
Draft

**ADVISORY BOARD ON
RADIATION AND WORKER HEALTH**

National Institute for Occupational Safety and Health

**STATUS REPORT ON RESUSPENSION ISSUES AT THE
NEVADA TEST SITE**

Contract No. 211-2014-58081

Revision 0

Prepared by

John Mauro, PhD, CHP

Lynn Anspaugh, PhD

Robert Barton

Amy Meldrum

S. Cohen & Associates

1608 Spring Hill Road, Suite 400

Vienna, Virginia 22182

July 2015

Disclaimer

This document is made available in accordance with the unanimous desire of the Advisory Board on Radiation and Worker Health (ABRWH) to maintain all possible openness in its deliberations. However, the ABRWH and its contractor, SC&A, caution the reader that at the time of its release, this report is pre-decisional and has not been reviewed by the Board for factual accuracy or applicability within the requirements of 42 CFR 82. This implies that once reviewed by the ABRWH, the Board's position may differ from the report's conclusions. Thus, the reader should be cautioned that this report is for information only and that premature interpretations regarding its conclusions are unwarranted.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 2 of 44
---	----------------------------------	---	----------------------------

S. COHEN & ASSOCIATES: <i>Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program</i>	Document No. NTS Resuspension Issues Status
	Effective Date: Draft – July 21, 2015
	Revision No. 0 (Draft)
Status Report on Resuspension Issues at the Nevada Test Site	Page 2 of 44
Task Manager: _____ Arjun Makhijani, PhD Date: _____	Supersedes: N/A
Project Manager: _____ John Stiver, CHP Date: _____	Peer Reviewer(s): Arjun Makhijani, PhD John Stiver

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	07/21/2015	Initial issue

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 3 of 44
---	----------------------------------	---	----------------------------

TABLE OF CONTENTS

Abbreviations and Acronyms	5
Executive Summary	7
1.0 Background.....	10
2.0 Major Overarching Issues	14
3.0 The Air Sampling Data and Their Usefulness in Reconstructing Ubiquitous Internal Environmental Doses to NTS Workers.....	15
3.1 The Use of Air-Sampling Data for Pu-239/240.....	17
3.2 Other Radionuclides.....	20
3.3 Earlier Time Periods	21
3.4 Radionuclides that Had Decayed Before the RIDP Data Were Collected.....	24
3.5 Calculations of Dose from Inhalation	25
4.0 Dose from Ingestion of Soil.....	27
5.0 The Mass Loading Approach for Inhalation.....	27
6.0 Applications of the TBD Procedure in Actual Dose Reconstruction for Claimants.....	31
References.....	35
Appendix A: Latest Issues Resolution Matrix Dated December 14, 2012	38
Appendix B: Partial Evaluation of the McArthur Data and Their Use in the TBD.....	42

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 4 of 44
---	----------------------------------	---	----------------------------

LIST OF FIGURES

Figure 1. Air-Sampling Locations in 1997	18
Figure 2. Resuspension Factor as a Function of Time after Deposition.....	23
Figure 3. Accrued Dose (Coefficient) for Extra-Thoracic Lymph Nodes (LNet) as a Function of Time Following Intake of Pu-239	27
Figure 4. Screenshot of Word Document Included in Some NOCTS Files Providing Guidance on the Application of Environmental Intakes.....	34

LIST OF TABLES

Table 1. Calculations of Dose with Use of the Mass-Loading Approach (1 mg/m ³)	29
Table 2. Calculations of Dose from the Nine Radionuclides also considered in Table 2.....	30
Table 3. Characterization of the Application of Environmental Doses to Relevant NTS Claimants.....	31
Table 4. Environmental Intake Rates Observed in Relevant NTS Dose Reconstructions.....	32
Table 5. Observations Concerning Ambient Environmental Dose Assignment to NTS Claimants.....	33

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 5 of 44
---	----------------------------------	---	----------------------------

ABBREVIATIONS AND ACRONYMS

Advisory Board or ABRWH	Advisory Board on Radiation and Worker Health
Bq	Becquerel
CAD	chronic annual dose
Ci	Curie
cm	centimeter
DC	dose coefficient
DOE	U.S. Department of Energy
DR	dose reconstruction
EE	energy employee
ER	evaluation report
ET	extra-thoracic
g	gram
GSD	geometric standard deviation
HPGe	high purity germanium
hr	hour
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules of Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
kt	kiloton
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LNet	extra-thoracic lymph nodes
m	meter
m ²	square meter
m ³	cubic meter
μCi/cc	microcurie per cubic centimeter
mg	milligram
mm	millimeter
mR	milliroentgen
μR	microroentgen

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 6 of 44
---	----------------------------------	---	----------------------------

ML	mass loading
NaI	sodium iodide
nCi	nanocuries
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH/OCAS Claims Tracking System
NTS	Nevada Test Site
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
ORERP	Off-Site Radiation Exposure Review Project
pCi	picocuries
POC	probability of causation
R	Roentgen
REECo	Reynolds Electrical and Engineering Company
rem	roentgen equivalent man
RIDP	Radionuclide Inventory and Distribution Program
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SNL	Sandia National Laboratories
Sv	Sievert
t	ton
TBD	technical basis document
TIB	technical information bulletin
TTR	Tonopah Test Range
WG	Work Group

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 7 of 44
---	----------------------------------	---	----------------------------

EXECUTIVE SUMMARY

A detailed review and analysis is provided of the sections of the Nevada Test Site (NTS) Technical Basis Document (TBD) describing the methods, data, and assumptions used to derive the annual radionuclide inhalation rates for workers at the NTS from chronic environmental exposures to radionuclides resuspended from soil (ORAUT 2012). It is important to note that the TBD acknowledges that internal doses from airborne activities cannot be reconstructed for outdoor operational activities between 1951 and 1992 when various tests, events, and incidents occurred. This is the reason Special Exposure Cohorts (SECs)¹ were granted for these time periods. The current TBD addresses the reconstruction of what is referred to as “environmental doses,” which represent time periods and exposure settings that are best described as more quiescent conditions. This distinction is important when evaluating models, data, and assumptions used in the TBD for this specific purpose. The present version of the TBD does not consider enhanced local exposure to material resuspended as a result of activities such as soil disturbances on the NTS. The latter activities would be expected to produce much larger exposures to employees in the field.

Before proceeding with our review of the TBD, we would like to commend NIOSH for making use of the considerable amount of air- and soil-sampling data that has been compiled at the NTS as a means to assign at least some doses to NTS workers who are not covered by the SEC. In addition, notwithstanding some of our commentaries and criticisms of the TBD, we would like to acknowledge the creative and innovative strategies NIOSH has adopted in making use of the available air-sampling and soil-sampling data and the Hicks’ tables to extrapolate back in time as a means to reconstruct doses before these data became available.

Given our understanding of the scope of the TBD and the methods used to reconstruct long-term chronic inhalation doses from the resuspension of radionuclides in soil, SC&A has a number of concerns that should be discussed with the NTS Work Group (WG), including the following:

1. On page 12, Section 4.1.2 of the TBD, the following statement is made:

Therefore, dose reconstructions for individuals employed at NTS during the period from 1951 through December 31, 1992, but who do not qualify for inclusion in the SEC, can be performed using these data as appropriate.

We have a concern with this statement, because the TBD actually provides a protocol for reconstructing the internal doses from resuspension of radionuclides from January 1, 1963, through December 31, 1992.² This statement should be corrected. We also have a concern with the following statement made in Appendix A of the TBD:

If an internal exposure was suspected, bioassay was performed. Managing radioactive material in the form of devices was episodic and limited to a few

¹ SEC #00055; January 27, 1951, through December 31, 1962, and SEC #00070 and #00084; January 1, 1963, through December 31, 1992.

² . The logical end point is December 31, 1992, but ORAUT (2012) includes the date 2000.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 8 of 44
---	----------------------------------	---	----------------------------

workers (e.g., radiation safety and industrial hygiene personnel, miners, and experimenters). These workers are identified on the rosters that were published before the event, and these workers are likely to have bioassay results in the DOE records.

It is our understanding that an SEC was granted in part because there was inadequate bioassay data and many employees were exposed in situations where there were no rosters, thereby precluding the ability to develop a coworker model. This topic was discussed thoroughly during the NTS WG meetings on October 29, 2008 (ABRWH 2008); April 23, 2009 (ABRWH 2009a); and December 15, 2009 (ABRWH 2009b).

2. A method for analyzing chronic environmental exposures associated with resuspension processes is provided for the time period beginning in January 1, 1963, approximately 6 months after the “last above ground test.”³ Inspection of the Anspaugh et al. (2002) resuspension factor equation reveals that by 180 days after deposition, the resuspension factor drops down to about $5 \times 10^{-9}/\text{m}$. For earlier times, closer to the end of above-ground testing, the resuspension factors, according to the Anspaugh model, are orders of magnitude greater. SC&A believes that it is possible to back extrapolate the dose reconstruction to mid-1962, at the end of aboveground testing. Such calculations would be more complete and will likely reveal substantially higher doses from resuspension during that 6-month period. The intended time period of coverage for these calculations should be discussed and agreed upon with the members of the NTS WG. There is no reason that the important time period of July 1962 to December 31, 1962, is not included in the material in the TBD. Further confusion on this point arises from the following statement on page 42 of the TBD under “Instruction to Dose Reconstructors:”

With the exception of cases that can be worked using the bounding assumption in ORAUT-OTIB-0018 (ORAUT 2005), environmental inhalation and ingestion intakes listed in Tables 4-7 and 4-11, respectively, shall be applied starting in 1964.

OTIB-0018 seems to be an inappropriate reference within the context of outdoor chronic exposures at the NTS. OTIB-0018 is more appropriately employed indoors at sites that have a comprehensive health physics and airborne monitoring program, which is not the case for the NTS.

3. It is important that the time period to be covered be carefully considered by the members of the NTS WG. SC&A believes that the logical time period to be covered is July 1962 through December 31, 1992. The method of environmental occupational dose reconstruction is strongly based upon measurements of the concentrations of Pu-239/240

³ ORAUT (2012) repeatedly refers to Small Boy (July 14, 1962, “low” yield) as the last aboveground test. Actually, the last aboveground test was Little Feller I (July 17, 1962, “low” yield). Other aboveground, surface, or cratering tests during the month of July 1962 were Sedan (July 6, 1962, 104 kt, fission yield less than 30%); Little Feller II (July 7, 1962, “low” yield), and Johnnie Boy (July 11, 1962, 500 t). Sedan and Johnnie Boy were cratering events. The Sedan event was the most important event in terms of release of radionuclides. The event data are taken from DOE (2000).

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 9 of 44
---	----------------------------------	---	----------------------------

in air samples starting in 1971. SC&A was originally concerned that the air-sampling locations were not representative of the locations where workers were exposed. We originally detailed these concerns in the Anspaugh report dated October 21, 2008 (Anspaugh 2008). At that time, these concerns were based on the assumption that our interest was in “active environments” where operational activities were ongoing. However, within the context of using these air-sampling data as a means to characterize airborne Pu-239/240 concentrations during relatively quiescent conditions, referred to as chronic environmental exposure, these concerns are greatly diminished. It is important to note that the current scope of dose estimation from residual radioactivity is limited to environmental dose not associated with work activities. Exposure during work-related activities that disturb soil is not included within the scope of the TBD.

4. The soil radionuclide inventory data collected in the 1980s by the Radionuclide Inventory and Distribution Program (RIDP) (Kordas and Anspaugh 1982; McArthur 1991) characterized soil contamination at the site during the 1980s. However, the TBD extrapolates back in time to derive the soil contamination levels that were present on January 1, 1963,⁴ so that doses could be reconstructed from the resuspension process during early years following the end of aboveground testing. One of the limitations of the back extrapolation process used in the TBD is there is evidence that some areas were decontaminated (McArthur 1991, p. 34) before the RIDP measurements were made. Also, significant contamination occurred in Areas 20 and 30 from Plowshare activities after 1963, and the Baneberry event in 1970 produced major contamination in Areas 8 and 12. These concerns need to be addressed in terms of the degree to which the TBD remains scientifically sound and claimant favorable, notwithstanding these events.
5. Derivation of the concentration of relatively short-lived radionuclides in soil for January 1, 1963, employed the Hicks’ tables (Hicks 1982) for the Small Boy event that occurred on July 14, 1962. In fact, the contamination in soil on January 1, 1963, reflects fallout from numerous tests that resulted in surface contamination, such as the Sedan test on July 6, 1962, and Little Feller II on July 7, 1962, which occurred shortly before Small Boy, and Little Feller I that occurred after Small Boy on July 17, 1962. As such, NIOSH should address whether tests shortly before and after Small Boy on July 14, 1962, could also have contributed substantively to the fallout levels in soil derived for January 1, 1963. In a related matter, the protocol used in the TBD to account for fractionation is overly simplistic and appears to rely primarily on the Small Boy event. NIOSH will need to demonstrate that the approach used to account for fractionation does not substantively underestimate doses.
6. The levels of contamination observed in soil by the RIDP performed in the 1980s captured some contamination that occurred many years subsequent to the termination of aboveground testing. This is a concern that needs to be addressed, because the TBD is based on the assumption that all radionuclides observed in soil in the 1980s were as a result of aboveground testing that occurred in July 1962. However, some of the contamination was deposited many years later. NIOSH should explain how this affects

⁴ SC&A believes that this back extrapolation should have been done to July 1962.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 10 of 44
---	----------------------------------	---	-----------------------------

the dose reconstruction process. In a related manner, the TBD makes use of the Anspaugh equation to derive resuspension factors in order to calculate airborne mass loadings and associated intake rates after January 1, 1963. NIOSH needs to discuss how these resuspension factors might be affected if there are locations where soil contamination occurred well after January 1, 1963.

7. In order to prepare tables of doses to each organ and from each radionuclide as a function of time [which would have required an enormous number of Integrated Modules of Bioassay Analysis (IMBA) runs], NIOSH elected to prorate all doses based on the intake rate of Sr-90 beginning on January 1, 1963, and moving forward in time as the resuspension factors decline according to the Anspaugh equation and the radionuclide concentrations decline by radioactive decay. A review of the methods used to perform these calculations, as provided in Appendix A of the TBD, reveals that errors have been made in its use of equation A-2, which could profoundly affect the dose fractions provided in Figures A-5 through A-11, and the doses calculated and reported in Tables 4-9, 4-14, and A-10.
8. A comparison of actual NIOSH dose reconstructions with the guidance provided in the TBD reveals that there are discrepancies and inconsistencies between the TBD guidance and the actual dose reconstructions. These inconsistencies need to be discussed with the WG.

In summary, SC&A is in accord with the basic approach employed by NIOSH, but finds that the starting date should be pushed back to mid-1962. There are also some errors in the calculations that need to be corrected and some assumptions that need to be refined. SC&A has provided some interim calculations based on simpler approaches that can be used as quality checks, which should help in our discussions of the TBD with the WG. In addition, SC&A generally agrees with NIOSH that reconstructing environmental doses during the period of atmospheric testing would be too complex to be feasible as a general matter. However, if there are some claimants with non-SEC cancers who might benefit from a partial environmental dose, this issue might be revisited on a case-by-case basis.

1.0 BACKGROUND

This report describes SC&A's understanding of one of the issues that has been a matter of ongoing discussion; namely Issue 5 in the Issues Resolution Matrix as provided in "Update of the Nevada Test Site (NTS) Issues Resolution Matrix Based on the SC&A Review of the NIOSH Site Profile for the Nevada Test Site," prepared by Arjun Makhijani, Ph.D. and delivered to NIOSH and the Board on December 12, 2012 (SC&A 2012). The issue, as originally stated by SC&A, is as follows:

Resuspension model and resuspension factor are not scientifically defensible or claimant favorable, due to a variety of factors. Doses may be underestimated by an order of magnitude or more. Mass-loading approach would be preferable for internal dose.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 11 of 44
---	----------------------------------	---	-----------------------------

This current report addresses Issue 5 (and related issues) and its status as we understand it as of June 2015. As a means to begin this discussion, the following was excerpted directly from Section 5.3, “Discussion,” of SC&A’s December 12, 2012, report:

The intake due to resuspension of previously deposited radionuclides was among the issues discussed in great detail during the 2006–2009 review of site profile and SEC issues. This review included preparation of papers by SC&A and NIOSH, as well as revisions of the environmental occupational dose section of the site profile. The following list summarizes the major points in the discussions, which are documented in papers, as well as in the transcripts of the NTS WG meetings in the 2006–2009 period.

SC&A prepared a paper on resuspension elaborating on the problems found in the site profile and recommending approaches to intake estimation (Anspaugh 2006). In particular, this paper suggested that a mass loading model was more appropriate than using resuspension coefficients for times more than 2 years after the initial radionuclide deposition.

NIOSH developed and published a mass loading model in response to SC&A’s review of the issue (NIOSH 2007). SC&A prepared a brief response (Anspaugh 2007).

NIOSH also developed a model based on estimating resuspension intakes using measured air concentration data (Rollins 2007). This new model replaced the mass loading model and was incorporated into Rev. 1 of the Occupational Environmental Dose volume of the site profile (ORAUT 2008, Attachment A).

SC&A published a review of ORAUT 2008 (Anspaugh 2008). This was discussed extensively at the NTS WG meeting held on October 29, 2008 (ABRWH 2008).

NIOSH revised its occupational environmental dose site profile (ORAUT 2010) to reflect the fact of the SEC having been granted, but mostly left Rev. 1 (ORAUT 2008) unchanged. The air concentration model was carried over into Rev. 2 of the document (ORAUT 2010, Attachment A).

NIOSH responded to a number of SC&A comments made during its review or during WG discussions, such as adjusting for decay and selective deposition of refractory radionuclides. During the WG discussions, SC&A raised some questions about the choice of soil contamination values and, for some situations, such as the omission of Area 30 soil data (ABRWH 2007a, p. 20, for instance) and higher values for resuspension with higher mass loading values for short periods of time (ABRWH 2007b, p. 46, for instance) that are still not fully addressed.

During WG discussion of SC&A’s review of Rev. 1 of the occupational environmental dose site profile (ORAUT 2008b), NIOSH stated that occupational environmental doses were not meant to be applied to workers in the field. For

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 12 of 44
---	----------------------------------	---	-----------------------------

these cases, NIOSH proposed to apply an occupational internal dose, either by using bioassay measurements or applying a coworker model. Occupational environmental dose was meant to be applied to situations where workers were not in areas where testing or test preparations were being carried out (ABRWH 2008, pp. 150–184).

Finally, SC&A notes that the revised ER [Evaluation Report] stated that environmental occupational dose could be calculated on a claimant-favorable basis for NTS workers (NIOSH 2010, pp. 65–66).

In “Section 5.4 Status and Conclusion” of SC&A (2012), it states the following:

The NTS SEC-00084 for the period January 1, 1963, to December 31, 1992, was granted on the grounds of infeasibility of estimating internal dose with sufficient accuracy (NIOSH 2010). In reviewing the extensive and complex record, it appears to SC&A that NIOSH and SC&A were in agreement that occupational environmental dose can be estimated. Therefore, it appears to SC&A that this is a site profile issue that could be used to calculate partial doses for non-covered cancers.

The most recent version of the occupational environmental dose site profile does not address some of the issues raised in Anspaugh (2008) and the subsequent WG discussion in October 2008 (ABRWH 2008) for estimating partial doses for non-SEC cancers. It would therefore appear to merit review.

One of the challenges both NIOSH and SC&A encountered in addressing alternative methods for estimating the chronic long-term airborne dust loadings that many workers experienced pertained to the use of the resuspension-factor approach versus the mass-loading approach, including other strategies that used air-sampling data. Early in our deliberations, NIOSH agreed that the mass-loading approach might be best suited for these circumstances and adopted a bounding mass loading of 5 mg/m³, which was discussed during several WG meetings. The mass-loading approach was considered feasible, because contamination levels in soil were comprehensively characterized by RIDP reports authored by McArthur⁵ and others (the results can be expressed in either pCi/m² or Bq/g of surface contamination), and together with appropriate empirically derived resuspension factors, expressed in terms of pCi/m³ per pCi/m² (or 1/m), could be used to derive airborne concentrations of radionuclides. Alternatively, by using the RIDP data to express the radionuclide concentrations in the soil in units of Bq/g, the airborne radionuclide concentrations could be estimated by the mass-loading approach. Specifically, numerous reports cite a range of airborne mass loadings expressed in units of mg/m³ and, knowing the surficial concentration of radionuclides in soil, the airborne concentration of radionuclides can be estimated. Both methods are widely used to estimate the airborne concentrations of radionuclides due to resuspension processes. As will be discussed later, NIOSH, in its latest

⁵ The latest Occupational Environmental Dose TBD, ORAUT-TKBS-0008-4, Rev. 3, cites six reports (McArthur and Kordas 1985, 1987; McArthur and Mead 1987, 1988, 1989; McArthur 1991) which provide the results of soil contamination investigation for different NTS areas. McArthur (1991) provides a useful overview of the entire program, which covered many years in the 1980s.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 13 of 44
---	----------------------------------	---	-----------------------------

TBD, elected to use neither the resuspension-factor approach nor the mass-loading approach.⁶ Instead, NIOSH elected to use actual plutonium air-sampling data that were collected beginning in the early 1970s and soil-sampling data (which included many radionuclides) collected in the 1980s as a means to reconstruct exposures during the 1980s, but also as the basis for back-extrapolating exposures to January 1, 1963. However, as will be discussed later in this report, NIOSH also employed resuspension factors to address internal exposures during a portion of this time period.

Earlier in our deliberations, and at the suggestion of SC&A, NIOSH attempted to use the mass-loading approach to estimate the airborne concentration of radionuclides, because it had access to a considerable amount of soil-contamination data as reported in numerous investigations (McArthur and Kordas 1983, 1985; McArthur and Mead 1987, 1988, 1989; McArthur 1991) as part of the RIDP. However, NIOSH stated that, when applying a bounding mass loading of 5 mg/m³ to the radionuclide concentrations observed in soil to estimate the airborne concentrations of radionuclides, the derived doses were “just extraordinary” (ABRWH 2014, pp. 75–76) and were “extremely high and not reasonable” (ABRWH 2014, p. 69). However, these calculations were not documented (ABRWH 2014, p. 75). SC&A believes that such calculations may have been in error, and in any event, the calculations should have been documented and presented to the NTS WG, as NIOSH had previously indicated that they intended to use such an approach (ABRWH 2009a).

With this summary of the historical background of the status of the resuspension issue as of December 14, 2012, the following presents (1) a discussion of NIOSH’s use of air-sampling data as a means to estimate chronic radionuclide intake rates from the resuspension of ubiquitous levels of radionuclides in soil; (2) the use of the resuspension-factor approach, which also makes use of data from the RIDP, but applies resuspension factors to these data to derive the airborne radionuclide concentrations during the years 1963–1965; (3) a description of the use of the Hicks’ tables in order to account for short-lived radionuclides; (4) a description of the mass-loading approach, which was not used by NIOSH, but which makes use of estimates of the chronic outdoor dust loading and the RIDP data characterizing the radionuclide concentrations in soil; and (5) an evaluation of how NIOSH has implemented their approach in 241 relevant claims for energy employees (EEs) who were onsite after 1962 and had a probability of causation (POC) less than 50%.

To a large extent, the descriptive material provided here is kept at the conceptual level, because the actual implementation of the strategies as adopted in the TBD is quite complex. We do go into some detail when discussing some of the deficiencies in the basic strategy adopted by NIOSH and the data used to implement that strategy.

Given the long and complex history of issues related to reconstructing environmental doses at the NTS, it is instructive to begin with the latest version of the issues resolution matrix, which is reproduced in Appendix A. Inspection of Appendix A and a review of the most recent version of the NTS Occupational Environmental Dose TBD (ORAUT 2012) dated August 24, 2012, reveals

⁶ The Anspaugh et al. (2002) resuspension equation was used only to increase the airborne concentrations for the years of 1963–1965.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 14 of 44
---	----------------------------------	---	-----------------------------

that SC&A, NIOSH, and the Advisory Board need to revisit the available data, and how it can be best used to reconstruct environmental internal doses at the site. These are the topics that we believe require further discussion.

The August 24, 2012, version of the Occupational Environmental Dose TBD (ORAUT 2012) is extensive and describes briefly the myriad activities that took place at the NTS. Inspection of the table of contents alone provides insight into the complexity of the activities and incidents that took place at various locations throughout this large site at various times that resulted in the deposition of radionuclides onto the soil in both localized and widespread areas due to aboveground testing that terminated in 1962, belowground testing that continued up to 1992, Plowshare activities that were active from 1962 through 1968, tunnel operations, drill-back operations, and other activities too numerous to reiterate here. After carefully reading the 2012 TBD, it appears that NIOSH acknowledges that doses to operational personnel cannot be reconstructed from January 27, 1951 (the beginning of aboveground testing), through December 31, 1992 (the end of all testing). These exposures are referred to as “occupational exposures,” as opposed to “environmental exposures.” This distinction is important, because it was not entirely understood during previous discussions. Specifically, occupational exposures are those associated with specific activities, campaigns, and incidents (which NIOSH acknowledges cannot be reconstructed with sufficient accuracy and therefore establishes the basis for the SECs). However, to NIOSH’s credit, the TBD tries to find ways to reconstruct environmental doses to workers who are not covered as members of the SEC class, which include primarily workers with certain types of cancers, including skin cancer, prostate cancer, chronic lymphocytic leukemia, and other types. Environmental exposures and their associated internal doses are best thought of as exposures to the long-term average airborne dust loadings that represented a sort of ubiquitous cloud over most of the site and resulted in a baseline of internal exposures to all workers at the site. It is the purpose of this report to explore what doses can and cannot be reconstructed for the workers not covered by the SECs, and the most appropriate strategies and data that can be used to at least assign some doses to these workers. As will become apparent, the strategy adopted by NIOSH is best referred to as a combination of the air-sampling, soil-sampling, and resuspension-factor approaches, while an alternative plausible strategy explored here by SC&A is best referred to as the mass-loading approach.

As will be discussed in subsequent sections of this report, we are in agreement with the use of Pu air-sampling data and with the 1980s soil-characterization data for long-lived radionuclides as a starting point for deriving ubiquitous chronic internal exposures during these time periods and using these data, along with the Hicks’ tables, to back-extrapolate internal doses to the 1960s, including the selected use of resuspension factors. We have some reservations about use of long-lived radionuclide soil data that we will explain, and we believe that the mass-loading approach could be used instead of resuspension factors for the purpose of deriving airborne concentrations of radionuclides for time periods when actual airborne sampling data are not available.

2.0 MAJOR OVERARCHING ISSUES

There are two overriding major issues that should be discussed by the members of the WG. The first is whether some attempt should be made to distinguish the potential doses to persons actually working in the field versus those who were simply performing clerical or other

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 15 of 44
---	----------------------------------	---	-----------------------------

activities. The distinction between these two groups of workers had been discussed during the April 23, 2009, meeting of the WG (ABRWH 2009a), and NIOSH had indicated that they would develop a dual approach. As can be inferred from the above, NIOSH has abandoned the concept of a dual approach and has developed a model only for those persons not actively engaged in the field. SC&A agrees with this strategy. Much of the rest of this document discusses the TBD as it currently exists, identifying areas that appear to be overly simplistic, in error, or difficult to understand.

The second overarching issue is the time period to be covered for calculations of environmental occupational exposure. The contents of the present version of the TBD relate only to time periods from January 1, 1963, and beyond. The person who wrote the introduction to the TBD apparently intended that the document should cover the period "...from 1951 through December 31, 1992..."⁷ There is no apparent reason for a starting point of January 1, 1963, other than using material that had been previously prepared by NIOSH in an effort to reconstruct doses and recommend denial of SEC petition #00084. SC&A agrees that it is virtually impossible to consider environmental doses all the way back to 1951, but believes that the logical starting time for the calculation of such doses is mid-July 1962, at the "end" of atmospheric testing, and not January 1, 1963.

3.0 THE AIR SAMPLING DATA AND THEIR USEFULNESS IN RECONSTRUCTING UBIQUITOUS INTERNAL ENVIRONMENTAL DOSES TO NTS WORKERS

Inspection of the TBD reveals that one of the sources of data that is useful for performing partial dose reconstructions includes internal dosimetry data (i.e., bioassay data) that are available for at least some workers. Of course, such circumstances can only be addressed on a case-by-case basis,⁸ and, as such, are not discussed any further here. However, we do need to discuss other sources of data that might be useful for partial dose reconstructions. For example, Section 4.2.1.2 of the TBD describes data collected at air-sampling stations. In the past, SC&A was critical of these data, because they were not always located at the most useful locations for reconstructing internal exposures to workers and may very well have missed time periods that could have been associated with elevated levels of airborne radionuclides. In addition, the types of data were not always as complete as we would have liked in terms of quantifying the concentrations of specific radionuclides that could have been important contributors to internal

⁷ An important distinction has been made in the current TBD concerning the "end" of atmospheric testing in July 1962. The word end is in quotations, because there continued to be major Plowshare activities that released large quantities of radionuclides through 1968, and there were major breaches of containment, such as the Baneberry shot in 1970.

⁸ It is noteworthy that at NTS WG meetings, NIOSH and SC&A agreed that sufficient bioassay data do not exist for workers who were potentially exposed on the flats and even in the tunnels. And, given that the stated goal is to provide a method for the reconstruction of occupational environmental doses from 1951 through 1992, the usefulness of bioassay data for dose reconstruction is suspect mainly because no bioassays were performed during the earlier periods of the operation of the NTS. Such material was discussed thoroughly during the NTS WG meetings on October 29, 2008 (ABRWH 2008); April 23, 2009 (ABRWH 2009a); and December 15, 2009 (ABRWH 2009b).

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 16 of 44
---	----------------------------------	---	-----------------------------

dose. We believe that NIOSH would not have any dispute with these types of concerns regarding the air-sampling data. However, the current TBD now focuses on those circumstances where the air-sampling data can be used. In addition, we also discuss alternative strategies that can supplement the use of air-sampling data to perform partial dose reconstructions.

Given this perspective, the following sections describe SC&A's understanding of how NIOSH plans to perform partial dose reconstructions using available air-sampling data and the RIDP data as the starting point for these calculations. Specifically, the 2012 TBD explains that NIOSH plans to take advantage of the airborne Pu-239/240 concentration data collected from numerous continuously operating air-sampling stations. NIOSH also plans to take advantage of the radionuclide soil inventory data compiled in the 1980s under the RIDP to understand the mix of long-lived radionuclides in soil at various locations during the time period that the data were collected.

Given knowledge of the airborne concentration of Pu-239/240 (and also other isotopes of plutonium) at a given location and given time period, and also the concentrations of long-lived radionuclides in soil at those locations and time periods (e.g., Am-241, Co-60, Cs-137, Pu-238, Pu-239/240, Sr-90, Eu-152, Eu-154, and Eu-155) provided by the RIDP, one can estimate the airborne concentrations of these radionuclides at those locations and time periods by taking advantage of the measured ratio of Pu-239/240 to other radionuclides in soil and then multiplying that ratio by the measured concentration of Pu-239/240 in air at that location. It seems obvious that the inhalation and ingestion of radionuclides can be reconstructed where the air-sampling data are representative of the radionuclide concentration in soil and locations of the workers. As discussed later in this report, we identify some concerns regarding whether the air-sampling data are representative of the radionuclide concentrations in soil because of the locations of the air samplers. However, we also discuss some of the strategies NIOSH has adopted for using these data in a manner that helps to ameliorate many of these concerns. This topic warrants some discussion with NIOSH and the WG.

NIOSH argues that, not only can they perform partial dose reconstructions for those time periods where data are available characterizing the Pu-239/240 levels in soil and in air, but they can use that data to back extrapolate to time periods where air-sampling data and soil-inventory data are limited or entirely lacking. However, there are many challenges associated with trying to use the existing air-sampling data and soil-inventory data as a means to reconstruct internal doses for time periods and locations where such data do not exist. Many of these limitations and strategies for their resolution are described in Appendix A to the TBD and explored further in this report.

For earlier years, the concentrations of the radionuclides in soil and air will be higher because of subsequent radioactive decay, natural attenuation, and cleanup operations. Radiative decay is readily accounted for. However, natural attenuation and cleanup are more problematic. Specifically, the concentrations of long-lived radionuclides measured in soil in the 1980s are used to extrapolate back to the 1960s without taking into consideration natural attenuation or cleanup. The implications are that the concentrations of radionuclides in soil in the 1960s and 1970s could have been considerably higher than those derived by back-extrapolating using 1980s data if natural attenuation is not taken into consideration. In addition, there are locations that were remediated before the 1980s. For those locations, the actual concentrations of

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 17 of 44
---	----------------------------------	---	-----------------------------

radionuclides in soil prior to remediation would be higher than those derived by back-extrapolating using 1980s data, if remediation is not taken into consideration. As will be discussed later in this report, NIOSH was very selective and conservative in choosing which soil contamination data collected in the 1980s were used to perform the back-extrapolations. It appears that this strategy, as implemented by NIOSH, helps to ameliorate this concern. This matter will require some discussion with NIOSH and the WG.

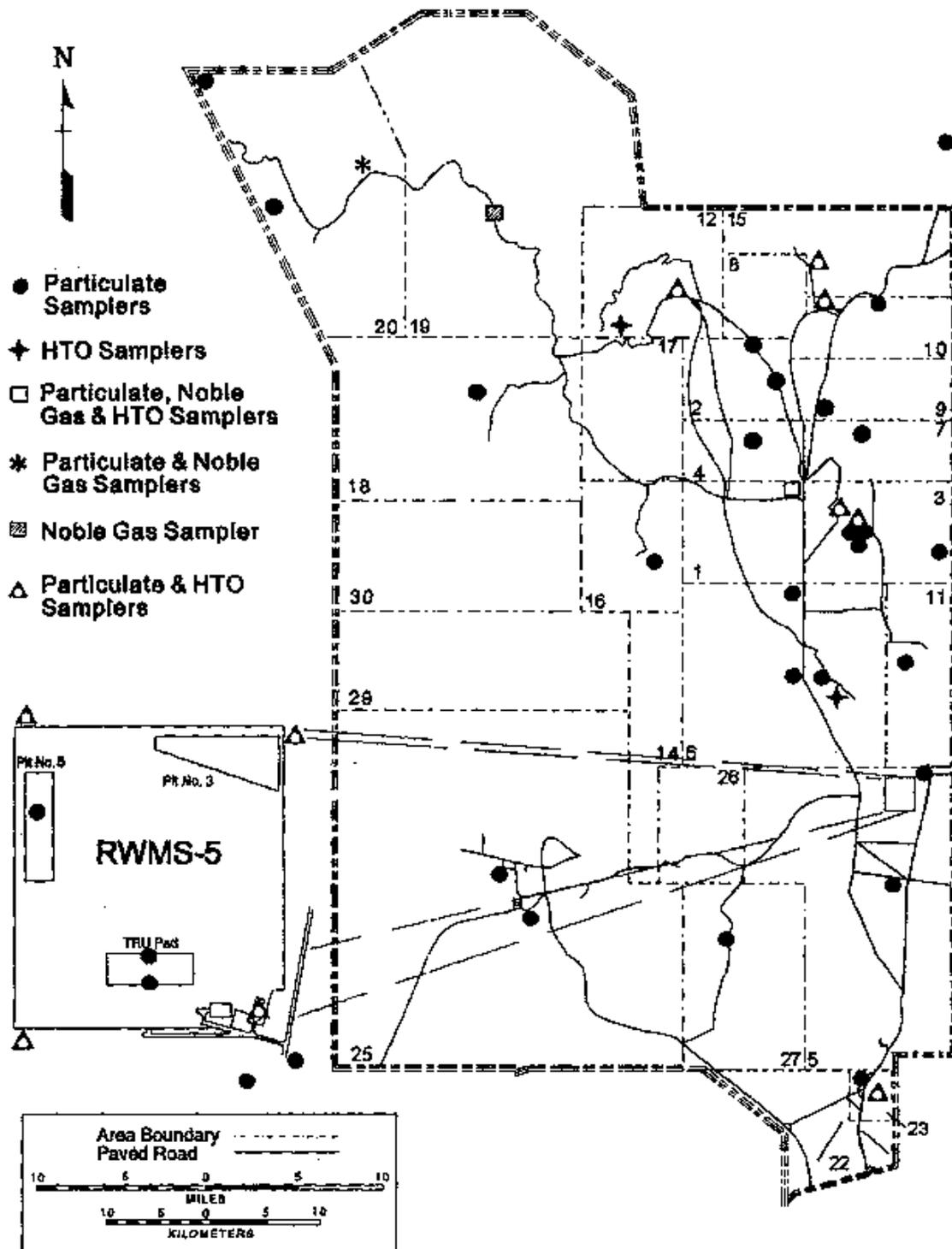
An additional concern with the back-extrapolation process is that many of the shorter-lived radionuclides present in soil in the 1960s and 1970s will have decayed away by the time that the RIDP data were collected in the 1980s. In order to overcome this challenge, and at least try to assign environmental doses to workers during the early years (i.e., from January 1, 1963,⁹ into the 1980s), NIOSH proposes to take advantage of the Hicks' tables, with due consideration of fractionation and the fact that the potential for resuspension of fresh fallout is far greater than that for aged fallout. The following presents a brief description of how the RIDP data and the Hicks' tables can be used for back-extrapolating the radionuclide concentrations in soil prior to the time that the RIDP data were collected. Much of the material summarized in the following sections was excerpted from Attachment A of the TBD. However, as the material is summarized, we point out some of the deficiencies associated with performing these types of back-extrapolations; deficiencies that warrant further discussion by the WG.

3.1 THE USE OF AIR-SAMPLING DATA FOR PU-239/240

As explained in Attachment A to the TBD, air samples were collected at the NTS from 15 stations from 1971 to 2001 and measured to determine the airborne concentration of Pu-239/240; additional sampling stations were later established at a number of other locations, such as Areas 2, 3, 4, 7, and 9 (see Figure 1, which is reproduced from the TBD). As explained in the TBD, the locations of the air-sampling stations were based on a number of factors, including areas where elevated plutonium levels might be expected, areas where large numbers of workers were located, and primarily areas where electric power was readily available. In addition, in 1988, the number of air-sampling stations was increased as a result of the requirements of DOE Order 5400.1. Table 4-2¹⁰ of the TBD presents a detailed summary of the average atmospheric concentrations of Pu-239/240 observed under this program by year and location, as originally reported in annual NTS environmental reports.

⁹ Again, SC&A does not understand why NIOSH chose to start their calculations of environmental occupational dose at January 1, 1963. Their method could have been used to calculate doses for the July 1962 period through December 31, 1992.

¹⁰ These data are reproduced in Table A-1 of the TBD, but the column headings on page 62 are mislabeled.



Source: TBD, Figure 4-1

Figure 1. Air-Sampling Locations in 1997

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 19 of 44
---	----------------------------------	---	-----------------------------

For the moment, let us not concern ourselves with the correlation between the location of the particulate air-sampling stations and the locations of the measured concentrations of radionuclides in soil. If we were interested in estimating the annual intake of Pu-239/240 due to resuspension from soil, we would want to know the degree to which these sampling locations represent the Pu-239/240 concentration in the breathing zone of workers at the time a given worker was at a given location. Clearly, the data are not adequate for that purpose. But currently NIOSH is not trying to reconstruct the intake of radionuclides for a particular person at a particular time. NIOSH is trying to estimate the average intake by individuals who might have been present at any or many locations over a given time period, but who were not working in the field where soil disturbances were taking place. Data in Table 4-2 of the TBD show the average annual concentration (pCi/m³) of Pu-239/240 over time and location for 20 areas and from 1971 through 2001, as reported in annual NTS environmental reports. On its surface, it would appear that this is a comprehensive air-sampling program. However, keep in mind that the site is over 1,000 square miles of desert and mountain terrain, where the types of tests and incidents varied widely as a function of time and location.

In order to place a plausible upper bound on the annual intake of Pu-239/240 for a given worker for a given year for chronic environmental exposures, one might assign the highest average annual concentration of Pu-239/240 measured among all areas for a given year, considering all locations. For example, for 1974, the average airborne Pu-239/240 concentration across all sampling locations was 8.64×10^{-5} pCi/m³ and the maximum was 2.11×10^{-4} pCi/m³. Using the maximum average concentration as the Pu-239/240 concentration to which the worker was continuously exposed in 1974 certainly seems to be a reasonable upper bound for chronic environmental exposure. Keep in mind that this is a baseline exposure for chronic environmental exposures and not occupational exposures associated with specific operational campaigns. It appears that, at a minimum, a Pu-239/240 annual inhalation intake rate for a particular year can be assigned at least for years where air-sampling data were collected. However, there are years and locations where no data are provided. For those locations and years, there is some question whether plausible upper bound Pu-239/240 intake rates can be assigned based solely on air-sampling data.

In principle, these data could also be used to reconstruct Pu-239/240 intakes for time periods before air-sampling was performed. However, it could be argued that such calculations could overestimate Pu-239/240 exposures during earlier years if no plutonium was deposited at a given location at an earlier time period of interest. Of course, such a situation would tend to overestimate the plutonium exposures at those earlier time periods. Conversely, it could also be argued that the plutonium deposited in soil in the earlier years may have weathered or have been removed between the time of its deposition and the time that the air-sampling data were collected. This would tend to result in an underestimate of the plutonium concentrations in air prior to the institution of airborne monitoring program. Clearly, extrapolating backward in time has its challenges, but we believe that these challenges should not preclude an attempt to assign at least some environmental doses to workers. For example, by selecting the location and year with the highest annual average airborne plutonium concentration for the purposes of partial dose reconstruction, there is a level of assurance that reconstructed internal exposures are claimant favorable for all workers during those time periods, and also for earlier time periods where back-extrapolation was required. One could also argue that this strategy would be reasonable for

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 20 of 44
---	----------------------------------	---	-----------------------------

earlier time periods and locations, even for locations that were cleaned-up prior to the commencement of the air-sampling program.

3.2 OTHER RADIONUCLIDES

In an effort to assign doses due to additional radionuclides that were not included in the analyses of the air-sampling data, NIOSH plans to make use of data collected under the RIDP. The RIDP soil-inventory data were collected in the 1980s and estimate the total inventory (Ci) of nine¹¹ radionuclides in each of 21 areas. The areal size of each NTS area is provided, which therefore allows one to estimate the average areal deposition density of each radionuclide in the year the data were collected. Table 4-4 of the TBD presents the inventory (Ci) of the 9 radionuclides in each of 21 areas as detected above background (which includes consideration of global fallout as part of ubiquitous background levels in soil) in the soil-inventory program, along with the size of each area in square miles.¹² It is important to note that Pu-239/240 is included in these data; this establishes a relationship between the Pu-239/240 concentration in soil and in air. Table 4-5 of the TBD then presents the average deposition density of each radionuclide in each of the 21 areas expressed in units of Bq/m².

At this point, it is instructive to develop a better understanding of how the values in Table 4-4 of the TBD were derived under the RIDP. The methods section of McArthur (1991) explains that the program extended from 1974 through 1984 and began with a series of aerial surveys performed by EG&G using rotary wing aircraft mounted with NaI(Tl) detectors in order to identify locations with elevated gamma-emitting activities. This helped to target the more contaminated areas of the site, at least for gamma emitters. The major data-collection activities were made with the use of an HPGe detector mounted on a tracked vehicle. Spectra were accumulated for later analysis by the technique generally referred to as in situ gamma spectrometry. Analysis of the in-situ data required that the relaxation depth of radionuclides in soil be determined. For this purpose, soil samples were collected at incremental depths down to 15 cm, but some (such as those collected at the Sedan test site) extended down to 30 cm.¹³ Sampling locations were based on a 400- or 500-foot grid for the regions of higher activity. The samples were screened through a 10-mesh (1.7 mm) screen to obtain only fine grained samples. The samples were then analyzed by gamma spectrometry and, with the assumption that the radionuclide activity in soil decreases exponentially with depth in soil, the inventory was estimated by using the relaxation lengths of each gamma emitter in soil. The top few cm of a few soil samples were collected and analyzed radiochemically for Sr-90, Pu-238, Pu-239/240, and Am-241. Ratios were then calculated for the different radionuclides that could not be measured directly by gamma spectroscopy, e.g., the ratio of Sr-90 to Cs-137. The concentrations were then decay corrected to be expressed as the concentrations and inventories as of January 1,

¹¹ Additional radionuclides were detected in some of the areas.

¹² The size of Area 30 is mistakenly given in Table 4-4 as 0.03 square miles; the correct value is 0.3 square miles. The correct value was used by NIOSH in subsequent calculations.

¹³ The Sedan event created a very large crater with massive amounts of throw-out deposited on top of native soil. Deeper depths of soil samples were required in order to analyze the distribution with depth of radionuclides due to this unusual situation.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 21 of 44
---	----------------------------------	---	-----------------------------

1990.¹⁴ Radionuclide isopleths were then constructed, so that a complete picture of the radionuclide contamination pattern over the contaminated areas of the site can be displayed in terms of nCi/m² and also µR/hr (with a lower level of 100 µR/hr). The RIDP reports provide information on the number of soil samples collected in each grid, and more detailed information is available in each of the separate reports published by McArthur as the senior author. Because of the importance of the RIDP, SC&A performed a spot-check analysis of the data. The results are provided in Appendix B. As may be noted, we were able to confirm many of the values reported in the TBD. However, not all information is provided in the supporting documents to allow a complete independent review of the values provided in the TBD.

In principle, one could assign a plausible upper bound of the intake of Pu-239/240 for a given year (as described above) and estimate the intake of the eight other radionuclides by the ratio of Pu-239/240 to the other radionuclides present in the soil. Of course, some judgment will need to be made regarding which of the 21 areas should be used to assign ratios. Under worst-case conditions, the area that gives the highest intakes of other radionuclides would tend to place an upper bound on the chronic baseline intake of the other radionuclides for a given year. Such an approach would help to overcome many of the challenges associated with reconstructing doses, such as those identified and discussed above.

The TBD acknowledges that the portion of the NTS where the RIDP data are provided is limited to only about one-third of the entire area of the NTS. However, the areas selected for the RIDP were those with measurable levels of contamination in soil above ubiquitous background. Hence, it certainly appears that a combination of the air-sampling data and the RIDP soil-inventory data can be used to assign chronic intakes of these nine radionuclides to workers. In addition, if high-end air-sampling and soil-inventory data are used, reconstructed doses associated with the chronic inhalation of these nine radionuclides would seem to be reasonably bounding. As presented in Table 4-6 of the TBD, this is, in fact, the approach adopted in the TBD to reconstruct radionuclide intake rates.

Because these are very large areas, one could argue that the activity in soil in a given area represents the average over a very large area, and some workers may have been at locations with radionuclide concentrations that are relatively higher than the average. This may be true for some workers, but keep in mind that we are interested in annual intakes, and there should be an averaging process if workers did not remain in one location for the entire year. In addition, not knowing the location of the workers, there is little recourse but to use high-end air-sampling and soil-inventory data collected from the entire site in order to provide a level of assurance that worker exposures are not underestimated, at least for “environmental exposures.”

3.3 EARLIER TIME PERIODS

Because the air-sampling data for Pu-239/240 extend from 1971 to 2001, and the RIDP soil data represent the activity in soil in the 1980s, intakes extending back to earlier years for these radionuclides can be estimated by decay correction. For example, Table 4-5 in the TBD presents

¹⁴ The January 1, 1990, RIDP data were subsequently decay corrected to January 1, 1963, by NIOSH and displayed in Table 4-5 of the TBD.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 22 of 44
---	----------------------------------	---	-----------------------------

the average soil contamination levels (Bq/m²) of the nine radionuclides in 21 areas for 1963 (i.e., the first year after the termination of aboveground testing)¹⁵ by simply adjusting for radioactive decay from the values reported under the RIDP. Table 4-6 of the TBD presents the concentration of eight radionuclides in soil scaled to the level of Pu-239/240 for 1963.

However, NIOSH acknowledges that extrapolation back to January 1, 1963, must involve more than just radioactive decay. At this point, a critical implicit assumption is made that the resuspension factor in the 1970s and 1980s is equal to 10⁻⁹/m. Then, in order to account for increased resuspension during the earlier years of 1963–1965, use is made of the Anspaugh et al. (2002) resuspension equation,¹⁶ which is given as eq. (4-2) in the TBD:

$$S_f = [10^{-5} e^{-0.07t} + 6 \times 10^{-9} e^{-0.003t} + 10^{-9}] \times 10^{\pm 1} \text{ m}^{-1}$$

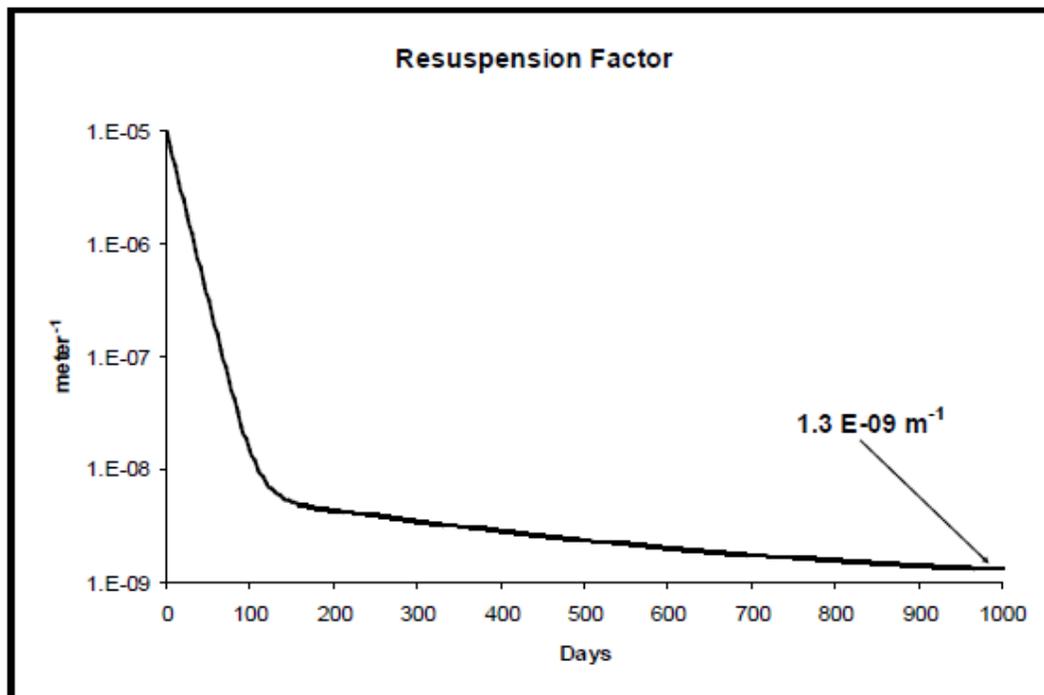
The following figure, excerpted directly from Figure 4-2 of the TBD, shows how the resuspension factor changes as a function of time following initial deposition of radionuclides. It is important to note that, at the end of the equation, there is an uncertainty factor of 10 higher and 10 lower than the curve depicted in Figure 1. Therefore, the curve is actually a thick “ribbon” with error bars extending a factor of 10 above and below the curve. In light of this, consideration should be given to multiplying the resuspension factors by a factor of 10 in order to ensure claimant favorability. In addition, note that, in the first 100 days following initial deposition, the resuspension factor declines by several orders of magnitude, and from then on declines very slowly, revealing the importance of the 6-month period beginning in July 1962 and ending on January 1, 1963, the time period that was not addressed in the TBD. These two characteristics of the Anspaugh resuspension model need to be taken into consideration for the time periods where the Anspaugh equation is used in the TBD.

In order to make the correction for increased resuspension at early times, NIOSH calculates a ratio of the integral of the Anspaugh equation over the time period of 180 to 545 days to the integral of 10⁻⁹/m. The result of this calculation is 3.12, which is the correction for increased resuspension during calendar year 1963. Similar values for 1964 and 1965 are 1.72 and 1.24, respectively. As we have previously noted, SC&A does not understand why this back extrapolation is carried out only to January 1, 1963. Extrapolation should extend back to July 1962.¹⁷ If the Anspaugh equation is integrated from 0 to 180 days, the computed ratio is 799, which indicates the importance of resuspension at early times.

¹⁵ Again, there should be no reason not to correct the data back to July 1962.

¹⁶ A slightly modified model with better characterized uncertainty was published by Maxwell and Anspaugh in 2011.

¹⁷ According to DOE (2000), 30 underground tests were carried out between the last atmospheric test in July 1962 and the end of 1962, so it is clear that substantial activity was ongoing at the NTS. An additional 29 tests were conducted at the NTS in the first 6 months of 1963; work in preparation for the latter tests was likely going on during the last 6 months of 1962.



Source: TBD, Figure 4-2

Figure 2. Resuspension Factor as a Function of Time after Deposition

It is important to reiterate that the TBD makes use of the highest measured air concentration of Pu-239/240 of $4.3 \times 10^{-3} \text{ pCi/m}^3$ from Area 9 in 1972; this is a very claimant-favorable assumption, because it is assumed that this highest concentration is typical of the airborne concentration of Pu-239/240 from 1966 through 1992. NIOSH then calculated the highest inhalation intake of Pu-239/240 by multiplying that value by an inhalation rate of $2,400 \text{ m}^3/\text{year}$ and converting from pCi to Bq and derived an intake value of 0.381 Bq/year . The intake values for the other eight radionuclides reported by the RIDP were calculated as ratios to the Pu-239/240 values. Again, the claimant-favorable assumption was made that the maximum values of the additional eight radionuclides were used. Hence, the last row in Table 4-6 of the TBD presents the inhalation-intake rate of the nine radionuclides for January 1, 1966.¹⁸ SC&A agrees that, in theory, these values represent the highest inhalation-intake rates for 1966 and beyond, as derived from the air-sampling data and soil-inventory data representative of the 1980s. We believe that this strategy helps to account for the possibility that doses might have been underestimated because of natural attenuation and cleanup of some areas prior to the measurements made under the RIDP in the 1980s.

It is noteworthy that the methodology adopted in the TBD for deriving the scaling factors in Table 4-6 of the TBD is the use of the maximum values in Table 4-6 for deposition density, which are from Area 20 for four (Am-241, Pu-238, Co-60, and Eu-155) of the eight radionuclides. Area 20 did not have a single nuclear test prior to April 1965, and the major Plowshare experiments in Area 20 were Palanquin (April 14, 1965), Cabriole (January 26,

¹⁸ The correction factors for short-term resuspension rates in 1963–1965 must also be applied.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 24 of 44
---	----------------------------------	---	-----------------------------

1968), and Schooner (December 8, 1968). These three shots produced large amounts of contaminated soil in Area 20, with smaller amounts elsewhere on the NTS. And some areas, particularly Area 25, were cleaned up before the RIDP measurements were made.

It is clear that the simplifying assumption made in the TBD, i.e., that all of the radionuclide inventories were laid down in July 1962, might result in an underestimate (post-1965 to 1968) or overestimate (pre-1965 to 1968) of the intakes as a function of time after January 1, 1963, and there is still the unresolved issue of neglecting the last 6 months of 1962. Additional discussion with respect to these matters would be helpful.

3.4 RADIONUCLIDES THAT HAD DECAYED BEFORE THE RIDP DATA WERE COLLECTED

Given that data from the air-sampling program are relatively representative of the long-term chronic environmental Pu-239/240 concentrations experienced by some workers, it seems that a plausible upper bound can be assigned for the chronic baseline environmental intake of the radionuclides measured by the air-sampling and soil-inventory programs. However, we know that during atmospheric testing, which ended in July 1962, a very large number of radionuclides were released to the atmosphere and deposited in the surrounding soil. Most of these radionuclides were relatively short-lived and would not have been detected by the RIDP performed in the 1980s. In theory, one could stop at this point and not try to address this issue. However, to its credit, NIOSH took advantage of the Hicks' tables to try to include relatively short-lived radionuclides (e.g., Ce-144 and Ru-106) in the dose reconstruction associated with chronic environmental exposures (not operational exposures) for the time periods following aboveground testing. Section 4.2.1.2.6 of the TBD addresses this issue; most of the important material is contained in Appendix A of the TBD.

For the purpose of reconstructing doses to downwind residents from the NTS (Church et al. 1990), a Hicks' table was developed for each test, which presents the ground concentration of a large number of radionuclides (Bq/m^2) as a function of time after detonation normalized to 1 mR/hr at 12 hours post-detonation (commonly noted as H+12). Data for a total of 152 fission products and 25 activation products are included in the Hicks' tables. These values were based on fundamental principles governing the production of fission and activation products associated with a given detonation, along with validation of the predicted values by collecting and analyzing debris samples after each shot. The tables were originally developed to allow researchers, who had historical measurements of external gamma-exposure rates at downwind locations after a test, to estimate the soil-surface contamination levels of a large number of fission and activation products on soil as a function of time after a test. Given the exposure-rate information and the Hicks' tables, it was possible to infer the ground deposition of all fission and activation products. In effect, these tables provide the relative concentration or inventory of a broad range of fission and activation products on soil at any time and location following a test, if you have either a measurement of the mR/hr, or if you have an estimate of the concentration of a given radionuclide in soil at a given location and time after a test based on other measurements, such as those performed under the RIDP. The TBD takes advantage of the RIDP data by using

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 25 of 44
---	----------------------------------	---	-----------------------------

Sr-90¹⁹ concentrations measured in the 1980s to back-calculate the concentrations of Sr-90 in soil in earlier years. With the use of ratios of other radionuclides-to-Sr-90, estimates could be made of the concentration of 177 fission and activation products in soil in the earlier years, before many of them decayed away. Because the starting point for calculating the Sr-90 concentrations in the earlier years was to use the high-end concentration of Sr-90 as measured by the RIDP in the 1980s, this strategy appears to be scientifically reasonable and claimant favorable.

There are a number of complicating factors that must be taken into consideration when using the Hicks' tables at the NTS for predicting radionuclide concentrations in soil shortly after a given test. The first complication is that about 100 aboveground tests were performed, and the fallout on the ground from each test at any given location represents a layering of the fallout from many tests. NIOSH elected to use the fallout pattern and associated Hicks' table for one of the last atmospheric tests at the NTS (Small Boy), which took place in July 1962. An issue that requires additional discussion is whether other, earlier tests could have contributed to the doses shortly after the end of aboveground testing in July 1962.

Section A.6 of the TBD takes the analysis a step further by taking into consideration a phenomenon referred to as fractionation. As stated in Section A.6 of the TBD, "Fractionation is a phenomenon due to chemical and physical separation of the radionuclides in the fireball in the first few minutes after detonation." This means that refractory elements, such as beryllium, sodium, manganese, iron, copper, yttrium, zirconium, niobium, rare earths, thorium, uranium, neptunium, and americium, condense and fall out more quickly than other less refractory elements, and this process is affected by the mass of material in the vicinity of the detonation. A degree of judgment is required when determining how fractionation is taken into consideration for a given test and the objectives of the test. The Hicks' tables that were used by NIOSH to support the reconstruction of environmental exposures onsite were actually originally derived for the purpose of evaluating offsite exposures. As a result, the Hicks' tables understate the relative abundance of refractory elements onsite and overstate the presence of volatile elements. While it is desirable to address this issue, we do not believe that it should prevent NIOSH from proceeding with the use of the Hicks' tables.

3.5 CALCULATIONS OF DOSE FROM INHALATION

Working with the soil concentration values derived for January 1963 and associated inhalation rates, along with the resuspension factor adjustment factors for deriving inhalation rates after July 1, 1963, the authors of the TBD undertook a very complex and not explicitly documented series of calculations, wherein they took the International Commission on Radiological Protection (ICRP 2011) dose coefficients for the 177 radionuclides for each of the ICRP listed organs and went through a calculation of dose as a function of time. The starting point in time is a critical, but poorly defined, factor. If NIOSH was true to the material existing up to this part of their document, they would have started at January 1, 1963; but their multiple figures (A-2 through A-11) have abscissa labeled "Days after Detonation," and the starting point is shown as

¹⁹ The Hicks' tables do not include values for Pu-239/240, so it is not possible to continue normalization to values of Pu-239/240 in the process used by NIOSH.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 26 of 44
---	----------------------------------	---	-----------------------------

0. The series of curves provided in the figures express the fraction of total dose contributed by Sr-90 for each organ as a function of time. The graphical results show some curvature, but NIOSH fit a straight line to such curves. One such fit for debris from the Small Boy event is given for the lungs as:

$$y = 0.0001x + 0.0074 ,$$

where y is the fraction of total dose contributed by ^{90}Sr and x is time. This is equation A-2 as given in the TBD. One unexplained fact here is that this equation does not match the equation shown in Figure A-2, which should have been the same as equation A-2. The authors then state the following:

Integrating Equation A-2 for SMALL BOY from 0 to 365 days and dividing the results by 365 (the value that represents the integrated total dose for 1 year), it was determined that for the first year after detonation the lung dose from ^{90}Sr represented 0.0000738 or about 0.00738% of the dose from all 177 radionuclides.

There are two problems with this. The first is the implication that time zero is the time of the last detonation (i.e., July 1962), but this appears to be impossible, given that the authors show in their Table A-9 that the relative dose to the thyroid is the same as for 17 other organs. Due to the affinity of the thyroid for short-lived radioiodines, this cannot be correct.

The second problem is the integration. A reproduction of what the authors *said* they did is the following:

$$\frac{\int_0^{365} (0.0001x + 0.0074)dx}{365} = \frac{\frac{0.0001x^2}{2} + 0.0074x}{365} \Big|_0^{365} = 0.026$$

The calculated value of 0.026 is obviously very different from 0.0000738. The above equation is, in fact, the classic definition of an average of the function over the 365-day period, and according to the authors' Figure A-2, the average value has to be about midway between 0.00 and 0.05. The authors' contention that they have calculated an integrated total dose does not match the reproduction of what they said they did. Because of our uncertainty in how the doses were actually calculated, it is not possible to continue with our review of the methods used in the TBD. It is a matter of some urgency that NIOSH explains or corrects their calculations on how they got from Table 4-7 to Table 4-8.

There is, however, one more issue of concern. We understand that it is necessary to feed information in the form of annual dose into IREP. This is easy enough, if the dose from a radionuclide is delivered completely within 1 year. However, some radionuclides are long-lived in terms of both physical and biological half-lives and, following intake, deliver dose over more than 1 year. An example of the importance of this is shown in Figure 3 for the intake of Pu-239 and subsequent dose over time to the extra-thoracic lymph nodes. For this "organ" and a few others, it is very important to consider the dose to the organ beyond just the first year.

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

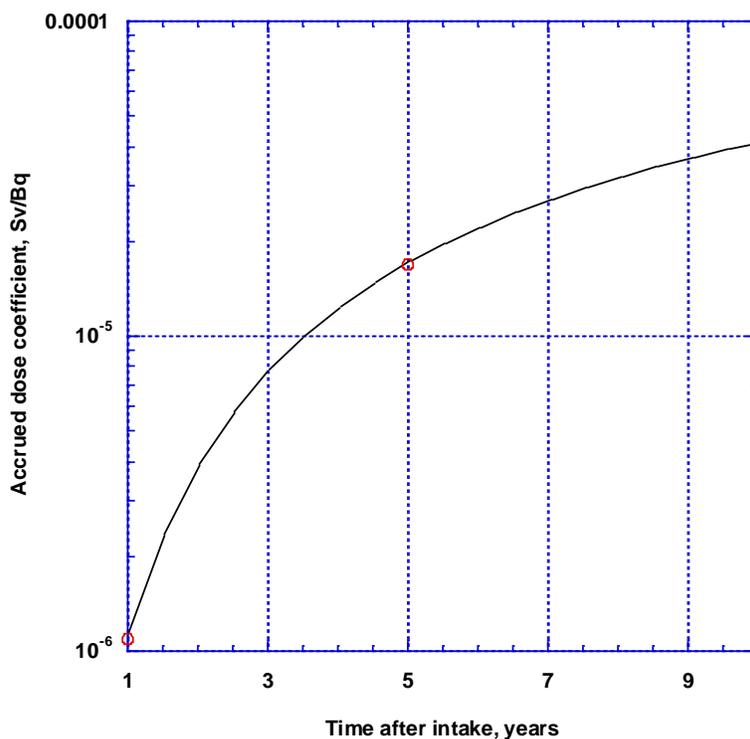


Figure 3. Accrued Dose (Coefficient) for Extra-Thoracic Lymph Nodes (LNet) as a Function of Time Following Intake of Pu-239

Note that only a small fraction of the total dose has been accrued during the first year. The curve represents a 9-degree polynomial fit to the ICRP (2011) dose coefficients. The red dots are the actual dose coefficients for 1, 5, and 10 years following intake.

NIOSH should clarify whether they have considered annual doses in subsequent years from the intake of radionuclides in preceding years.

4.0 DOSE FROM INGESTION OF SOIL

The method of calculating dose from ingestion is very similar to the method of calculating dose from inhalation. Although consideration of dose from ingestion is beyond the scope of Issue 5, we do note that the same problems exist as noted above for the inhalation pathway.

5.0 THE MASS LOADING APPROACH FOR INHALATION

One of the original issues raised by SC&A during the review of the NTS site profile (i.e., Issue 5) was whether the mass-loading approach was a more appropriate strategy for reconstructing inhalation doses from the resuspension process at the NTS, as opposed to the use of the resuspension-factor approach. In order to explore this question, this section reconstructs

Effective Date:	Revision No.	Document No.	Page No.
July 21, 2015	0 (Draft)	NTS Resuspension Issues Status	28 of 44

the inhalation-intake rates using the mass-loading approach and compares those values to the values derived in the TBD.

A simple method that can be used to compare the results of the airborne Pu-239/240 approach for determining inhalation-intake rates (as provided in Table 4-7 of the TBD) and those obtained using the mass-loading approach is to take advantage of the radionuclide-concentration values provided in Table 4-10 of the TBD. Table 4-10 presents the concentration of the radionuclides at the surface of the soil.²⁰

Consistent with the approach used by NIOSH, we have chosen the highest values for each radionuclide shown in Table 4-10 with the exclusion of Area 30, which was heavily contaminated in 1968, but which is isolated. The highest values by area are for Area 20²¹ for Am-241, Pu-238, Co-60, Eu-154, and Eu-155; Area 10 for Cs-137 and Sr-90; Area 8 for Pu-239/240; and Area 5 for Eu-152. As with the NIOSH stated goal of dose calculations, we chose the radionuclide type that would give the highest accrued dose for 1 year. For some organs, we also include the accrued dose for 5 years, in order to indicate the problem noted above in Figure 3. We took dose coefficients directly from the ICRP (2011). Calculations of dose, D (Sv), are made according to:

$$D = C \times DC \times ML \times IR \times K ,$$

where C is the concentration in soil (Bq/g), DC is the dose coefficient (Sv/Bq), ML is the mass loading (mg/m³), IR is the breathing rate fixed at 2,400 m³/year, and K is a constant equal to 0.001 g/mg.

The results of the calculations are shown in Table 1 for $ML = 1$ mg/m³. From a practical perspective, only the ET, ET1, and LN(et) doses are of interest, because they are not covered by the SEC. However, doses to other organs are provided simply to demonstrate that the inhalation doses are, in fact, not unreasonably high using the mass-loading approach (even at a chronic dust loading of 1 mg/m³), as stated by NIOSH (see above discussion regarding this issue). The highest 1 year dose from a 1-year intake is 4.37×10^{-4} Sv (0.0437 rem) to the bone surface, and the highest dose over 5 years from a 1-year intake is 2.49×10^{-3} Sv (0.249 rem). There are also relatively high doses to the lungs, ET1 and ET. Contrary to the undocumented findings of NIOSH discussed above, these dose values do not seem to be “extraordinarily high.” A major point of interest is that almost the entire dose is due to the three actinide radionuclides.

Comparable values of dose are not presented in the TBD, but we can make a comparison for the nine radionuclides shown in our Table 1 by simply multiplying the scaled inhalation intakes (Bq/yr) given in TBD Table 4-7 by the same dose coefficients shown in our Table 1. Our

²⁰ SC&A originally believed that radionuclide concentrations reported in Table A-10 of the TBD were the average concentrations in the top 15 cm of soil. Discussions with Dr. Anspaugh, who was intimately involved in the research performed at the NTS at this time, explained that these concentrations were derived by plotting the concentrations of individual radionuclides as a function of depth, and extrapolating back to the concentrations at zero depth.

²¹ We have previously noted that Area 20 was not appreciably contaminated until 1965, but in this instance, for the sole purpose of exploring this dose reconstruction issue, we continue to use the process adopted by NIOSH.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 29 of 44
---	----------------------------------	---	-----------------------------

Table 2 shows the results of this calculation resulting from 1 year of intake according to the scaled inhalation intakes for 1963. The results are smaller with the highest 1-year dose of 7.34×10^{-5} Sv being to the bone surface; again doses are dominated by the three actinide nuclides.

The calculations shown in our Table 2 were made with an arbitrary mass loading of 1 mg/m^3 . The implications of these calculations are that (1) mass loading is a reasonable approach, (2) a mass loading of 0.168 mg/m^3 gives the same dose as the resuspension method, and (3) 1 mg/m^3 is reasonable and would be more claimant favorable. It is SC&A's opinion that the mass-loading approach deserves reconsideration, especially for possible use in considering the occupational environmental dose that would have been received by employees working in dusty conditions. In such situations, a mass loading of 1 mg/m^3 would be reasonable.

Table 1. Calculations of Dose with Use of the Mass-Loading Approach (1 mg/m^3)

Radionuclide soil data are from Table 4-10 of the TBD (1963 values). Dose coefficients are from the ICRP (2011).

Type:	M	M	M	S	F	[F]	M	M	M	
Radionuclide:	Am-241	Pu-238	Pu-239	Co-60	Cs-137	Sr-90	Eu-152	Eu-154	Eu-155	
Soil conc (Bq/g):	1.607	2.5	3.28	20.946	3.321	1.45	1.45	3.122	16.031	
Dose coefficients (Sv/Bq)										
Bone surface, 1 year	2.0E-05	2.7E-05	2.5E-05	1.9E-09	6.0E-09	5.7E-08	1.2E-08	3.1E-08	1.20E-08	
Bone surface, 5 year	1.4E-04	1.4E-04	1.4E-04	4.1E-09	6.6E-09	1.8E-07	5.6E-08	1.4E-07	4.90E-08	
Liver, 1 year	6.9E-06	4.5E-06	4.2E-06	3.8E-09	5.9E-09	4.8E-10	1.8E-08	2.6E-08	3.90E-09	
Liver, 5 year	2.7E-05	2.7E-05	2.6E-05	8.6E-09	6.5E-09	6.0E-10	8.1E-08	1.1E-07	1.60E-08	
Red marrow, 1 year	1.6E-06	2.7E-06	2.5E-06	2.4E-09	5.7E-09	4.0E-08	4.9E-09	7.3E-09	1.10E-09	
Red marrow, 5 year	1.0E-05	1.3E-05	1.2E-05	5.4E-09	6.3E-09	1.2E-07	2.1E-08	3.1E-08	4.30E-09	
ET, 1 year	1.2E-05	1.2E-05	1.2E-05	3.7E-08	1.2E-08	3.0E-09	1.6E-08	2.4E-08	5.50E-09	
ET, 5 year	1.4E-05	1.4E-05	1.3E-05	6.3E-08	1.3E-08	3.1E-09	1.9E-08	2.7E-08	6.00E-09	
ET1, 1 year	2.8E-05	3.0E-05	1.5E-06	1.3E-06	1.9E-06	2.2E-06	1.1E-06	2.4E-06	5.10E-07	
LN(et), 1 year	3.8E-07	4.2E-07	3.9E-07	2.5E-08	1.0E-08	4.8E-10	1.1E-08	1.2E-08	8.30E-10	
Lungs, 1 year	2.2E-05	2.2E-05	1.9E-05	5.0E-08	5.5E-09	5.1E-10	2.6E-08	5.2E-08	1.20E-08	
Thymus, 1 year	2.1E-08	6.2E-08	5.8E-08	5.0E-09	5.7E-09	4.8E-10	1.8E-09	2.0E-09	1.10E-10	
Thymus, 5 year	1.2E-07	2.7E-07	2.5E-07	1.2E-08	6.3E-09	6.0E-10	4.5E-09	4.6E-09	2.20E-10	
Doses, Sv, from one year of intake										
Bone surface, 1 year	7.71E-05	1.62E-04	1.97E-04	9.55E-08	4.78E-08	1.98E-07	4.18E-08	2.32E-07	4.62E-07	4.37E-04
Bone surface, 5 year	5.40E-04	8.40E-04	1.10E-03	2.06E-07	5.26E-08	6.26E-07	1.95E-07	1.05E-06	1.89E-06	2.49E-03
Liver, 1 year	2.66E-05	2.70E-05	3.31E-05	1.91E-07	4.70E-08	1.67E-09	6.26E-08	1.95E-07	1.50E-07	8.73E-05
Liver, 5 year	1.04E-04	1.62E-04	2.05E-04	4.32E-07	5.18E-08	2.09E-09	2.82E-07	8.24E-07	6.16E-07	4.73E-04
Red marrow, 1 year	6.17E-06	1.62E-05	1.97E-05	1.21E-07	4.54E-08	1.39E-07	1.71E-08	5.47E-08	4.23E-08	4.25E-05
Red marrow, 5 year	3.86E-05	7.80E-05	9.45E-05	2.71E-07	5.02E-08	4.18E-07	7.31E-08	2.32E-07	1.65E-07	2.12E-04
ET, 1 year	4.63E-05	7.20E-05	9.45E-05	1.86E-06	9.56E-08	1.04E-08	5.57E-08	1.80E-07	2.12E-07	2.15E-04
ET, 5 year	5.40E-05	8.40E-05	1.02E-04	3.17E-06	1.04E-07	1.08E-08	6.61E-08	2.02E-07	2.31E-07	2.44E-04
ET1, 1 year	1.08E-04	1.80E-04	1.18E-05	6.54E-05	1.51E-05	7.66E-06	3.83E-06	1.80E-05	1.96E-05	4.29E-04
LN(et), 1 year	1.47E-06	2.52E-06	3.07E-06	1.26E-06	7.97E-08	1.67E-09	3.83E-08	8.99E-08	3.19E-08	8.55E-06
Lungs, 1 year	8.48E-05	1.32E-04	1.50E-04	2.51E-06	4.38E-08	1.77E-09	9.05E-08	3.90E-07	4.62E-07	3.70E-04
Thymus, 1 year	8.10E-08	3.72E-07	4.57E-07	2.51E-07	4.54E-08	1.67E-09	6.26E-09	1.50E-08	4.23E-09	1.23E-06
Thymus, 5 year	4.63E-07	1.62E-06	1.97E-06	6.03E-07	5.02E-08	2.09E-09	1.57E-08	3.45E-08	8.46E-09	4.76E-06

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Table 2. Calculations of Dose from the Nine Radionuclides also considered in Table 2

These calculations are performed using the methodology given in NIOSH's TBD.

Type:	M	M	M	S	F	[F]	M	M	M	
Radionuclide:	Am-241	Pu-238	Pu-239	Co-60	Cs-137	Sr-90	Eu-152	Eu-154	Eu-155	
Scaled inhalation intakes, Bq/year										
1963	0.70	1.08	1.19	9.08	2.47	4.84	10.61	0.45	6.96	
1964	0.38	0.59	0.65	4.98	1.35	2.65	5.81	0.25	3.81	
1965	0.28	0.43	0.47	3.61	0.98	1.92	4.22	0.18	2.77	
All subsequent years	0.223	0.347	0.381	2.91	0.792	1.55	3.4	0.144	2.23	
Doses, Sv, from intake during 1963										Sum, Sv
Bone surface, 1 year	1.40E-05	2.92E-05	2.98E-05	1.73E-08	1.48E-08	2.76E-07	1.27E-07	1.40E-08	8.35E-08	7.34E-05
Bone surface, 5 year	9.80E-05	1.51E-04	1.67E-04	3.72E-08	1.63E-08	8.71E-07	5.94E-07	6.30E-08	3.41E-07	4.18E-04
Liver, 1 year	4.83E-06	4.86E-06	5.00E-06	3.45E-08	1.46E-08	2.32E-09	1.91E-07	1.17E-08	2.71E-08	1.50E-05
Liver, 5 year	1.89E-05	2.92E-05	3.09E-05	7.81E-08	1.61E-08	2.90E-09	8.59E-07	4.95E-08	1.11E-07	8.01E-05
Red marrow, 1 year	1.12E-06	2.92E-06	2.98E-06	2.18E-08	1.41E-08	1.94E-07	5.20E-08	3.29E-09	7.66E-09	7.30E-06
Red marrow, 5 year	7.00E-06	1.40E-05	1.43E-05	4.90E-08	1.56E-08	5.81E-07	2.23E-07	1.40E-08	2.99E-08	3.62E-05
ET, 1 year	8.40E-06	1.30E-05	1.43E-05	3.36E-07	2.96E-08	1.45E-08	1.70E-07	1.08E-08	3.83E-08	3.62E-05
ET, 5 year	9.80E-06	1.51E-05	1.55E-05	5.72E-07	3.21E-08	1.50E-08	2.02E-07	1.22E-08	4.18E-08	4.13E-05
ET1, 1 year	1.96E-05	3.24E-05	1.79E-06	1.18E-05	4.69E-06	1.06E-05	1.17E-05	1.08E-06	3.55E-06	9.72E-05
LN(et), 1 year	2.66E-07	4.54E-07	4.64E-07	2.27E-07	2.47E-08	2.32E-09	1.17E-07	5.40E-09	5.78E-09	1.57E-06
Lungs, 1 year	1.54E-05	2.38E-05	2.26E-05	4.54E-07	1.36E-08	2.47E-09	2.76E-07	2.34E-08	8.35E-08	6.26E-05
Thymus, 1 year	1.47E-08	6.70E-08	6.90E-08	4.54E-08	1.41E-08	2.32E-09	1.91E-08	9.00E-10	7.66E-10	2.33E-07
Thymus, 5 year	8.40E-08	2.92E-07	2.98E-07	1.09E-07	1.56E-08	2.90E-09	4.77E-08	2.07E-09	1.53E-09	8.52E-07

6.0 APPLICATIONS OF THE TBD PROCEDURE IN ACTUAL DOSE RECONSTRUCTION FOR CLAIMANTS

In order to understand the degree to which the methods described in the TBD were actually performed, SC&A examined the claim files of energy employees (EEs) who were onsite after 1962 and had a probability of causation (POC) less than 50%. These criteria were chosen to target the NTS claimants who were likely to have environmental doses assigned per the TBD. Additionally, only cases that have been evaluated after ORAUT 2012 was approved were considered. A total of 241 claimants were identified and their dose reconstruction documentation examined. An overall summary of these claims is found in Table 3.

Table 3. Characterization of the Application of Environmental Doses to Relevant NTS Claimants

Category	Total #	Percent of Total
Total Relevant Claims	241	-
Full Internal and External DR	127	52.7%
Overestimate DR	114	47.3%
Full TBD Intakes (Full Years, Entire Employment)	183	75.9%
Full TBD Intakes (Full Years, Partial Employment)	7	2.9%
10% TBD Intakes (Full Years, Entire Employment)	4	1.7%
OTIB-0018 Intakes (Entire Employment)	14	5.8%
OTIB-0018 Intakes (Partial Employment)	9	3.7%
Tonopah Test Range Intakes Assigned	5	2.1%
No Environmental Intakes Assigned	19	7.9%

As seen in Table 3, the “Full Internal and External” (i.e., best-estimate) and “Overestimate” dose reconstructions were fairly evenly split. For over three-quarters of the affected claimants, the maximum intake rates prescribed in the TBD (NIOSH 2012, Tables 4-7 and 4-11) were applied for each year of employment and assumed to apply to the entire year. It should be noted that the TBD prescribes the following concerning the application of environmental intakes:

If necessary, these intakes can be prorated for time less than a year for a best estimate if the worker was on site for only a fraction of the year. (ORAUT 2012, pg. 27)

SC&A did not identify any cases in which prorated intake rates were actually applied, and only one case in which prorated intakes appear to have been evaluated, but ultimately discarded for full year intakes.

Of the remaining cases that were not assigned full-year intakes for each year of employment, a variety of methods were observed. For example, 7 cases applied full-year TBD intakes, but not for every year of employment (see Observations 2a and 9a in Table 6). Four cases were observed in which only 10% of the annual TBD intakes were applied (see Observation 4). Twenty-three total cases applied ORAUT-OTIB-0018 (ORAUT 2005) methods for

reconstructing environmental internal dose (see Observations 1a, 1b, 3, and 8). Five cases applied intake rates associated with Tonopah Test Range (see Observation 7). Finally, 19 cases did not have environmental intakes assigned (see Observations 2a, 2b, 5, 9a, and 9b).

The maximum environmental intakes from the TBD can be found in Tables 4-6 and 4-11 of ORAUT 2012. ORAUT-OTIB-0018 intake rates are found in Table 4-1 that document. The intakes associated with Tonopah Test Range are found in Table 4-8 of ORAUT-TKBS-0037 (ORAUT 2013). Each of these intake rates are recreated in Table 4 for reference.

Table 4. Environmental Intake Rates Observed in Relevant NTS Dose Reconstructions

Radionuclide	TBD Inhalation Intake* (Bq/yr)	TBD Ingestion Intake (Bq/yr)	OTIB-0018 Inhalation (Bq/yr)	OTIB-0018 Ingestion (Bq/yr)	Tonopah Inhalation [†] (Bq/yr)	Tonopah Ingestion (Bq/yr)
Am-241	2.33×10^{-1}	4.02×10^1	–	–	4×10^{-4}	–
Pu-238	3.47×10^{-1}	6.25×10^1	–	–	2×10^{-4}	–
Pu-239/240	3.81×10^{-1}	8.20×10^1	–	–	8×10^{-5}	–
Co-60	2.91×10^0	5.24×10^2	–	–	–	–
Cs-137	7.92×10^{-1}	8.30×10^1	–	–	–	–
Sr-90	1.55×10^0	5.54×10^1	–	–	–	–
Eu-152	3.40×10^0	1.53×10^2	–	–	–	–
Eu-154	1.44×10^{-1}	2.42×10^1	–	–	–	–
Eu-155	2.23×10^0	4.01×10^2	–	–	–	–
Alpha**	–	–	1.78×10^2	3.74×10^1	–	–
Beta ³	–	–	1.78×10^5	3.74×10^3	–	–

* Note the inhalation intakes are slightly different for 1963–1965 due to scaling associated with early resuspension.

[†] It was observed in some cases that inhalation intakes were assigned based on Revision 00 of the TBD; based on the dose reconstruction calculation files, these intakes were slightly higher at 0.0005, 0.0002, and 0.0001 Bq/yr (Am-241, Pu-238, and Pu-239/240, respectively).

** Assumed to be radionuclide, which results in the highest organ-specific dose by year.

SC&A also had the following nine observations concerning the environmental intake assignment as shown in Table 5.

Table 5. Observations Concerning Ambient Environmental Dose Assignment to NTS Claimants

Observation #	Description of Observation	Example Case #'s
1a	OTIB-0018 was utilized instead of environmental intakes when the NTS employment period coincided with employment at another site (LLNL, LANL, SNL etc.).	7 Case Examples Provided
1b	OTIB-0018 was applied instead of environmental intakes when employment was at NTS and not another site.	11 Case Examples Provided
2a	Some employment periods after 1963 were not assigned environmental intakes, because there was no dosimeter assigned to the EE for those periods.	3 Case Examples Provided
2b	Lack of a dosimeter during certain employment periods after 1963 was not always used to preclude the assignment of environmental intakes.	4 Case Examples Provided
3	In some cases, OTIB-0018 was applied, but only for years after 1992.	9 Case Examples Provided
4	Four cases assigned only 10% of the environmental intake values. Only one of the four cases specifically mentioned this in the DR Report. Two of the four cases had POC values that were less than 10%; the other two were above 45%.	4 Case Examples Provided
5	Many cases did not evaluate ambient internal dose during NTS employment and cited the SEC and/or the lack of bioassay in the dose reconstruction report.	10 Case Examples Provided
6	One case assigned full environmental intakes from 1966–1989, although the EE's covered employment was only for a single day in 1971 and 1982.	1 Case Example Provided
7	Several cases did not apply NTS environmental intakes and instead applied Tonopah Test Range (TTR) intake values, which are significantly lower than NTS intake rates (See Table 1). Not all of these observed cases had overlapping employment at NTS/TTR.	6 Case Examples Provided
8	Both OTIB-0018 and environmental intakes were assigned to the same employment period in one case. However, the environmental intakes did not include plutonium (inhalation or ingestion) or americium (inhalation only).	1 Case Example Provided
9a	Some cases were not assigned environmental intakes, because the doses were deemed too low based on the short duration of covered employment.	5 Case Examples Provided
9b	Some cases were assigned full years' worth of environmental intakes even though covered employment was of short duration.	5 Case Examples Provided

Based on this review of relatively recently completed dose reconstructions, procedures, and instructions for application of environmental doses in the TBD, and used by the dose reconstructors, it appears that the dose reconstructions were not always performed in accordance with the procedures delineated in the TBD.

As was noted in Table 5 and Observation 4, four cases were identified that applied intake rates that were 10% of the TBD prescribed values. SC&A was able to trace this abnormality to a

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 34 of 44
---	----------------------------------	---	-----------------------------

word document that was sometimes included in NOCTS with the standard dose reconstruction documentation titled, “NTS DR Guidance [various dates].” The pertinent section on ambient environmental intakes is shown as a screenshot in Figure 4. As can be seen in this figure, for a “best-estimate” dose reconstruction, the area-specific inhalation/ingestion intakes can be used. In the event that the work location is unknown, 10% of the prescribed intake values can be utilized instead. This guidance and approach is not contained in the currently approved TBD. As noted earlier, the TBD instructs the dose reconstructor to prorate the maximum intake values to the energy employee’s covered employment for “best-estimate” cases.

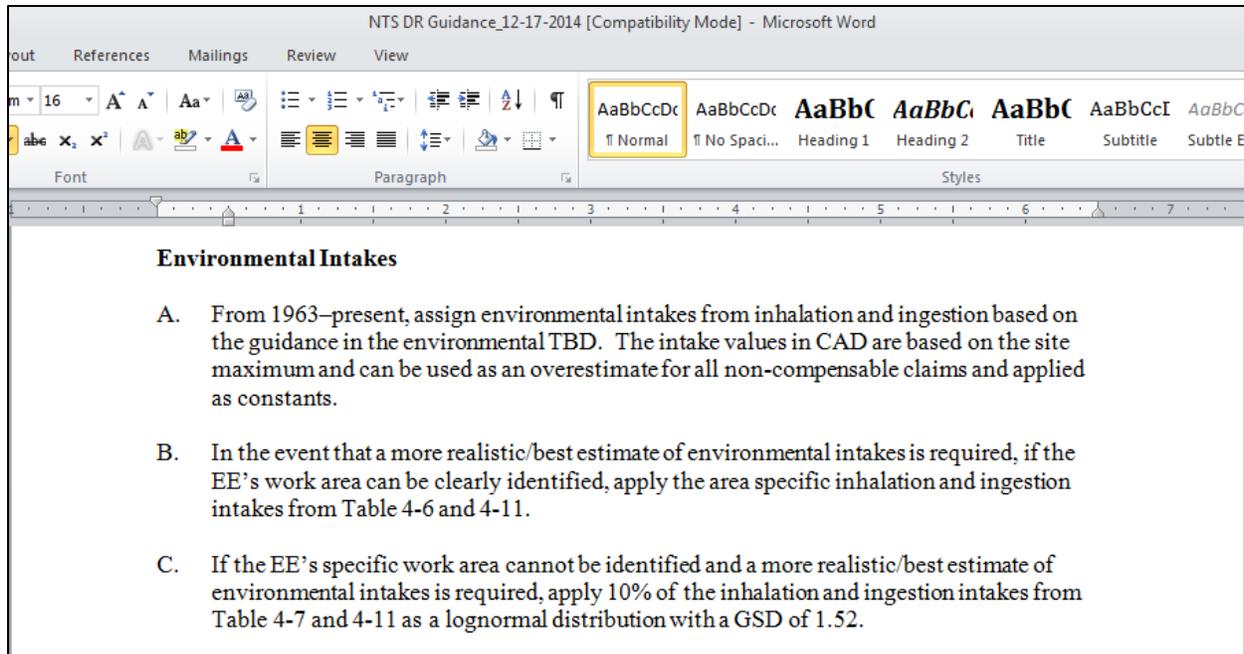


Figure 4. Screenshot of Word Document Included in Some NOCTS Files Providing Guidance on the Application of Environmental Intakes

SC&A did not observe a case in which an area-specific inhalation intake was utilized. However, SC&A did note that area-specific information was available in the four cases utilizing 10% of the TBD intakes. This information was generally in the form of the area in which external dosimeters were issued.

Based on these case reviews, there appears to be incongruity between the guidance provided in the site profile and the methods used in the actual dose reconstructions.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 35 of 44
---	----------------------------------	---	-----------------------------

REFERENCES

ABRWH 2007a. Nevada Test Site Work Group meeting transcript, March 27, 2007. Advisory Board on Radiation and Worker Health. On the web at <http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr032707.pdf>.

ABRWH 2007b. Nevada Test Site Work Group meeting transcript, August 7, 2007. Advisory Board on Radiation and Worker Health. On the web at <http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr080707.pdf>.

ABRWH 2008. Nevada Test Site Work Group meeting transcript, October 29, 2008. Advisory Board on Radiation and Worker Health. On the web at <http://www.cdc.gov/niosh/ocas/pdfs/abrwh/2008/wgtr102808.pdf>.

ABRWH 2009a. Nevada Test Site Work Group meeting transcript, April 23, 2009. Advisory Board on Radiation and Worker Health. On the web at <http://www.cdc.gov/niosh/ocas/pdfs/abrwh/2009/wgtr042309.pdf>.

ABRWH 2009b. Nevada Test Site Work Group meeting transcript, December 15, 2009. Advisory Board on Radiation and Worker Health. On the web at <http://www.cdc.gov/niosh/ocas/pdfs/abrwh/2009/wgtr121509.pdf>.

ABRWH 2015. Nevada Test Site Work Group meeting transcript, December 3, 2014. Advisory Board on Radiation and Worker Health. On the web at <http://www.cdc.gov/niosh/ocas/pdfs/abrwh/2014/wgtr120314.pdf>.

Anspaugh, L.R., 2006. "The Resuspension Pathway for Nevada Test Site Workers," Rev. 3. SC&A, Inc., Vienna, Virginia. October 8, 2006.

Anspaugh, L.R., 2007. "Preliminary List of Issues for "Ambient environmental intakes at the Nevada Test Site based on air sampling and soil contamination data," dated July 29, 2007." SC&A, Inc., Vienna, Virginia. August 6, 2007.

Anspaugh, L.R., 2008. "Comments on ORAUT-TKBS-0008-4, "Nevada Test Site–Occupational Environmental Dose." SC&A, Inc., Vienna, Virginia. October 21, 2008.

Anspaugh L.R., S.L. Simon, K.I. Gordeev, I.A. Likhtarev, R.M. Maxwell, and S.M. Shinkarev, 2002. "Movement of radionuclides in terrestrial ecosystems by physical processes." Health Phys 82:669–679; 2002.

Bechtel SAIC 2006. "Inhalation Exposure Input Parameters for the Biosphere Model," ANL-MGR-MD-000001, Rev. 04, Bechtel SAIC Co., Las Vegas, Nevada. June 2006.

Church B.W., D.L. Wheeler, C.M. Campbell, R.V. Nutley, L.R. Anspaugh. 1990. "Overview of the Department of Energy's Off-Site Radiation Exposure Review Project (ORERP)." Health Phys 59:503–510; 1990.

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date:	Revision No.	Document No.	Page No.
July 21, 2015	0 (Draft)	NTS Resuspension Issues Status	36 of 44

DOE 2000. United States nuclear tests, July 1945 through September 1992. DOE/NV -- 209-Rev. 15: U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada. December 2000.

Hicks, H.G., 1982. "Calculation of the Concentration of Any Radionuclide Deposited on the Ground by Offsite Fallout from a Nuclear Detonation." Health Phys 42:585–600; 1982.

Kordas, J.F. and L.R. Anspaugh, 1982. "Nevada Test Site Radionuclide Inventory and Distribution—Project Operations Plan." Lawrence Livermore National Laboratory, Livermore, California. June 1, 1982.

Maxwell, R.M. and L.R. Anspaugh, 2011. "An improved model for prediction of resuspension." Health Phys 101:722–730; 2011.

McArthur, R.D., 1991. "Radionuclides in Surface Soil at the Nevada Test Site." Report DOE/NV/10845-02. Desert Research Institute, University of Nevada System, Las Vegas, Nevada, 1991. [SRDB Ref ID: 7872]

McArthur, R.D. and J.F. Kordas, 1983. "Radionuclide Inventory and Distribution Program: The Galileo Area." Report DOE/NV/10162–14. Desert Research Institute, University of Nevada System, Las Vegas, Nevada, 1983.

McArthur, R.D. and J.F. Kordas, 1985. "Nevada Test Site Radionuclide Inventory and Distribution Program: Report #2, Areas 2 and 4," Report DOE/NV/10162–20. Desert Research Institute, University of Nevada System, Las Vegas, Nevada, 1985.

McArthur R.D. and S.W. Mead, 1987. Nevada Test Site radionuclide inventory and distribution program: Report #3, Areas 3, 7, 8, 9, and 10." Las Vegas, Nevada: Desert Research Institute, University of Nevada System; Report DOE/NV/10384–15; 1987.

McArthur R.D. and S.W. Mead, 1988. "Nevada Test Site radionuclide inventory and distribution program: Report #4, Areas 18 and 19." Las Vegas, Nevada: Desert Research Institute, University of Nevada System; Report DOE/NV/10384–24; 1988.

McArthur R.D. and S.W. Mead, 1989. "Nevada Test Site radionuclide inventory and distribution program: Report #5, Areas 5, 11, 12, 15, 17, 18, 19, 25, 26, and 30." Las Vegas, Nevada: Desert Research Institute, University of Nevada System; Report DOE/NV/10384–26; 1989.

NIOSH 2007. "NIOSH Responses to S. Cohen & Associates Comment Related to Issues Involving Resuspension and Soil Contamination: Comments 5, 6, 7, and 23," National Institute for Occupational Safety and Health, Cincinnati, Ohio. March 23, 2007.

NIOSH 2010. "SEC Petition Evaluation Report for Petition SEC-00084, Nevada Test Site," Rev. 1, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio. January 25, 2010.

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.

Effective Date:	Revision No.	Document No.	Page No.
July 21, 2015	0 (Draft)	NTS Resuspension Issues Status	37 of 44

ORAUT 2005. “Internal Dose Overestimates for Facilities with Air Sampling Programs,” ORAUT-OTIB-0018, Rev. 01, Oak Ridge Associated Universities Team, Cincinnati, Ohio. August 9, 2005.

ORAUT 2008. “Technical Basis Document for the Nevada Test Site: Occupational Environmental Dose,” ORAUT-TKBS-0008-2, Vol. 4, Rev. 01, Oak Ridge Associated Universities Team, Cincinnati, Ohio. May 27, 2008.

ORAUT 2010. “Technical Basis Document for the Nevada Test Site: Occupational Environmental Dose,” ORAUT-TKBS-0008-4, Vol. 4, Rev. 2, Oak Ridge Associated Universities Team, Cincinnati, Ohio. April 15, 2010.

ORAUT 2012. “Nevada Test Site – Occupational Environmental Dose,” ORAUT-TKBS-0008-4, Rev. 3, Oak Ridge Associated Universities Team, Cincinnati, Ohio. August 24, 2012.

ORAUT 2013. “Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range, Nevada.” ORAUT-TKBS-0037 Rev. 01. Oak Ridge Associated Universities Team, Cincinnati, Ohio. January 25, 2013.

Rollins, G. 2007. “Ambient Environmental Intakes at the Nevada Test Site Based on Air Sampling and Soil Contamination,” Oak Ridge Associated Universities Team, Cincinnati, Ohio. July 29, 2007.

REECO. 1971. “Environmental Radioactivity at the Nevada Test Site. July, 1968 through June, 1969,” NVO-410-16, Reynolds Electrical & Engineering Co., Inc., Las Vegas, Ohio.

SC&A 2012. “Update of the Nevada Test Site (NTS) Issue Resolution Matrix Based on the SC&A Review of the NIOSH Site Profile for the Nevada Test Site,” SCA-SP-IM2012-0042, Rev. 1. SC&A, Inc., Vienna, Virginia. December 12, 2012.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 38 of 44
---	----------------------------------	---	-----------------------------

APPENDIX A: LATEST ISSUES RESOLUTION MATRIX DATED DECEMBER 14, 2012

On December 14, 2012, the NTS matrix was updated and contained the following exchange of information between SC&A and NIOSH:

Review of unaddressed items appears to be warranted.

NIOSH Response

The following assumptions (in italics) are excerpts from (Anspaugh 2008). The NIOSH replies to the assumptions are in regular bold.

Assumption 1: No Contamination of the NTS Occurred after July 1962.

This assumption has already been examined extensively in the section of this document following the Introduction. As noted, there were many contaminating events that produced substantial new depositions on soil. The contribution of the Buggy event was even acknowledged in Rollins (2008a)²² although it was ignored. Events specifically mentioned in the reports of the environmental surveillance program were Pike, Nash, Hupmobile, Buggy, Door Mist, Schooner, and Baneberry. Events Buggy, Schooner, and Baneberry were even noted to have contaminated potable water at the NTS.

NIOSH Response:

While it is true that there were many controlled and uncontrolled releases to the environment after 1962, the vast majority of these releases were of noble gases and volatile iodines which would not have contributed significantly to soil contamination (DOE 1996). Of the non-volatiles reported (e.g., W-187, Sr-91, Cs-138, Ru-106, etc.), most had half-lives on the order of hours or days and would only be a concern to individuals participating in early reentry operations. As shown by Rollins (2007b), exposure to these short-lived fission and activation products would be expected to result in minimal doses to the non-presumptive cancers affecting the larynx (ET2 and LNET), skin, and prostate.

Also, it should be noted that DOE evacuated non-essential workers from downwind areas of the NTS prior to all tests to minimize potential for radiation exposure. In addition, after releases, surveys were conducted to characterize the fallout fields and to implement controls to prevent inadvertent entry into these areas.

The only mention of potentially contaminated potable water was in December of 1968 and January, 1969 REECo (1971). The maximum concentration was 1.54×10^{-6} $\mu\text{Ci/cc}$ measured on January 19, 1969, at the Area 2 Men's Restroom. However, these elevated levels quickly dissipated and the mean concentration for all samples taken at this location for 1969 was 4.60×10^{-9} $\mu\text{Ci/cc}$ compared with 6.41×10^{-9} $\mu\text{Ci/cc}$ for 1968; well below the

²² This reference called here is the same as ORAUT (2008), as cited in the main text.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 39 of 44
---	----------------------------------	---	-----------------------------

alert level of 1.0×10^{-7} $\mu\text{Ci/cc}$ for unidentified radionuclides. Thus, anyone drinking water at this location during 1968 and 1969 would be expected to receive inconsequential internal dose.

Assumption 2: The Air Concentrations Recorded by the Air Samplers of the NTS Environmental Surveillance Program During 1971 and Beyond Can Be Used to Derive the Air Concentrations That Would Have Been Seen at these Same Air-Sampler Locations During 1963–1970.

As demonstrated above by the detailed consideration of the contaminating events at NTS during 1963–1970 and the results of the environmental surveillance air-sampling program, there were several substantial excursions noted in the air concentrations due to massive releases at the NTS. The last such release occurred in December 1970. Thus, it is impossible for air-sampling results during the 1971–2001 period to reproduce these massive excursions that occurred in 1963–1970.

NIOSH Response

The purpose of the calculations performed by Rollins (2007b) was not to try to predict air sampler measurements between 1963 and 1970 but was to provide a claimant-favorable method of assigning environmental intakes to individuals not associated with operations. This was done by selecting the highest integrated air concentration measured for Pu-239, as part of the environmental surveillance program, anywhere on site between 1971 and 2001 and correlating it with other radionuclides (decay corrected) persisting in the NTS soils across the site to estimate their relative intakes. NIOSH believes the “massive excursions” that occurred as a result of controlled and uncontrolled releases are relatively unimportant to organ dose because of their brief duration and because nonessential personnel were not exposed to them due to the required, pre-test, downwind evacuations.

Assumption 3: More Generally, the Air Concentrations Actually Experienced by the Workers at the NTS.

This is a more difficult issue, as there do not appear to be any objective data on the inhalation of radionuclides at the NTS as measured with a personal air sampler and in comparison to any of the locations of the environmental surveillance network. It is known, however, that these air-sampling stations were typically located next to cafeterias and dispensaries, where there would be relatively little dust. On the other hand, there were many types of work that would have raised large amounts of dust. One outstanding example of a major dust raising event was the movement of drilling rigs, such as the one shown in Fig. 18, from one location to another without disassembly. The drill rig was raised with hydraulic jacks, and large steel beams were placed through the rig. Then four “coasters,” one of which is shown in Fig. 19, were attached to the beams. The two beams and one of the coasters are shown in Fig. 20. The presumed path of one such movement is shown in Fig. 21.

There has been substantial concern about mass loading and exposure to persons, if there might be a volcanic eruption that would influence the Yucca Mountain waste-storage site. As part of the evaluation process, there has been a substantial effort to evaluate possibly enhanced mass

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 40 of 44
---	----------------------------------	---	-----------------------------

loading due to outdoor activities in a post eruption environment. The evaluation has consisted of reviewing relevant literature and in conducting measurements of mass loadings in Amargosa Valley, Nevada. These studies are described in Bechtel SAIC (2006).

The authors of Bechtel SAIC (2006) considered mass loadings in several environments; two of interest to us are the “Inactive Outdoor Environment,” which would be similar to the locations where the NTS environmental surveillance air samplers were located. Their review of data and of measurements made as part of the Yucca Mountain evaluation program resulted in their description of mass loading in this environment with a triangular distribution with a mode of 0.060 mg m^{-3} , a minimum of 0.025 mg m^{-3} , and a maximum of 0.100 mg m^{-3} .

The “Active Outdoor Environment” was also considered, and would include activities such as driving bulldozers, tractors, heavy construction machinery, etc. Their evaluation of literature values and of their contracted measurements in Amargosa Valley was again a description by a triangular distribution, but now with a mode of 3 mg m^{-3} , a minimum of 1 mg m^{-3} , and a maximum of 10 mg m^{-3} .

Thus, according to the evaluation of the Yucca Mountain evaluation group, the mass loading experienced by a bulldozer driver would be on the order of 3 divided by 0.06, or 50 times higher than the concentration of dust in an inactive outdoor environment. Of course, a person driving a bulldozer would not be exposed to such levels 100% of the time, but it is obvious that a stationary air sampler located next to a cafeteria or dispensary would not give a realistic indication of a working person’s exposure.

It is also well to remember the words of some of the early investigators of the NTS environmental surveillance program:

Results of environmental surveillance in sampling activity values cannot be used in calculating personnel exposure doses.

As a final point, it has often been assumed by NIOSH personnel that “Controlled Areas” at the NTS are fenced and that it not possible to enter such areas. This is hardly the case, as many Controlled Areas are “controlled” by nothing more than a warning sign. Fig. 22 is a photo of one such Controlled Area, which actually has a road right through it.

NIOSH Response

As stated above, the purpose of the calculations performed by Rollins (2007b) was not to try to predict intakes associated with operational activities but was to provide a claimant favorable method of assigning environmental intakes to individuals not associated with operations. Therefore, it would be reasonable to position the samplers (cafeterias and dispensaries) where they would be unlikely to be exposed to dust clouds associated with operational activities (e.g., moving drilling rigs).

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 41 of 44
---	----------------------------------	---	-----------------------------

Assumption 4: There Were No Clean-Ups of Radioactive Materials Between 1962 and the Time Period When Measurements of Surface Radionuclides Were Made by the Radionuclide Inventory and Distribution Program (RIDP) in the 1980s.

The measurements of surface-soil contamination performed by investigators of the RIDP are critical to the methodology developed in Rollins (2008a) for the reconstruction of internal doses via both inhalation and incidental ingestion of soil. The RIDP measurements were not made for the purpose of reconstructing doses, but rather for defining the amounts and locations of existing contamination for the purposes of control and future clean-up (Kordas and Anspaugh 1982). Between 1962 and the time of the measurements made by the investigators of the RIDP, there was an active program on cleaning up contaminated soil.

McArthur and Mead (1989) specifically mention that much of the Nuclear Rocket Development Station in Area 25 had been cleaned up before the RIDP measurements were started in February 1984. Thus, the fourth assumption must be considered as invalid, as well. The surface soil activities measured in the 1980s cannot be depended upon to represent activity present in 1963–1970, decay corrected or not.

NIOSH Response

McArthur (1991) identified a total of 510 square miles of contaminated soils (about a third of the total NTS area) containing more than 2,000 curies of radioactivity. This radioactivity was related to radionuclides that are persistent in the environment and are important to organ dose. Although there were efforts to decontaminate some of the more highly contaminated areas, these efforts focused on contaminated equipment and large, nonrespirable particles. The efforts made to decontaminate Nuclear Rocket Development Station in Area 25 would likely have had little effect on the air concentrations measured in Area 7 that were used to estimate environmental intakes.

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 42 of 44
---	----------------------------------	---	-----------------------------

APPENDIX B: PARTIAL EVALUATION OF THE MCARTHUR DATA AND THEIR USE IN THE TBD

All of the data presented in McArthur 1991 is gathered from five reports written for the Radionuclide Inventory and Distribution Program (RIDP). Each of the five reports covered a handful of ‘areas’ of the Nevada Test Site (NTS). Three measurement techniques were used to assess the extent of soil contamination at NTS: aerial surveys, in situ spectrometry, and soil samples. The aerial measurements were conducted first in order to find areas with elevated levels of radiation so that they could be surveyed via in situ spectrometry. The in-situ spectrometry measurements were conducted with a collimated HPGe detector mounted on a vehicle, and measurements were taken in a regular, grid-like pattern for some parts of each area. Soil samples were collected at a few locations where an in-situ measurement was also taken. The soil samples were taken along transecting lines that aligned with the ground zero of an associated test location. Samples were analyzed primarily to understand how concentrations of the radionuclides differed as a function of depth in soil to calculate the inverse relaxation length. A handful of samples were analyzed for ^{90}Sr , ^{238}Pu , $^{239,240}\text{Pu}$, ^{137}Cs , and ^{241}Am . Various ratios of these nuclides were calculated so that inventories of ^{90}Sr , ^{238}Pu , and $^{239,240}\text{Pu}$ could be estimated from ^{137}Cs and ^{241}Am inventories.

We found that when calculating the radionuclide inventories for the areas, the in-situ measurements appeared to be used rather than the soil samples. Page 34 of McArthur 1991 talks about the decay correction done for the inventory calculations and states that, “The survey date used for each area was the approximate date of the highest in situ measurements.” Also, in McArthur and Kordas 1983 (the first of the five RIDP reports) the methods section states, “Therefore, we believe that the activities in the Galileo ground zero area derived from the in-situ data are a much better estimate of the true activity than those derived from soil sampling.” This document also states that the methods described in it are to be used for the future RIDP reports.

Example Area/Nuclide to Check Numbers

Pages 31 through 34 of Appendix A in McArthur 1991 indicate where in the RIDP reports the inventory values were taken from. We chose to first look at ^{137}Cs in Area 10, since it had the highest inventory for ^{137}Cs . McArthur 1991 Appendix A indicates that the data for this area were taken from the third RIDP report (McArthur and Mead, 1987). However, when reading the document to find the in-situ data, we found that the actual data were not available. What is presented in RIDP 3 is a series of figures that depict the Areas surveyed, and, at each in-situ measurement point, there is a marker. The legend for the figures says that each marker is representative of a range of concentrations for the given radionuclides. For example, Figure 10 of RIDP 3 gives the measured activities of ^{137}Cs in Areas 8 and 10, but the range of possible concentrations for each point is quite large. Therefore, we were unable to reproduce exactly how the inventories were calculated starting from the raw in situ data itself. Upon reading other RIDP reports, it was found that RIDP reports 4 and 5 appear to give numerical values for the in-situ measurements.

Table A-2 of McArthur 1991 provides the inventory of each Area and its regions as taken from their respective RIDP reports, and has not been decay-corrected in any way. Appendix A of

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 43 of 44
---	----------------------------------	---	-----------------------------

McArthur 1991 says that the inventories in Table A-2 for Area 10 were the sum of the inventories for regions SE-1 and SE-2, plus 65% of the inventory for SE-3. Table A-1 of McArthur 1991 gives the assumed concentrations of the ‘unsurveyed’ regions of each area for various nuclides, which is used for Table A-2 as well. Table 5 of RIDP 3 gives the inventory of each radionuclide for the regions that comprise Areas 8 and 10, as well as the area of each region, and, using these data, we were able to reproduce the inventories for all nine nuclides that are given in Table A-2.

The inventories in Table A-2 still need to be decay-corrected to become the values given in Table 5 of McArthur 1991, which is also Table 4-4 of the NTS TBD 4. McArthur 1991 clearly states that the decay corrections were done such that the inventories in Table 5 are representative of January 1, 1990. We tried to do the decay corrections for ¹³⁷Cs, ⁹⁰Sr, ²⁴¹Am, and ^{239,240}Pu using the half-lives given by Table 1 of McArthur 1991. We were able to reproduce the inventory values for Area 10 in Table 5 of McArthur (Table 4-4 of the TBD) for ¹³⁷Cs, ²⁴¹Am, and ^{239,240}Pu, within error and significant figure constraints. However, there is a large discrepancy in the inventory we calculated for ⁹⁰Sr and what is reported in the documents. (See below).

Nuclide	SC&A Calculation (Ci)	In Document (Ci)
Cs-137	84.3	84
Sr-90	68.1	55
Am-241	19.4	19
Pu-239,240	106	110

When trying to figure out why we could not reproduce the decay-corrected ⁹⁰Sr inventory, we noticed that McArthur 1991 mentions several times that the data from the RIDP reports (those that are in Table A-2) were re-evaluated and in some cases recalculated to give the inventories in Table 5 of McArthur 1991 and Table 4-4 of the NTS TBD. It is our best guess that the ⁹⁰Sr data (and others for different nuclides/areas) were reevaluated by McArthur, and a different inventory value was established. McArthur 1991 mentions that the data from the five RIDP reports were reevaluated so that measurements that were below the MDA were treated consistently.

Overall, while we can replicate the data in Table A-2 of McArthur 1991, we cannot replicate all of the inventory values in Table 4-4 of the NTS TBD due to the fact that some data from the RIDP reports were reevaluated when calculating the inventories present in Table 4-4. Also, the actual in-situ data are not available in most of the RIDP reports, just ranges of activity on a map of each area.

Going from Table 4-4 to Table 4-5

Considering the same four nuclides (¹³⁷Cs, ⁹⁰Sr, ²⁴¹Am, and ^{239,240}Pu) for Area 10, we attempted to reproduce the values listed in Table 4-5 of the NTS TBD. Using the values given in Table 4-4 as is, we first divided the inventory (Ci) by the given area (mi²), and converted this to Bq/m². These values then need to be decay corrected back to 1963. The NTS TBD does not specifically state the date that the values are decay corrected to, just that it is corrected to 1963. We assume a date of January 1, 1963 as the date for decay correction. For three of the four nuclides, we

Effective Date: July 21, 2015	Revision No. 0 (Draft)	Document No. NTS Resuspension Issues Status	Page No. 44 of 44
---	----------------------------------	---	-----------------------------

selected for Area 10, we were able to reproduce the Bq/m² for 1963, as given in Table 4-5 within rounding error. For ¹³⁷Cs, the value calculated was 1.11E05, and the value we calculated is 1.15E05. Hence, good agreement. However, when we use a starting date of January 1, 1991 and a ¹³⁷Cs half-life of 30 years (instead of 30.2), then we calculate 1.15E05 Bq/m² for the 1963 decay-corrected ¹³⁷Cs contamination. We also noticed that on page 20 of the NTS TBD, it is stated that "...because the data in Table 4-4 are representative of soil contamination in 1991, the values in Table 4-5 were decay-corrected to the beginning of 1963."

As stated earlier, McArthur 1991 clearly states several times that the inventory values presented were decay corrected to January 1, 1990. This raises questions as to whether some of the data in Table 4-5 used 1991 as a starting year instead of 1990 for decay-correction, and at the very least, the wording in the TBD should be changed to reflect that the McArthur data are representative of 1990. This one-year difference is not that much of an issue for the longer-lived nuclides, but if the wrong year was used for decay correcting the shorter-lived nuclides, it could require some corrections.