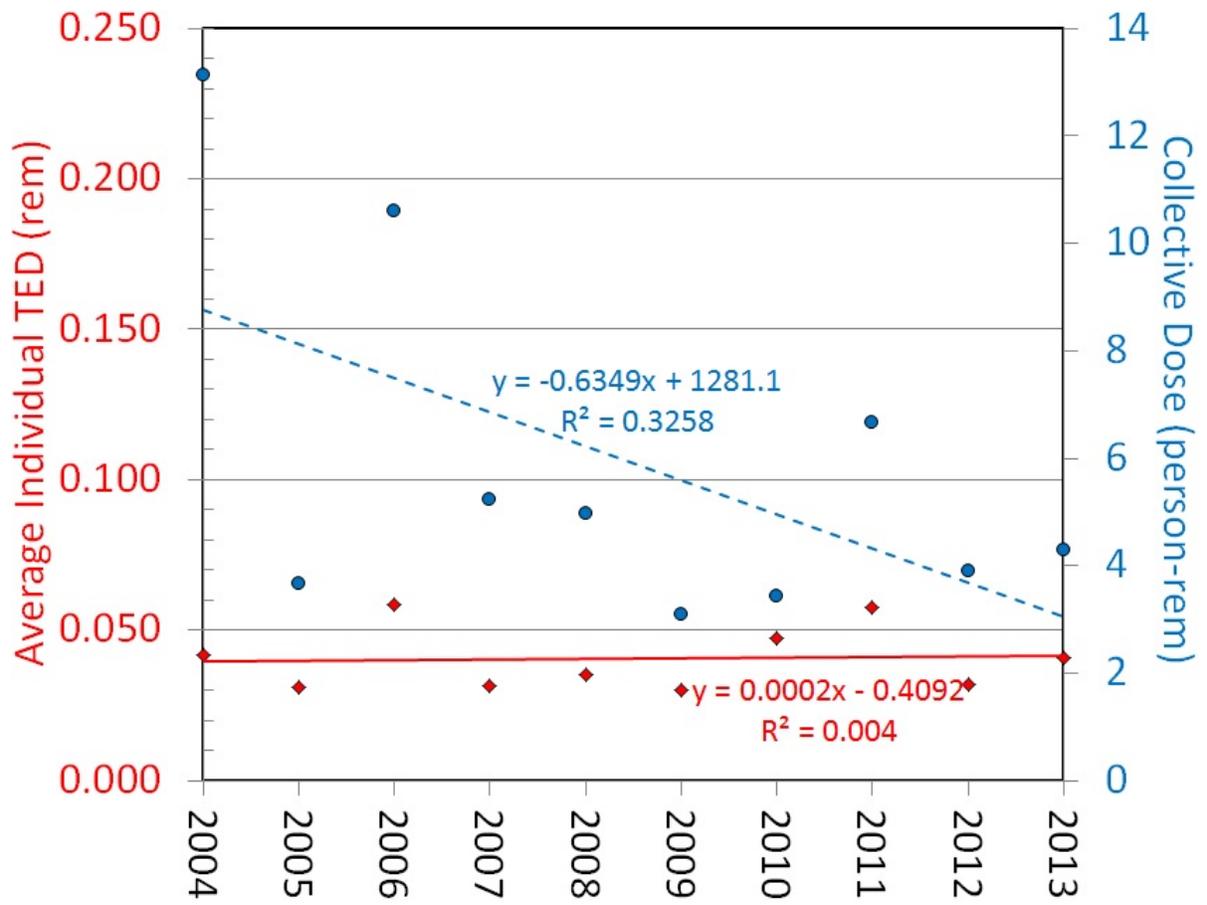


Figure 1. Ten-year trend of average individual Total Effective Dose (TED) measurements (i.e., ≥ 0.010 rem) and collective TED. Average individual TED measurements are in red (values on left vertical axis) and collective TED in blue (values on right vertical axis). Trend lines with corresponding equations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

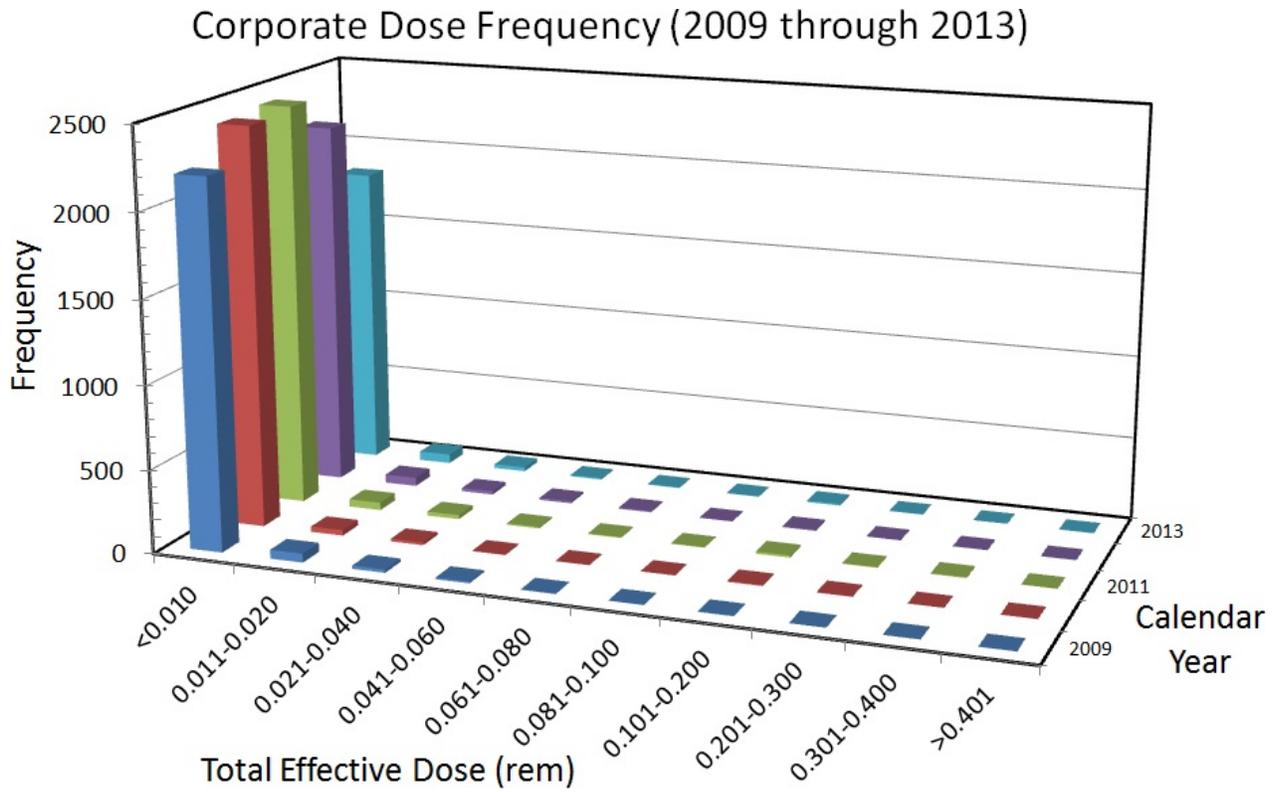


Figure 2. Histogram of Individual Total Effective Dose Measurements at SNL/NM for the monitoring period starting 1 January 2009 and ending 31 December 2013.

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 (63.5%) of the individuals monitored during the 2013 calendar year were with Divisions 1000 and 4000. It may be worthy to note that over three-quarters (78.0%) of the collective dose was received by Division 1000 and 4000 during the five-year period ending in 2013.

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 2013 Calendar Year

	Participants	Collective TED (person-rem)
Division 0000	22 (1.1%) ^a	0.012 (0.3%) ^b
Division 1000	576 (29.8%) ^a	1.434 (33.3%) ^b
Division 2000	203 (10.5%) ^a	0.627 (14.6%) ^b
Division 3000	20 (1.0%) ^a	0.179 (4.2%) ^b
Division 4000	653 (33.8%) ^a	1.292 (30.0%) ^b
Division 5000	150 (7.8%) ^a	0.074 (1.7%) ^b
Division 6000	65 (3.4%) ^a	0.295 (6.9%) ^b
Division 8000	148 (7.7%) ^a	0.300 (7.0%) ^b
Division 9000	1 (0.1%) ^a	0.000 (0.0%) ^b
Division 10000	94 (4.9%) ^a	0.093 (2.2%) ^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 0.311 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 2009 through 31 December 2013 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 2009 through 31 December 2013

	2009	2010	2011	2012	2013
Average (in rem)	0.102	0.107	0.106	0.099	0.112
Median (in rem)	0.101	0.108	0.104	0.100	0.111
Standard Deviation (in rem)	0.008	0.008	0.011	0.010	0.007
Minimum (in rem)	0.084	0.082	0.087	0.071	0.098
Maximum (in rem)	0.123	0.125	0.146	0.118	0.131
# of Locations Monitored	38	38	38	38	36

To provide a historical perspective, average annual environmental dosimetry results from 1 January 1991 through 31 December 2013 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 ($R^2 = 0.0863$). Although the equation for the trend line has a positive slope indicating a very slight increase in measured dose, the weak correlation coefficient suggests that this trend is inconclusive.

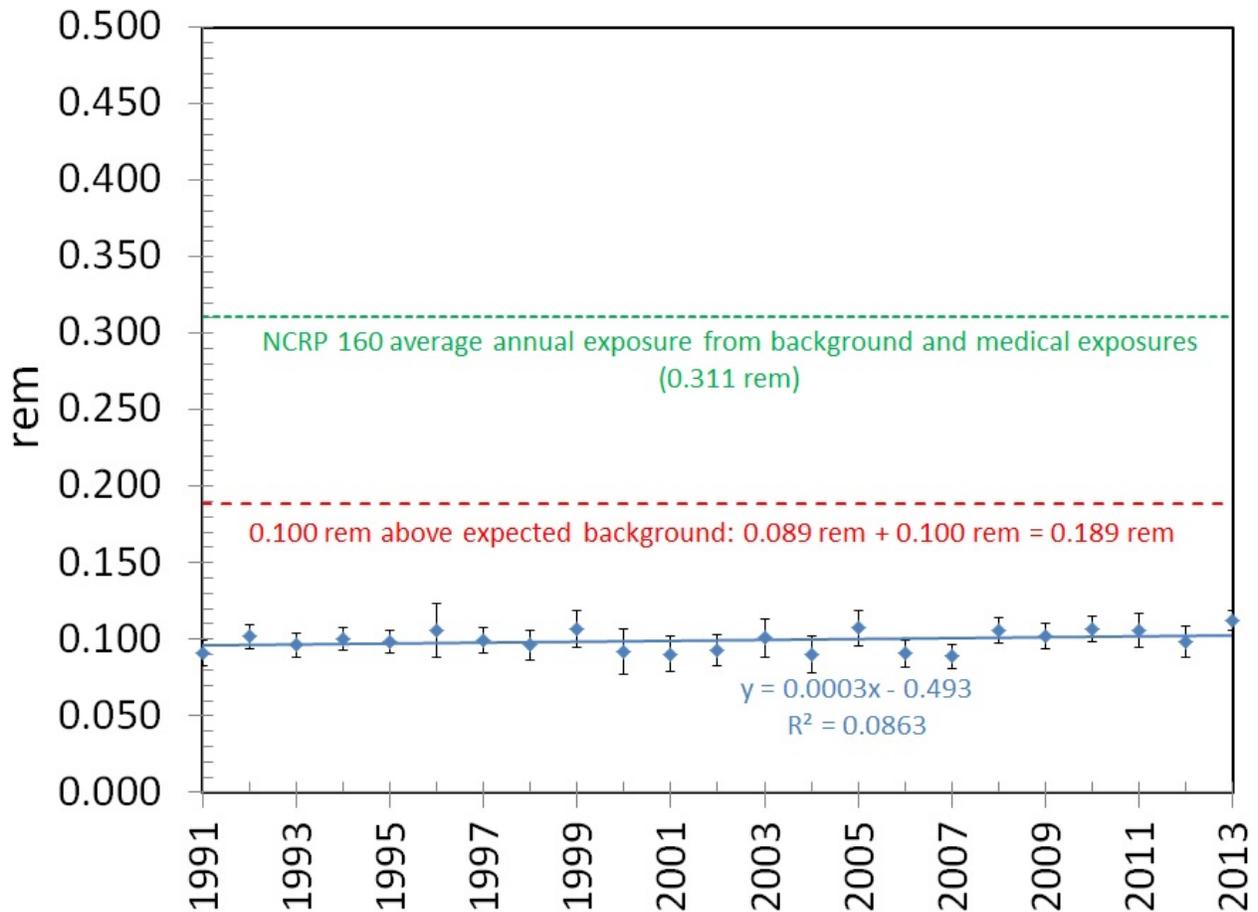


Figure 3. Average annual environmental TLD measurement for the monitoring period starting 1 January 1991 and ending 31 December 2013. Error bars represent the 1-sigma sample standard deviation of measurements collected. The red dotted line represents the sum of the 0.100 rem public dose limit and 0.089 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 worthy to note that the majority (78.0%) 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 2009 to 31 December 2013. Environmental monitoring data demonstrate that environmental exposures are protective of public health. Since 1 January 1991, one annual environmental TLD dose measurement (0.221 rem) obtained at the northwestern corner of the Radioactive and Mixed Waste Management Facility (RMWMF) in 1997 exceeded 0.189 rem. This was a facility monitor that did not monitor dose to the general public. However, this is a SNL-controlled location with a low rate of occupancy. A potentially impacted individual would be a member of the SNL workforce who is not a radiological worker. Assuming an occupancy factor of 1/8 (12.5 percent occupancy), and the impacted member of the workforce spends 2,000 hours per year at the uncontrolled location, the corresponding dose would have been 0.006 rem, well below the annual dose limit to a member of the public.

$$\left(\frac{1}{8}\right)\left(\frac{2,000 h}{8,760 h}\right)(0.221 rem) = 0.006 rem$$

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.

DISTRIBUTION

4 Lawrence Livermore National Laboratory
Attn: N. Dunipace (1)
P.O. Box 808, MS L-795
Livermore, CA 94551-0808

1	MS0651	Nathan Elliott	4121
1	MS0651	Sarah Goke	4121
1	MS1103	Robert Miltenberger	4128
1	MS1103	Ted Simmons	4128-2
1	MS1103	A. Ross Miller	4128-3
1	MS1142	Michael Spoerner	1387
1	MS1151	Todd Culp	4128-1
1	MS1151	Michael Moore	4144
1	MS 1190	Mark Herrmann	1600
1	MS1198	Mark Miller	4144
1	MS1197	Hazel Barclay	1001
1	MS1197	Kathleen Moore	1659
1	MS0899	Technical Library	9536 (electronic copy)

