SC&A S. COHEN & ASSOCIATES
AN EMPLOYEE-OWNED COMPANY

February 12, 2009

Mr. David Staudt
Center for Disease Control and Prevention
Acquisition and Assistance Field Branch
Post Office Box 18070
626 Cochrans Mill Road – B-140
Pittsburgh, PA 15236-0295

Re: Contract No. 200-2009-28555, Task Order 1: SCA-TR-TASK1-0022, *Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range in Nevada*

Dear Mr. Staudt:

S. Cohen & Associates (SC&A, Inc.) is pleased to submit to the Advisory Board Document No. SCA-TR-TASK1-0022, *Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range in Nevada*. This site profile has been reviewed for Privacy Act-restricted information and cleared with minor clarifications. The document has also been reviewed and cleared for public distribution by the Department of Energy (DOE).

SC&A believes it is obligated to bring one particular issue of potential regulatory significance to the attention of the Advisory Board and NIOSH, with possible referral to DOE for follow-up. Finding 5.13 of our review of the Site Profile for Sandia National Laboratory cites a concern for "inaccurate dose record for reactor personnel" at Sandia. This concern comes from our determination that reactor operators at the Sandia Pulse Reactor may have exceeded applicable annual dose limits during the time period from 1962 through 1982, because of non-representative external badge readings. This discrepancy was attributed to the inability of the torso-worn badge to adequately measure the severe radiation field gradient surrounding the reactor vessel during maintenance activities. SC&A found references to this discrepancy in its review of onsite documentation and was able to corroborate it through interviews with Sandia health physics personnel of that era.

While corrective action apparently was undertaken in the early-1980s to both reduce exposure and improve dosimetry, it is not clear that the earlier inaccurate radiation dose records were corrected for the individuals and time periods in question. This is of particular significance, given that most of the operators involved received annual doses approaching annual limits even without such corrections. With correction of their dose records, many of these individuals would have exceeded their 5 rem annual limit repeatedly. Besides regulatory concerns, this issue will clearly have implications for dose reconstruction for the former workers involved.

Should you have any questions, please contact me at 732-530-0104.

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, Board Chairperson
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ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range in Nevada

Contract No. 200-2004-03805
Task Order No. 1
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February 2009

Disclaimer

S. Cohen & Associates: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-TASK1-0022
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Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range in Nevada	Page 1 of 80
Task Manager: _________________________ Date: ___________ Joseph Fitzgerald	Supersedes: N/A
Project Manager: _________________________ Date: ___________ John Mauro	

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ACRR	Annular Core Research Reactor, TA-V
Advisory Board	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
ALARA	As Low as Reasonably Achievable
AMAD	Activity Median Aerodynamic Diameter
AP	Anterior Posterior
BZA	Breathing Zone Air
CAM	Continuous Air Monitor
CATI	Computer Assisted Telephone Interview
CEDE	Committed Effective Dose Equivalent
CEP	Controls for Environmental Pollution
CFR	*Code of Federal Regulations*
Ci	Curies
DOE	Department of Energy
DR	Dose Reconstruction or Dose Reconstructor
dpm	Disintegrations per Minute
DU	Depleted Uranium
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ESE	Entrance Skin Exposure
GM	Geometric Mean
GSD	Geometric Standard Deviation
H-3	Tritium
HT	Tritium Gas
HTO	Tritiated Water
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
JTA	Joint Test Assembly
keV	Kilo electron Volt
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory
LAT	Lateral

LLNL	Lawrence Livermore National Laboratory
LOD	Limit of Detection
LWDS	Liquid waste disposal system
MAP	Mixed Activation Products
MDA	Minimum Detectable Activity
MDL	Minimum Detectable Dose
MFP	Mixed Fission Products
MND	Missed Neutron Dose
MPD	Missed Photon Dose
MT	Metal Tritides
MW	Megawatt
NIOSH	National Institute for Occupational Safety and Health
NM	New Mexico
n/p	Neutron-to-Photon Ratio
NTA	Eastman Kodak Nuclear Track Film Type A
NTS	Nevada Test Site
OBT	Organically Bound Tritium
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
OTIB	ORAU Technical Information Bulletin
PBFA	Particle Beam Fusion Accelerator
PFG	Photofluorography
POC	Probability of Causation
PPG	Pacific Proving Grounds
R&D	Research and Development
REECo	Reynolds Electrical and Engineering Company, Inc.
rem	Roentgen Equivalent Man
SABRE	Sandia Accelerator and Beam Research Experiment
SC&A	S. Cohen and Associates
SEC	Special Exposure Cohort
SER	Sandia Engineering Reactor (TA-V, circa 1957)
SNL	Sandia National Laboratories, Albuquerque, New Mexico

SPR	Sandia Pulse Reactor (Facility), TA-V
SRDB Ref ID	Site Research Database Reference Identification (number)
STC	Special Tritium Compound
TA	Technical Area
TBD	Technical Basis Document
TIB	Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
TTR	Tonopah Test Range

1.0 EXECUTIVE SUMMARY

This report provides the results of an independent audit conducted by S. Cohen and Associates (SC&A) of the site profile for Sandia National Laboratories (SNL) developed by the National Institute for Occupational Safety and Health (NIOSH). This audit was conducted during the period December 1, 2007–August 31, 2008, in support of the Advisory Board on Radiation and Worker Health (Advisory Board or Board) in the latter's statutory responsibility under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) to conduct such reviews and advise the Secretary of Health and Human Services on the "completeness and adequacy" of the EEOICPA program.

The bulk of the historic activities at SNL in New Mexico were related to the non-nuclear aspects of nuclear weapons design. This work included weapons design and testing, production engineering, stockpile maintenance, and stockpile surveillance. It also involved a spectrum of routine offsite activities from 1945 to the present, including operations at a number of Sandia Corporation sites in California, Mississippi, Nevada, and Tennessee. SNL employees also routinely spent time at other DOE facilities. SNL was responsible for surveillance of the nation's stockpiled weapons, and accordingly, staff members were stationed at various storage sites to monitor, maintain, and assemble the weapons.

It is recognized in the Oak Ridge Associated Universities Team (ORAUT) SNL technical basis document (TBD), ORAUT-TKBS-0037 (ORAUT 2007a), that the potential for chronic intakes at SNL was far less than at DOE production sites because of the nature of the tasks performed at SNL. Nevertheless, the potential for monitored and unmonitored intakes did exist throughout the history of the site. Occupational internal dose could have been received by an individual from an intake of radioactive material while performing tasks within buildings and structures at SNL, or from activities taking place outside of buildings, such as with the burial of waste or the monitoring of nuclear or non-nuclear tests. High external radiation fields existed at the research reactors and accelerators during their operations. Residual contamination existed around the various outdoor test ranges, where kinetic impacts, explosions, or high temperature burns were used to test the hardiness of warhead designs using surrogate material, such as depleted uranium.

The SNL was operated as the Z-Division and later Albuquerque Branch of Los Alamos Scientific Laboratory (LASL) from 1945 until 1949. SNL was created in 1945 to perform ordnance engineering and assembly aspects of LASL's design work. Nuclides with the widest historical and current application throughout the SNL facilities include H-3, U-238, U-234, U-235, fission and activation products, such as Sr-90, Cs-137, Zn-65, Co-60, Ta-182 and, to a lesser degree, Pu-238, Pu-239, Pu-240, Pu-241, and Am-241. In the early days, there were many similarities, common operations, and dosimetry practices used at both Los Alamos National Laboratory (LANL) and SNL. Therefore, when reviewing dose estimation procedures, it is important, to keep in mind the similarities in common operations performed and the radiological sources used.

1.1 FINDINGS

SC&A finds that the existing site profile does not address inaccurate dose records for operators at the Sandia Pulse Reactor (SPR) resulting from under-recording of external gamma/neutron dose received during shutdown maintenance activities. This under-recording resulted from inadequate dosimetry during the early years of SPR operation for a severe gradient of exposure levels experienced by personnel working close to the reactor vessel, leading to an underestimate of whole-body dose by at least a factor of 1.75, and likely higher, prior to installation of additional shielding in 1982. As annual dose levels for these operators were among the highest at SNL, approaching the annual limit of 5 rem in some cases, this would have significant implications for the accuracy of dose reconstruction. While known to SNL management at the time, no retroactive correction was apparently made to individual dose records.

As the TBD acknowledges, no formal routine bioassay program existed at SNL prior to 1992, leading to the likelihood that workers in areas containing radioactive materials may have had the potential for internal exposures that would not have been monitored. With their work areas in many cases being unknown, a backup means of estimating dose is not apparent in the TBD. The instructions given for dose reconstructors in the site profile do not appear to be adequate for determining or quantifying the radioactive isotopes to which unmonitored or even monitored workers may have been exposed. Assigning potential missed dose by work location is particularly questionable in the absence of complete work history records. Furthermore, the feasibility of this approach is questionable for site-wide workers and workers involved in offsite activities in Nevada and other locations. In cases where work area information is not available, the TBD should provide further instruction.

For tritium, it is important that the dose reconstructor chooses claimant-favorable forms of tritium for the dose estimation if there is a lack of process knowledge about the form that may have been involved with exposures. The dose to the lung from intakes of metal tritides (MTs) can be underestimated by orders of magnitude if it is incorrectly assumed that the dose can be calculated with the methods used for tritiated water (HTO).

For external radiation dosimetry, SC& A finds that there are insufficient analyses of radiation fields, doses, and uncertainties in the TBD. ORAUT-TKBS-0037 (ORAUT 2007a) does not cover the subject of photon and neutron radiation energy fields and associated doses with related uncertainties as a function of work location and time periods sufficient to allow the dose reconstructor to accurately assign dose. For example, no relevant neutron calibration information is provided, nor is a clear uncertainty value provided that can be applied for neutron doses as a function of time. The neutron-to-photon ratio (n/p) value cited in the TBD is based on a relatively small number of records over an 8-year time span and would likely not be representative of laboratory conditions over that timeframe.

With respect to data completeness and adequacy for internal dosimetry, SC&A finds that the SNL electronic database is incomplete for internal doses, and hard copy bioassay records are not complete in individual radiation exposure files. There is also a lack of data regarding specific radionuclides to which workers were potentially exposed. Additionally, the adequacy of offsite vendor data has been suspect at times, suggesting a need for further verification of data completeness and accuracy. Exposure data for workers at offsite facilities frequented by SNL workers (e.g., atmospheric nuclear weapons testing) may not be readily available and need to be addressed for the benefit of the dose reconstructor. In light of these shortcomings, the verification process for determining the completeness and consistency of the internal dosimetry information provided electronically and in hard copy from other sites requires careful consideration for use in dose reconstruction.

For external dosimetry, SC&A found that there is little treatment of the completeness or adequacy of external dose records, i.e., the dose information they may or may not contain; the different recording systems; and different recording methods/programs used after switching to electron data storage.

1.2 SCOPE AND APPROACH

SC&A's review focused on the TBD that makes up the SNL in Albuquerque, New Mexico, and the Tonopah Test Range (TTR), Nevada, site profile. The TBD addresses introduction, site description, internal dose, external dose, occupational medical dose, and environmental occupational dose as they pertain to historic occupational radiation exposure to SNL workers. The TBD was issued in 2007. As "living" documents, TBDs are constantly being revised as new information, experience, or issues arise. For the SNL site profile in particular, interviews with NIOSH and ORAUT staff underscored their ongoing and extensive efforts to upgrade the existing TBD.

SC&A's review process included a review of the TBD and supporting documents; one onsite visit to conduct interviews with site experts and review documents available at the site; and an exchange of questions and answers between SC&A and its NIOSH and ORAUT counterparts. The TBD was evaluated for completeness, technical accuracy, adequacy of data, compliance with stated objectives, and consistency with other site profiles, as stipulated in the *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). A complete list of the SNL TBD and its supporting documents that were reviewed by SC&A is provided in Attachment 1.

Issues presented in this report are sorted into the following categories, in accordance with SC&A's review procedures:

(1) Completeness of data sources
(2) Technical accuracy
(3) Adequacy of data
(4) Consistency among site profiles
(5) Regulatory compliance

Following the introduction and a description of the criteria and methods employed to perform the review, the report discusses the major issues identified during our review. The issues were carefully reviewed with respect to the five review criteria. Several of the issues were designated as primary findings, because they represent key deficiencies in the TBD that need to be corrected, and which have the potential to substantially impact at least some dose reconstructions. Others have been designated "secondary findings" to both connote their importance for the technical adequacy and completeness of the site profile, and to indicate that they have been judged by SC&A to have relatively less influence on dose reconstruction or the ultimate significance of estimated worker doses.

1.3 SUMMARY OF FINDINGS

Finding 1: Potential Shortcomings Exist in Completeness and Adequacy of Dosimetry Records

Apparent shortcomings in the completeness, accuracy, and availability of radiation dose data should be addressed in any ongoing revision of the SNL site profile report. The SNL electronic database is incomplete, and hard copy bioassay records are not complete in individual radiation exposure files and lack data regarding specific radionuclides to which workers were potentially exposed. LANL was considered the primary source of bioassay prior to 1991; however, reviews of the LANL bioassay data in previous reviews by SC&A and by ORAUT found the LANL bioassay data to be incomplete or inadequate (SC&A 2006, Vitkus et al. 2007). Additionally, the adequacy of offsite vendor data is suspect, suggesting a need for further verification of data completeness and accuracy. The site profile does not fully address the significance of radiological incidents, how they may have contributed to worker dose, and how they would be addressed in dose reconstruction. In light of these shortcomings, the verification process for determining the completeness and consistency of the dosimetry information provided electronically and in hard copy requires careful consideration for use in dose reconstruction.

Finding 2: Inaccurate Dose Record for Reactor Personnel

The site profile does not address inaccurate dose records for SPR operators due to under-recording of external gamma/neutron dose received during shutdown maintenance activities. This under-recording resulted from inadequate dosimetry at the time for a severe gradient of exposure levels experienced by personnel working close to the reactor vessel, leading to an underestimate of whole-body dose by at least a factor of 1.75 and likely higher prior to installation of additional shielding in 1982. As annual dose levels for these operators were among the highest at SNL, approaching the annual limit of 5 rem in some cases, this would have significant implications for the accuracy of dose reconstruction. While known to SNL management at the time, no retroactive correction was apparently made to individual dose records. While some attempt was made to incorporate head dose readings in estimating whole-body dose for 1982 and forward in time, it is unclear to what extent that was done, because head dosimeters were not always worn by workers in later years.

Finding 3: Site-wide Workers not Bioassayed for Potential Internal Intakes before 1992

It is of concern to SC&A that prior to 1992, when no formal routine bioassay program existed at SNL, workers in areas containing radioactive materials may have had the potential for internal exposures that would not have been monitored, and with their work areas in many cases being unknown, a backup means of estimating dose is not apparent in the TBD. The instructions given the dose reconstructors in the site profile by NIOSH/ORAUT do not appear to be adequate for determining or quantifying the radioactive isotopes to which unmonitored or even monitored workers may have been exposed. Assigning potential missed dose by work location is questionable, particularly in the absence of complete work history records. Furthermore, the feasibility of this approach is questionable for site-wide workers. In cases where work area information is not available, the TBD should provide further instruction.

Finding 4: Use of Air Monitoring Data in Dose Estimation is Problematic

Bioassay monitoring of workers was primarily dependent on the air monitoring program, as opposed to and in default of a routine bioassay monitoring program. With inadequate air sampling or no air sampling data for some years of operation, this brings into question the effectiveness of the special bioassay monitoring program and the use of air sampling data as a substitute for bioassay sampling, as stipulated in the TBD. It appears that without routine bioassay monitoring, dependence upon air sampling for detecting exposures to workers likely led to unmonitored intakes by workers over the years at SNL, or intakes that could not be measured or estimated accurately, due to use of area air monitoring data. Furthermore, reliance on field indicators to trigger special bioassay, particularly in areas where air monitoring equipment placement is inadequate or non-existent, is problematic. Some consideration should be given in the TBD to the representativeness of the sampling and the consistent use of field indicators as a trigger for bioassay.

Finding 5: Inadequate Treatment of Potential Radiological Exposure Sources

SC&A finds that further evaluation is warranted for radionuclides handled by workers at SNL to determine the extent of potential exposures, periods of exposure, quantities handled, and impacts on dose reconstruction to specific organs. Attempts should be made to evaluate archived bioassay data where it is available, and determine whether these data are complete and representative enough to develop a bounding or coworker dose. Appropriate methods for internal monitoring were not always available for all years of potential exposure. NIOSH/ORAUT should develop missed dose methodologies in the absence of monitoring data based on available data, technical reports, and other sources of information to ascertain potential exposure to non-traditional radionuclides. Additional consideration should be given to the exposure hazards associated with operation of accelerators, target handling, component activation, and byproduct radiation.

Finding 6: Lack of Guidance Provided to Support Dose Estimation for Offsite Work Activities

SNL took an active role in conducting weapons effects, ground motion, air pressure, crater phenomena, and other studies during the testing of weapons. SNL workers were responsible for the arming and firing of weapons from 1951 through 1992, and for monitoring, maintaining, and assembling weapons at storage sites. A recharacterization of the extent of SNL involvement in weapons testing and other offsite activities (e.g., research on hydrodynamic testing, treaty verification, and assignments to other DOE sites) should be completed. Offsite activities related to the weapons and components testing, surveillance, in-field retrofit and modifications, treaty verification, and managing storage sites and their corresponding monitoring programs have not been adequately addressed in the SNL TBD. This is confounded by the absence of offsite data in the SNL exposure files and the lack of direction to the dose reconstructors on when to request data from other sites. While it is understood that under EEOICPA protocols, NIOSH establishes work locations to enable dosimetry records to be obtained, including work at other Atomic Energy Commission (AEC) or Department of Energy (DOE) sites, it is not clear from the SNL, Nevada Test Site (NTS), or Pacific Proving Grounds (PPG) site profiles how visiting SNL employees were monitored for neutron and internal radiation exposures. Internal and external exposure hazards during field testing require further consideration to determine if appropriate internal and external monitoring occurred. If adequate monitoring did not occur at these offsite work locations, the TBD does not provide instructions for bounding these potential exposures. A missed dose methodology should be included for unmonitored or inadequately monitored personnel who participated in weapons testing and other field activities. Where available, references to other site profiles are appropriate. Methodologies for activities at continental tests outside of Nevada require treatment in the site profile, a separate site profile, or a technical information bulletin (TIB).

Finding 7: The Maximizing and Best-Estimate Intake Parameters for Tritium may not be Appropriate

Bounding techniques proposed in ORAUT-OTIB-0066, *Calculation of Dose from Special Tritium Compounds* (ORAUT 2007b), cannot be effectively developed and applied without some basic understanding of the compounds handled and the extent to which individuals were exposed. From the recommendations in ORAUT-OTIB-0066, it is stated that "the selection of the appropriate tritium compound in an intake evaluation must usually be based on process knowledge of the source terms in the workplace." It is important that the dose reconstructor chooses claimant-favorable forms of tritium for the dose estimation if there is a lack of process knowledge about the form that may have been involved with exposures. The dose to the lung from intakes of MTs can be underestimated by orders of magnitude if it is incorrectly assumed that the dose can be calculated with the methods used for HTO (ORAUT 2007b).

Finding 8: Environmental Source Terms are Inadequately Characterized for use in Performing the Exposure Assessments for Airborne Exposures

The environmental exposure calculations used for assessing intakes of airborne radionuclides provided in the SNL Environmental Dose TBD, ORAUT-TKBS-0037 (ORAUT 2007a), used source term data that may be inaccurate, incomplete, and not claimant favorable. There are periods of time that NIOSH could not find any emission or environmental monitoring data to calculate the actual air concentrations to which unmonitored workers could have been exposed. The methods that NIOSH used to assign intakes for some of these areas were not clearly explained and, in some cases, when the methods were explained, there is a question as to the validity of the assumptions used. For some areas of environmental exposure, NIOSH appears to have left out potentially significant radionuclides in the assessment of environmental dose.

Finding 9: The Environmental External Dose Component is developed with Inadequate Justification and may be Incomplete

The assignment of the environmental external doses from TLD data does not have a clear basis and is not supported with any analysis of background and onsite environmental dosimeters to accurately determine if there were higher levels onsite. There was no discussion detailing the dosimeter locations that were placed onsite and whether these were representative for estimating non-monitored worker dose. Assessment of possible doses from radioactive particles on skin was missing, in disagreement with discussion in the Scope of the TBD (ORAUT 2007a, Section 1.2), which identified this as being covered in the environmental dose section.

Finding 10: Criteria for Badging Workers are not defined

ORAUT-TKBS-0037 (ORAUT 2007a) does not provide any information concerning the criteria for badging workers at the SNL during the period 1949–2007. The criteria that were used to determine who was badged, for what type of exposure (i.e., photon, beta, and neutrons), and how the badging policy varied as a function of work location/facility and time needs to be addressed in the TBD for dose reconstruction purposes and to assist in determining if the coworker data presented in the TBD are valid.

Finding 11: Lack of Dosimetry Record Information

Throughout the Occupational External Dose section of ORAUT-TKBS-0037 (ORAUT 2007a), the dose data records are referred to as containing the necessary and correct dose for exposed workers throughout the entire period from 1949–2007. However, except for the brief statement on page 99 concerning the electronic files records created since 1986, there is no mention of the actual dose records; the dose information they may or may not contain (i.e., if neutron and photon components were recorded separately, or only the total penetrating dose was retained during certain periods as was the practice at some of the labs); the different recording systems (such as the change-over from handwritten to computerized records); and different recording methods/programs used after switching to electron data storage.

Finding 12: Insufficient Analyses of Radiation Fields, Doses, and Uncertainties

ORAUT-TKBS-0037 (ORAUT 2007a) does not cover the subject of photon and neutron radiation energy fields and associated doses with related uncertainties as a function of work location and time periods sufficiently to allow the dose reconstructor to accurately assign dose. For example, no relevant neutron calibration information is provided, nor is a clear uncertainty value provided that can be applied for neutron doses as a function of SNL time period. The n/p ratio value cited in the TBD is based on a relatively small number of records over an 8-year time span and would likely not be representative of laboratory conditions over that timeframe.

1.4 OPPORTUNITIES FOR IMPROVEMENT

(1) The Table 6-8, "*Calibration and irradiations*" has entries with question marks in the Operations columns and no entries in the Radiation type, Energy selection, keV [kilo electron volt], and Percentage column.

(2) The first paragraph on page 104 uses the term "*(P2/C7)*" without defining these terms.

(3) The first paragraph on page 106, which is below Table 6-11, should be located above Table 6-11, because it refers to the "*Table 6-11 below*."

2.0 SCOPE AND INTRODUCTION

The review of the Sandia National Laboratories (SNL) in Albuquerque, New Mexico and the Tonopah Test Range (TTR), Nevada, Site Profile was conducted during December 2007–August 31, 2008, by a team of SC&A health physicists and technical personnel. Given the classified nature of some of the records for which access was needed, arrangements were made through the Department of Energy (DOE) for special clearances, as well as declassification reviews of notes taken and interviews conducted with site personnel and former workers. Two members of the SC&A team hold "Q" clearances that permitted unencumbered access for this review.

Two team members also participated in the Nevada Test Site (NTS) site profile review conducted by SC&A in 2005, and are currently involved in the Special Exposure Cohort (SEC) petition review from which relevant issues were derived that apply to SNL personnel involved with nuclear testing activities at NTS and other such sites. Likewise, several members of the team conducted the site profile review of the Los Alamos National Laboratory (LANL) in 2006 (SC&A 2006), and a number of dosimetry and records issues from that site have relevance to SNL.

SC&A understands that site profiles are living documents, which are revised, refined, and supplemented with technical information bulletins (TIBs) as required to help dose reconstructors. Site profiles are not intended to be prescriptive or necessarily complete in terms of addressing every possible issue that may be relevant to a given dose reconstruction. It is recognized that NIOSH has data capture activities ongoing at SNL while this review is underway. Likewise, additional guidance documents were being issued that, while not reflected yet in the current SNL site profile TBDs, would serve to mitigate some of the gaps and issues raised in this report (where appropriate, these recent issuances have been so noted).

2.1 REVIEW SCOPE

Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) of 2000 and federal regulations defined in Title 42, Part 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program*, of the *Code of Federal Regulations* (42 CFR Part 82), the Advisory Board on Radiation and Worker Health (Advisory Board or Board) is mandated to conduct an independent review of the methods and procedures used by the National Institute for Occupational Safety and Health (NIOSH) and its contractors for dose reconstruction. As a contractor to the Advisory Board, S. Cohen and Associates (SC&A) has been charged under Task 1 to support the Advisory Board in this effort by independently evaluating a select number of site profiles that correspond to specific facilities at which energy employees worked and were exposed to ionizing radiation.

This report provides a review of ORAUT-TKBS-0037, *Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range, Nevada*, Rev. 00 (ORAUT 2007a). This document is supplemented by generic TIBs that provide additional guidance to the dose reconstructor.

Implementation guidance is also provided by so-called "workbooks," which have been developed by NIOSH for selected sites to provide more definitive direction to the dose reconstructors on how to interpret and apply TBDs, as well as other available information.

SC&A, in support of the Advisory Board, has critically evaluated the SNL Site technical basis document (TBD) as follows:

- Determine the completeness of the information gathered by NIOSH in behalf of the site profile, with a view to assessing its adequacy and accuracy in supporting individual dose reconstructions
- Assess the technical merit of the data/information
- Assess NIOSH's use of the data in dose reconstructions

SC&A's review of this site profile document focuses on the quality and completeness of the data that characterized the facility and its operations, and the use of these data in dose reconstruction. The review was conducted in accordance with *Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004), which was approved by the Advisory Board.

The review is directed at "sampling" the site profile analyses and data for validation purposes. The review does not provide a rigorous quality control process, whereby actual analyses and calculations are duplicated or verified. The scope and depth of the review are focused on aspects or parameters of the site profile that would be particularly influential in deriving dose reconstructions, bridging uncertainties, or correcting technical inaccuracies.

The SNL TBD serves as a site-specific guidance document used in support of dose reconstructions. The site profile provides the health physicists conducting dose reconstructions on behalf of NIOSH with consistent general information and specifications to support their individual dose reconstructions. This report was prepared by SC&A to provide the Advisory Board with an evaluation of whether and how the TBD can support dose reconstruction decisions. The criteria for evaluation include whether the TBD provides a basis for scientifically supportable dose reconstruction in a manner that is adequate, complete, efficient, and claimant favorable. Specifically, these criteria were viewed from the lens of whether dose reconstructions based on the TBD would provide for robust compensation decisions.

The basic principle of dose reconstruction is to characterize the radiation environments to which workers were exposed, and determine the level of exposure the worker received in that environment through time. The hierarchy of data used for developing dose reconstruction methodologies is dosimeter readings and bioassay data, coworker data and workplace monitoring data, and process description information or source term data.

2.2 ASSESSMENT CRITERIA AND METHODS

SC&A is charged with evaluating the approach set forth in the site profile that is used in the individual dose reconstruction process. The document is reviewed for completeness, technical accuracy, adequacy of data, consistency with other site profiles, and compliance with the stated objectives, as defined in SC&A 2004. This review is specific to the SNL Site Profile, supporting TIBs, and dose reconstruction worksheets; however, items identified in this report may be applied to other facilities, especially facilities with similar source terms and exposure conditions. The review identifies a number of issues, and discusses the degree to which the site profile fulfills the review objectives delineated in SC&A's site profile review procedure.

2.2.1 Objective 1: Completeness of Data Sources

SC&A reviewed the site profile with respect to Objective 1, which requires SC&A to identify principal sources of data and information that are applicable to the development of the site profile. The two elements examined under this objective are (1) determining if the site profile made use of available data considered relevant and significant to the dose reconstruction, and (2) investigating whether other relevant/significant sources are available, but were not used in the development of the site profile.

2.2.2 Objective 2: Technical Accuracy

Objective 2 requires SC&A to perform a critical assessment of the methods used in the site profile to develop technically defensible guidance or instructions, including evaluating field characterization data, source term data, technical reports, standards and guidance documents, and literature related to processes that occurred at SNL. The goal of this objective is to analyze the data according to sound scientific principles, and then evaluate this information in the context of dose reconstruction.

2.2.3 Objective 3: Adequacy of Data

Objective 3 requires SC&A to determine whether the data and guidance presented in the site profile are sufficiently detailed and complete to conduct dose reconstruction, and whether a defensible approach has been developed in the absence of data. In addition, this objective requires SC&A to assess the credibility of the data used for dose reconstruction. The adequacy of the data identifies gaps in the facility data that may influence the outcome of the dose reconstruction process. For example, if a site did not monitor all workers exposed to neutrons who should have been monitored, this would be considered a gap and thus an inadequacy in the data. An important consideration in this aspect of our review of the site profile is the scientific validity and claimant favorability of the data, methods, and assumptions employed in the site profile to fill in data gaps.

2.2.4 Objective 4: Consistency among Site Profiles

Objective 4 requires SC&A to identify common elements within site profiles completed or reviewed to date, as appropriate. In order to accomplish this objective, the SNL TBD was compared to other TBDs reviewed to date. This assessment was conducted to identify areas of inconsistencies and determine the potential significance of any inconsistencies with regard to the dose reconstruction process.

2.2.5 Objective 5: Regulatory Compliance

Objective 5 requires SC&A to evaluate the degree to which the site profile complies with stated policy and directives contained in 42 CFR Part 82. In addition, SC&A evaluated the TBDs for adherence to general quality assurance policies and procedures utilized for the performance of dose reconstructions.

2.3 DOSE RECONSTRUCTION UNDER EEIOCPA

In order to place the above objectives into the proper context as they pertain to the site profile, it is important to briefly review key elements of the dose reconstruction process, as specified in 42 CFR Part 82. Federal regulations specify that a dose reconstruction can be broadly placed into one of three discrete categories. These three categories differ greatly in terms of their dependence on and the completeness of available dose data, as well as on the accuracy/uncertainty of data.

Category 1: Least challenged by any deficiencies in available dose/monitoring data are dose reconstructions for which even a partial assessment [or minimized dose(s)] corresponds to a probability of causation (POC) value in excess of 50%, assuring compensability to the claimant. In some cases, such partial/incomplete dose reconstructions with a POC greater than 50% may involve only a limited amount of external or internal data. In extreme cases, even a total absence of a positive measurement may suffice for an assigned organ dose [based on limits of detection (LOD)] that results in a POC greater than 50%. For this reason, dose reconstructions in this category may only be marginally affected by incomplete/missing data or uncertainty of the measurements. In fact, regulatory guidelines recommend the use of a partial/incomplete dose reconstruction, the minimization of dose, and the exclusion of uncertainty for reasons of process efficiency, as long as this limited effort produces a POC of equal to or greater than 50%.

Category 2: A second category of dose reconstruction defined by federal guidance recommends the use of "worst-case" assumptions. The purpose of worst-case assumptions in dose reconstruction is to derive maximal or highly improbable dose assignments. For example, a worst-case assumption may place a worker at a given work location 24 hours per day and 365 days per year. The use of such maximized (or upper bound) values, however, is limited to those instances where the resultant maximized doses yield POC values below 50%, which are not compensated. For this second category, the dose reconstructor needs only to ensure that all potential internal and external exposure pathways have been considered, and that the approach is scientifically supportable.

The obvious benefit of worst-case assumptions and the use of maximized doses in dose reconstruction is efficiency. Efficiency is achieved by the fact that maximized doses avoid the need for precise data and eliminates consideration for the uncertainty of the dose. Lastly, the use of bounding values in dose reconstruction minimizes any controversy regarding the decision not to compensate a claim.

Although simplistic in design, the TBD must, at a minimum, provide information and data that clearly identify (1) all potential radionuclides, (2) all potential modes of exposure, and (3) upper limits for each contaminant and mode of exposure to satisfy this type of a dose reconstruction. Thus, for external exposures, maximum dose rates must be identified in time and space that correspond to a worker's employment period, work locations, and job assignment. Similarly, in order to maximize internal exposures, highest air concentrations and surface contaminations must be identified.

Category 3: The most complex and challenging dose reconstructions consist of claims where the case cannot be dealt with in one of the two categories above. For instance, when a minimum dose estimate does not result in compensation, a next step is required to make a more complete estimate. Or, when a worst-case dose estimate that has assumptions that may be physically implausible results in a POC greater than 50%, a more refined analysis is required. A more refined estimate may be required either to deny or to compensate. In such dose reconstructions, which may be represented as a "reasonable" or "best-case" estimate, NIOSH has committed to resolve uncertainties in favor of the claimant. According to 42 CFR 82, NIOSH interprets "reasonable estimates" of radiation dose to mean the following:

> *… estimates calculated using a substantial basis of fact and the application of science-based, logical assumptions to supplement or interpret the factual basis.* ***Claimants will in no case be harmed by any level of uncertainty involved in their claims, since assumptions applied by NIOSH will consistently give the benefit of the doubt to claimants.*** [Emphasis added.]

SC&A's draft report and preliminary findings will subsequently undergo a multi-step resolution process. Prior to and during the resolution process, the draft report is reviewed by the DOE Office of Health, Safety, and Security to confirm that no classified documents or information have been incorporated into the report. Resolution includes a transparent review and discussion of draft findings with members of the Advisory Board Working Group, petitioners, claimants, and interested members of the public. This resolution process is intended to ensure that each finding is evaluated on its technical basis in a fair and impartial basis. A final report will then be issued to the full Advisory Board for deliberation and a final recommendation.

All review comments apply to the Rev. 00 version of the SNL component TBD, which is the most recently published version. Site expert interviews were conducted with SNL workers to help SC&A obtain a comprehensive understanding of the radiation protection program, site operations, and historic exposure experience.

Attachment 2 provides summaries of the interviews conducted by SC&A during the course of this review. The interviewees included staff from the SNL and were conducted by Joseph Fitzgerald (SC&A/Saliant Inc.) and Robert Bistline (SC&A/Saliant Inc.) from April 23–24, 2008.

On February 3, 2008, SC&A sent questions to NIOSH as part of its evaluation of the TBD. These questions are reproduced in Attachment 3, along with the written responses provided by NIOSH and ORAUT on March 21, 2008. Additional questions stemming from the review were submitted by SC&A to NIOSH on February 29, 2008, with a NIOSH/ORAUT response received in the same March 21, 2008 response. These additional questions and the corresponding responses are also provided in Attachment 3.

2.4 REPORT ORGANIZATION

In accordance with directions provided by the Advisory Board and with site profile review procedures prepared by SC&A and approved by the Advisory Board, this report is organized into the following sections:

(1) Executive Summary
(2) Scope and Introduction
(3) Vertical Issues and Secondary Issues
(4) Overall Adequacy of the Site Profile as a Basis for Dose Reconstruction

Based on the issues raised in each of these sections, SC&A prepared a list of findings, which are provided in the Executive Summary. Issues are designated as findings if SC&A believes that they represent deficiencies in the TBD that need to be corrected, and which have the potential to have a substantial impact on at least some dose reconstructions. Issues can also be designated as Secondary Issues if they simply raise questions, which, if addressed, would further improve the TBD and may possibly reveal deficiencies that will need to be addressed in future revisions of the TBD.

3.0 VERTICAL ISSUES AND SECONDARY ISSUES

SC&A has developed a list of key issues regarding the *Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range, Nevada Site Profile*. These issues relate to each of the five objectives defined in SC&A's review procedures (SC&A 2004). Some issues are related to a particular objective, while others cover several objectives. Many of the issues raised below are applicable to other DOE and Atomic Weapons Employer sites, and should be considered in the preparation and revision of other site profiles.

3.1 POTENTIAL SHORTCOMINGS EXIST IN COMPLETENESS AND ADEQUACY OF DOSIMETRY RECORDS

The completeness, accuracy, and availability of data for use in dose reconstruction and as a basis for the internal coworker approach should be validated to demonstrate its usefulness. Several potential shortcomings were noted in regard to bioassay data, incident data, and the verification of information from external sources.

First, bioassay records before 1989 have been found in paper or microfiche format in the data archive; however, the records are limited to uranium, plutonium, and tritium bioassay, and are not typically located and incorporated by SNL as a part of the claimant file. Data provided to NIOSH for dose reconstruction are limited to summary reports, including dose information in some years for tritium, plutonium, and uranium. The limited hardcopy bioassay data appear indicative of incomplete individual exposure files and/or a limited bioassay program.

Likewise, with respect to completeness of scope, the site profile does not fully address the significance of radiological incidents (onsite and offsite), how they may have contributed to worker dose, where information is provided in individual exposure records, and how the incidents should be addressed in dose reconstruction. Claimant data, relying primarily on summary reports, do not consistently incorporate exposures arising from onsite or offsite incidents. The TBD itself acknowledges offsite occupational exposures to unencapsulated radioactive materials, for which no bioassay data exist. Many of these situations involved exposure to fission and activation products that apparently were not found in the archived bioassay data. In addition, it is not clear that the accuracy of data from offsite sources [e.g., the bioassay services contractor, Controls for Environmental Pollution (CEP), and LANL] has been considered in the evaluation of data.

In light of these key questions, the verification process should be reviewed to assure that internal dosimetry information provided to dose reconstructors is accurate, complete, and consistent. Where data gaps cannot be corrected, clear instructions should be provided to allow for a consistent and claimant-favorable approach to dose reconstruction.

Data Completeness

There is limited bioassay data available for SNL workers prior to 1992, when a routine monitoring program was implemented. The TBD indicates that archived records contain data for uranium, plutonium, and tritium. Analysis of the source terms indicates that individuals were exposed to tritium (H-3), uranium (U-234, U-235, and U-238), fission and activation products (e.g., Sr-90, Cs-137, Zn-65, Co-60, Ta-182), plutonium (Pu-238, Pu-239, Pu-240, and Pu-241), and americium (Am-241), yet adequate bioassay data is not available for several of these nuclides. The bioassay data available at SNL are minimal prior to 1970, and consists primarily of tritium data. The TBD indicates there are few bioassay results available in the electronic record, and these records may be incomplete:

> *There are few results of bioassay of individual SNL workers found in the electronic records prior to 1989.* (ORAUT 2007a, pg. 61)

> *Also, the potential exists that not all of the early bioassay records have been transferred to the current database. These early records were transferred to microfilm or microfiche beginning in 1967 (Argall 2007b) and a summary of the resultant dose (or 0.00 rem if the results were <MDA) was entered into an electronic database. However, this information may not have been captured in the current database and thus not provided with the dose records supplied by DOE.* (ORAUT 2007a, pg. 95)

Furthermore, the 1991 DOE "Tiger Team" assessment of SNL (DOE 1990) found several deficiencies regarding accuracy and completeness of personnel radiation dosimetry:

> *Personnel exposure files do not contain all the radiological information related to personal exposures and radiation working conditions as required by DOE Order 5480.11.*

A documented ORAUT communication regarding the availability of early SNL bioassay records for use in development of a coworker model indicates that "a further search of records for old bioassay data at this time would not be warranted" (Connell 2006). A recently retired SNL employee stated that SNL already searched for the pre-1992 records without success (Connell 2006). NIOSH/ORAUT indicates in the TBD that they are conducting additional data retrieval efforts to obtain additional individual bioassay information:

> *Recent data capture efforts at SNL have identified large volumes of bioassay data. These data will be used in the coworker analysis. Once this analysis is completed the TBD will be revised to incorporate the use of these data for claims that warrant an internal dose assessment but lack monitoring data in their case files provided by DOE.*

In light of prior decisions against further retrieval efforts, there appears to be significant doubt that existing data archives will resolve all concerns about the adequacy of internal dose information. The records in question originated prior to 1989, and retrieval can be labor intensive. Although the TBD indicates that data searches are performed as claims are received, the extent of such searches is not well defined, and it is not clearly stated that SNL is including archived data in the individual radiation exposure files. The internal dosimetry TBD acknowledges potential exposures to fission and activation products and pure americium, none of which are mentioned in regard to archived dosimetry records. If the archives contain dosimetry records that can contribute relevant dose information to the claims evaluations, a comprehensive search of hardcopy monitoring data and subsequent validation of these hardcopy records against the electronic data should be pursued, particularly given the apparent limited internal monitoring conducted at SNL. Where gaps cannot be resolved from existing records, the TBD should address the feasibility of adequate dose reconstruction.

Data Accuracy

Historically, SNL relied heavily on outside vendors to provide bioassay data. Concerns about the accuracy and completeness of data from these support contractors have not been fully considered in the SNL TBD.

The SNL TBD indicates dosimetry services were provided by LANL for some periods of time:

> *Also, it is likely the bioassay records and external dosimetry records for workers employed by SNL prior to November 1, 1949* [Argall 2007c] *when the Z-Division officially separated from LANL, may only be located in the LANL Bioassay database*. (ORAUT 2007a, pg. 60)

The TBD also states the following:

> *Because of statements made during interviews with individuals currently involved with the bioassay program, out-sourced bioassay and a Memorandum of Understanding with LANL were considered to be the prime source of bioassay results for years before 1991.* (ORAUT 2007a, pg. 60)

The LANL Bioassay Repository database, used to provide information for LANL claimants and evaluated in the LANL site profile review, has been found to be incomplete (SC&A 2006). It is unclear whether and where Po-210 urinalysis data and other bioassay data have been fully incorporated into the LANL Bioassay Repository. Furthermore, verification and validation have only been partially completed, and may raise questions regarding the completeness and accuracy of internal dose estimates.

In the evaluation report for LANL, data deficiencies were identified for particular radionuclides and time periods at LANL. Table 1, a recreation of Table 7-8 from the LANL petition evaluation report, specifies data deficiencies by period and radionuclide.

Table 1. Summary of LANL Data Deficiencies listed by Period and Radionuclides
(Source: Vitkus et al. 2007)

Period	Radionuclides with No Reconstruction Data or Method
1943–1949	Tritium, MPF/MAP, Am-241 (if no Pu data and pending validation of newly identified bioassay data), Th-232, Th-230, Ac-227, Pa-231, and Cm-244
1950–1969	MPF/MAP (without the validation of the newly identified air monitoring data), Am-241 (if no Pu data or from "pure" process), Th-232, Th-230, Ac-227, Pa-231, Np-237, and Cm-244.
1970–1975[(a)]	MPF/MAP, Am-241 (if no Pu data or from "pure" process), Th-232, Th-230, Ac-227, Pa-231, Np-237, and Cm-244.

(a) Some radionuclide maximum intakes possibly could be inferred from the chest counting data. However, at the time of this report, an analysis of this technique has not been performed. This technique most likely could not be used for Cm-244 due to the 18.7-y half-life and with only a 10% yield 14 keV x-ray. References to direct work with Cm end in 1975, other than burial grounds and minor residual contamination in TA-1 Building 3 and ML.

If LANL was the prime source of bioassay results for the years before 1991, this could have a significant impact on the internal dose assessments of SNL workers. Data deficiencies during the 1943–1949 time period would clearly impair the ability to conduct dose reconstructions on SNL workers who were a part of the Z-division of LANL during this time. From 1950 to 1975, there are data deficiencies for mixed fission products/mixed activation products (MFP/MAP), which have been identified as a major contributor to internal dose at SNL. SNL housed several reactors and accelerators, and was heavily involved in testing that potentially resulted in exposures to fission and activation products.

The SNL TBD is incomplete in its consideration of missed dose to unmonitored exposed workers potentially exposed to all the various MFPs and MAPs, including activation products produced by accelerators. Whole-body and lung counting were the primary methods for determining intakes of fission and activation products; however, these were performed as a result of suspected intakes and not as a routine monitoring program. It is noted on page 80 that SNL has always been a center for research, and small-scale use of various radionuclides occurred throughout the history of the site. Little or no documentation has been found on bioassay for these nuclides. Instructions given in Section 5.5.3 only hold true if the work records are complete and specific about the work areas to which the individuals were assigned. Certainly next-of-kin claimants will not be able to provide helpful information on worker locations, given the fact that NIOSH recognizes on page 57 that many of the exposure histories and work records are not specific about the work areas to which individuals were assigned.

In addition to concerns regarding LANL bioassay data, the SNL TBD describes bioassay results from a commercial laboratory, CEP, that were invalidated due to inappropriate process and data integrity (ORAUT 2007a, pg. 59):

> *The results of bioassay samples analyzed between August 1992 and April 1994 by a commercial laboratory were invalidated based on the results of spike samples and other issues surrounding the integrity of the data (Potter 1994; DOE 1994).*

No explanation is provided, however, on how the TBD will address acute uptakes that may have occurred during this time period. Considering the importance of bioassay data from LANL and

CEP, further verification of data completeness and accuracy is warranted. It would be highly desirable for the verification and validation process to be used and identified in the revised site profile.

Incidents

The site profile does not fully address the significance of radiological incidents, how they may have contributed to worker dose, and how they would be addressed in dose reconstruction (this issue has been addressed in other site profiles, albeit inconsistently). It is not likely that NIOSH has specific information on who was monitored and who was not, how samples were collected during such incidents, and how these samples were handled and processed, especially in the early days. The data provided by SNL is limited to summary data and does not appear to include any information on personal contamination or incidents.

Incidents and accidents are mentioned twice in the TBD, but apparent discrepancies exist. Under Section 2.5, Major Site Incidents, a single incident is called out:

> *A single incident of "serious overexposure" at SNL occurred in 1960…. No other major site incidents were ever recorded at SNL.* (ORAUT 2007a, pg. 20)

Later in the document, Table 5-32 lists 12 additional exposure incidents occurring between 1967 and 1993 (ORAUT 2007a, pg. 95). The listing of 12 exposure incidents appears to conflict with the statement that there was only 1 major incident at SNL. Large gaps appear to exist for incidents in the early years, with the TBD listing only one incident in 1960 and no incidents prior to 1960 or from 1961–1966. Experience with other sites indicates that incidents were not routinely recorded in the early years, but were significant when they occurred. Furthermore, little consideration is given to episodic environmental releases. The TBD should investigate the existence of an incident database or other source material for radiological incidents. These data could be valuable in the evaluation of external, internal, and environmental dose.

While it is clear that judgment needs to be exercised regarding what accidents and incidents need to be reviewed and included in site profile characterization, it is important to identify available information regarding key accidents and incidents and assure their availability and use by dose reconstructors. This is especially true when worker radiation exposure files do not contain all the radiological information related to personal exposure. It is also important, for the site profile to evaluate this accident history for its implications to dosimetry adequacy and the completeness of dose reconstruction data. Furthermore, the inclusion of all personnel monitoring data from classified incidents in individual radiation exposure files should be verified.

Other Records Issues

Additional data may exist for early SNL workers in the Medical Records at LANL. In a report on the LANL radiological records program, reference is made to radiation data in Medical Records:

> *Prior to January 1953, all exposures to beta and gamma radiation were reported to Medical Records for transposing into each individual Personnel Medical File.* (LANL 1956)

Records found in medical files included hazard reports, whole-body and extremity dose information, nasal count data, personnel exposure record – airborne contamination reports, and incident reports. These records were not available in the corresponding radiological files examined. The hazard reports provide information on radiological hazards to which an individual was exposed during the course of their work (i.e., uranium, plutonium, polonium, beta, neutron x-ray, gamma, or other sources of radiation). Routine and special nasal counts from the 1940s reside in the medical file. Reports such as those labeled "Personnel exposure record – Airborne contamination" provide airborne concentration data for areas where an individual was assigned. These data should be requested for Z-Division workers in addition to occupational x-ray and incident reports from medical records provided by LANL staff. At the present time, the additional radiological information is not provided in the claimant package, underscoring the importance of verifying the completeness of information received for dose reconstruction.

No references have been provided concerning the details associated with stockpile stewardship, weapons storage, or offsite assembly, disassembly, and retrofitting. More detail on particular radionuclides of concern for the SNL managed storage sites should be provided to the dose reconstructor.

In summary, apparent shortcomings in the completeness, accuracy, and availability of radiation dose data should be addressed in any ongoing revision of the SNL site profile report. The SNL electronic database is incomplete, and hardcopy bioassay records are not complete in individual radiation exposure files and lack data regarding specific radionuclides to which workers were potentially exposed. Additionally, the adequacy of offsite vendor data is suspect, suggesting a need for further verification of data completeness and accuracy. Exposure data for workers at offsite facilities frequented by SNL workers (e.g., atmospheric nuclear weapons testing) may not be readily available and need to be addressed for the benefit of the dose reconstructor. In light of these shortcomings, the verification process for determining the completeness and consistency of the internal dosimetry information provided electronically, in hard copy, and from other sites requires careful consideration for use in dose reconstruction.

3.2 INACCURATE DOSE RECORDS FOR REACTOR PERSONNEL

The Sandia Pulse Reactor (SPR-1) facility was operational from October 1962 to June 1969, with successive reactor designs (SPR-2 and 3) becoming operational up through the present. External doses received by reactor operators (approximately 4–6 individuals at any given time) were among the highest recorded at SNL over that time period, due to elevated radiation fields present during shutdown maintenance periods and the proximity of personnel conducting these activities. A review of SNL's "Incident/Unusually High Radiation Exposures," by organization and by year from 1979 to 1989 (SNL 1979–1989),[1] showed that half or more of these high exposures were being received by SPR personnel. These annual doses were compiled by SNL management for those individuals receiving 0.5 rem or more; for SPR reactor operators, the range of annual external doses received for the sampled period of 1979–1989 ranged up to 2.74 rem, with cumulative doses for some operators as high as 37.7 rem for 1989 and 20 rem for 1988.

In fact, the persistent high exposure level of the SPR operators was of such concern at SNL that steps were taken beginning in 1982 via a "SPR Dose Reduction Project" (Philbin 1982) to review exposure data, identify dose reduction strategies, and design a reactor maintenance shield for use during maintenance activities. From interviews (Attachment 2), it was also indicated that additional reactor workers needed to be recruited, given the "burn" rate of these high dose activities. An August 24, 1982, memorandum from the DOE Albuquerque field office manager (R. Romatowski) to the SNL Director (A. Narath) further expressed concerns over elevated doses at SPR, suggesting that the 5-rem annual dose limit was too often being viewed merely as an operational target, with "minimum annual exposure per individual [varying] from 3.5 to 4.5 REM," ignoring the tenets of the "as low as reasonably achievable" (ALARA) guidance (Romatowski 1982).

In April 1982, a meeting was held at SNL Area V (where SPR is sited) to discuss a recently discovered dosimetry issue bearing on the exposures monitored at SPR (SNL 1982). An SNL health physicist indicated that SPR personnel performing "lower stand" maintenance activities during reactor shutdowns had been working in a radiation field involving a "severe gradient," with the following findings:

> *The dose to the head could be as much as five times as great as to the body. At the beginning of the quarter, only one badge was worn per person during any two week period. That badge was worn in various locations depending on the individual involved. The locations varied from the shirt collar to the pants pocket. During the second week of February* [1982], *it was found that the gradient existed especially when personnel performed lower stand maintenance on SPR III. To attempt to account for the difference, all personnel began to wear head badges in addition to the normal body badge. After these badges were processed, it became apparent that the doses to the head (and to the lens of the eye) were significantly larger than the whole body doses. (SNL 1982)*

From interviews with longstanding SNL health physics personnel (see Attachment 2), it was learned that the average ratio between doses received by the head versus the trunk in these maintenance activities was about 1.75 (i.e., the head received almost double the exposure of the trunk) after the maintenance shield (or shroud) was installed in the early 1980s. However, health physics personnel added that this ratio would have been much higher (than 1.75) before the shroud was installed. While some attempt was made to incorporate head dose readings in estimating whole-body dose for 1982 and forward in time, it is unclear to what extent that was

[1] SNL (Sandia National Laboratories) 1979–1989 developed a listing of incidents/unusually high radiation exposures that is included in archive file box #121072. Also included are unofficial annual compilations of SNL employees with radiation dose equal to or in excess of 0.50 rem.

done, because head dosimeters were not always worn by workers in later years (i.e., not enforced by management). **Based on the same feedback, it is apparent that no attempt was made to correct the pre-1982 dose records for the SPR reactor operators involved**.

The implications for dose reconstruction are clear. The SPR operators were among the highest exposed at SNL, with quarterly and annual doses approaching specified DOE dose limits (5 rem/year), with 3 rem/quarter before 1988 in a number of cases year after year. Lack of an adjustment for the severe exposure gradient found at the SPR of a factor of 1.75 or more would lead to a significant underestimation of external dose. The post-1982 dose reconstruction for these workers would also need to reflect some evaluation of the approach taken by SNL over that time period to accommodate this exposure gradient when they assigned the dose of record. The current version of the site profile does not acknowledge this issue or provide a means for the dose reconstructor to make necessary adjustments in dosimetry calculations.

3.3 SITE-WIDE WORKERS NOT BIOASSAYED FOR POTENTIAL INTERNAL INTAKES BEFORE 1992

Section 5.5 of the site profile provides the dose reconstructor instruction that when a worker does not have monitoring results in the DOE records, their work locations should be reviewed and potential for exposure determined for these locations:

> *When a worker does not have monitoring results in the DOE records, their work locations should be reviewed. These locations should be compared to the radioactive materials listed for locations in previous sections. Job titles are not necessarily the most accurate indicator of potential for exposure.* (ORAUT 2007a, pg. 95)

This instruction is problematic in light of the statement made earlier in the TBD:

> *Many of the exposure histories and work records are not specific about the work areas to which individuals were assigned. However, when information about the work location is available, Table 5-1 can be used to determine probable nuclides.* (ORAUT 2007a, pg. 57)

Work area information that is either absent or inadequate makes determining whether exposures have occurred (and to which radioisotopes) difficult, if not impossible. Likewise, for site-wide workers (e.g., security guards and maintenance personnel), their routine access to a broad range of SNL radiological facilities and sites would make such source term assignments particularly problematic, if it is not feasible to identify their work locations. When specific work areas are not identified in the records provided by DOE, the dose reconstructor does not have a sufficient basis for utilizing the information in Table 5-1, which highlights potential radionuclides of concern by work area. The TBD has not presented a mechanism for assigning dose to site-wide workers in the absence of routine bioassay results.

One worker category—security inspectors or guards—illustrates the difficulty in applying the TBD's work area criteria to site-wide workers. The site profile states in Section 5.1.2 ("The Bioassay Program") that "security inspectors were required to participate in a routine bioassay program and have annual whole-body counts and urinalyses." However, as indicated elsewhere in the site profile, a formal routine bioassay program did not exist at SNL prior to 1992, although bioassays were apparently provided to workers judged to have a potential for intake above administrative levels. Security guards and other support workers having site-wide access to radiological areas (e.g., maintenance and cleanup personnel) would have had unrestricted access to experimental sites and contaminated areas. From interviews with guards with tenures prior to 1992 (see Attachment 2), it is clear that they were required to stand guard where special nuclear material (plutonium and enriched uranium) was being handled, and where radiological components containing DU and thorium were being tested. They were likewise required to conduct routine surveillance of all SNL facilities and areas, some of which were contaminated. However, from their recollection, they were never bioassayed (the only "urine samples" they provided were apparently for their annual physical health examinations). One guard indicated that he actually wore self-contained breathing apparatus at a highly contaminated site, but was not bioassayed afterwards. He also indicated that guards would routinely eat their lunches while on station in radiological areas. The facility-specific means of assigning missing dose due to assumed radiological source terms (as applied in the site profile) would not be feasible for such workers because of their site-wide access to a range of potential sources that had the potential for intakes. Therefore, a means of dose estimation for this cohort of workers is not evident in the site profile.

Therefore, it is of concern to SC&A that prior to 1992, when no formal routine bioassay program existed at SNL, workers in areas containing radioactive materials may have had the potential for internal exposures that would not have been monitored, and with their work areas in many cases being unknown, a backup means of estimating dose is not apparent in the TBD. The instructions given the dose reconstructors in the site profile do not appear to be adequate for determining or quantifying the radioactive isotopes to which unmonitored or even monitored workers may have been exposed. Assigning potential missed dose by work location is questionable, particularly in the absence of complete work history records. Furthermore, the feasibility of this approach is questionable for site-wide workers and workers involved in offsite activities in Nevada and other locations. In cases where work area information is not available, the TBD should provide further instruction.

3.4 USE OF AIR MONITORING DATA IN DOSE ESTIMATION IS PROBLEMATIC

There was no formal routine bioassay monitoring program and little documentation existed regarding the internal dosimetry program before 1992. The site profile notes that routine bioassay sampling was not a general practice, and bioassay was confined to suspected intakes of radioactive materials or when a worker exceeded an administrative threshold. Less than 100 individuals participated in the bioassay program each year from the beginning of the program through 1991. ORAUT-TKBS-0037 (ORAUT 2007a) notes that the potential for monitored and unmonitored intakes has existed throughout the history of the site.

The trigger for special sampling was based on field indicators, such as incidents, high results of air sampling, Continuous Air Monitor (CAM) alarms, and/or nasal swipes. In lieu of bioassay samples, the TBD recommends intakes be derived from airborne contamination levels (ORAUT 2007a, Section 5.4.2):

> *Intake parameters can be derived from airborne contamination levels for buildings with the highest exposure potential or highest intakes for various periods. Maximum and average airborne contamination levels for selected buildings are listed in Table 5-29. Examples of incidents and intakes are listed in Table 5-32. Average airborne contamination levels either are derived as simple averages or are reported as averages listed in reports. Simple averaging is assumed for SNL reports, but no information on the methods used to obtain these reported averages is available.*

There are several issues associated with the use of air sampling as a means of determining potential internal exposures. The following statement is a well documented fact [and affirmed in Whicker et al. (1997) and the SNL Site Profile in the Occupational Internal Dosimetry TBD]:

> …*selection of the location of the CAM was critical to the reliability of the response. The typical location of CAMs at the ventilation exhaust point of a room was not considered optimal. Results also suggest that when a worker causes the release and is at or near the release point, the worker could be exposed for a significant period before a radioactive cloud reaches the CAM.* [These] …*limitations suggest that, without other interventions, the possibility exists that workers could be exposed to intakes that did not trigger alarms.*

The TBD (pg. 93) states that CAMs were placed near the point of release where the air concentration would be at a maximum as a backup detection device. SC&A does not understand this statement. First, how can one determine in advance where a point of release is going to occur? Second, if the CAMs were placed at the point of release after the release incident, this would not necessarily represent the exposure the workers would have experienced.

The TBD [page 91 of ORAUT-TKBS-0037 (ORAUT 2007a)] further states the following:

> *Studies have shown that room air concentration is not necessarily an accurate predictor of intake because of the variations in respiratory conditions and particle dispersion within an area. Even BZA samples are not always an accurate predictor of the amount of intake (Whicker 2004). However, maximum and average airborne concentrations can be helpful in establishing boundary conditions for intakes or for determining which locations had potential for inhalation intakes.*

Whicker et al. (1997) notes that air sampling and CAMs are not dependable for predicting intakes because of the locations of the monitoring devices with respect to the workers and the air flows in work areas. Workers may be exposed for significant periods before a radioactive cloud reaches the CAM or air sampler, and the possibility exists that workers could be exposed to intakes that did not trigger alarms. The air reaching the air sampler may not be at all representative of the air to which the worker was exposed. Simple averaging without information on the method used does not appear to maximize the intake parameter assumptions.

The general area air sample results available to NIOSH and the dose reconstructors do not appear to be useful for adequately bounding the potential air concentrations that may have existed in the breathing zones of workers potentially exposed to uranium, plutonium, tritium, or mixed fission and activation products at the site.

Section 5.4 (pg. 91) of the TBD also states the following:

> *Airborne concentrations were not available for all years of operation, especially for fission products. The reported results often do not include the volume of air through the filter; therefore, it is not possible to determine the actual airborne concentration.*

It was noted in concern #393 (page 1,322) of the Tiger Team Report (DOE 1992a) that personnel were permitted to enter and work in areas with potential airborne contaminants that had not been monitored, as required by DOE Order 5480.11 (DOE 1988). The Tiger Team report also noted in concern #392 (DOE 1992a) the occurrence of incorrect readings for Remote Area Monitors, and in concern #391, that readings were not being taken while radiation instruments were removed for calibration. These Tiger Team findings and those noted in the beginning of this Section 5 are highly indicative of the likelihood that potential uptakes occurred during operations at the site, as well as at sites visited by SNL workers, that were likely not monitored and recorded.

The fact that the TBD even notes that airborne concentrations are not available for all years of operation, especially for fission products; that air volumes through the filters are often not included, so airborne concentrations cannot be determined; that Remote Area Monitors indicated incorrect readings; and that simple averaging of airborne contamination levels was assumed, but no information on the methods used to obtain these averages is available makes the TBD-stipulated use of air monitoring data for dose reconstruction highly questionable.

Again, general area air results available to NIOSH and the dose reconstructors do not appear to be useful for adequately bounding the potential air concentrations for any of the radionuclides that may have existed in the breathing zones of workers/claimants. This is true for both onsite work activities, as well as work performed offsite in research, weapons testing, and weapons stockpile maintenance and surveillance conducted by SNL workers.

Bioassay monitoring of workers was primarily dependent on the air monitoring program, as opposed to and in default of a routine bioassay monitoring program. With inadequate air sampling or no air sampling data at all, this brings into question the effectiveness of the special bioassay monitoring program and the use of air sampling data as a substitute for bioassay sampling. It certainly appears that without routine bioassay monitoring, dependence upon air sampling for detecting exposures to workers likely led to unmonitored intakes by workers over the years at SNL, or intakes that could not be measured or estimated accurately due to use of area air monitoring data. Furthermore, reliance on field indicators to trigger special bioassay, particularly in areas where air monitoring equipment placement is inadequate or non-existent, is problematic. Some consideration should be given in the TBD to the representativeness of the sampling and the consistent use of field indicators as a trigger for bioassay.

3.5 INADEQUATE TREATMENT OF POTENTIAL RADIOLOGICAL EXPOSURE SOURCES

The predominant radionuclides encountered at SNL are tritium, uranium, and fission and activation products (e.g., Sr-90, Cs-137, Zn-65, Co-60, and Ta-182). Other radionuclides handled at SNL included plutonium (Pu-238, Pu-239, Pu-240, Pu-241), americium (Am-241), Tc-Mo-99, Po-210, radium, thorium (Th-228, Th-232), U-233, Cm-244, Cf-252, C-14, Na-22, Se-75, P-32, S-35, I-125, I-131, N-13, O-15, and other accelerator activation products. The quantities handled ranged from fractions of a gram to kilograms. These potential radiological exposure sources are identified and addressed in the site profile, but other pertinent sources are not.

One such area is onsite waste disposal. Wastes disposed in pits during the early years included uranium (depleted, natural, and enriched), thorium, barium, enriched lithium, tritium beds, neutron generator tubes and targets, plutonium contaminated wastes, and plutonium contaminated weapons test debris from the NTS. An analysis of these waste streams from the standpoint of occupational radiological significance should be conducted and additional radionuclides of concern identified.

Another radiological source that can be better characterized for the benefit of dose reconstructors is accelerators. Radiation exposure at SNL accelerators includes hazards from prompt radiation generated by intentional or accidental beam losses in the beam line. The principal hazards are photons and neutrons. Without appropriate shielding, skyshine can likewise be a problem. Induced activity can occur in beam-line components, cooling water for components, air (e.g., N-13 and O-15), shielding material, the ground, and groundwater. The possible impact from photo-fission also should be considered, where fissile materials are used as targets. While there is typically a delay period prior to entry into the accelerator area that serves to reduce potential exposures, entry may still involve some exposure as a function of target material, maintenance required, and experimental exigencies. The TBD needs to review such potential radiation sources and characterize their significance.

Analysis of Available Bioassay Data

The TBD indicates routine sampling was not a general practice, and that bioassay was performed in response to suspected uptakes of radioactive material or when a worker exceeded an administrative threshold (Hasenkamp 1961). NIOSH captured a collection of bioassay data from the archives at SNL, which they indicate will be considered in the update of the site profile. Little information is provided regarding the bioassay data available from the SNL records archive. A brief review of the bioassay sampling data for SNL workers available on the NIOSH Site Research Database indicates gross alpha, gross beta, plutonium, tritium, and uranium results are available back to the 1950s. A majority of these samples were collected for tritium analysis.

Limited samples were collected for plutonium, uranium, gross alpha and gross beta analysis. Very few bioassay samples were obtained for Po-210, Np-237, S-35, actinides, and C-14 through the years. In-vivo counting was available for gamma emitters through LANL starting in 1955. In 1993, SNL established a whole-body counting program. There are relatively little data available on the internal dosimetry program prior to establishment of a formal bioassay program in 1992.

A more detailed analysis of the completeness and representativeness of the archived data is needed. Information on types of bioassay available, relative exposure potentials, and work locations of individuals who were monitored should be addressed. Since bioassay was conducted primarily in response to incidents, it is unclear whether all potentially exposed workers were monitored, or even whether the most exposed workers were monitored.

Uranium

Depleted, natural, and enriched uranium were handled at SNL. Depleted uranium (DU) was encountered at TTR, Coyote Canyon, and weapons storage facilities. Dose assignment to unmonitored potentially exposed workers is based on the maximum counts for depleted uranium and U-235 taken in 1989 with the Helgeson lung counter. Dose reconstructors are instructed to use the maximum results from this dataset for overestimating assumptions. Early uranium bioassay data provided total uranium. Although the TBD provides a table of activity fractions, information on what enrichments of uranium were handled, in what locations, and for what time periods is not clear from the TBD. The use of maximum results for DU and U-235 departs from the default assumption in other TBDs, wherein guidance is provided that such activity should be attributed to U-234. This is because U-234 is the most significant dose contributor in the decay chain of uranium isotopes in natural or enriched uranium sources. There is also no mention of assumptions made for workers handling U-233.

The SNL considered the potential for intakes of uranium to be small, because they considered most uranium to be of the nonrespirable particle size (ORAUT 2007a). Thus, incidents involving individuals working with uranium may have been considered low risk and not properly monitored. However, a number of tests with DU involved high kinetic impacts, explosions, and high-temperature burns, all of which would have led to extensive small particle volatization. Other examples of potential exposures to uranium are noted in the TBD on pages 75 and 76. Likewise, it is noted on page 96 of the TBD that workers handling weapons assemblies at weapons storage sites may have been exposed to unsealed uranium, especially before 1957.

Because no preservative was used in the sample collection bottles, the TBD notes that plating occurred. An acid wash would be required to collect the uranium that could have been plated out on the surface of the bottle during sample transport and storage. It is not noted in the TBD when this problem was discovered and how many years this may have been a problem. If an acid wash was not used and less uranium was collected, there would have been an underestimation of the amount of uranium uptakes for workers. This problem may also exist with the plutonium urine samples that were taken over the same time period, leading to a similar underestimation of plutonium uptakes.

Plutonium

While the site profile does address missed intakes for plutonium in the early years on page 67, it likewise states that the long-term excretion pattern of plutonium isotopes can permit plutonium intakes that produced bioassay results below the detection threshold to become detectable as the sensitivity of the analysis technique improved over time. The date of the intake may not be directly related to the last bioassay result below the detection level. Although this is all true, the workers may have had early plutonium bioassay results below the detection level, and then either terminated or retired without further sampling. Thus, significant early intakes of plutonium could have been missed in the dose of record.

Mixed Activation and Fission Products

It appears that whole-body and lung counting, as well as bioassay analysis, have been done for the most likely fission and activation products found at SNL since 1992. However, routine bioassay sampling appears to be limited to only several of these, and in-vivo counting done only in suspected incidents prior to 1992. It is not clear to SC&A whether termination whole-body or lung counts were done for individuals that had worked with fission or activation products prior to 1992. It is likewise unclear how dose reconstruction is to be done for workers potentially exposed to Sr-90. Section 5.2.5 (ORAUT 2007a) states that urinalyses are very sparse, that samples were apparently sent to an outside laboratory, and that dose can currently be reconstructed only when Sr-90 results are actually listed for an individual.

Other Radionuclides

The TBD acknowledges the presence of pure americium, thorium, neptunium, selenium, polonium, tantalum, and strontium, yet it is unclear how dose will be assessed to unmonitored workers from these radionuclides. The TBD indicates that radionuclides like Se-75 and tantalum can be detected in gamma spectroscopy of urine; yet gross gamma data are rare. There is no direction provided for how to assess unmonitored dose from thorium. The radionuclides and available bioassay techniques should be evaluated to ascertain whether bioassay coverage was available for all years of potential exposure. The presumption is that gross beta urine analysis can be used to detect mixed fission and activation products; however, gross beta results are minimal in the early years. In order to effectively assign unmonitored dose to workers, there must be a clear understanding of the time period radionuclides were handled or produced, either intentionally or as a byproduct or trace material, and who was potentially exposed. This should be evaluated against bioassay available at the time to ascertain whether there was coverage for these radionuclides. Air monitoring data is proposed in lieu of personnel monitoring; however, there are problems associated with the use of this data to bound internal dose to primary as well as secondary radionuclides (see Section 3.4).

In summary, SC&A finds that further evaluation is warranted for radionuclides handled at SNL by workers onsite and offsite to determine the extent of potential exposures, periods of exposure, quantities handled, and impacts on dose reconstruction to specific organs. Attempts should be made to evaluate archived bioassay data where it is available, and determine whether these data are complete and representative enough to develop a bounding or coworker dose. Appropriate methods for internal monitoring were not always available for all years of potential exposure. NIOSH/ORAUT should develop missed dose methodologies in the absence of monitoring data, based on available data, technical reports, and other sources of information, to ascertain potential exposure to non-traditional radionuclides. Additional consideration should be given to the exposure hazards associated with operation of accelerators, target handling, component activation and byproduct radiation.

3.6 LACK OF GUIDANCE PROVIDED TO SUPPORT DOSE ESTIMATION FOR OFFSITE WORK ACTIVITIES

Offsite activities and associated exposures are acknowledged, but the importance of involvement in these activities is underestimated. Offsite operations involving exposure to radionuclides that are not adequately treated in the TBD include the following:

- Assembly, disassembly, retrofit, and modifications to weapons in the field and at assembly plants
- Firing and arming of weapons for testing
- Radiation and weapons-effects testing
- Data collection activities during testing
- Verification of treaty compliance
- Response to international radiological emergencies

Early missions focused on research and development (R&D) for the weapons program and subsequent field testing activities. The missions involved considerable work off the SNL New Mexico site, as described by the TBD:

> *From 1945 to the present, SNL employees have routinely been involved in operations at a number of Sandia Corporation sites. These sites include Livermore, California; Hattiesburg, Mississippi; NTS, Nevada; Clarksville, Tennessee; and Salton Bay Station, California. SNL employees also routinely spent time at other DOE facilities…. SNL has also been responsible for surveillance of the nation's stockpiled weapons (Ullrich 1998). Since 1949 when weapons storage sites were opened and until 1967, SNL stationed staff at the storage sites to monitor, maintain, and assemble the weapons [7].*
> (ORAUT 2007a, pg. 54)

Dose reconstructors are cautioned in the TBD about potential offsite exposure (ORAUT 2007a, pg. 95):

> *Dose reconstructors should note any indication that a worker might have accompanied their equipment to a test site or a weapons storage site where the potential for intake could have been higher than at the SNL site where the design or fabrication took place. Also, SNL workers assigned to weapons storage sites may have handled unsealed materials (McConn 2006) and did not participate in*

> *bioassay monitoring programs at the storage site or immediately upon return to SNL (Argall 2007a).*

Information available for dose reconstruction, especially for workers involved in testing and special projects, is limited, inadequate, and sometimes not available. The TBD indicates that exposure data from other sites may not be available in the SNL radiation exposure file (ORAUT 2007a, pg. 95):

> *Dosimetry records from other sites are typically not included in the dosimetry records supplied for the SNL site. If records are not found, but exposure at other sites is indicated, then these records can be requested or site technical basis documents can be consulted.*

The treatment of dose reconstruction for offsite activities in the TBD is inadequate, given the limited availability of exposure data for offsite activities and the shortcomings in monitoring that may have been conducted at offsite locations.

Weapons and Components Testing and Monitoring

As previously mentioned, SNL workers were actively involved in weapons and components testing at various locations. In fact, SNL had test locations at the Salton Sea Base, the Tonapah Test Range, and Coyote Canyon. The TBD provides some information on weapons tests in Table 5-3; however, this is not all-inclusive of the test activities in which SNL was involved (ORAUT 2007a):

> *Table 5-3 lists some of the weapons tests and other related activities to assist the dose reconstructor in identifying terms that might be referenced in personnel records or the telephone interview* [Argall 2007d]. *Workers whose routine jobs did not involve work with nuclear materials could have encountered internal exposures while participating in weapons testing*.

SNL took a much broader role in weapons testing than the TBD indicates. Its involvement in testing included support to atmospheric, underwater, and underground tests. SNL staff first became involved in weapons testing during the Able and Baker tests for Operation Crossroads in 1946:

> *Z-Division began moving to Albuquerque in September of 1945, with the field testing organization leading the way and the final group arriving in February 1947…. The group immediately began testing to improve the Fat Man design, and initiated development efforts for the new Mk IV, the first new weapon designed in the postwar period. However, planning for Operations Crossroads, the first postwar nuclear test, interrupted this work. Held in the summer of 1946, Crossroads absorbed the attention of Los Alamos and Z-Division months before the actual tests*. (Ullrich 1998)

SNL participated in the evaluation of weapons effects at several atmospheric tests, including Operation Sandstone, Operations Ranger, Greenhouse, Buster-Jangle, Tumbler-Snapper, Upshot-Knothole, Castle, Ivy, Teapot, Plumbob, Redwing, Hardtack I, Argus, and Hardtack II. They participated in weapons effects studies from underwater detonation during Operation Wigwam. These operations occurred at the NTS and the PPG from 1948–1958. Arming and firing of test devices has been SNL's responsibility since Operation Greenhouse in 1951 (Banister 1994). The TBD's list of nuclear tests includes only Operation Crossroads, occurring in 1946, and Operation Sandstone, occurring in 1948, for the period of atmospheric testing.

The TBD indicates that SNL was involved in underground testing conducted between 1962 and 1973. SNL was involved in its first tunnel shot at NTS, the Rainer Shot, in September 1957, and continued its involvement until 1992. Detonations of devices in tunnels and drilled shafts focused on conducting effects tests to study the response of nuclear weapons to radiation. Other studies included ground motion, air pressure, and cratering phenomena studies. SNL continued its arming and firing function for Lawrence Livermore National Laboratory (LLNL) shots until the end of testing. SNL was also involved in a nonproliferation experiment in 1993 (Banister 1994).

Two SNL-sponsored tests, Cypress (February 12, 1969) and Camphor (June 29, 1971) were executed in G-tunnel. These tests were conducted to expose components and experiments to radiation, and determine the effects. Cypress was successful, but a containment failure occurred during the Camphor event, allowing debris to escape into the tunnel (Banister 1994).

SNL took an active interest in the Plowshare Project. In addition to tests conducted at PPG and NTS, SNL workers were involved in studies at Fallon, Nevada; Hattiesburg, Mississippi; Farmington, New Mexico; and Colorado. SNL took extensive free-field and surface ground motion measurements for the Milrow and Cannikin tests in Amchitka, Alaska, and provided arming and firing for Cannikin.

Other Offsite Activities

Many of the early component field tests were conducted at Salton Sea Base involved use of Joint Test Assemblies (JTAs). Johnson (1996) explains how these tests were conducted:

> *For quality assurance of the stockpile, a bomb was selected at random and taken from the stockpile. After removal of its nuclear core, Sandia replaced the core with a Joint Test Assembly (JTA) package that simulated the bomb's electrical functions and transmitted data on how it performed. Sandia then handed it to an aircraft crew for use as if during a combat mission. The crew flew to the Salton Sea and dropped the bomb on their own. The military service then evaluated the crew's accuracy while Sandia analyzed the bomb performance…. The range crew sometimes referred to these as JTA tests.*

The JTA package may have substituted DU for plutonium. As a result, consideration should be given to potential exposure at Salton Sea Base.

The JTA tests were continued at Yucca Flats and the Tonopah Test Range in Nevada. The TBD acknowledges in the site description that testing at TTR involved components containing DU. In 1962, Project Roller Coaster was initiated, which included a series of four nuclear weapons tests that resulted in plutonium dispersal in the surrounding soils. SNL conducted the Double Tracks test to investigate the impacts of one-point safety detonations on ground deposition. As a part of this test, burros, dogs, and sheep were exposed to respirable amounts of plutonium and uranium. Animal stations became contaminated not only from the detonation, but also from the contaminated urine and feces excreted by the animals, which contributed to potential plutonium exposure. Three Clean Slate shots were designed to compare weapons accidents in open storage, storage in igloos, and storage in igloos with earth covers. A minor animal experiment was done during Clean Slate 2. Clean Slate tests used plutonium during the detonation experiments, and high explosives coupled with uranium as a substitute for plutonium for other tests (NVO 1964). About 700 individuals investigated the abilities of weapons storage igloos to contain accidental blasts (Johnson 1996). Cleanup occurred following the shots, but further remediation of the area was required in 1996 to reduce the level of transuranic radionuclides in some areas to less than or equal to 200 pCi/g (Sanchez et al. 2001). Animal housing areas were particularly contaminated.

SNL participated in One-Point Safety Studies at Coyote Canyon and NTS. A series of nuclear device tests with DU were conducted in Coyote Canyon to study fallout and particle sizes from a variety of staged accidents. It is clear from the site profile and other operational histories that use of DU was prevalent at many of the test sites (e.g., TTR and Coyote canyon), and that tests involved repeated kinetic impacting, explosions, and high-temperature burns leading to extensive volatization of radiological material. This potential seems to be corroborated by whole-body count measurements taken by Hegelson in 1989 (HSS 1989), as cited in the site profile, where uptakes of DU and U-235 were noted (notwithstanding that low-level uranium urinalyses were often confounded by the elevated natural uranium levels in the local environment). This early work eventually led to Project 57 in 1957 and Project Roller Coaster in 1962 (Banister 1994). SC&A finds that further research is warranted on hydrodynamic and other field tests conducted at this location to better define exposure conditions.

Adequacy and Completeness of Dose Estimation for Offsite Activities

Several NIOSH documents indicate an inability to conduct dose reconstruction for specific activities in which SNL workers were involved. This is complicated by SNL's lack of monitoring upon return from offsite activities. SNL personnel worked side by side with Alaskan, Reynolds Electrical and Engineering Company (REECo), and Pacific Proving Group (PPG) workers during atmospheric, underground, and underwater testing. NIOSH has identified problems with dose reconstruction for PPG (SEC-00020, Harrison-Maples 2005) and NTS (SEC-00055, Harrison-Maples et al. 2006). In their evaluation of the feasibility of completing dose reconstruction for employees working at the PPG from 1946 through 1962, NIOSH clearly indicates that workers had the potential for internal exposure (Harrison-Maples 2005):

> *The principal potential source of internal radiation doses for members of the class would have been inhalation or ingestion due to contamination caused by the fallout from the nuclear detonations.*

Furthermore:

> *Fallout associated with some of the detonations, both on the land surface and in the water, was a potential source of internal exposure. The possibility existed for inhalation and ingestion of radiological particles during a fallout event as well as exposure to re-suspended fallout remnants at some later date. Radiological particles on the land surface could potentially have been disturbed and re-suspended by wind, personnel traffic through contamination areas, construction activities disturbing contaminated soil, or by decontamination efforts, and been inhaled or ingested by personnel operating in contaminated areas (Harrison-Maples, 2005).*

SEC-00020 indicates that due to lack of data, it was not feasible to perform reconstruction of internal dose from inhalation of radionuclides at PPG:

> *NIOSH finds that the external monitoring records and operational histories available are sufficient to complete external dose reconstruction for these employees, with the exception of neutron exposure, which was not fully evaluated. Existing NIOSH procedures could be used to estimate possible occupational medical exposures. However, NIOSH lacks access to source term data, bioassay or internal monitoring data to estimate internal doses associated with potential inhalation of radionuclides.*

The same potential for internal exposure also existed during the atmospheric tests at the NTS. SEC-00055 (Harrison-Maples et al. 2006) further indicates that calculation of internal dose is not feasible:

> *Consequently, based on the available data, NIOSH is unable to estimate with sufficient accuracy internal exposures and resulting doses for the class of employees covered by this evaluation. The initial class for which feasibility was considered by NIOSH in response to SEC Petition SEC-00055 comprised laboratory assistants who worked at the NTS from January 27, 1951 through December 31, 1962. The basis for the infeasibility of dose reconstruction for the petitioner's specific claim was the inability of NIOSH to adequately address potential exposures associated with the changing and undefined source term during multiple atmospheric tests at the NTS. While it is very likely that individuals in the forward areas during atmospheric nuclear testing would have received exposure exceeding those of other groups of workers, NIOSH is unable to determine which workers were or were not potentially exposed to the changing radiological conditions during atmospheric nuclear testing.*

The current class definitions for the PPG and NTS SECs specify DOE employees, contractors or subcontractors who were monitored, or should have been monitored, at PPG and NTS, respectively. Although SNL scientists and staff were actively involved in testing operations along with those employed at PPG and NTS, it is unclear in the SNL TBD how such offsite exposures are to be addressed under these circumstances. Furthermore, later testing eras are still being evaluated as part of the NTS SEC petition review. Participation in these events could have led to significant internal exposures for some SNL workers and should be thoroughly considered in the SNL TBD.

In summary, SNL took an active role in conducting weapons effects, ground motion, air pressure, crater phenomena, and other studies during the testing of weapons. SNL workers were responsible for the arming and firing of weapons from 1951 through 1992. They were responsible for monitoring, maintaining, and assembling weapons at storage sites. A recharacterization of the extent of SNL involvement in weapons testing and other offsite activities (e.g., research on hydrodynamic testing, treaty verification, assignments to other DOE sites) should be completed. Offsite activities related to the weapons and components testing, surveillance, in-field retrofit and modifications, treaty verification, and managing storage sites and their corresponding monitoring programs have not been adequately addressed in the SNL TBD. This is confounded by the absence of offsite data in the SNL exposure files and the lack of direction to the dose reconstructors on when to request data from other sites.

While it is understood that NIOSH under EEOICPA protocols establish work location, including work at other AEC or DOE sites, to enable dosimetry records to be obtained, it is not clear from the SNL, NTS, or PPG site profiles how visiting SNL employees were monitored for neutron and internal radiation exposures. Internal and external exposure hazards during field testing require further consideration to determine if appropriate internal and external monitoring occurred. If adequate monitoring did not occur at these offsite work locations, the TBD does not provide instructions for bounding these potential exposures. A missed dose methodology should be included for unmonitored or inadequately monitored workers who participated in weapons testing and other field activities. Where available, references to other site profiles are appropriate. Methodologies for activities at continental tests outside of Nevada require treatment in the site profile, a separate site profile, or a TIB.

3.7 THE MAXIMIZING AND BEST-ESTIMATE INTAKE PARAMETERS FOR TRITIUM MAY NOT BE APPROPRIATE

The potential for tritium exposure in multiple forms existed at SNL. Tritium is a radionuclide with wide historical and current application at SNL. It is also encountered as a significant contaminant on tools, parts and surfaces, and targets. Table 5-1 of the TBD indicates tritium use in Buildings 891, 884, 807, 844, and 819, Technical Area (TA)-II and TA-III, the Particle Beam Fusion Accelerator (PBFA)-II, the Sandia Accelerator and Beam Research Experiment (SABRE), the Annular Core Research Reactor, Hot Cell Facility, and the SPR. Tritium was (and is) encountered in several forms; tritiated water (HTO), tritiated gas (HT), organically bound tritium (OBT), and metal tritides (MTs).

Unclear and sometimes conflicting instructions are provided to dose reconstructors regarding tritium dose assignment. Page 96 of the SNL TBD states the following:

> ***Chronic intakes of tritium are possible and not uncommon as shown in the summary of 1989 tritium bioassay results by Hallman (1990)*** *—"several workers had bioassay results between 10 and 74 μCi/L in 1989." — These*

> *maximum results can be used to determine overestimating doses for unmonitored workers.* ***However, there is no evidence to suggest that workers with potential for tritium intake were not monitored****.* [Emphasis added.]

Monitoring frequencies were established such that acute uptakes of HT and HTO could be missed. Potential tritium uptakes are assumed to be from HTO, when exposures actually may be from special tritium compounds (STCs). Tritium urine sampling began at SNL in 1949 (Argall 2007b). Although tritium urinalysis existed, urine sampling for tritium was done quarterly. This is ineffective and inadequate in many cases for tritium uptakes in the form of HT or HTO, because the effective half-life in the body is substantially shorter than 3 months. A weekly sampling frequency is typically recommended for exposed workers in order to capture acute intakes. The urine bioassay data for tritium dose reconstruction is thus very suspect and may be of little value for use by the dose reconstructors, given the relatively short biological half-life of tritium in the body.

In the absence of bioassay data, the worker is assigned the maximum dose as determined by a set of tritium bioassay results from several workers in 1989 and after. The representativeness of these workers, as compared with all workers exposed to tritium, is not discussed in the TBD. As an alternative to bioassay sampling, the TBD recommends the use of air sampling. ORAUT-TKBS-0037 (ORAUT 2007a, pg. 94) states the following:

> *Maximum and average airborne contamination levels for selected buildings are listed in Table 5-29. Examples of incidents and intakes are listed in Table 5-32. Average airborne contamination levels either are derived as simple averages or are reported as averages listed in reports. Simple averaging is assumed for SNL reports, but no information on the methods used to obtain these reported averages is available.*

The problems of simple averaging have been addressed in Issue 3.4 regarding the use of air sampling data. Likewise, this approach appears to be inappropriate for maximizing and best-estimating tritium intake, particularly when one looks at the tritium contamination levels in Buildings 642, 805, and 806, and statements made in Section 5.2.3, page 72, of the TBD (ORAUT 2007a):

> *Smear surveys of Building 642 in 1972 indicated significant tritium contamination on tools and target area parts. Some smears indicated more than 5×10^6 dpm of tritium on parts and surfaces, especially those related to the target. Contamination was also found on the floors of the area. Buildings 805 and 806 are also a potential source of intakes — "Smearable tritium of 2000 dpm or less was considered a clean area.*

The TBD further states on page 74 that for tritium intakes, an administrative control was established for individuals with urine bioassay of 20 μCi/L (which represented approximately 0.25 rem or 1/20 of the 5 rem annual dose from AEC requirements). Workers who exceeded this administrative control would have been excluded from tritium work until they reached 10 μCi/L. Is this administrative control an arbitrary value established by SNL? Does this mean that 10 μCi/L is the chronic missed dose that NIOSH will be using for all tritium workers and security inspectors that used tritium sights on their M-16 rifles? The approach provided for assigning tritium dose for monitored workers at LLNL (ORAUT 2007a, pg. 74) appears logical, but it is not clear if this will be the assigned chronic dose for SNL employees working in tritium areas.

The TBD directs the dose reconstructor to assume HTO in the absence of compound specific data or work area. The TBD refers the dose reconstructor to specific guidance provided in *Tritium Calculations with IMBA* (NIOSH 2003), when the dose records indicate an exposure to tritium labeled compounds. Additional guidance is available in *Calculation of Dose from Special Tritium Compounds*, OTIB-0066 (ORAUT 2007b), and *Technical Information Bulletin: Tritium Calculations and Missed Dose Estimates*, OTIB-0011 (ORAUT 2004d).

Urinalysis techniques were the same for all forms of tritium, including STCs. Tritium in metal hydrides is a special chemical form for tritium, also called MTs. MTs are somewhat insoluble forms of tritium compounds (Inkret et al. 1999, Cheng et al. 1997) that do not exhibit similar biokinetic behavior to the more common forms of tritium, such as HTO or elemental tritium. Tritium from MTs does not enter the systemic compartment as quickly as HTO after inhalation and, therefore, the interpretation of tritium urine bioassay data cannot be treated with standard tritium excretion models (McConville and Woods 1995). Due to being relatively insoluble, inhaled MTs deliver the highest component of dose contribution to the lungs. Tritium from these particles also can convert to OBTs from contact with lung tissue and further complicate the metabolic process (DOE 2004). The analysis for metal tritides has been shown not to be detectable by the analytical methods used for HTO, and thus the missed dose or overestimating assumption potential for tritium would be much greater than that given as guidance for dose reconstructors on page 74 of the site profile.

The main types of OBTs found are tritiated solvents, tritiated oil, and solid particulates (e.g., organic dust, plastics, etc.). The dose from intakes of OBTs can be different than HTO intakes of the same activity and is dependent on the specific chemical compound in which the material is bound. The effective dose equivalent per unit uptake has been estimated to be two times larger for OBT than HTO (DOE 2004). OBTs in the form of solid particulates reside in the lungs for a longer period of time, resulting in higher dose to the lungs. ORAUT-OTIB-0066 (ORAUT 2007b) states that "a Type 1 calculation underestimates systemic dose approximately 30% for intakes of OBT because half of the intake is not uniformly distributed in the body-water space." In the recommendations from ORAUT-OTIB-0066, it is stated that this method (from ORAUT-OTIB-0011, ORAUT 2004d) can be used without modification to calculate doses from intakes of OBTs to all organs and tissues, which appears to be unfavorable for claimants if it underestimates systemic dose by approximately 30%. More information on how prevalent OBTs are in the SNL work environments should be gathered, and consideration given to the potential difference in resulting dose.

The dose consequences from STCs may be significantly larger than those from HTO; therefore, dose reconstructors need to be familiar with the special tritium compounds handled, the quantities of material, the locations and time periods of potential exposure, and the physical behaviors of tritium compounds in the environment (e.g., conversion to HTO, formation of rust) to correctly characterize tritium exposure. Furthermore, they should be made aware of the characteristics of STC excretion in urine to enable them to distinguish between STCs and tritiated water or gas, at least in some cases.

Bounding techniques proposed in ORAUT-OTIB-0066, *Calculation of Dose from Special Tritium Compounds* (ORAUT 2007b), cannot be effectively developed and applied without some basic understanding of the compounds handled and the extent to which individuals were exposed. From the recommendations in ORAUT-OTIB-0066, it is stated that "the selection of the appropriate tritium compound in an intake evaluation must usually be based on process knowledge of the source terms in the workplace." It is important that the dose reconstructor chooses claimant-favorable forms of tritium for the dose estimation if there is a lack of process knowledge about the form that may have been involved with exposures. The dose to the lung from intakes of MTs can be underestimated by orders of magnitude if it is incorrectly assumed that the dose can be calculated with the methods used for HTO (ORAUT 2007b).

3.8 ENVIRONMENTAL SOURCE TERMS ARE INADEQUATELY CHARACTERIZED FOR USE IN PERFORMING THE EXPOSURE ASSESSMENT FOR AIRBORNE EMISSIONS

The environmental exposure calculations used for assessing intakes of airborne radionuclides provided in the SNL environmental dose TBD, ORAUT-TKBS-0037 (ORAUT 2007a), used source term data that may be inaccurate, incomplete, and not claimant favorable. There are periods of time for which NIOSH could not find any emission or environmental monitoring data to calculate the actual air concentrations that to which unmonitored workers could have been exposed. The methods that NIOSH used to assign intakes for some of these areas were not clearly explained, and in some cases when the methods were explained, there is a question on the validity of the assumptions used. For some areas of environmental exposure, NIOSH appears to have left out potentially significant radionuclides in the assessment of environmental dose.

In Section 4.2.1 of the TBD (ORAUT 2007a), NIOSH appears to rely on site environmental monitoring reports (Millard et al. 1984) for tritium release information, but it appears these reports are not always clear on whether or not releases occurred. In Table 4-4, the TBD assumes that constant 3E+03 Bq intakes occur each year from 1948–1972 in TA-I and TA-II, because NIOSH could not find any monitoring data for this period and therefore used the average for all monitored data collected afterwards. This table shows that intakes for 1978 and 1979 were 6E+4 and 7E+4 Bq, respectively; this is 20 to 25 times higher than the 1948–1972 assumed annual intake level. This indicates the potential for significant variable releases and intakes, and further discussion is needed on why these could not have occurred in the earlier years. For years from 1980 through 1995, Table 4-4 shows very low tritium intakes for TA-I, TA-II, and TA-IV. This appears unusual with intakes being much higher in the preceding and following years, and discussion is needed to support this.

The TBD does not discuss the potential for source terms that could cause environmental exposures from the operations in Thunder Range within the Coyote Test Field. Table 2-2 of the TBD identifies that there were fire and explosion tests at this location and that DU was the major radionuclide in the area. If these tests did use DU, there is some probability that contaminated soil could have been at this area which could get resuspended and expose personnel through the air pathway. In particular, high temperature burns and explosions would have generated volatized small particle DU that would have been widely dispersed and respirable to nearby workers.

The development of the intake estimates for TA-III is not described in significant detail and the assessment for this area appears somewhat arbitrary. The TBD states that there was no emission monitoring for the area before 1973, and it identifies that there were diffuse sources of airborne radionuclide releases. The TBD does not state how it estimated the air concentrations that caused intakes in this area. There is no discussion on any air monitoring in TA-III for emissions from waste landfills after 1973. If resuspension modeling of contaminated soils was used to estimate the air concentrations, detailed information about the resuspension factors and levels of soil contamination assumed needs to be presented.

An available environmental monitoring report that covers earlier years at the site (Brewer 1973) states that the Sandia Engineering Reactor (SER) in Area V, a 5 megawatt (MW) research reactor that was water cooled, had a liquid waste disposal system (LWDS) that connected to a drain field and later to an evaporation pond. There is no discussion on the final disposition of the drain field and pond, such as remediation and disposal of the contaminated soils that must have been left. This situation could have left contaminated soil with resuspension potential for this area that could have also affected TA-III, because TA-V is within the boundary of TA III. It is not apparent that NIOSH accounts for this potential source of environmental exposure in the TBD. This report states that a soil, water (including potable water wells), and vegetation sampling program started in 1959. It also states that starting in 1969 soil sampling was done in the Area 3 radioactive waste site areas and Area V liquid waste disposal pond. This further suggests a soil contamination resuspension issue. Another issue regarding the environmental intake estimates for TA-V is the lack of the gaseous fission products from 1961–1966 shown in Table 4-6. These were years that the SER and SPR Facility were operating and Table 2-2 in the TBD shows it is likely for these reactors to produce “reactor-produced” radionuclides similar to the Annular Core Research Reactor (ACRR), so it is not clear why the start up of the ACRR in 1967 was the initial and only source of the gaseous fission products assumed by NIOSH.

Section 4.3, “Radionuclide Screening SNL New Mexico,” (ORAUT 2007a) states that no effluent monitoring information is available before 1973. The environmental report covering 1964–1972 (Brewer 1973) states in a footnote: “Stack release data available on AEC Form 789A submitted annually.” It is not apparent that NIOSH has made an effort to retrieve this stack monitoring data. It also is apparent that NIOSH may not have reviewed any of the environmental monitoring data (ambient air, soil, vegetation, water) that may be available for these years because this data is not discussed in the TBD (only post-1980 environmental TLD data for ambient external exposure is discussed). If these data are available to NIOSH, it is likely that the estimates of exposures and intakes NIOSH has developed for these years could be presented with more certainty if the data was reviewed.

There is no discussion in the TBD regarding fugitive emissions that could have given rise to environmental doses. The Tiger Team inspections (Smith 1991) made a finding stating that the air quality management program needed to add a requirement for the line organization to minimize fugitive emissions wherever possible, and develop a standard operating procedure for the control of fugitive emissions. Therefore, it can be assumed that there may have been some activities that released airborne radionuclides as fugitive emissions having exposure potential which could only have been accounted for through ambient air monitoring or a resuspension model because the source was not monitored at the point of emission.

Section 2.4.6 of the TBD describes the activities at the Tonopah Test Range (TTR), and identifies tests involving components containing depleted uranium (DU). It also states that "there is some evidence of DU contamination at the site." DU is not considered by NIOSH in the environmental dose source term at TTR in this TBD, and there is no discussion why it is not considered. NIOSH estimates the radionuclide intakes for all years at TTR going back to 1963 using air monitoring data from 1996–1997, which analyzed for Pu isotopes and Am-241. Proposing that it is reasonable to assume the air concentrations were similar in the earlier years may not be accurate when considering that soil radionuclide concentrations and resuspension rates could be different due to weathering of the soil. In the LANL Occupational Environmental Dose TBD ORAUT-TKBS-0010-4, Rev. 00 (ORAUT 2004c), it is stated that soil with older contamination (such as the soil at TTR in 1996–1997) is less of a resuspension issue than soil recently contaminated (such as in the earlier years at TTR) because erosion and downward migration of radionuclides from the upper soil layers diminish the source term over time.

In Section 4.5.1 of the TBD (ORAUT 2007a), NIOSH states that the 1991 Tiger Team assessment questioned emission monitoring adequacy. The site's response was to eventually improve monitoring systems, leading to increased reporting of effluents, with the increasing trend continuing through 2004. This infers that earlier monitoring data (before the 1990's) may have been lacking some emissions reporting. It is not apparent that NIOSH has assessed the impact that inferred incompleteness and inadequacy of the earlier monitoring data could have had on the emissions estimates. This section of the TBD also states "years with data vary by facility, but the most complete information is available for 1991 and later." NIOSH typically used facility-specific averages to fill in these data gaps. This approach assumes that effluent controls (such as filters, height of stacks) and workloads were similar throughout these periods. It is not clear that NIOSH verified the appropriateness of these assumptions for using the approach of extending averages during periods of data gaps.

3.9 THE ENVIRONMENTAL EXTERNAL DOSE COMPONENT IS DEVELOPED WITH INADEQUATE JUSTIFICATION AND MAY BE INCOMPLETE

The assignment of the environmental external doses from TLD data does not have a clear basis, and is not supported with any apparent analysis of background and onsite environmental dosimeters to accurately determine if there were higher levels onsite. There is no discussion detailing the dosimeter locations that were placed on site and whether these were representative for estimating unmonitored worker dose. Assessment of possible doses from radioactive particles on skin is missing, in disagreement with discussion in the Scope of the TBD (ORAUT 2007a, Section 1.2) which identified this as being covered in the environmental dose section.

The TBD states that external radiation dose information for SNL is available for 1980 to 2004. Reported doses for 1980 to 1985 and 1993 to 1999 were reported as site averages plus one standard deviation without identification of doses at specific monitoring locations. This leaves a lot of periods and locations requiring estimation of external doses without directly applicable data. The TBD assigns "< 1 mrem/yr" for environmental external dose in TA I and TA II from 1948–1979 without any discussion or defense of this determination. For other periods the TBD assigns 5 mrem/yr (TA-I, TA-II from 1980 to 2004, TA-III from 1961 to 2004) or 10 mrem/yr (TA-IV from 1980 to 2004, TA-V from 1961 to 2004) and states that this is claimant favorable without further discussion. Using environmental TLDs to determine an above background dose from emissions/radiation fields can be difficult if the detected levels are similar to background stations (choosing an appropriate background station is potentially difficult because of the need for similar background source factors—soil, geology, altitude). An example of data that challenges the assessment by NIOSH is available in the 1986 Environmental Monitoring Report (Millard et al. 1986). Table 4 in this document gives an onsite environmental TLD range of 88–153 mrem annually. The range for the offsite environmental TLDs was 77–99, which could be assumed to represent the regional background dose. Averages were 108 for the onsite TLDs and 89 for the offsite TLDs. This data appears to indicate that onsite doses above background could have been more than 10 mrem.

Regarding radioactive particles on skin of unmonitored workers that could give a high localized skin dose, NIOSH does not appear to address this in the environmental dose section, although it is stated to be covered in this section according to the scope of the TBD (Section 1.2). Depleted uranium was handled at both SNL (New Mexico) and SNL-TTR, per statements in the TBD, and because it is often in soil contamination left from explosives testing, it can be a source of radioactive particles on the skin due to becoming airborne from resuspension. The U-238 component of DU can impart a significant dose to the skin and shallow tissue near the particle from the strong beta radiation emitted by its progeny Pa-234m. This type of exposure is discussed thoroughly in *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium* (Battelle 2006).

3.10 CRITERIA FOR BADGING WORKERS WERE NOT DEFINED

ORAUT-TKBS-0037 (ORAUT 2007a) does not provide any information concerning the criteria for badging workers at the SNL during the period 1949–2007. The criteria that were used to determine who was badged, for what type of exposure (i.e., photon, beta, and neutrons), and how the badging policy varied as a function of work location/facility and time needs to be addressed in the TBD for dose reconstruction purposes and to assist in determining if the coworker data presented in the TBD is valid. Based on interviews with SNL health physics personnel (see Attachment 2), line managers in each department made the decision regarding which workers were badged or bioassayed, leading to issues of consistency between SNL departments and over time. Dose data for badged workers with ≥50 mrem of penetrating gamma dose is provided in Table 6-4, and for non-penetrating dose, it is listed in Table 6-5 of the TBD. However, it is not presently known if this data is representative of all workers at SNL at all locations for each year listed. This data could represent only highly exposed workers, average workers, cohort badging, or even random badging during some periods.

In the present TBD, the dose reconstructor is not provided with sufficient information needed to determine if a claimant should have been monitored and was not, or if a claimant was not monitored because the worker was located in a non-radiation work area and did not need to be monitored. Additionally, the badging policies as a function of time and location need to be further separated into photon, beta, and neutron badging criteria. A thorough review of this topic is needed in the SNL TBD to provide guidance to the dose reconstructor for reasonable dose assignments.

3.11 LACK OF DOSIMETRY RECORD INFORMATION

Throughout the Occupational External Dose section of ORAUT-TKBS-0037 (ORAUT 2007a), the dose data records are referred to as containing the necessary and correct dose for exposed workers throughout the entire period from 1949–2007. However, except for the brief statement on page 99 concerning the electronic file records created since 1986, there is no mention of the actual dose records; the dose information they may or may not contain (i.e., if neutron and photon components were recorded separately, or if only the total penetrating dose was retained during certain periods, as was the practice at some of the labs); the different recording systems (such as the change-over from handwritten to computerized records); and different recording methods/programs used after switching to electron data storage.

The major areas of concern are as follows:

Data Integrity and Completeness

Verification of data during transfer between systems (i.e., comparison of original records to electron data systems) is needed to ascertain the integrity of the dose data that will be used in dose reconstruction, and also for the coworker dose data. Additionally, no mention is made in the TBD concerning data completeness, i.e., there must be some methodology established to assure that all records were transferred during each system change-over. These are data accuracy issues that must be addressed to determine if the dose data contained in the current records are a correct representation of the original data recorded.

Meaning of Different Dose Terms

The form in which the data was recorded is important. For example, if the neutron and photon penetrating doses at SNL were sometimes combined and entered as one value, it will make it difficult for the dose reconstructor to separate them out for individual dose assignments in the IREP Input tables. In the 1960 AEC Report (AEC 1960), the only listings are "Total Body," "Total Wrist," and sometimes only "Total." There is also an apparent conflict regarding the use of dose terms on page 99 of the TBD, where it states that starting around 1971, the Whole Body Dose = Deep Dose + Neutron Dose. However, to arrive at the n/p value of 0.36 in Table 6-9 of the TBD, one must assume that the deep dose data (Column K) in Widner 2006c, Tab "All DD >49," contains the total of the neutron *plus* the photon dose, as illustrated in Table 2.

Note that it must be assumed that the deep dose value contains both the photon *plus* the neutron doses instead of just the photon dose in this case; or, if the Deep Dose contains only the photon dose value, then the values in Table 6-9 of the TBD are not correct, i.e., the n/p geometric mean (GM) would be 0.25 instead of 0.36.

Table 6-4 uses the term "penetrating dose" in the title and lists "gamma dose" in the column headers. However, when looking at the detailed data lists [Widner 2006a and associated spreadsheet, Widner 2006c, Tabs "87" through '05"][2], it was found these values were take from the deep dose (column K), which, as demonstrated above, appears to contain photon *plus* neutron doses and would not be appropriate for use in determining coworker gamma (photon) dose. Additionally, the data contained in the currently available reference Widner 2006a (and associated spreadsheets Widner 2006b, 2006c, 2006d, and 2006e) do not contain a data sheet for 1985 or any useful data for 1986. Table 6-5, however, lists *gamma* dose values for these two years.

Table 2. Calculation of 1987–2005 Neutron-to-Photon Values for Table 6-9 of TBD

Year	Deep Dose	Neutron Dose	p=(DD-N)	n/p
1987	**1310**	160	1150	0.14
1991	**1230**	110	1120	0.10
1992	**924**	135	789	0.17
1987	**880**	160	720	0.22
1991	**804**	113	691	0.16
1990	**786**	100	686	0.15
1987	**730**	120	610	0.20
1988	**970**	400	570	0.70
1989	**651**	112	539	0.21
1988	**760**	290	470	0.62
1988	**720**	300	420	0.71
1988	**500**	150	350	0.43
1989	**373**	120	253	0.47
2005	**396**	168	228	0.74
1987	**430**	290	140	2.07
1987	**320**	210	110	1.91
			GM=	**0.36**

Shallow and Nonpenetrating Dose

It important to determine what meaning the terms *Shallow* and *Nonpenetrating* dose had when they were entered into the original data sheets, and how they were defined in each data system as they were transferred between data systems. Table 6-5 on page 100 of the TBD uses both the term "nonpenetrating' and "shallow." Additionally, it covers only the period of 1977–2005, and does not contain data or instructions for the dose reconstructor concerning the values to use for assigning nonpenetrating coworker dose for the period 1949–1976, when nonpenetrating doses were not measured and/or recorded. The data contained in the currently available reference Widner 2006a and associated spreadsheets Widner 2006b, 2006c, 2006d and 2006e do not contain a data sheet for 1985 or any useful data for 1986. Table 6-5, however, lists *nonpenetrating* dose values for these two years. Random checks of data values in the reference,

[2] Thomas E. Widner performed these analyses whle employed as a contractor to the Oak Ridge Associated Universities Team (ORAUT).

Widner 2006a, and associated spreadsheet Widner 2006c, indicate that these references do not contain all the data entries used to create Table 6-5 for 1985–2005. Attempts to duplicated values in this table from the data sheets lead to a lower number of entries found in the data sheets than are listed in the table. For example, for 1987, the table lists 138 workers with a mean dose of 370 mrem, but Widner 2006c, Tab "87," only lists 114 workers with a shallow dose ≥50 mrem and with a calculated mean dose of 428 mrem.

Dose terms should be consistent and defined when used in the TBD, and the TBD should investigate their meanings when they were used in the different record systems and provide this information for use by the dose reconstructor. A small amount of information concerning dose recording terms is provided in the TBD on pages 98, 99, and 104. However, this information may not be sufficient to provide the dose reconstructor with the tools necessary to sort out the details of the dose data contained in a claimant's records.

Background Subtraction

An issue not addressed in the TBD was if SNL's dosimetry practice was to subtract background badge readings from the workers' badge readings before recording the final dose. This issue is important to the dose reconstructor when determining if environmental external site doses should be assigned.

3.12 INSUFFICIENT ANALYSES OF RADIATION FIELDS, DOSES, AND UNCERTAINTIES

ORAUT-TKBS-0037 (ORAUT 2007a) does not cover the subject of photon and neutron radiation energy fields and associated doses/uncertainties as a function of work location and time periods sufficiently to allow the dose reconstructor to accurately assign dose.

Energy Calibration

Some information concerning the expected energy ranges is provided in the TBD in Table 6-8 for beta/photons and in Table 6-11 for neutrons. However, except for the period 1959–1971 for beta/gamma calibration listed in Table 6-1, the TBD does not specify what photon calibration energies were used for different locations at the SNL and how these changed with time. Neutron calibration is only mentioned in Table 6-2 for Nuclear Track Film Type A (NTA) film, but NIOSH recommends not using NTA data; therefore, no relevant neutron calibration information is provided.

Neutron-to-Photon Ratio Values and Application Dates

The text in the TBD (ORAUT-2007a, page 104) indicates that the following:

> *There should not typically be significant neutron dose exposure of unmonitored workers. However, if estimation of neutron dose is called for, the recommended option is to apply the neutron-to-photon distribution data from Table 6-9 to measured or estimated missed or unmonitored photon doses.*

NIOSH states that one n/p value (0.39, cited on page 104, Table 6-9) (Widner 2006d) was determined by evaluation of worker neutron doses from 1977 to 1984 data (38 annual records). NIOSH considers this to be representative of the dose to workers in the 1949–1976 time period. NIOSH has not provided enough additional dose data beyond the 38 annual records to validate that this assumption is correct. NIOSH further states the following:

> *This process of calculating a neutron dose is based on the assumption that the distribution of neutron doses to unmonitored workers is equivalent to the distribution of neutron doses measured for monitored workers.*

Again, NIOSH has not provided enough validation data to document this assumption. The text also does not adequately validate that one n/p value (0.36) obtained from 1987 to 2005 data (16 annual records) is applicable and sufficient for the period from 2005–2007 (Widner 2006a). This is too large a time period for varied neutron exposures in various locations and conditions, especially using 1977–1984 data for early 1949–1976 workers. There is no evidence provided in the TBD to support the assumption that these 38 records from an 8-year time span, coupled with 16 records during a 19-year time span (usable data points available from only 7 of these 19 years, as noted below), accurately reflect the n/p values the workers were exposed to, considering the many changes that took place in operations, source terms, shielding, and radiation protection practices.

For the period 1949–1986, 38 annual records were used to calculate the n/p value of 0.39 based on 1977–1984 data, as these were the years that had both reliable neutron (from TLD readings) ≥100 mrem and photon doses ≥100 mrem. The number of data points used in each year is listed in the following table:

Table 3. Calculation of 1949–1986 Neutron-to-Photon Ratio Values for Table 6-9 of the TBD

Year	# of records
1949–1976	0
1977	12
1978	3
1979	7
1980	5
1981	2
1982	4
1983	2
1984	3
1985	0
1986	0
Sum =	***38***

This shows that only 8 years of data was used to calculate n/p values to cover a time span of 38 years of operations.

Not only are data from relatively short time intervals used to cover wide time spans, but examination of the details of the dose data used to create the n/p value of 0.36 for 1987–2005 listed in Table 6-9 of the TBD shows an even narrower period of usable data. Sixteen annual records were used to calculate the n/p value of 0.36 based on 1987–2005 data, but only the years 1987–1992 and 2005 had usable data (i.e., had both neutron and photon doses ≥100 mrem). Therefore, while it is true 19 years (1987–2005) of data were analyzed, only 7 years of data were used to cover this time period. The number of data points used in each year is listed in the following table:

Table 4. Calculation of 1987–2005 Neutron-to-Photon Ratio Values for Table 6-9 of the TBD

Year	# of records
1987	5
1988	4
1989	2
1990	1
1991	2
1992	1
1993	0
1994	0
1995	0
1996	0
1997	0
1998	0
1999	0
2000	0
2001	0
2002	0
2003	0
2004	0
2005	1
Sum =	***16***

MDL Values for Early TLDs

Section 6.5, page 102, second paragraph, of the TBD (ORAUT 2007a) states that “Because of the lack of site-specific data on MDLs for the early TLDs used 1971–1990, these dosimeters are estimated to have had MDLs between those for the film badges and the more advanced TLDs.” Additionally, footnote c of Table 6-10 on page 105 states that “Because of the lack of site-specific data on MDLs for the early TLDs used 1971–1989, these dosimeters are estimated to have had MDLs between those for NTA film and the more advanced TLDs.” These assumptions need to be supported by documentation, especially in view of the fact that the NTA film data is not considered reliable and will not be used.

Missed versus Unmonitored Neutron Dose

Page 105 addresses missed neutron dose (MND), based on LOD, but goes on to describe **when** (not **how**) to assign MND. To be consistent with other DOE site TBDs, the worker should be assigned MND by use of [n/p × p] whenever the worker was badged for neutrons, even if there is a zero or <LOD reading. If the worker was badged, a recorded or MND should be assigned; the dose reconstructor should not have the option of deciding if neutron dose should be assigned if the worker was badged for neutrons. Additionally, the worker should not be assigned MND or missed photon dose (MPD) when unmonitored, but where he could have been exposed.

Missed dose (as defined by NIOSH) is to be assigned to **monitored** workers, due to the limits of the dosimeter or recording practices, not to unmonitored workers who were not wearing a dosimeter; a missed dose cannot be associated with a worker not wearing a badge. A worker that was not monitored, but should have been monitored, should be assigned a valid **coworker** dose. The TBD (ORAUT 2007a) goes on to state that "For periods before 1971, distribution of n/p values from Table 6-9 should be applied to the **recorded** gamma doses to estimate **missed** neutron doses. Table 6-10 lists the neutron missed dose for those exposed to neutrons." [Emphasis added.] Applying the n/p value to **recorded** dose provides a neutron dose based on a measured dose, not an MND based on the dosimeter's photon dose MDL. Therefore, this apparently should read "…to estimate **unmonitored** neutron dose…," not **missed** neutron dose. Unmonitored and MND appear to be intermixed in Sections 6.7 and 6.8 of the current TBD, which may make it difficult for the dose reconstructors to use consistent and correct methods to assign unmonitored and MNDs.

<u>Uncertainty values</u>

Section 6.4, page 101 of the TBD, contains some information concerning bias and uncertainty factors. It appears from the first paragraph that the recommended photon error is ± 30% for all energies and all dosimetry systems. However, it goes on to list other photon dose uncertainties in Table 6-6. It is not clear in the current TBD if the dose reconstructor is to use the ± 30% uncertainty factor for photon doses, or some combination of the uncertainty factors listed in Table 6-6. Additionally, it is not clear what final uncertainty value NIOSH is recommending the dose reconstructor use for neutron doses as a function of time period; i.e., values for *overall bias*, *range in bias*, *systematic*, and *random uncertainty* factors are listed, but no combined final values for the dose reconstructor to use are provided.

When determining some of the values in Table 6-6, the TBDs for Hanford (ORAUT 2004a) and Argonne National Lab - East (ORAUT 2006b) were cited as references for beta/gamma film, TLD, and NTA film data. However, no information was presented in the SNL TBD to substantiate using these other facility values for SNL. Additionally, Table 6-6, page 101, and Table 6-10, page 105, list data for NTA film. However, page 101 and 105 recommend using the n/p method to determine measured and MND. It could be assumed that NIOSH included the NTA film data for completeness, but does not intend that it be used by the dose reconstructor in reconstructing doses in actual cases; but this is not stated in the TBD and could be a point of confusion for the dose reconstructor.

3.13 SECONDARY ISSUES

3.13.1 The Site Profile Table 5-24 is of very Limited Value and it is Uncertain why the MDA for the Whole-Body Counting in Table 5-24 is approximately Twice as Big in 2001 as it was in 1994.

Table 5-24 on page 85 of ORAUT-TKBS-0037 (ORAUT 2007a) is of very limited value, as it is based on averages of whole-body counts of only 3 individual workers in 1994 and a single worker in 2005. There is no indication whether these measurements represent normal unexposed individuals, other than the statement that the individual measured in 2005 was said to be a "typical individual."

It is difficult to understand the two columns in Table 5-24, where the first column is for 1993–2000, which must be based on the three measurements in 1994, but then a change in MDA in 2001, when the only other evaluation was based on a single individual in 2005. It is not explained in Section 5.3.2 why the MDA degraded by approximately a factor of 2 from 1994 to 2001. It would seem more reasonable that the MDA would improve with time, unless some change occurred during this time period that is not given in the site profile.

3.13.2 The Site Profile Recommends the Use of the LANL MDA Values for Bioassay Analysis Performed at SNL before 1992. Better Justification should be Provided.

The site profile (ORAUT. 2007a, pg. 68) states the following:

> *Minimum detectable activity levels for bioassay performed at SNL before 1992 are not generally available unless listed with specific sample results. However, analytical techniques and instrumentation similar to those used at LANL were used at SNL; therefore, the MDAs would likely have been similar (Argall 2007a).*

This is a major assumption on the part of NIOSH. It would be helpful if NIOSH could provide further documentation to support this assumption, other than noting a "likely" similarity. The differences in laboratory conditions and technician differences make this assumption questionable, if not invalid.

3.13.3 The TBD lacks a Discussion of Other Potential Medical X-ray Exposures and the Procedures needed to Maximize Medical X-ray Dose

Section 3.0 of the SNL TBD (ORAUT 2007a), Occupational Medical Dose, references ORAUT-OTIB-0006, Rev. 03 (ORAUT 2005), regarding dose reconstruction from occupationally related diagnostic x-ray procedures in the TBD reference list, but fails to discuss its use and application at SNL in regards to additional special job-related medical x-rays. OTIB-0006 goes a long way in ensuring that occupational medical exposures are included, and that all forms of medical x-ray exposure are identified when determining a worker's potential exposure. OTIB-0006 Rev. 03 concludes that other examinations may be included, such as special job exams (e.g., special chest radiography for respirator certification; for beryllium workers, asbestos workers, food handlers etc.) and termination exams. The potential for exposure from these other medical x-ray dose exposures is not discussed, nor addressed, in the SNL TBD (ORAUT 2007a). When the individual medical record is lacking in specific information, the TBD also offers no other default means to develop a realistic medical x-ray history that might also include these special job examinations or termination examination that might be a part of the annual physical. The Occupational Medical Dose section of the SNL TBD (ORAUT 2007a), in this regard, does not refer the dose reconstructor to Revision 3 of OTIB-0006 (ORAUT 2005).

Another factor not discussed in the TBD is the potential and impact of x-ray procedures utilized by medical authorities to do special screening and to evaluate the result of injury and trauma.

In Table 3-1, in the SNL TBD (ORAUT 2007a), it is mentioned that for the period 1953–1966, "Selected individuals could have received standard 14 by 17-in PA chest radiographs in addition to PFG" (ORAUT 2007a, pg. 21). It goes on the say at the end of that entry that "In the absence of any records of X-ray procedures, the dose from the photofluorography (PFG) should be assigned on an annual basis for this period." There is, however, no guidance for the dose reconstructor on which groups or individuals should receive an annual 14 in ×17 in chest x-ray during the years 1953 to 1966 when the medical record is silent on such annual chest x-rays. The TBD (ORAUT 2007a, pg. 22) also states that "The review of employee medical records indicated that SNL took PA chest films for most but not all employees on an annual or biennial frequency through 1966..." The TBD should provide guidance to the dose reconstructor, unless contrary to what appears in the worker's medical record, that specifies assignment to the worker of a dose for both an annual PFG and an annual 14 in x 17 in chest x-ray, unless the employee's medical record indicates otherwise.

The Occupational Medical Dose section of the TBD also does not discuss the application of ORAUT-PROC-0061 (ORAUT 2006a) that instructs dose reconstructors to:

> *As described in Section 6.0, unless otherwise noted in Table A-1 the following procedures apply: For a maximizing assessment, the organ doses should be multiplied by 1.3 and treated as a constant in IREP; for a best estimate assessment, the organ doses should be assigned as a normal distribution in Parameter 1 with 30% of the organ dose entered in Parameter 2 in IREP; and for a minimizing assessment, the organ doses should be assigned as a constant in IREP.* (ORAUT 2006a, pg. 13)

There is no entry for SNL in Attachment A, Table A-1 of PROC-0061 (ORAUT 2006a). When PROC-0061 is updated, SNL should be added to the table. The TBD does not discuss, when determining a maximizing estimate, the multiplication of organ dose by a factor of 1.3 to account for uncertainty. The TBD also does not instruct the dose reconstructor to use PROC-0061 when applying the maximizing approach. It, therefore, appears that the multiplication factor of 1.3 has not been applied to SNL medical x-ray dose when applying the maximizing approach.

3.13.4 The Reference in the SNL TBD for Stout 2005 does not include the Backup Documentation Cited

SNL X-ray History (Stout 2005) is used as the source of documentation in six places in the SNL TBD (ORAUT 2007a), but lacks the backup documentation. This reference is a memorandum from Kay Stout to Ron Kathren that only includes a discussion of the lack of shielding for lumbar spine examinations in the 1950's and TLD measurements on a dummy to obtain x-ray doses. This reference is used in five other places as the source of Table 3-1 data on frequency and types of medical examinations; as providing information regarding interviews with former x-ray technologists Kay Sanderville and Louise Bland; as providing information with a former x-ray technologist on the type of apparatus used from 1953 to 1958; as providing information on an August 28, 1978 Herb Abbott survey performed on the x-ray unit at that time; as mention of a correction made 11 days after the survey report; and as the source of information on periodic lumbar spine examinations prior to 1978. This leaves documentation lacking for positions taken by NIOSH unsupported in these five instances.

3.13.5 The TBD does not adequately describe the Approach and Data used in the Exposure Calculations

NIOSH does not describe the emissions of airborne effluents with enough details to allow a thorough review of their source term development. The 69 radionuclides it says are identified in all of the emissions data it reviewed (ORAUT 2007a, Section 4.3) could be listed in a table or appendix by facility.

There is no discussion covering a comparison of site ambient (air, soil, vegetation, water) monitoring data with the air concentrations estimated from modeling stack/vent emissions. This can be used to confirm that emissions monitoring is accurate and claimant favorable or identify disagreement between the two methods of estimating exposures. Uranium-238 was identified as the only uranium isotope of concern for emissions and intakes, but no U-234 or U-235 was considered even though it is shown in the site description that the site handled natural uranium and different levels of enriched uranium. In other NIOSH TBDs, the assumption is the uranium inhaled or ingested is U-234 when there are types other than DU. This is because U-234 is the most significant dose contributor of the uranium isotopes in natural or enriched uranium sources (it has the highest dose factor of the three isotopes, and is the highest activity component for any level of enrichment). If the site performed uranium mass analysis, rather than isotopic analysis of environmental and emission samples (which appears to be the case at SNL), it is most appropriate to assume U-234 is all of the uranium detected. Unless there was isotopic analysis of emission samples that NIOSH is aware of or they are sure that only depleted U was involved in U emissions, they should use U-234 instead of U-238.

Some assumptions made in the exposure conditions and calculations may neither be representative nor claimant favorable. One example is the breathing rate, which may be higher for construction, maintenance, and outdoor workers with labor intensive work than with light activity. The particle size distribution of the particulates for inhalation intakes is assumed to be

5μm AMAD per Table 2-2 in the TBD; however, this may not be applicable to environmental aerosols and NIOSH should determine if there is a range of particle sizes that should be used in dose calculations to assess the most claimant favorable dose.

NIOSH does not discuss the level of uncertainty in the stack/vent emissions monitoring in any detail. It may be possible that uncertainties (standard deviations) could have been reported in the original stack emissions concentration data to determine the laboratory component of the source term uncertainty. For stack emission concentration results that are near the detection limit the counting uncertainty alone can be a significant fraction of the result. Assuming a GSD of 2 may be reasonable, but it is not obvious that this is connected to an attempt to propagate component uncertainties to obtain a total uncertainty for the intake estimates.

3.13.6 The TBD does not give Guidance on Combining the Environmental Intakes from Emissions at More Than One TA (i.e., Multiple TA Internal Exposures) and does not address Inadvertent Ingestion

There is the possibility for unmonitored workers in one technical area (TA) to get exposure to plumes emitted from another TA. The TBD provides no discussion on adding intakes from other TAs together for an employee that worked in one TA and received internal exposure from another TA. The discussion on environmental external dose in Section 4.0 states that it can be assumed there are plumes from one TA that affect other TAs external doses, therefore intakes (internal dose) from environmental releases may also involve sources outside of the TA the workers was assigned to. It is apparent that the radionuclide intake tables for the different TA's are only applicable to an employee that worked only in that TA. The TBD needs to give direction on adding intakes from plumes emitted at TAs outside of the TA that the worker was assigned to.

The TBD states the environmental dose section covers only unmonitored workers (assumed to be those not assigned dosimeters or bioassays). The NIOSH document, OTIB-0014, *Assignment of Environmental Internal Doses for Employees Not Exposed to Airborne Radionuclides in the Workplace* (ORAUT 2004b), states that internal dose (from an environmental pathway) to a monitored employee can be assigned when it is from a radionuclide for which they are not monitored (i.e., bioassay or air sampling). An example of this would be a worker that routinely works with uranium and submits bioassays for uranium analysis who also receives environmental exposure to tritium through emissions from another facility that handles tritium.

The scope statement in the environmental dose discussion (ORAUT 2007a, Section 4.1.2) states that the section covers inadvertent ingestion. In section 4.6, it is just stated that this did not occur at either the New Mexico or TTR sites. No details were given on how this determination was made. OCAS-TIB-009, *Estimation of Ingestion Intakes* (OCAS 2004), gives guidance on how to estimate ingestion intakes from air concentrations (fallout) and this could be used for inadvertent ingestion from environmental emission because NIOSH is using air concentration calculations to estimate all intakes at both sites.

3.13.7 Reliance on CATI in the Absence of Complete Records

The SNL site profile relies on the Computer Assisted Telephone Interviews (CATIs), in the absence of complete records, to identify potential exposures to metal tritides and offsite source terms. The following excerpts from the TBD clarify these functions of the telephone interview:

> *The telephone interview might provide indications that an energy employee had worked in locations where a potential for exposure to MT existed*. (ORAUT 2007a, pg. 73)
>
> *Work at off site locations is indicated by either the Department of Energy records or the telephone interview [18]. Offsite dosimetry records are typically not contained in the SNL records, but are supplied directly from the appropriate sites [19]. If the telephone interview or work history indicates that the worker participated in nuclear weapons testing, and if no dosimetry records are found for that period, then the individual's site profiles can be reviewed to obtain information necessary to calculate potential missed dose*. (ORAUT 2007a, pg. 60)
>
> *The table of nuclear weapons tests is included here to assist the dose reconstructor in recognizing the names of these tests in the event that these names are mentioned in the telephone interview or other records*. (ORAUT 2007a, pg. 108)

Part of the rationale for conducting a CATI is to ensure the completeness and accuracy of the assumptions incorporated into a particular dose reconstruction. Reliance on telephone interviews to identify situations where potential exposures occurred (such as exposure to metal tritides and offsite exposure) presents several problems. These difficulties must be taken into consideration, particularly when information from the interview is an exclusive source for determining the assignment of dose or the retrieval of additional records.

Classification and Claimant Knowledge: SNL was involved in a variety of research and development, stockpile stewardship, and testing activities that are of a classified nature. As such, an individual has to have the appropriate clearance and need-to-know for access to particular information. Due to the complexity of work assignments or, in some cases, classified work assignments or locations, family member claimants may not know what the employee did. In fact, energy employees without a need-to-know may not always know to what source terms they were exposed. For example, many of the details about work with metal tritides remains sensitive. It is not reasonable to assume that all employees working around this material would be aware of their exposure, and it is certainly not reasonable to assume that surviving family members would have adequate information. Even if an energy employee is knowledgeable, classification concerns may prevent them from discussing such work in the context of an unclassified interview.

Interview Process Limitations: The CATI process requires the interviewer to ask questions from a script that may not trigger relevant memories and information. For example, the interview does not specifically ask about temporary assignments or visits to other DOE sites. The claimant is expected to recognize the importance and relevance of such information and to provide it without specific prompting. Regarding sources of potential exposure, there is a significant discrepancy in the interview process for energy employee claimants versus survivor claimants. While the energy employee interview form specifically asks what types of radioactive material an individual was exposed to, the survivor interview form does not. Coworker interviews may offer some possibilities to offset survivor claimants' lack of knowledge, but coworker interviews are not commonly conducted. Finally, it is not reasonable to assume that claimants have the scientific knowledge to recognize the importance of special exposure conditions, such as exposure to special forms of tritium or other radionuclides. Without specific prompting, many claimants may not be in a position to determine which exposure conditions may be relevant to the dose reconstruction.

Additional Sources of Information: Offsite work conducted by SNL, including shots at Nevada Test Site (NTS), Pacific Proving Grounds (PPG), and other continental sites, is well documented in event-specific reports. In fact, SNL has compiled lists of departments and individuals involved in particular tests. In addition, NTS incident reports list specific individuals involved in particular incidents, including laboratory staff. These information sources can link individual workers to offsite exposure conditions without relying on the claimant to produce the information. If these information sources could be compiled and referenced during claim reviews, they could enhance the accuracy and equity of the claim review process for energy worker and survivor claimants. An effort to compile this information would ensure that offsite dose (at least from NTS) was appropriately considered. An alternative would be to request worker exposure and incident data for all SNL claimants from key sites such as NTS, PPG, and SNL-Livermore. In the case of exposure to special forms of radionuclides, the claimant favorable approach would be to assume a claimant was exposed to the special chemical form given that this form of the radionuclide produces a higher organ dose.

In summary, it is not reasonable to rely on claimants to know, remember, identify, and communicate critical information regarding offsite exposures or special chemical forms, particularly in the absence of direct queries. The highly classified nature of many SNL operations increases the level of concern for this site, because many claimants could be unaware of (or inhibited from discussing) specific exposure conditions. In order to minimize reliance on claimant knowledge and memory, NIOSH/ORAUT should consider claimant favorable assumptions in the case of unknowns, and should request data from key SNL locations for all SNL claimants who require a maximizing or best estimate approach.

4.0 OVERALL ADEQUACY OF THE SITE PROFILE AS A BASIS FOR DOSE RECONSTRUCTION

The SC&A procedures call for both a "vertical" assessment of a site profile for purposes of evaluation specific issues of adequacy and completeness, as well as a "horizontal" assessment pertaining to how the profile satisfies its intended purpose and scope. This section addresses the latter objective in a summary manner by evaluation of (1) how, and to what extent, the site profile satisfies the five objectives defined by the Advisory Board for ascertaining adequacy; (2) the usability of the site profile for its intended purpose, i.e., to provide a generalized technical resource for the dose reconstructor when individual dose records are unavailable; and (3) generic technical or policy issues that transcend any single site profile that need to be addressed by the Advisory Board and NIOSH.

4.1 SATISFYING THE FIVE OBJECTIVES

4.1.1 Objective 1: Completeness of Data Sources

The completeness, accuracy and availability of data for use in dose reconstruction and as a basis for coworker approaches should be validated to demonstrate its usefulness. Verification of data during transfer between systems (i.e., comparison of original records to electron data systems) is needed to ascertain the integrity of the dose data that will be used in dose reconstruction, and also for the coworker dose data. Additionally, no mention is made in the TBD (ORAUT 2007a) concerning data completeness, i.e., there must be some methodology established to assure that all records were transferred during each system change-over. These are data accuracy issues that must be addressed to determine if the dose data contained in the current records are a correct representation of the original data recorded.

Throughout the Occupational External Dose section of ORAUT-TKBS-0037 (ORAUT 2007a), the dose data records are referred to as containing the necessary and correct dose for exposed workers throughout the entire period from 1949–2007. However, except for the brief statement on page 99 concerning the electronic file records created since 1986, there is no mention of the actual dose records. The dose information may, or may not, demonstrate: (1) if neutron and photon components were recorded separately; (2) if they were only recorded and retained as the total penetrating dose, which was the practice at some labs; (3) if there were different recording systems used (such as the change-over from hand written to computerized records); and/or if different recording methods/programs were used after switching to electron data storage.

The SNL electronic database is incomplete, and hard copy bioassay records are not complete in individual radiation exposure files; they lack data regarding specific radionuclides to which workers were potentially exposed. LANL was considered the primary source for bioassay services prior to 1991; however, reviews of the LANL bioassay data in previous reviews by SC&A and by the ORAUT found the LANL bioassay data to be incomplete or inadequate (SC&A 2006, Vitkus et al. 2007). Additionally, the adequacy of offsite vendor data is suspect, suggesting a need for further verification of data completeness and accuracy.

There is limited bioassay data available for SNL workers prior to 1992 when a routine monitoring program was implemented. Bioassay records before 1989 have been found in paper or microfiche format in the data archive; however, the records are limited to uranium, plutonium and tritium bioassay, and are not typically retrieved by SNL as a part of the claimant file. Data provided to NIOSH for dose reconstruction is limited to summary reports, including dose information in some years for tritium, plutonium, and uranium. Analysis of the source terms indicate that individuals were exposed to tritium (H-3), Uranium (U-234, U-235, U-238), fission and activation products (e.g., Sr-90, Cs-137, Zn-65, Co-60, Ta-182), plutonium (Pu-238, Pu-239, Pu-240, Pu-241), and americium (Am-241), yet adequate bioassay data is not available for several of these nuclides. The limited hardcopy bioassay data appears indicative of incomplete individual exposure files and/or a limited bioassay program.

Likewise with respect to completeness of scope, the site profile does not fully address: (1) the significance of radiological incidents (onsite and offsite); (2) how these incidents may have contributed to worker dose; (3) where information is provided in individual exposure records; and (4) how the incidents should be addressed in dose reconstruction. Claimant data, relying primarily on summary reports, does not consistently incorporate exposures arising from onsite or offsite incidents. Reliance on the claimants to remember, identify, and communicate critical information regarding offsite exposures or special chemical forms, particularly in the absence of direct queries, is not adequate. The highly classified nature of many SNL operations increases the level of concern for this site, because many claimants could be unaware of (or inhibited from discussing) specific exposure conditions.

In light of these key questions, the validation and verification process should be reviewed to assure that internal and external dosimetry information provided to dose reconstructors is accurate, complete, and consistent. Where data gaps cannot be corrected, clear instructions should be provided to allow for a consistent and claimant favorable approach to dose reconstruction.

4.1.2 Objective 2: Technical Accuracy

SC&A finds that the existing site profile does not address inaccurate dose records for SPR operators due to under-recording of external gamma/neutron dose received during shutdown maintenance activities. This under-recording resulted from inadequate dosimetry at the time for a severe gradient of radiation fields experienced by personnel working close to the reactor vessel. Such under-recording can lead to an underestimate of whole body dose by at least a factor of 1.75, and likely higher, prior to installation of additional shielding in 1982. As annual dose levels for these operators were among the highest at SNL, approaching the annual limit of 5 rems in some cases, this would have significant implications for the accuracy of dose reconstruction. While known to SNL management at the time, no retroactive correction was apparently made to individual dose records maintained by the Department of Energy.

For external radiation dosimetry, SC& A finds that there are insufficient analyses of radiation fields, doses, and uncertainties in the TBD (ORAUT 2007a). Information concerning the criteria for badging workers at the SNL is lacking during the period 1949–2007. The TBD does not cover the subject of photon and neutron radiation energy fields and associated doses with related uncertainties as a function of work location and time periods. The lack of specifics on energy fields, associated doses, and their uncertainties is not sufficiently developed to allow the dose reconstructor to accurately assign dose. Some information concerning the expected energy ranges is provided in the TBD (ORAUT 2007a) in Table 6-8 for beta/photons and in Table 6-11 for neutrons. However, except for the period 1959–1971 for beta/gamma calibration listed in Table 6-1, the TBD does not specify what photon calibration energies were used for different locations at the SNL and how these changed with time. Neutron calibration is only mentioned in Table 6-2 for NTA film, but NIOSH recommends not using NTA data; therefore, no relevant neutron calibration information is provided, nor is a clear uncertainty value provided that can be applied for neutron doses as a function of SNL time period. The single n/p ratio value cited in the TBD is based on a relatively small number of records over an 8-year time span and would likely not be representative of laboratory conditions over that timeframe and beyond.

As the TBD acknowledges, no formal routine bioassay program existed at SNL prior to 1992, leading to the likelihood that workers in areas containing radioactive materials may have had the potential for internal exposures that would not have been monitored. With their work areas in many cases being unknown, a backup means of estimating dose is not apparent in the TBD. The instructions given for dose reconstructors in the site profile do not appear to be adequate for determining or quantifying the radioactive isotopes to which unmonitored, or even monitored workers, may have been exposed. Assigning potential missed dose by work location is particularly questionable in the absence of complete work history records. Furthermore, the feasibility of this approach is questionable for site-wide workers (e.g., security guards and maintenance staff) and workers involved in offsite activities in Nevada and other locations. In cases where work area information is not available, the TBD should provide further instruction.

Bioassay monitoring of workers was primarily dependent on the air monitoring program as opposed to, and in default of, a routine bioassay monitoring program. With inadequate air sampling, or no air sampling data at all, this brings into question the effectiveness of the special bioassay monitoring program and the use of air sampling data as a substitute for bioassay sampling. It certainly appears, without routine bioassay monitoring, that dependence upon air sampling for detecting exposures to workers likely led to unmonitored intakes by workers over the years at SNL. It also could have led to intakes that could not be measured or estimated accurately due to use of area air monitoring data. Furthermore, reliance on field indicators to trigger special bioassay is problematic, particularly in areas where air monitoring equipment placement is inadequate or non-existent. Some consideration should be given in the TBD to the representativeness of the sampling, and the consistent use of field indicators as a trigger for bioassay.

SC&A finds that further evaluation is warranted for radionuclides handled at SNL by workers, on and offsite, to determine the extent of potential exposures, periods of exposure, quantities handled, and impacts on dose reconstruction to specific organs. Attempts should be made to evaluate archived bioassay data where it is available, and determine whether these data are complete and representative enough to develop a bounding or coworker dose. Appropriate methods for internal monitoring were not always available for all years of potential exposure. For tritium, it is important that the dose reconstructor chooses claimant favorable forms of tritium for the dose estimation if there is a lack of process knowledge about the form that may have been involved with exposures. The dose to the lung, from intakes of metal tritides, can be underestimated by orders of magnitude, if it is incorrectly assumed that the dose can be calculated with the methods used for HTO. The SNL TBD (ORAUT 2007a) is incomplete in it consideration of missed dose to unmonitored exposed workers potentially exposed to all the various MFPs and MAPs, including activation products produced by accelerators. Additional consideration should be given to the exposure hazards associated with operation of accelerators, target handling, component activation and byproduct radiation. NIOSH/ORAUT should develop missed dose methodologies in the absence of monitoring data based on available data, technical reports, and other sources of information to ascertain potential exposure to non-traditional radionuclides.

SNL took an active role in conducting weapons effects, ground motion, air pressure, crater phenomena, and other studies during the testing of weapons. SNL workers were responsible for arming and firing of weapons from 1951 through 1992. They were responsible for monitoring, maintaining, and assembling weapons at storage sites. A re-characterization of the extent of SNL involvement in weapons testing and other offsite activities (e.g. research on hydrodynamic testing, treaty verification, assignments to other DOE sites) should be completed. Offsite activities related to the weapons and components testing, surveillance, in-field retrofit and modifications, treaty verification, and managing storage sites and their corresponding monitoring programs have not been adequately addressed in the SNL TBD. This is confounded by the absence of offsite data in the SNL exposure files and the lack of direction to the dose reconstructors on when to request data from other sites.

While it is understood that NIOSH, under EEOICPA protocols, establishes work location (including work at other AEC or DOE sites to enable dosimetry records to be obtained), it is not clear from the SNL, and other NTS, or PPG site profiles how visiting SNL employees were monitored for neutron and internal radiation exposures. Internal and external exposure hazards during field testing require further consideration to determine if appropriate internal and external monitoring occurred. If adequate monitoring did not occur at these offsite work locations, the TBD does not provide instructions for bounding these potential exposures. A missed dose methodology should be included for unmonitored or inadequately monitored personnel who participated in weapons testing and other field activities. Where available, references to other site profiles are appropriate. Methodologies for activities at continental tests outside of Nevada require treatment in the site profile, a separate site profile, or a TIB.

4.1.3 Objective 3: Adequacy of Data

Historically, SNL relied heavily on outside vendors to provide bioassay data. Concerns about the accuracy and completeness of data from these support contractors have not been fully considered in SNL's TBD. If LANL was the prime source of bioassay results for years before 1991, this could have a significant impact on the internal dose assessments of SNL workers. Data deficiencies during the 1943–1949 time period would clearly impair the ability to conduct dose reconstructions on SNL workers, who were a part of the Z-division of LANL during this time. From 1950 to 1975, there are data deficiencies for mixed fission products/mixed activation products (MFP/MAP), which have been identified as a major contributor to internal dose at SNL.

SNL housed several reactors, accelerators, and was heavily involved in testing that potentially resulted in exposures to fission and activation products.

In addition to concerns regarding LANL bioassay data, the SNL TBD describes bioassay results from a commercial laboratory, CEP, which were invalidated based on the results of quality control samples and other data integrity issues (ORAUT. 2007a, pg. 59). No explanation is provided, however, on how the TBD will address acute uptakes which may have occurred during this time period. Considering the importance of bioassay data from LANL and CEP, further verification of data completeness and accuracy is warranted. It would be highly desirable for the verification and validation process to be used and identified in the revised site profile.

The environmental exposure calculations used for assessing intakes of airborne radionuclides provided in the environmental dose section of the SNL TBD, ORAUT-TKBS-0037 (ORAUT 2007a), used source term data that may be inaccurate, incomplete and not claimant favorable. There are periods of time that NIOSH could not find any emission or environmental monitoring data to calculate the actual air concentrations to which unmonitored workers could have been exposed. The methods that NIOSH used to assign intakes for some of these areas were not clearly explained, and, in some cases when the methods were explained, there is question on the validity of the assumptions used. For some areas of environmental exposure, NIOSH appears to have left out potentially significant radionuclides in the assessment of environmental dose. It is not apparent that NIOSH has assessed the impact that inferred incompleteness and inadequacy of the earlier monitoring data could have had on the emissions estimates.

DU is not considered by NIOSH in the environmental dose source term at Tonopah Test Range (TTR) in this TBD, and there is no discussion why it is not considered. NIOSH estimates the radionuclide intakes for all years at TTR, going back to 1963, by using air monitoring data from 1996–1997, which analyzed for Pu isotopes and Am-241. Proposing that it is reasonable to assume the air concentrations were similar in the earlier years may not be accurate, particularly when considering that soil radionuclide concentrations and resuspension rates could be different due to weathering of the soil.

The assignment of the environmental external doses from TLD data does not have a clear basis, and is not supported with any analysis of background and onsite environmental dosimeters to accurately determine if there were higher levels onsite. There was no discussion detailing the dosimeter locations that were placed on site and whether these were representative for estimating non-monitored worker dose. Assessment of possible doses from radioactive particles on skin is missing, and is in disagreement with discussion in the Scope of the TBD (ORAUT 2007a, Section 1.2) which identifies this as being covered in the environmental dose section.

There is no discussion on any air monitoring in TA-III for emissions from waste landfills after 1973 (ORAUT 2007a).

The TBD states that there was no emission monitoring for the area before 1973, and it identifies that there were diffuse sources of airborne radionuclide releases. The TBD (ORAUT 2007a) does not state how it estimated the air concentrations that caused intakes in this area. There is no discussion on any air monitoring in TA-III for emissions from waste landfills after 1973.

NIOSH may not have reviewed environmental monitoring data (ambient air, soil, vegetation, water) that may be available for these years because this data is not discussed in the TBD (ORAUT 2007a). Only post-1980 environmental TLD data for ambient external exposure is discussed. There is also no discussion in the TBD regarding fugitive emissions that could have given rise to environmental doses.

NIOSH does not discuss the level of uncertainty in the stack/vent emissions monitoring in any detail. It may be possible that uncertainties (standard deviations) could have been reported in the original stack emissions concentration data to determine the laboratory component of the source term uncertainty.

4.1.4 Objective 4: Consistency among Site Profiles

The SNL TBD attempted to include offsite activities, such as those at NTS and TTR, in the site description. This inclusion is an improvement over the site profiles for LANL and LLNL. The TBD indicates to the dose reconstructor that data from facilities other than SNL may have to be requested for a full dose reconstruction, and informs them that TBDs from other facilities may apply.

Table 6-8, footnote a on page 104, indicates that a multiplication factor of **1.876** should be used to obtain the low-energy photon dose, but the text in the paragraph below the table lists a multiplication factor of **1.86** to obtain the low-energy photon dose.

In the second sentence of the last paragraph on page 105 of Section 6.9, it states, "…100% fission spectrum neutrons (0.1 to 1 MeV) is used." However, in Table 6-11on page 106 for *Reactor operations*, the neutron energy is listed as **0.1–2 MeV** at 100%.

4.1.5 Objective 5: Regulatory Compliance

No regulatory compliance issues were identified by SC&A in the SNL Site Profile.

4.2 USABILITY OF SITE PROFILE FOR INTENDED PURPOSES

4.2.1 Ambiguous Dose Reconstruction Direction

The site profile points out that because of the perception that the potential for intakes at SNL was small, the routine bioassay program was not formalized until after 1992. Before that time, monitoring for intakes was not regularly performed. Then, for plutonium and uranium (ORAUT 2007a, pp. 67 and 76), it notes that a special sampling program would be initiated when a radiological incident occurs or "A **positive routine bioassay sample result is obtained that indicates the possibility of an unexpected dose of 100 mrem CEDE or more"** (emphasis added). This may be valid after 1992; however, there was no formalized routine bioassay monitoring program prior to 1992.

ORAUT 2007a (pg. 76) further notes the following:

> *Because no workers participate in a routine bioassay program, there is no protocol for routine sampling on a Friday or Monday (Potter 2006c).*

Then it goes on to state the following:

> *According to a 1993 memorandum, individuals handling 10 μCi or more of DU would be required to participate in the bioassay program (SNL 1992c).*

Which of these statements is true?

The appearance of conflicting statements in the case of tritium is described in Finding 3.7.

If the neutron and photon penetrating doses at SNL were sometimes combined and entered as one value, it will make it difficult for the dose reconstructor to separate them out for individual dose assignments in the IREP Input tables.

Unmonitored dose and MND appear to be intermixed in Sections 6.7 and 6.8 of the current TBD, which may make it difficult for the dose reconstructors to use consistent and correct methods to assign unmonitored and MNDs.

It is not clear what final value NIOSH is recommending the dose reconstructor use for the uncertainty for neutron doses as a function of time period; i.e., values for **overall bias**, **range in bias**, **systematic** and **random uncertainty** factors are listed, but no combined final values are provided for the dose reconstructor to use.

Determination of shallow and nonpenetrating doses from original data sheets covers only the period of 1977–2005, and does not contain data or instructions for the dose reconstructor concerning the values to use for assigning nonpenetrating coworker dose for the period 1949–1976, when nonpenetrating doses were not measured and/or recorded.

The TBD does not address if SNL's standard dosimetry practice was to subtract background badge readings from the workers' badge readings before recording the final dose. This issue is important to the dose reconstructor when determining if environmental external site doses should be assigned.

4.2.2 Inconsistencies and Editorial Errors in the Site Profiles

Dose terms should be consistent and defined when used in the TBD, and the TBD should investigate their meanings when they were used in the different record systems and provide this information for the dose reconstructor. A small amount of information concerning dose recording terms is provided in the TBD on pages 98, 99, and 104; however, this information may not be sufficient to provide the dose reconstructor with the tools necessary to sort out the details of the dose data contained in a claimant's records.

4.3 UNRESOLVED POLICY OR GENERIC TECHNICAL ISSUES

A number of issues identified in the SNL TBD review represent potential generic policy issues that transcend any individual site profile. Issues raised in the review that are common to other ongoing investigations include dose assessments for STCs, dose reconstruction to workers involved in weapons testing, the adequacy of bioassay techniques to evaluate exposure to non-routine radionuclides, and the lack of characterization of external exposure fields, particularly neutron exposure.

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ATTACHMENT 1: NIOSH TECHNICAL DOCUMENTS CONSIDERED DURING THE REVIEW PROCESS

Technical Basis Document

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ATTACHMENT 2: SITE EXPERT INTERVIEW SUMMARY

[TBD]

ATTACHMENT 3: KEY QUESTIONS AND RESPONSES FOR NIOSH/ORAU REGARDING SITE PROFILE DOCUMENTS

SC&A submitted questions related to Revision 00 of the SNL Site Profile Documents (dated August 8, 2007) to NIOSH on **February 21 2008**. The NIOSH/ORAUT team provided written responses to these questions on March 21, 2008. Both the questions and responses have been provided below.

Site Description

1. The TBD indicates that SNL employees have routinely been involved in operations at a number of Sandia Corporation sites. These sites included SNL-Livermore; Hattiesburg, Mississippi; the Nevada Test Site; Clarksville, Tennessee; and Slaton Bay Station, California. Furthermore, Table 5-3 includes nuclear weapons tests that occurred at Bikini Atoll and Fallon, Nevada. SNL also stationed staff at the weapons storage facilities (pg. 54, 57). The TBD indicates that exposure data from these sites may not be included in the SNL dosimetry records. With incomplete records, how can NIOSH with certainty determine whether workers were potentially exposed at these other facilities? For which sites is NIOSH automatically pursuing dose records other than SNL?

   ORAUT: Records are routinely requested from facilities other than SNL based on documented employment at other facilities.

2. Is it assumed that the dose reconstruction for 1945–1949 is covered under the LANL site profile?

   ORAUT: Although work performed in the early years prior to 1950 was for the LANL site, SNL was considered a separate entity starting in 1949, according to the DOE Office of Heath, Safety and Security website. The Sandia site profile covers the time at the Albuquerque facility with some references to LANL. ORAUT will use the best available information to complete dose reconstructions.

Occupational Internal Dose

1. On page 76, paragraphs 4 and 5 under **Sampling Protocol**, aren't these two paragraphs conflicting? "Because **no workers participate in a routine uranium bioassay program**, there is no protocol for routine sampling on a Friday or Monday." And, "According to a 1993 memorandum, individuals handling 10 μCi or more of DU **would be required to participate in the bioassay program**." (emphasis added)

   ORAUT: The second statement says "would be" required to participate, indicating that no workers were working with the specified quantity of material but would be placed on a program if such work should occur. Also, the lack of a routine program doesn't mean that there is no monitoring at all for uranium workers. The first paragraph in the section discusses incident, confirmatory, and follow-up samples. It's agreed that this section could be expanded to make this clearer.

2. Doesn't the first paragraph of the **Sampling Protocol** section also appear to have conflicting statements? "Historically and currently, **there has been no routine sampling program for uranium."** And, "A special sampling program would be initiated when a radiological incident occurs or **a positive routine bioassay sample result is obtained** that indicates the possibility of an unexpected dose of 100 mrem CEDE or more." (emphasis added)

   ORAUT: Agreed. It would appear that generic information about a special sampling program was included in this paragraph rather than information specific to the particular nuclide under discussion.

3. The TBD mentions several times that bioassay results performed by Controls for Environmental Pollution (CEP) between 1992 and 1994 should be considered invalid. How does NIOSH plan to assess incidental intakes during this time period?

   ORAUT: Currently, cases where individuals have monitoring after the CEP period can be done using standard assumptions, except in the case of short-retained nuclides, such as H-3, because the later result can be used to put an upper bound on intakes. Missed dose can be calculated for those with endpoints during the CEP period assuming the Sandia requested MDA at the end of their employment. We're currently in the process of looking at a coworker study, including the determination of whether we can bound those two years with the earlier and later data.

4. The TBD refers to a memorandum of understanding between SNL-NM and LANL to conduct bioassay for tritium from 1945–1949. The evaluation report for SEC-00051 has stated that dose reconstruction is not feasible for tritium from 1943–1949. How can NIOSH reconstruct dose for tritium samples analyzed at LANL for Sandia when it was determined tritium dose at LANL cannot be reconstructed?

   ORAUT: SEC determination at LANL does not cover Sandia and infeasibility for a nuclide does not necessarily apply. In the absence of other data, tritium data for Sandia employees would be evaluated assuming LANL did the analyses.

5. The TBD indicates that SNL had an MOU with LANL to perform whole-body and lung counting for workers. Furthermore, the TBD indicates that whole-body counts were performed for workers with potential intakes of fission and activation products. The evaluation report for SEC-00051 has stated that reconstruction is not feasible for mixed fission and activation products from 1943–1975 which encompasses some years where whole-body/chest counting was available at LANL. How can NIOSH/ORAUT reconstruct dose for SNL workers when it was determined dose reconstruction for mixed fission products (MFP)/Mixed Activation Products (MAP) at LANL is not feasible?

   ORAUT: The infeasibility at LANL is not because of inadequacies in the whole body counting technique but one of insufficient data for individuals who should have been monitored but were not. This issue would not automatically carry over to Sandia.

Occupational External Dose

1. **Uncertainty –** Section 6.4 of the TBD contains some information concerning bias and uncertainty factors. It appears from the first paragraph that the recommended photon error is ±30% for all energies and all dosimetry systems (is this correct, or is the dose reconstructor (DR) to use some combination of the uncertainty factors listed in Table 6-6?). Additionally, it not clear what final value NIOSH is recommending the DR use for the uncertainty for neutron doses as a function of time period; i.e., values for *Overall bias*, *Range in bias*, *Systematic* and *Random* Uncertainty factors are listed, but no combined final values for the DR to use are provided. Could NIOSH please clarify this issue by stating the final uncertainty values for photons and neutrons the DR is to use?

   ORAUT: The photon dose component is typically evaluated using a constant dose for IREP parameter #1 in which the measured dose is multiplied by 1.3 using a claimant favorable option for the Site Profile stated ±30% variability. Prior to 1972, neutron doses are determined by multiplying the measured and missed photon dose times a neutron-to-photon ratio and using the photon dose uncertainty. From 1972 the measured neutron dose is used in the dose reconstruction along with a calculated missed neutron dose.

2. **Early TLD Minimum Detectable Limits (MDLs) –** Section 6.5, page 102, second paragraph, of the TBD states that "Because of the lack of site specific data on MDLs for the early TLDs used 1971–1990, these dosimeters are estimated to have had MDLs between those for the film badges and the more advanced TLDs." Additionally, Footnote c. of Table 6-10 on page 105 states that "Because of the lack of site specific data on MDLs for the early TLDs used 1971–1989, these dosimeters are estimated to have had MDLs between those for NTA film and the more advanced TLDs." This assumptions needs to be supported by documentation. Could NIOSH provide further support for using this methodology?

   ORAUT: ORAUT-OTIB-0008, "A Standard Methodology for Overestimating External Doses Measured with Thermoluminescent Dosimeters" lists a history of implementation of TLD-based external dosimetry programs at DOE sites. Because TLDs have technical advantages over film dosimeters such as near tissue-equivalent response and general insensitivity to many environmental parameters, the limit of detection for TLDs is lower than film dosimeters. The highest limit of detection for photon TLD dosimeters from all the sites listed in the OTIB is 0.020 rem which is the limit of detection used for the Sandia site when TLDs were implemented. This should be a reasonable estimate for the TLDs used at Sandia.

3. **Use of NTA data –** Table 6-6, page 101, and Table 6-10, page 105, lists data for NTA film. However, page 101 and 105 also recommends using the n/p method to determine measure and missed neutron dose. Is it correct to assume the NTA data is included for completeness and *not* to be used by the Dose Reconstructor (DR) in reconstructing doses in actual cases?

   ORAUT: The NTA film data is included for completeness. The neutron-to-photon ratios should be used prior to 1972. As with all sites that fit in this category, a comparison should be performed using the actual positive neutron dosimeter results and the dose calculated based on an N:P ratio, using the higher of the two.

4. **Use of thermoluminescent dosimeter (TLD) n/p data for what time period(s) –** Table 6-9 on page 104 of the TBD lists recommended n/p values to be used for workers that were not monitored for neutrons. It is not clear from the TBD if these values are to be used *only* for unmonitored workers, when neutron dose reconstruction is needed, for the time periods of 1977–1984 and 1987–2005 when this data was obtained, or if these n/p values are also to be used for workers that were monitored using NTA film, or should have been monitored but were not, during 1949–1971 because of the problems with the NTA film response as stated on page 101 of the TBD, second paragraph of Section 6.4 and also during other years when TLDs were used. Could NIOSH please provide a statement concerning the time period(s) and conditions when the n/p values in Table 6-9 are to be applied?

   ORAUT: The parameters of the distributions of neutron-to-photon dose ratio distributions in Table 6-9 are used prior to 1972 when thermoluminescent dosimeters replaced NTA film at SNL-NM for neutron dosimetry. Whether or not to assign neutron doses for unmonitored workers is determined based on the records provided as discussed in the first paragraph of section 6.7.

5. **Use of TLD n/p data for all periods –** If the n/p values in Table 6-9 on page 104 of the TBD are to be used to assign neutron dose to workers during the 1949–1971 time period when NTA film was used and during other years when TLDs were used, what has NIOSH done to verify the use of this limited number of n/p values (over a limited time period) to all other time periods and exposure conditions when operating conditions, sources, shielding, and safety precautions varied considerably from the later time period (during which the n/p values were determined)?

   ORAUT: The distribution of measured neutron and photon doses and the associated variability is indicative of worker exposures with the TLD. For earlier years, the uncertainty of the distribution is used to provide a reasonable estimate of the neutron to photon dose ratio to be used. The use of the 95th percentile ratios from Table 6-9 is expected to provide a claimant-favorable option.

Occupational Medical Exposure

1. In the (Stout 2005) memorandum of December 14, 2005, it was pointed out that, as a result of the review of a few film jackets, there appeared to be no shielding for lumbar spine examinations done in the 1950s. In developing the calculated ESEs for lumbar spines in Table 3-2 (ORAUT 2007a, pg. 26), how was this lack of shielding taken care of in developing the calculated ESEs in Table 3-2 (ORAUT 2007a, pg. 26)? Please explain how this is resolved in developing the more realistic value of 400 mR for the ESE for an AP lumbar spine and an AP angle lumbar spine radiograph and the more realistic ESE of 2,250 mR for a LAT lumbar spine radiograph and a LAT Lumbar spine spot film during the period 1953 to 1978, based on BRH 1970, pp. 159–160?

   ORAUT: None of the ESEs would have been reduced to account for use of gonadal shielding, even if evidence of its use was found for Sandia.

Occupational Environmental Dose

1. In the section covering ambient external radiation (4.4), NIOSH discusses the monitoring done by Sandia with environmental TLDs and their modeling of external doses from plumes of short-lived activation products. It is not clear how NIOSH estimated the three environmental external doses (<1 mrem, 5 mrem, 10 mrem) assigned to workers at SNL-NM shown in Table 4-2. Did NIOSH base the external radiation doses for workers at SNL-NM on the TLDs or modeling of exposure from plumes or both?

   ORAUT: Based on the TBD, it appears that plumes of short-lived activation products was used prior to 1980, and starting in 1980 TLDs were used.

   If it was based on TLDs, did NIOSH determine these were in locations of maximum environmental exposure and did NIOSH find appropriate background TLD values to subtract from the onsite TLD measured doses?

   ORAUT: Many area locations were monitored including areas that were monitored because of higher external dose rates. Outliers were removed from the data prior to the analysis. Additionally, some of the higher results were used to apply higher doses to adjacent areas as a claimant-favorable assumption. The doses include either external radiation doses, doses from passing plumes, or both, depending on the years.

2. NIOSH uses 1996–1997 ambient air monitoring data to estimate intakes and doses from resuspension of Pu-238, Pu-239/240, and Am-241 at TTR that occurred several years earlier. In the LANL Occupational Environmental Dose TBD (Cehn and McDowell-Boyer 2004), it is stated that soil with older contamination is less of a resuspension issue than soil recently contaminated because erosion and downward migration of radionuclides from the upper soil layers diminish the source term over time. Why does NIOSH assume that using 1996–1997 air monitoring data to estimate intakes as much as 33 years earlier is being claimant favorable with respect to the inference from the LANL TBD statement that the older soil (that was there in 1996–1997) may not have generated as much of a resuspension source as the contaminated soil did in the earlier years (going back to 1963)?

   ORAUT: Section 4.2.2 discusses how each of the Clean Slate sites was cleaned up shortly after each test. Test-related debris was bladed into a hole at ground zero and backfilled. Fences were built around each test area for control. Therefore, for the majority of workers at TTR, the resuspension values mentioned would result in reasonable dose estimates. For the few workers that worked on the cleanup of the Clean Slate sites in 1963, higher values would be more appropriate. For those workers another method would have to be used to calculate an internal dose.

Document Requests

1. Throughout the TBD (Buddenbaum et al. 2007) ORAUT references discussions with SNL retirees and current staff. ORAUT also calls out interviews conducted with [names redacted]. SC&A requests access to interviews, notes, and correspondence between ORAUT

and current or former workers at SNL. Furthermore, SC&A requests access, under appropriate security protocol, to classified interviews that may have been conducted. Interview information is not currently available in the ORAU Site Research Database.

ORAUT: When interviews were documented, the documentation is uploaded to the Site Research Database. There are some cases where interviewers did not document the interviews performed, and references to these interviews will not appear in future revisions of the Site Profile. The Site Research Database remains the repository for project documents, including interview notes.