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

December 8, 2005

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

Re: Contract No. 200-2004-03805, Task Order 1: Draft Review of the NIOSH Site Profile for the Rocky Flats Plant

Dear Mr. Staudt:

S. Cohen & Associates (SC&A) is pleased to submit our draft review of the NIOSH site profile for the Rocky Flats Plant, consisting of our evaluation of "Revision 0" of six technical basis documents (TBDs) for introduction, site description, and occupational internal, external, medical, and environmental dose, respectively. We understand that some or all of these TBDs are under active revision and have reflected that understanding with respect to findings and issues that we have identified.

While this report was completed in October 2005, it was submitted to the Department of Energy on November 3, 2005, for purposes of confirming that there is no classified or Unclassified Controlled Nuclear Information (UCNI) national security information inadvertently included. DOE returned this draft report with such certification in a December 1, 2005 letter.

Given the time required for obtaining DOE clearance of this report for public release, SC&A proceeded to brief the Advisory Board on Radiation and Worker Health (ABRWH) on one key finding contained in the report at the Advisory Board meeting in Knoxville, Tennessee, on October 17, 2005. This finding addressed our concern over NIOSH's use of the median MDA (minimum detectable activity) values for plutonium and americium, which appear unduly low and likely to yield body burdens or organ doses that would be non-conservative, given the uncertainties involved. This finding, and its technical basis, was taken as an excerpt from the draft report and provided NIOSH for review prior to the November 16th issue resolution meeting held by the ABRWH working group in Cincinnati.

In accordance with an informal agreement reached at the November 16th meeting, we are preparing an issue resolution matrix of the findings cited in this report and will provide it to the Advisory Board and NIOSH by December 14, 2005. An issue resolution meeting would presumably be scheduled at a mutually agreeable date and time thereafter.

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As indicated in earlier communications, we greatly appreciate the assistance and cooperation provided by Brant Ulsh and his team during the course of our review.

Sincerely,

John Mauro, PhD, CHP
Project Manager

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Draft

ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute of Occupational Safety and Health

Rocky Flats Plant Site Profile Review

Contract No. 200-2004-03805
Task Order No. 1
SCA-TR-TASK1-0008

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December 8, 2005

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.

S. COHEN & ASSOCIATES: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-TASK1-0008 Effective Date: Draft — December 8, 2005 Revision No. 0
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Task Manager: _____ Date: _____ Joseph Fitzgerald	Supersedes: N/A
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ACRONYMS AND ABBREVIATIONS

Advisory Board	Advisory Board on Radiation and Worker Health
A-P	Anterior-Posterior
AEC	Atomic Energy Commission
AED	Activity Equivalent Diameter
AMAD	Activity Median Aerodynamic Diameter
Bq	Becquerel
BR	Brass
CATI	Computer-Assisted Telephone Interview
CD	Cadmium
CDC	Centers for Disease Control and Prevention
CDPHE	Colorado Department of Public Health and Environment
CF	Calibration Factors
CFR	*Code of Federal Regulations*
Ci	Curie
CWA	Clean Water Act
D&D	Decontamination and Decommissioning
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
dpm	Disintegrations per Minute
DR	Dose Reconstruction
DTPA	Diethylenetriaminepentaacetate
DU	Depleted Uranium
EALER	Elevated Ambient Levels of External Radiation
EDTA	Ethylenediaminetetraacetic acid
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
EPA	Environmental Protection Agency
ESE	Entry Skin Exposure
EU	Enriched Uranium
FBI	Federal Bureau of Investigation
GeLi	Germanium Lithium

GAO	General Accounting Office
HCEC	House Committee on Energy and Commerce
HEU	Highly-Enriched Uranium
HHS	Health and Human Services
IAAP	Iowa Army Ammunition Plant
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
INL	Idaho National Laboratory
IREP	Interactive RadioEpidemiological Program
keV	Kiloelectron Volt
LAP	Laboratory Accreditation Program
LOD	Limit of Detection
µCi	Microcurie
MCW	Mallinckrodt Chemical Works
MDA	Minimum Detectable Activity
MMD	Mass Median Diameter
mR	Milliroentgen
mrad	Millirad
mrem	Millirem
NCRP	National Council on Radiation Protection and Measurements
NDRP	Neutron Dose Reconstruction Protocol
NDT	Nondestructive Testing
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Occupational Claims Tracking System
NPDES	National Pollutant Discharges Elimination System
NTA	Eastman Kodak Nuclear Track Film Type A
NTS	Nevada Test Site
NU	Natural Uranium
OCAS	Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory

OW	Open Window
PA	Posterior-Anterior
PFG	Photofluorography
PIC	Pocket Ionization Chamber
POC	Probability of Causation
POS	Process Operation Sheets
PPE	Personnel Protective Equipment
ppm	Parts Per Million
RAC	Risk Assessment Corporation
RadCon	Radiological Control
RCRA	Resource Conservation and Recovery Act
RDGs	Radiation Generating Devices
RFP	Rocky Flats Plant
RU	Recycled Uranium
SAAM	Selective Alpha Air Monitor
SC&A	S. Cohen and Associates
SRS	Savannah River Site
STP	Sewage Treatment Plant
TBD	Technical Basis Document
TIB	Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
TLND	Thermoluminescent Neutron Dose
TRU	Transuranics
Y-12 Plant	Y-12 National Security Complex
ZPPR	Zero Power Plutonium Reactor

1.0 EXECUTIVE SUMMARY

This report provides the results of an independent audit conducted by S. Cohen and Associates (SC&A) of the technical basis documents (TBDs) that make up the site profile for the Rocky Flats Plant (RFP) developed by the National Institute for Occupational Safety and Health (NIOSH). This audit was conducted during the period July 15 through September 30, 2005, in support of the Advisory Board on Radiation and Worker Health (Advisory Board) in the latter's statutory responsibility under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) to conduct such reviews and advise the Secretary of Health and Human Services (HHS) on the "completeness and adequacy" of the EEOICPA program.

Located in Golden, Colorado (sixteen miles northwest of Denver), the RFP covered 6,550 acres of land, and included more than a hundred buildings and other structures. The site is composed of a 384-acre industrial area surrounded by an operational buffer zone. Rocky Flats was built in 1951 and began operations in 1952. The plant's primary mission was to produce plutonium weapon components for nuclear weapons. Production activities involved the fabrication of plutonium, uranium, beryllium, and stainless steel parts. Other activities included chemical processing for recovery of plutonium from scrap material; research and development work in metallurgy; machining; assembly; nondestructive testing; coatings; remote engineering; and chemistry and physics. Parts were made at the facility and shipped elsewhere for assembly (Norton et al. 1992). Dow Chemical Company (1952–1975), Rockwell International Corporation (1975–1989), EG&G Corporation (1990–1995), and Kaiser-Hill (1995–present) have operated the plant for the Department of Energy (DOE). The plant ceased plutonium operations in November 1989, and began its transformation into an environmental restoration cleanup site in 1993. The plutonium production facilities have been decontaminated and dismantled, with overall site closure scheduled for 2006.

This review included unclassified interviews of site experts by SC&A personnel at the Denver Federal Center,[1] as well as conference calls between Oak Ridge Associated Universities (ORAU) and SC&A counterparts regarding specific TBDs that make up the RFP site profile. The TBDs were evaluated for their completeness, technical accuracy, adequacy of data, compliance with stated objectives, and consistency with other site profiles, as stipulated in the *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). As "living" documents, TBDs are constantly being revised as new information, experience, or issues arise. In addition to this TBD, other RFP and DOE Complex-wide TBDs were reviewed by SC&A. A complete list of the RFP TBDs, as well as supporting Technical Information Bulletins (TIBs), that were reviewed by SC&A is provided in Attachment 1.

This review found the NIOSH site profile (and its constituent TBDs) for RFP to be an adequate accounting for most, but not all, of the plutonium exposure and dosimetric history of the plant, falling short in obtaining some key data and fully characterizing several underlying issues fundamental to guiding dose reconstruction. It is clear that NIOSH recognizes some of these

[1] While the review was unclassified, all material generated from worker interviews and document review were submitted to classification screening to assure that no sensitive information was inadvertently included in this report.

issues and has indicated that a number of ongoing initiatives are underway to obtain missing data or generate needed guidance (e.g., new TIB addressing highly insoluble oxides and guidance on co-worker dose assignment assumptions and methodology). It is also clear that some additional implementation guidance may reside in "workbooks," which are developed by NIOSH as a means to provide implementation guidance to the dose reconstructor; these resources were not within the stipulated scope of this review for RFP, but will be reviewed as part of the FY2006 program.

One of SC&A's key concerns is NIOSH's use of median MDA (minimum detectable activity) values for plutonium and americium, which appear unduly low and likely to yield body burdens or organ doses that would be non-conservative, given the uncertainties involved. Given the limited data and uncertainties of the key variables (e.g., sample count time, detector counting efficiency, self-absorption, and various sampling assumptions) from which MDAs are defined, SC&A understands the need to apply certain assumptions to bridge these gaps in information. However, the concern is that a number of these assumptions are not adequately supported and may not be claimant favorable. Likewise, the use of these assumed median MDA values, themselves, in dose reconstruction, may be inappropriate. This is because urine activity levels monitored at RFP for plutonium and americium were likely well in excess of assumed median MDA values, most notably where workers were assigned "zero" or "background" readings in the past when urinalysis results were found to be less than 10% of the tolerance level. SC&A believes more conservative assumptions should be applied in the formulation of MDA values that would more realistically reflect the range of uncertainties involved.

Likewise, a number of historical issues and discrepancies cast doubt on the validity, and in some instances, the integrity, of dose records being relied upon for EEIOCPA dose reconstruction— ones which are not adequately reflected in the TBDs that make up the site profile. Evidence exists that there is a potential for missed occupational external, internal, and environmental dose, due to the incompleteness and questionable quality of data being used in dose reconstruction. These missed doses may have occurred as a result of incomplete monitoring records and inadequate monitoring techniques. There may also be a data integrity issue associated with the external dose record.

The SC&A review finds that the internal dosimetry TBD (Falk 2004) lacks definitive direction in some instances and has gaps that need to be addressed. There is limited guidance for use by the dose reconstructor regarding the process and assumptions that should be used to calculate internal dose. Notably, this TBD does not provide clear guidance for assessment of dose for unmonitored workers, nor does it specifically address what "missed dose" may exist and how it is to be addressed. The use of the assumed default particle size of 5 μm AMAD needs to be reconsidered for those RFP operations for which actual particle size measurements exist (e.g., an 0.3 μm mass median diameter for airborne particles involved in at least two fires at RFP, which may be typical of "high-fired" plutonium generated in processes involving temperatures exceeding 400°–600° C). The approaches regarding solubility need to be reviewed, particularly for Type "S" or "Super-S" plutonium compounds whose high insolubility may lead to more exposure to gastrointestinal and respiratory tract organs. The assumptions (e.g., full equilibrium) regarding the methodologies to assess the internal exposure to depleted uranium based on

estimates of ^{238}U activity may not be claimant favorable for some circumstances. The internal dose potential for the ingestion pathway was not considered.

The external dosimetry sections of the TBDs and supporting TIBs, while providing pertinent historical data and technology information on dosimetry systems and records, fall short in addressing potential missed and unmonitored dose, particularly in the early years of operation (1950s through mid-1960s). The use of neutron track plates, and the uncertainties in neutron track counting with these and NTA film, indicates there may be important missed dose that was not entered into claimant records. The Neutron Dosimetry Reconstruction Project Protocol (NDRP) was designed to remedy these deficiencies by recounting original tracks and providing a corrected estimated individual neutron dose. However, the recently issued NDRP report does not cover non-Pu workers, nor is it applicable to unmonitored or non-neutron workers. There is a resultant need to use neutron/photon ratios and film/TLD comparisons to correctly determine past neutron doses. The TBD (Langsted 2004) only briefly addressed these two issues, which could be important in generating correction factors for under-monitored workers or for monitored worker missed dose.

The issue of unmonitored workers, particularly from the early 1950s to the early 1960s, is not developed in the TBDs from the standpoint of the extent of the problem and how dose estimation would be handled, particularly the application of co-worker doses. Assignment of dosimeters to workers using the "10% of the radiation protection guide" policy was apparently based on *a priori* administrative decisions, not necessarily on actual survey results, as evidenced by gaps identified in the NDRP report and supported by site expert interviews. This underscores the need for NIOSH to corroborate, for the purpose of co-worker dose assignment, the extent to which badged workers represented the maximally exposed individuals during the early years of plant operation.

The RFP occupational medical dose TBD does not adequately address the contribution of historic radiation exposure from occupationally necessitated medical x-ray exposure of workers at Rocky Flats. By confining consideration to one pre-employment and a chest x-ray annually, it may underestimate potential dose by excluding consideration of x-ray procedures required for special requirements, e.g., respiratory protection certification, and work related injuries. The TBD does not document that x-ray equipment did not exceed the diagnostic range, or whether it was greater than 80 kVp, as no evidence of radiation surveys exist prior to 2001. The TBD does not adequately address the potential dose from photofluorography (PFG) units, since some workers may have had multiple PFG exams in a year.

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

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

Following the introduction and a description of the criteria and methods employed to perform the review, the report discusses the strengths of the TBD, followed by a description of the major issues identified during our review. The issues were carefully reviewed with respect to the five review criteria. Several of the issues were designated as findings, because they represent deficiencies in the TBDs that need to be corrected, and which have the potential to substantially impact at least some dose reconstructions.

1.1 SUMMARY OF STRENGTHS

NIOSH/ORAU has supplemented the RFP site profile documents with a number of TIBs that provide further direction to the dose reconstructor. Attachment 1 lists four TIBs that all have direct bearing on the RFP dose reconstruction process. SC&A has reviewed these carefully and has found each to be of significance in providing help to the dose reconstructor. These documents were beneficial in understanding the application of the six RFP TBDs to the dose reconstruction process. NIOSH is working on an additional TIB that will specifically address uptakes of Super Type S.

The TBD traced the history of the various functions and processes at the RFP that could contribute to worker radiation dose, as well as describing the major use of the many individual buildings at the complex. In addition, operation accidents and incidents through November 1976 are listed in Attachment 2C of the site description TBD. The two major fires occurring in 1957 and 1969 were covered in some detail. Inclusion of major accidents and incidents is an improvement over previous site profiles. Overall, with the notable exception of recycled uranium and other radiological materials shipped onsite, the site description TBD provides an accurate and reasonable characterization of the history and operational activities at the RFP for the period of production.

NIOSH/ORAU provided a detailed overview of routine and neutron dosimeters from the inception of production through the present. The external TBD includes a discussion of the effectiveness of dosimeters relative to low-energy photon and neutron spectra in plutonium production areas. Techniques are included to assist dose reconstuctors in determining radiation type and energy. Methodologies for missed external dose calculations are covered for both unmonitored individuals and individuals with zero dose values. Site-specific correction factors have been developed to compensate for dosimeter inadequacy (e.g., NTA energy dependence) and uncertainty.

NIOSH/ORAU has provided a detailed history of the in-vivo and in-vitro programs at Rocky Flats. Techniques for plutonium, americium, uranium, and gross alpha bioassay, as well as limited data on other radionuclides, have been included in the internal TBD. The TBD has provided information on solubility, particle size, and isotopic composition for major source terms. Detailed descriptions of the lung counting systems have been provided for reference.

NIOSH/ORAU has provided helpful information on the interpretation of records, as well as examples of these records. This is perhaps the most helpful portion of the internal and external

TBDs to dose reconstruction. NIOSH/ORAU is encouraged to continue including information on interpretation of records and provision of example records in this and other site profiles.

1.2 SUMMARY OF FINDINGS

Finding 1. Suggested use of urine bioassay MDA values for plutonium and americium appear low and are likely to yield body burdens/organ doses that are proportionately low and, therefore, claimant unfavorable. NIOSH's use of median MDA (minimum detectable activity) values for plutonium and americium appear unduly low and likely to yield body burdens or organ doses that would be non-conservative, given the uncertainties involved. Given the limited data and uncertainties of the key variables (e.g., sample count time, detector counting efficiency, self-absorption, and various sampling assumptions) from which MDAs are defined, SC&A understands the need to apply certain assumptions to bridge these gaps in information. However, the concern is that a number of these assumptions are not adequately supported and may not be claimant favorable. Likewise, the use of these assumed median MDA values, themselves, in dose reconstruction, may be inappropriate. This is because urine activity levels monitored at RFP for plutonium and americium were likely well in excess of assumed median MDA values, most notably where workers were assigned "zero" or "background" readings in the past when urinalysis results were found to be less than 10% of the tolerance level. SC&A believes more conservative assumptions should be applied in the formulation of MDA values that would more realistically reflect the range of uncertainties involved.

Finding 2: Internal dosimetry TBD lacks definitive direction in some instances and has gaps that need to be addressed. There is limited guidance for use by the dose reconstructor regarding the process and assumptions that should be used to calculate internal dose. Notably, this TBD does not provide clear guidance for assessment of dose for unmonitored workers, nor does it specifically address what "missed dose" may exist and how it is to be addressed. The use of the assumed default particle size of 5 μm AMAD needs to be reconsidered for those RFP operations for which actual particle size measurements exist (e.g., a 0.3 μm mass median diameter for airborne particles involved in at least two fires at RFP). The approaches regarding solubility need to be reviewed, particularly for Type "S" or "Super-S" plutonium compounds whose high insolubility may lead to more exposure to gastrointestinal and respiratory tract organs. Uncertainties are not addressed in the TBD regarding the ^{241}Am assay of plutonium processed at RFP and how lung counting was calibrated to these values. The assumptions (full equilibrium) regarding the methodologies to assess the internal exposure to depleted uranium based on estimates of ^{238}U activity may not be claimant favorable for some circumstances. The sensitivity of the bioassay methods was not adequate to detect incidental intakes of insoluble compounds.

Finding 3: Interpretation of NTA film data for workers who were not included in NDRP re-evaluation is not evident; guidance on use of neutron/photon ratios not available. The use of neutron track plates, and the uncertainties in neutron track counting with these and NTA film, indicates there may be important missed dose that was not entered into claimant records. Although the TBD recommends the use of the Neutron Dosimetry Reconstruction Project (NDRP) assessed doses, this data has only recently become available for use in dose

reconstruction. Further discussion of this data and how it is to be used should be included in future revisions of the TBD. The NDRP report does not cover non-plutonium worker, non-neutron workers, or workers not monitored with NTA film. There is a resultant need to use neutron/photon rations and/or film/TLD comparisons to correctly determine past neutron doses. The TBD (Langsted 2004) only briefly addressed these two issues, which could be important in generating correction factors for under-monitored workers or for monitored-worker missed dose. This stems from a concern that workers exposed to neutrons in the early days of NTA film use at lower energy levels (between 0.25 and 0.4 MeV) will have missed dose that has not been accounted for in the TBD. The NTA film could not detect neutrons below a 0.8 MeV to 1.0 MeV threshold. NIOSH has attempted to obtain data from the Job Matrix Study that was developed by the University of Colorado (Ruttenber 2003). This information has not been made available and NIOSH is taking additional actions to gain access.

Finding 4: Unclear treatment in TBD of personal dosimeter placement and angular dependence. In the dose reconstruction process, the assignment of isotropic (ISO) or rotational (ROT) instead of anterior-posterior (AP) geometry in the TBD may not reflect the true radiation dose to some workers. In addition, the issue of angular dependence for different types of radiation and different dosimetry systems in use through the years is not sufficiently addressed in the TBD. There was a potential for partial body exposures in excess of the whole-body dosimeter reading (e.g., exposure to the head, face, and uncovered body parts during use of lead aprons; wearing dosimeters at chest height for glovebox operations). This issue has not been identified in the TBD. There is evidence that "elevated ambient levels of external radiation" (EALER) occurred at RFP with routine day-to-day storage of dosimeters, an issue of which NIOSH is aware, but is not addressed adequately in the TBD.

Finding 5: **The RFP occupational medical dose TBD does not adequately address the contribution of historic radiation exposure from occupationally necessitated medical x-ray exposure of workers at Rocky Flats.** The TBD includes only pre-employment and annual routine chest exams as representing the total occupational medical dose. Using this methodology, special job-required x-rays, such as x-rays for respiratory protection certification, and special exams for asbestosis and beryllium workers are potentially missed. Also, ORAUT-OTIB-0006 (Kathren and Shockley 2005), which is the basis document for all the TBD occupational medical exposures, further suggests the need for inclusion of special exams and termination exams, which are not included in the RFP TBD. Also omitted are x-ray exposures resulting from work-related injuries. A review of RFP medical records shows that there is no formal documentation to prove that workers did not get multiple x-ray exposures for work related to asbestos and beryllium exposure. The TBD does not document that x-ray equipment did not exceed the diagnostic range, or whether it was greater than 80 kVp, as no evidence of radiation surveys exist prior to 2001. The TBD does not adequately address the potential dose from photofluorography (PFG) units, since some workers may have had multiple PFG exams in a year. Overall, the TBD relies too heavily on the general information contained in ORAU-OTIB-0006 (Kathren and Shockley 2005), because there is no documentation on x-ray protocols or machine calibration requirements prior to 2001.

Finding 6: The site profile, while incorporating methodologies for assignment of missed dose, has not adequately bound exposure conditions, compensated for calibration errors and technology deficiencies, and addressed possible data integrity issues, all of which may contribute to missed dose. A number of historical issues cast doubt on the validity of recorded doses. In the case of external dosimetry, these issues included problems with algorithms, calibrations, placement of dosimeters in relation to aprons, individuals not wearing and/or improperly wearing their dosimeters, and uncertainty with the conditions under which zero or null doses were assigned. In some cases zeros may have been recorded in lieu of legitimate dose estimates. Neutron exposures to workers during peak production in the 1950s and 1960s were likely to be unmeasured – particularly given; (a) relatively primitive neutron counting techniques; (b) the informal, non-binding nature of criticality safety and neutron exposure requirements, and (c) the small staff assigned at the time to address these hazards. With internal dosimetry, there were individuals not monitored and delinquencies in submittal of bioassay samples. The source data for calculation of airborne environmental dose is questionable based on effectiveness of environmental air sampling. The limited information on job titles, skills and tasks, work locations, time spent in the area, and radionuclides of concern further complicate issues, making it difficult to differentiate between radiological and non-radiological workers. Finally, the concentration of ^{241}Pu and the age of plutonium, itself, from recycled warheads need to be studied to ascertain the validity of plutonium intake estimates used in the internal dose TBD.

Finding 7: The internal TBD does not consider potential contribution of ingestion pathway. The internal dose potential for ingesting radionuclides has not been considered in the occupational internal dosimetry TBD (Falk 2004). The ingestion pathway should not be ignored, except for the organs related to the respiratory tract where the dose from inhalation predominates. For other organs, ingestion dose is often higher than any dose received from inhalation. This is particularly true for plutonium, americium, and uranium. The ingestion pathway was also not considered in the derivation of co-worker dose data. The use of bioassay results to back-calculate intake and doses will produce higher internal exposures for certain organs if the ingestion pathway is taken into account.

Finding 8: TBDs do not adequately address potential exposure contribution of recycled uranium and other radiation sources shipped onsite. The RFP site description TBD (Flack and Meyer 2004) does not provide an accurate assessment of the potential risks associated with recycled uranium. According to a U.S. Department of Energy report (DOE 2000), the DOE's Idaho National Environmental and Engineering Laboratory (INEEL) shipped quantities of ^{236}U recovered from previously irradiated reactor fuel in 1955 to the RFP. This represents a potential for significant gamma fields and a potential source of missed dose for RFP workers. Also the TBD makes only a passing reference to the processing of ^{233}U, but it is known that Rocky Flats received ^{233}U uranyl nitrate from Oak Ridge for processing into kilogram quantities of metal shapes from the mid 1960s to the early 1980s. Of particular concern is exposure to ^{232}U contaminants that are co-produced with ^{233}U irradiation of thorium and are substantially more radioactive than ^{238}U. The potential dose attributable to neptunium, thorium, curium, and tritium has not been addressed, and more specific guidance to dose reconstructors is needed, given the absence of bioassay data or air concentration data.

Finding 9: The occupational environmental TBD does not adequately address potential environmental exposure from ambient airborne releases and resuspension of contaminated soil. Routine and episodic ambient airborne releases have been brought into question, based on the adequacy of air monitoring results. Incidental releases determined by the state of Colorado are higher than the values used for the 1957 and 1969 fires in the TBD, resulting in non-claimant-favorable assumptions. The dose from resuspension of soil contaminated with plutonium, americium, and other radionuclides (e.g., ^{238}Pu, ^{137}Cs, and ^{237}Np) needs to be taken into consideration for soil contamination areas throughout the site, and should not be limited to the 903 Pad without some justification why other inactive waste sites (108 in all) are not included. SC&A also believes that resuspension of $^{239+240}$Pu and ^{241}Am throughout the site could be an important contributor to ambient dose for both monitored and unmonitored dose. In particular, the TBDs do not clearly address how internal dose assessments will consider the contribution of resuspended plutonium and americium to worker dose.

Finding 10: Hand and wrist doses are not adequately addressed in the external dosimetry TBD. The TBD needs to provide more information on how to account for extremity dose, since there was considerable hands-on work at RFP. Also, valid hand-to-wrist ratios are needed and could be useful in potentially much higher dose to workers' hands. It is not apparent that the VARSKIN software includes the predominant beta emitter, ^{234m}Pa that is present at the RFP.

Finding 11: The TBDs (Langsted 2004; Little and Meyer 2004) do not address the potentially significant doses from industrial x-ray and neutron generators for R&D and non-destructive (NDT) work done at RFP. These may represent potentially high radiation exposures sources with energy spectra for which a mismatch may have existed with dosimeter systems in use at the time calibrated for plutonium and uranium isotopes. Information, including the number of units, energies, periods of operations, and operating procedures, need to be identified, with some characterization performed of the potential radiation exposures involved, and if radiation doses were under-recorded or missed.

1.3 OBSERVATIONS

Observation 1: The RFP site profile does not address post-production (post-1992) decontamination and decommissioning activities and worker exposures. This period involved nuclear material storage, nuclear material stabilization and packaging, waste management, and decontamination and decommissioning, for which records show a history of contamination incidents and personnel exposure. Similarly, the environmental, safety, and health vulnerabilities associated with the storage of plutonium and high enriched uranium at RFP during these and previous time periods are not addressed. For example, in the 1990s, RFP held over metric tons of highly enriched uranium (HEU) consisting mostly of metals in the form of pits, part samples, and scrap.

Observation 2: The overlap in definition of phases of operation requires further study to identify dose from radionuclides such as tritium, thorium, enriched and depleted uranium $^{239+240}$Pu, ^{241}Pu and ^{241}Am which can be related to significant releases. A timeline is needed to

distinctly delineate phases of operation, data types and availabilities, as well as data sources used.

Observation 3: The use of the RATCHET air dispersion model is not able to take into account unexpected air flows around close-in buildings, where the height of those buildings may perturb estimates because of wake effects. This may be a confounding problem at RFP and needs to be addressed.

Observation 4: With an appropriate wound dose model not available, the cited approach for estimating wound-related uptakes in the internal dose TBD is claimant favorable for relevant types of cancer, except for lymph nodes and skin cancers. A more claimant-favorable approach for these affected organs needs to be addressed, for which a recently proposed model (Guilmette and Durbin 2003) for wound-site retention of soluble radionuclides may be relevant.

1.4 OPPORTUNITIES FOR IMPROVEMENT

Incomplete Personal Monitoring Data: NIOSH should make further efforts to identify the dosimetry systems and recording methods used to record each worker's exposure through the years, as these issues affect dose reconstruction. It is important that NIOSH succeed in gaining access to the University of Colorado's Job Exposure Matrix to more effectively identify worker job categories and enhance the ability to reconstruct dose for all special work assignments at the RFP. These data provide important insights into exposure durations, practices in which exposures may have occurred, changes in job classifications over time, and job responsibilities. This study should also be used to assist in identifying workers who may have been exposed to radiation from work-related tasks and were not badged, especially during the early years. However, the data from this matrix are not a panacea for the need to identify data quality and gaps, and to recover available personnel dose and plant operational records as they still exist. NIOSH likewise needs to work on more detailed extremity dose assignment factors, such as whole body-to-wrist-to-hand conversion factors for both beta/gamma and neutron exposures.

Internal dosimetry: In its ongoing revision of this TBD, NIOSH needs to consider strengthening it in terms of how it treats the various uncertainties, detection limits, and limitations that have been identified, particularly for chronic low-level intakes, and for the broader range of radionuclides historically present in RFP operations. Coupled with supporting TIBs and other guidance documents, the TBD needs to provide clear guidance regarding pertinent assumptions and approaches for estimating dose for unmonitored workers, workers exposed to various plutonium compounds of varying solubility and particle size, and the ingestion pathway.

Other Radionuclides: The TBD Site Description provides useful information regarding radionuclides handled in different buildings, but does not list the general types and quantities of radionuclides to which workers may have been exposed. Data compiled for offsite dose reconstruction for the surrounding public indicate that Rocky Flats handled at least 85 radioisotopes. A more complete characterization of radionuclides and their quantities needs to be completed. The dose contribution from ^{233}U and daughters should be evaluated and NIOSH

should place more emphasis and study on evaluating dose potential from radionuclides, such as tritium, thorium, enriched and depleted uranium $^{239+240}$Pu, ^{241}Pu, and ^{241}Am, which can be related to significant releases.

Neutron Monitoring: NIOSH should consult the NDRP for more defensible neutron dose data and incorporate this into their dose reconstructions. For those not in the NDRP cohort, neutron exposure should be investigated, and a methodology developed to determine a claimant-favorable neutron dose. Additionally, more use of neutron/photon ratios and/or film/TLD comparisons could be made to arrive at more individualized neutron doses and more robust neutron dose multiplication factors for assigning doses to unbadged workers, rather than relying on assigning average doses derived from the general working population.

Use of Site Expert Input: NIOSH should make a greater effort to take into account site expert information and investigate worker accounts. The on-site, first-hand experience of site experts provides original perspectives and information concerning site practices and exposure histories. NIOSH has incorporated only a limited amount of worker input into the latest versions of the TBD.

Occupational Medical Exposure: NIOSH should reconsider its interpretation of occupational medical exposure. The definition should be expanded to include all forms of medical exposures associated with job performance, to include illness and injury exams, return to work exams, special or certification exams, and work termination exams. NIOSH needs to further evaluate all medical and radiation survey records to better assess machine use and output parameters.

Post-Production Mission at Rocky Flats: NIOSH should address dose reconstruction for workers involved in the post-production mission at Rocky Flats. The post-production mission, now in its 16th year, has involved nuclear material storage, nuclear material stabilization and packaging, environmental restoration, waste management, and decontamination and decommissioning. All of these activities have resulted in employees working in various radiation environments, which should be described and characterized relative to radiation exposures and dose reconstruction.

Utilization of Incident Data for Dose Reconstruction: NIOSH should not rely on the *a priori* assumption that the files of individual claimants contain all relevant information on incidents involving the claimant. For monitored workers, ORAU and NIOSH rely primarily on the worker dose record and the Computer Assisted Telephone Interview (CATI) for potential exposure data on radiological incidents. Workers have often complained of poor record keeping and fabrication of records, which have been confirmed in congressional and Defense Nuclear Facilities Safety Board (DNFSB) investigations. Although the Rocky Flats Site Profile provides a list of accidents and incidents, as it now stands, it does not have a dedicated database or assessment for off-normal exposures and incidents (e.g., uranium and plutonium fires, explosions, spills, etc.). In fact, the list provided in the TBD does not contain incidents past November 1976. Careful evaluation of incident record keeping practices may indicate problems with the integrity of individual worker data in some settings and periods. Available incident databases, even if potentially incomplete, should be incorporated into dose reconstruction efforts.

This is particularly important for workers exposed during and after hundreds of incidents, including fires, explosions, leaks and spills. The Former Radiation Worker Medical Surveillance Program at Rocky Flats, which includes 875 participants, indicates that some workers involved in incidents received lung committed dose equivalents from 600 rem to 12,000 rem and bone surface committed dose equivalents from 500 rem to 32,000 rem. However, this program is limited by its voluntary nature and does not necessarily capture the degree and extent of exposures from all relevant incidents.

2.0 SCOPE AND INTRODUCTION

The review of the Rocky Flats Plant (RFP) site profile was conducted from July 15 through September 30, 2005, in support of the Advisory Board on Radiation and Worker Health (Advisory Board) in the latter's statutory responsibility under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) to conduct such reviews and advise the Secretary of Health and Human Services (HHS) on the "completeness and adequacy" of the EEOICPA program. This review included unclassified interviews of site experts by S. Cohen & Associates (SC&A) personnel at the Denver Federal Center, as well as conference calls between Oak Ridge Associated Universities (ORAU) and SC&A counterparts regarding specific Technical Basis Documents (TBDs) that make up the RFP site profile. While the review was unclassified, all material generated from worker interviews and document reviews were submitted to classification screening to assure that no sensitive information was inadvertently included in this report. The Rocky Flats site officially ceased plutonium operations in 1993 and was completing final closure activities at the time of this review. Therefore, no site activities were observable, and relevant records had been largely archived and not readily available during the site visit. There is currently an outstanding request for records from the RFP representatives.

2.1 REVIEW SCOPE

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

This report provides a review of the following six documents related to historical occupational exposures at the RFP site:

- ORAUT-TKBS-0011-1, *Technical Basis Document for the Rocky Flats Plant – Introduction, Rev. 00* (Little and Meyer 2004)

- ORAUT-TKBS-0011-2, *Technical Basis Document for the Rocky Flats Plant – Site Description, Rev. 00* (Flack and Meyer 2004)

- ORAUT-TKBS-0011-3, *Technical Basis Document for the Rocky Flats Plant – Occupational Medical Dose, Rev. 00* (Furman and Lopez 2004)

- ORAUT-TKBS-0011-4, *Technical Basis Document for the Rocky Flats Plant – Occupational Environmental Dose, Rev. 00* (McDowell-Boyer and Little 2004)

- ORAUT-TKBS-0011-5, *Technical Basis Document for the Rocky Flats Plant – Occupational Internal Dose, Rev 00* (Falk 2004)

- ORAUT-TKBS-0011-6, *Technical Basis Document for the Rocky Flats Plant – Occupational External Dosimetry, Rev. 00* (Langsted 2004)

These documents are supplemented by technical information bulletins (TIBs), which provide additional guidance to the dose reconstructor. A complete list of these documents is available in Attachment 1.

Implementation guidance is also provided by so-called "workbooks," which have been developed by NIOSH for selected sites to provide more definitive direction to the dose reconstructors on how to interpret and apply TBDs, as well as other available information. The SC&A team did not include review of workbooks related to the RFP site profile. The Advisory Board did direct SC&A, beginning in FY2006, to conduct an evaluation of 20 such workbooks in concert with its site profile reviews under Task 1. The workbook(s) associated with RFP will be evaluated in that context following issuance of this review.

Beyond the conduct of its independent interviews of site experts, the SC&A team is aware of and has requested access to a NIOSH database named "Top Hat," which contains NIOSH/ORAU-conducted worker interviews. It was the team's understanding that the database is undergoing modification in order to make it available online, and that it would be available for access by November 2005. A formal request has been made for such access, and an addendum to this report will be provided based on the results of an evaluation of information from that source.

SC&A, in support of the Advisory Board, has critically evaluated the RFP Site TBDs in order to:

- Determine the completeness of the information gathered by NIOSH in behalf of the site profile with a view to assessing its adequacy and accuracy in supporting individual dose reconstructions

- Assess the technical merit of the data/information

- Assess NIOSH's use of the data in dose reconstructions

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

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

not explicitly address the issue of radiation exposures to cleanup workers and decommissioning workers, as that is not addressed in the TBDs.

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

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

2.2 REVIEW APPROACH

SC&A's review of the TBDs and supporting documentation concentrated on determining the completeness of data collected by NIOSH, the adequacy of existing RFP personnel and environmental monitoring data, and the evaluation of key dose reconstruction assumptions. Site expert interviews were conducted as "non-classified" interviews in a secure facility at the Denver Federal Center and all notes taken were screened by RFP derivative classifiers.

Site expert interviews were conducted to help SC&A obtain a comprehensive understanding of the radiation protection program, site operations, and environmental contamination. Attachment 2 provides summaries of the interviews conducted by SC&A by teleconference or in person in Denver during the course of this review. The site experts included current and former staff from radiation control, operations, environmental monitoring, maintenance, and other organizations, as well as other site experts knowledgeable of particular elements of the RFP environmental safety and health program. These interviews were conducted during the course of the RFP site profile review. These individuals were given the opportunity to review the interview summary for accuracy. This is an important safeguard against missing key issues or misinterpreting some vital piece of information. A master summary of all interviews conducted was compiled and is included in Attachment 2. The summary is not intended to be a verbatim transcript, but paraphrases conversations held with site experts. References to specific site experts have been omitted for privacy reasons.

2.3 REPORT ORGANIZATION

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

(1) Executive Summary
(2) Scope and Introduction
(3) Assessment Criteria and Method
(4) Site Profile Strengths
(5) Vertical Issues
(6) Overall Adequacy of the RFP Site Profile as a Basis for Dose Reconstruction

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

Many of the issues that surfaced in the report correspond to more than one of the major objectives (i.e., strengths, completeness of data, technical accuracy, consistency among site profiles, and regulatory compliance.) Section 6.0 provides a list of the issues in summary form, and to which objective each particular issue applies.

The TBDs, in many ways, have done a successful job in addressing a series of technical challenges. In other areas, the TBDs exhibit shortcomings that may influence some dose reconstructions in a substantial manner.

3.0 ASSESSMENT CRITERIA AND METHODS

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

3.1 OBJECTIVES

SC&A reviewed the site profile with respect to the degree to which technically sound judgments or assumptions are employed. In addition, the review identifies assumptions by NIOSH that give the benefit of the doubt to the claimant.

3.1.1 Objective 1: Completeness of Data Sources

SC&A reviewed the site profile with respect to Objective 1, which requires SC&A to identify principal sources of data and information that are applicable to the development of the site profile. The two elements examined under this objective include: (1) determining if the site profile made use of available data considered relevant and significant to the dose reconstruction, and (2) investigating whether other relevant/significant sources are available but were not used in the development of the site profile. For example, if data are available in site technical reports or other available site documents for particular processes, and if the TBDs have not taken into consideration these data where it should have, this would constitute a completeness of data issue. The Oak Ridge Associated Universities (ORAU) site profile document database, including the referenced sources in the TBDs, was evaluated to determine the relevance of the data collected by NIOSH to the development of the site profile. Additionally, SC&A evaluated records publicly available relating to the RFP site and records provided by site experts.

3.1.2 Objective 2: Technical Accuracy

SC&A reviewed the site profile with respect to Objective 2, which requires SC&A to perform a critical assessment of the methods used in the site profile to develop technically defensible guidance or instruction, including evaluating field characterization data, source term data, technical reports, standards and guidance documents, and literature related to processes which occurred at RFP. The goal of this objective is to first analyze the data according to sound scientific principles, and then to evaluate this information in the context of compensation. If, for example, SC&A found that the technical approach used by NIOSH was not scientifically sound or claimant favorable, this would constitute a technical accuracy issue.

3.1.3 Objective 3: Adequacy of Data

SC&A reviewed the site profile with respect to Objective 3, which requires SC&A to determine whether the data and guidance presented in the site profile are sufficiently detailed and complete to conduct dose reconstruction, and whether a defensible approach has been developed in the absence of data. In addition, this objective requires SC&A to assess the credibility of the data used for dose reconstruction. The adequacy of the data identifies gaps in the facility data that may influence the outcome of the dose reconstruction process. For example, if a site did not monitor all workers exposed to neutrons who should have been monitored, this would be considered a gap and thus an inadequacy in the data.

3.1.4 Objective 4: Consistency Among Site Profiles

SC&A reviewed the site profile with respect to Objective 4, which requires SC&A to identify common elements within site profiles completed or reviewed to date, as appropriate. This objective was accomplished by reviewing key TBD assumptions for determining medical, environmental, internal and external dose from RFP and previously reviewed TBDs. This assessment was conducted to identify areas of inconsistencies and determine the potential significance of any inconsistencies with regard to the dose reconstruction process.

3.1.5 Objective 5: Regulatory Compliance

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

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

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

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

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

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

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

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

In order to achieve the five objectives described above, SC&A reviewed each of the six TBDs, their supplemental attachments, and TIBs, giving due consideration to the three categories of dose reconstructions that the site profile is intended to support. The six RFP TBDs provide well-organized and user-friendly information for the dose reconstructor when adequate data were available to do that comprehensively.

ORAUT-TKBS-0011-1, Rev. 00, *Technical Basis Document for the Rocky Flats Plant – Introduction* (Little and Meyer 2004), explains the purpose and the scope of the site profile. SC&A was attentive to this section because it explains the role of each TBD in support of the dose reconstruction process. During the course of its review, SC&A was cognizant of the fact that the site profile is not required by the EEOICPA or by 42 CFR Part 82, which implements the statute. Site profiles were developed by NIOSH as a resource to the dose reconstructors for identifying site-specific practices, parameter values, and factors that are relevant to dose reconstruction. Based on information provided by NIOSH personnel, SC&A understands that site profiles are living documents, which are revised, refined, and supplemented with TIBs as required to help dose reconstructors. Site profiles are not intended to be prescriptive nor necessarily complete in terms of addressing every possible issue that may be relevant to a given dose reconstruction. Hence, the introduction helps in framing the scope of the site profile. NIOSH may want to include additional qualifying information in the introduction to this and other site profiles describing the dose reconstruction issues that are not explicitly addressed by a given site profile.

ORAUT-TKBS-0011-2, Rev. 00, *Technical Basis Document for the Rocky Flats Plant – Site Description* (Flack and Meyer 2004), is an extremely important document because it provides a description of the facilities, processes, and historical information that serve as the underpinning for subsequent RFP TBDs. This document describes SC&A's review of this section and specifically addresses whether all of the potentially important site activities and processes are described, and whether characterization of source terms is complete/sufficient to support dose reconstruction.

ORAUT-TKBS-0011-3, Rev. 00, *Technical Basis Document for the Rocky Flats Plant – Occupational Medical Dose* (Furman and Lopez 2004), provides an overview of the sources, types of exposure, and the frequency of exams that workers potentially received. The TBD clearly acknowledges the paucity of actual data to substantiate doses or support individual worker dose contributions. The TBD recognizes and draws heavily upon assessments at other sites (e.g., the SRP) and the TIB on diagnostic x-rays. SC&A reviewed this section for technical adequacy and consistency with other NIOSH TBDs and procedures.

ORAUT-TKBS-0011-4, Rev. 00, *Technical Basis Document for the Rocky Flats Plant – Occupational Environmental Dose* (McDowell-Boyer and Little 2004), provides background information and guidance to dose reconstructors for reconstructing the doses to unmonitored workers outside of the facilities at the site who may have been exposed to routine and episodic airborne emissions from these facilities. SC&A reviewed this section from the perspective of the source terms and the atmospheric transport, deposition, and resuspension models used to derive the external and internal doses to these workers.

ORAUT-TKBS-0011-5, Rev. 00, *Technical Basis Document for the Rocky Flats Plant – Occupational Internal Dose* (Falk et al. 2005), presents background information and guidance to dose reconstructors for deriving occupational internal doses to workers. This section was reviewed with respect to background information and guidance regarding the types, mixes, and chemical forms of the radionuclides that may have been inhaled by the workers, the

recommended assumptions for use in reconstructing internal doses based on lung counts and in-vitro bioassay data, the methods recommended for use in the reconstruction of missed internal dose, and the methods recommended for characterizing uncertainty in the reconstructed internal doses.

ORAUT-TKBS-0011-6, Rev. 00, *Technical Basis Document for the Rocky Flats Plant – Occupational External Dose* (Langsted 2004), presents background information and guidance to dose reconstructors for deriving occupational external doses to workers. This section was reviewed with respect to background information and guidance regarding the different types of external radiation (i.e., gamma, beta, and neutron) and the energy distribution of this radiation to which the workers may have been exposed. We also reviewed the recommendations for converting external dosimetry data to organ-specific doses, the methods recommended for use in the reconstruction of missed external doses, and the methods recommended for characterizing uncertainty in the reconstructed external doses.

In accordance with SC&A's site profile review procedures, SC&A performed an initial review of the six TBDs, their supporting documentation, and applicable TIBs. SC&A then submitted questions to NIOSH with regard to assumptions and methodologies used in the site profile. These questions are provided in Attachment 3. A series of conference calls were then conducted with NIOSH and ORAU, and the SC&A team to allow NIOSH to provide clarifications and to explain the approaches employed in the site profile TBDs. A summary of the series of individual conference calls with NIOSH, ORAU, RFP staff, and SC&A is provided in Attachment 4.

An extensive comparison was done between the methodologies used in the RFP and other TBDs reviewed to date to determine environmental, internal, and external doses. In the case of occupational medical exposure, the limited data available warranted additional comparison to the SRP and Hanford TBDs. This comparison focused on the methodologies and assumptions associated with dose reconstruction and resultant values used to obtain a POC. A detailed analysis is provided in Attachment 5.

Prior to the conference call with NIOSH to discuss SC&A questions, SC&A prepared and shared with NIOSH a PowerPoint Presentation that provides a summary of the significant findings. The presentation, "NIOSH Rocky Flats Plant Site Profile TBDs" is provided in Attachment 6. Information provided in the conference call with NIOSH was evaluated against the preliminary findings to finalize the vertical issues[2] addressed in the audit report. There are three levels of review for this report. First, SC&A team members review the report internally. Second, SC&A project management and if necessary, outside experts, review all aspects of this report. The third level, referred to as the expanded review cycle, will consist of a review of this draft by the Advisory Board and NIOSH. The first two of these have been completed.

After the Advisory Board and NIOSH have an opportunity to review this draft, SC&A plans to request a meeting with Advisory Board members and NIOSH representatives to discuss the report. Following this meeting, we will revise this report and deliver the final version to the

[2] The term "vertical issues" refers to specific issues identified during our review, which were identified as requiring more in-depth analysis due to their potential to have a significant impact on dose reconstruction.

Advisory Board and to NIOSH. We anticipate that, in accord with the procedures followed during previous site profile reviews, the report will then be published on the NIOSH Web site and discussed at the next Advisory Board meeting. This last step in the review cycle completes SC&A's role in the review process, unless the Advisory Board requests SC&A to participate in additional discussions regarding the closeout of issues, or if NIOSH issues revisions to the TBDs or additional TIBs, and the Advisory Board requests SC&A to review these documents.

Finally, it is important to note that SC&A's review of the six TBDs and their supporting TIBs is not exhaustive. These are large, complex documents and SC&A used its judgment in selecting those issues that we believe are important with respect to dose reconstruction.

4.0 SITE PROFILE STRENGTHS

In developing a TBD, the assumptions used must be fair, consistent, and scientifically robust, and uncertainties and inadequacies in source data must be explicitly addressed. The development of the TBD must also consider efficiency in the process of analyzing individual exposure histories so claims can be processed in a timely manner. With this perspective in mind, we identified a number of strengths in the RFP site TBDs. These strengths are described in the following sections.

4.1 COMPLETENESS OF DATA

In general, the site description TBD (ORAUT-TKBS-0011-2) provides an accurate and reasonable characterization of the history and operational activities at the RFP for the period of production. The major functions of many of the production and support buildings were outlined, as well as the major process changes that occurred through the years. There are still some gaps related to processing of special materials and recycled uranium. The appendix provides a list of documented accidents/incidents in chronological order through November 1976. Detailed descriptions were provided for major incidents. This information can assist the dose reconstructors in determining whether additional exposure potential exists and whether the total dose reconstruction process is claimant favorable.

In developing the site profile, NIOSH drew upon information from the 415 reports compiled on the Site Profile Research Database. These include environmental reports beginning in 1960 that present data used for the determination of offsite exposure to the public. Process information was drawn from Rocky Flats health studies and technical documents obtained from public sources or through the site. NIOSH/ORAU obtained information on the dosimetry program from site experts knowledgeable in the area. They met with the United Steelworkers on June 23, 2004, to identify worker concerns and discuss the RFP TBDs. This interaction with workers helps provide valuable insight into the site operations and programs. In addition, the issuance or planned issuance of several TIBs reflects an ongoing effort by NIOSH to continually improve guidance provided to the dose reconstructor. For example, NIOSH is preparing a new ORAUT-OTIB-0049 that addresses methodologies for reconstructing dose from Super Type S and other insoluble forms of plutonium. This is purported to be an essential new tool to deal with high-fired plutonium oxide exposure that often have a much smaller particle size (Falk 2004).

4.2 ADEQUACY OF DATA

The TBDs benefited from having access to information and data that were compiled as a part of the RFP programs, as follows:

(1) Radiological control personnel have implemented improved procedures and technologies over time to reduce radiation dose to workers, and have improved personnel monitoring programs.

(2) RFP implemented an environmental monitoring program, including stack monitoring, in-perimeter monitoring, offsite monitoring, and groundwater monitoring.

(3) Starting in 1964, dosimeters were coupled with security badging, which helped ensure all personnel were provided dosimetry.

(4) NIOSH has provided in sample RFP dosimetry records and an explanation of how to interpret these records in both the internal and external TBDs. The inclusion of this type of information is commendable and should be continued with future site profiles.

(5) Figure C-13, presented in Appendix C (Falk 2004), an example of a data report, *Health Sciences Record*, that might be encountered in the claimant's file. In this example, the 'parts per million' by weight of ^{241}Am was calculated and recorded for the fecal and nose smears.

(6) NIOSH/ORAU have recognized the usefulness of the NDRP study and the job-exposure matrix compiled by the University of Colorado. They have recently received data from the NDRP study and are determining how to incorporate this data into dose reconstruction. They are actively pursuing the job-exposure matrix to assist in the development of co-worker doses.

Although RFP has significant quantities of personnel monitoring data, as well as environmental data, there are gaps in the information. Only a fraction of the population was monitored for radiation exposure in the early years of operation. In addition, multiple gaps appear in records of individuals that were likely monitored. Further records retrieval efforts may be prudent to fill some of these gaps.

4.3 TECHNICAL ACCURACY/CLAIMANT FAVORABILITY

The RFP TBDs exhibited the following strengths in terms of their technical accuracy and claimant favorability:

(1) NIOSH has provided a good description of the in-vivo and in-vitro monitoring programs over the period of operation. They have provided detailed descriptions of dosimeters used for both beta/gamma and neutron monitoring. The TBDs and OTIB made efforts to track the changes in dosimetry methods, calibration standards, and administrative limits for the period of 1951 to 2003 to assist in making the assigned dose claimant favorable. The chronological sequences of events at the RFP were outlined in the TBDs, along with associated tables of dosimetry methodology, sensitivity, and limitations as dosimetry changed over the years. The major areas of external radiation hazards were addressed as the functions of the RFP changed over time.

(2) The dose reconstructor generally uses the solubility that gives the best outcome to the claimant. Thus the current information provided in the TBD (Furman and Lopez 2004), is no longer valid and will be taken out.

(3) NIOSH has indicated that all of the interferences, if operative, are claimant favorable, as the dose reconstructor uses the recorded lung count data at face value.

(4) NIOSH developed a method for handling the variability of recovery and differences in the use of the mean value of the MDA or the extreme values. Fifty percent of samples have a sample-specific MDA higher than the median MDA for the process. The table on the bottom of page 44 gives the median and 5th percentile values of recoveries. The 5th percentile values of recoveries are an indicator of the variability at the worst-case end of the distribution.

(5) In calculating the total activity in the lung after an incident, NIOSH has developed a methodology to account for contributions from both the right and left lung. The DR gets the calibration for that period for two detectors, and then multiplies that calibration factor by 0.43. The net c/m data for the left chest divided by the adjusted calibration factor gives the total americium activity for that count.

(6) The occupational external dosimetry TBD (Langsted 2004) separated out the different types of radiation and their energy ranges to provide more detailed information for dose reconstruction (DR). This was not an easy task in view of the many changes in operations, radiation fields, dosimetry technologies, and administrative/regulatory mandates. A detailed discussion was provided of each type of radiation and its exposure potential, dosimetry, dose records, and applicable correction factors for DR.

(7) ORAUT-OTIB-0027 provides the dose reconstructor with additional information on calculating dose from low-energy photons and electrons, and dosimetry uncertainty values.

4.4 CONSISTENCY AMONG SITE PROFILES

(1) The RFP site profile has introduced a few new concepts not previously used in other site profiles. A respirable fraction of 1.0 is applied for environmental dose. This value is claimant favorable.

(2) RFP is the first site profile reviewed to date where the dose reconstructor is directed to use both the preceding and following periods to assign dose for gaps in the records. In previous site profiles, an unmonitored individual would receive a dose based on the limit of detection (LOD) and the exchange frequency.

(3) The inclusion of a methodology for skin contamination was a positive addition to the site profile. This is especially important in facilities that had routine personnel contamination incidents. A similar section should be included in other site profiles.

(4) Although internal uptakes by wounds have been an issue at other sites, the RFP site profile is the only site profile reviewed to date that provides direction on assessing uptakes via a wound site. Consideration is given to acute and long-term chronic injection as a mode of intake.

4.5 REGULATORY COMPLIANCE

The TBDs' use of personnel monitoring data and environmental monitoring data to determine dose is consistent with the requirements outlined in 42 CFR Part 82, as follows:

- Where in-vivo and in-vitro analyses are available, this information is provided for use in determination of internal dose.
- Where routine beta/gamma and neutron dosimeters are available and adequate, this information is provided for use in determination of external exposure.
- Where environmental measurements are available, these data are used as the basis for environmental dose.

NIOSH has effectively complied with the hierarchy of data required under 42 CFR Part 82 and its implementation guides for monitored workers (with the one exception being particle size where measured values were available for specific operations or incidents).

5.0 VERTICAL ISSUES

SC&A has developed a list of key issues regarding the RFP Site Profile. These issues relate to each of the five objectives defined in SC&A 2004. Some issues are related to a particular objective, while others cover several objectives. Many of the issues raised below are applicable to other DOE and Atomic Weapons Employer sites and should be considered in the preparation and revision of other site profiles.

5.1 ISSUE 1: MINIMUM DETECTABLE ACTIVITY

Suggested use of urine bioassay MDA values for plutonium and americium appear low and are likely to yield body burdens/organ doses that are proportionately low and, therefore, claimant unfavorable.

Defining the Issue

The inhalation of Type S plutonium (and americium) will not only yield very low excretion fractions in urine, but because plutonium is a pure alpha emitter, its quantitative detection in urine requires complex chemical separation before a sample may either be analyzed by gross alpha counting in a gas flow proportional counter or by means of alpha spectrometry that employs solid state surface barrier detectors.

For either method, accurate quantitative measurements require full knowledge of several crucial parameters that may include the following:

(1) The urine volume analyzed relative to a given individual's 24-hour urine excretion volume

(2) The chemical recovery fraction of the isotope extracted from urine

(3) Sample absorption, which is defined by the fraction of alphas absorbed (fully or partially) that precludes their inclusion in (1) gross alpha counting or (2) the full energy peak when alpha spectrometry is employed

(4) The counting geometry factor and the detector's counting efficiency (for 2 π counting geometry, the theoretical upper bound detection efficiency is 50%)

(5) The statistical uncertainty of converting counts observed in sample to an activity value (the magnitude of this uncertainty is defined by the total **count time** of the sample, the value of the blank count rate, and the detector background)

On page 12 of ORAUT-TKBS-0011-5, the following guidance is provided for dose reconstruction:

> *The minimum detectable activity (MDA) for plutonium is presented here for the* ***medium conditions****. By definition of the medial value, half of the sample-specific MDAs are lower than the median value, and half are higher. In most cases the dose reconstructor is not likely to have sufficient data to determine the sample-specific MDA,* ***so the median values should be used****.* [Emphasis added.]

Also included in the guidance are the following median MDA values, as given in Table 5.3.1.1.2-1 and reproduced herein:

Period	dpm/24-hr sample
1952 – 1953	0.57
1954–1962	0.51
1963	0.44
1964 – 1977	0.54
1978 – 1989	0.24
1990 – 1992	0.24
1993 –	0.020

Note: The unit of the MDA values starting with 1990 is dpm/sample.
Sample-specific MDA values in the record starting 1990, if found, should be used instead of the generic MDA values in this table.

Attachment A of the TBD (pp. 36–37) states that ". . . the general equation for the MDA is Equation 6 in the American National Standard, *Performance Criteria for Radiobioassay* (HPS 1996)," and presents this equation along with its many terms. Attachment A further states that "… Applying this equation to urinalysis methods at Rocky Flats involves determining the values of **each** variable for measurements of the analysis . . . as the methods evolved."

Statements of Concern

SC&A questions the validity of these median MDA values and their use in dose reconstruction for the following reasons:

(1) **NIOSH's ability to quantify critical terms, which define the ANSI equation for MDA**. In Attachment A of ORAUT-TKBS-0011-5, NIOSH openly states the following:

> *. . . the period from 1952 to 1971 for which many of the urinalysis logs have been located and analyzed to obtain the information needed to assess the MDA . . . urinalysis procedures were* ***primitive*** *and* ***evolving and numerous dosimetrically interesting events and intakes were occurring at Rocky Flats.*** [Emphasis added.]

NIOSH further implies that these logs/records were far from complete and frequently lacked critical information, as given in the following statements:

> *… Routine urine samples were **typically** 24-hr excretions, either one continuous 24-hr period (but not taken at the Rocky Flats site) or two 12-hr periods. Special urine samples could be 24-hr samples, overnight samples, or a single voiding. …The measurement of the sample **typically** involved counting the alpha radiation from the processed aliquant of the sample and determining the activity of the analyte in the original sample.*
>
> *… [for gross alpha counting] **Typical** counting time was 150 minutes,… although from 1952 to 1955 count times of 55, 60, and 75 minutes and in 1971 count times of 40 and 60 minutes, were also used. A spike sample and a reagent blank sample were processed with the workers' samples, sometimes less frequently. The result of the spike sample **may** or **may not** have been used to establish the value of the recovery of the analyte for the batch. Similarly, the result of the **blank** (counts per minute) **may** or **may not** have been used to establish the value of the blank subtracted from the total count rate of the sample. Detector efficiency was **stated** to be 0.50.*
>
> *…No documentation was found concerning the count time used to measure the detector background, but the count time is **likely** to be 150 minutes or longer…*
>
> *The blank count rate is method specific, and the application of the blank in the data analysis was **variable** between methods and within a method over time. The confounder was the intermittent, but **persistent, laboratory contamination** artifacts introduced into **blanks** and **worker samples**.* [Emphasis added.]

Given the limited data and/or the uncertainties of critical variables that define MDA, it is SC&A's opinion that the use of the median MDA value in instances where bioassay data are recorded as zero or background is likely to underestimate actual doses. Included among the unsupported assumptions used by NIOSH for deriving median MDA values are the following (as given on pg. 46 of the TBD):

- An assumed sample count time of 150 minutes
- A theoretical upper-bound detector counting efficiency
- The assumption that the analyzed sample value represents a full 24-hr urine value
- The assumption of zero sample self-absorption (i.e., $F_a = 1.00$)
- Assumptions regarding the value of S_o (that incorporate blank sample, detector background, etc.) that are not adequately explained/supported

(2) **The use of median MDA values in dose reconstruction is technically inappropriate since urine activities well in excess of median MDA values may not have been recorded as explained in the following statements (p. 38 of ORUAT-TKBS-0011-5)**:

> *Tolerance levels were used at Rocky Flats in the 1950s and 1960s as an indicator of the maximum permissible amount (activity) of a radionuclide excreted per day in a worker's urine. The technical basis for the values of tolerance levels used at Rocky Flats has not been identified. The significance is that* ***urinalysis results less than 10% of the tolerance level were recorded and reported as background (BK on the Urinalysis Record Card) or zero****, regardless of the underlying sensitivity of the method, with some exceptions.* [Emphasis added.]

For plutonium, the required reporting level of $ 0.88 dpm/24-hr is given; and for gross alpha, the required reporting level of 8.8 dpm/24-hr is given. This implies that lower values were recorded as either zero or background.

Summary Conclusions

Based on the information provided in ORAUT-TKBS-0011-5, it is the opinion of SC&A that cited median MDA values for Pu, Am, and possibly U are inappropriate for dose reconstruction. At a minimum, dose reconstruction should be based on the reporting level of a given analyte.

A more claimant-favorable approach that is recommended by SC&A is an MDA level that incorporates the average of **two** extreme conditions involving the following four issues:

(1) A high blank
(2) Low chemical recovery
(3) Low sample volume
(4) Significant sample self-absorption

As shown on page 47 of ORAUT-TKBS-0011-5, MDA values for two extreme conditions out of four yield the following average values:

Period	Average MDA (dpm/24-hr sample)
1952 – 1952	1.55
1954 – 1962	1.10
1963	1.30
1964 – 1971	1.61

5.2 ISSUE 2: OCCUPATIONAL INTERNAL DOSE

The Occupational Internal Dose TBD, ORAUT-TKBS-0011-5 (Falk 2004), and the Site Description TBD, ORAUT-OTIB-0011-2 ((Flack and Meyer 2004), were evaluated to determine

if adequate guidance was provided to perform a dose reconstruction of internal dose. The TBD was assessed with the following criteria:

(1) Does the TBD provide adequate background information?

(2) Does the TBD provide technical sound assumptions for the calculation of internal doses?

(3) Does the TBD provide guidance for addressing missed internal dose for monitored and unmonitored workers?

The Occupational Internal Dose TBD, ORAUT-TKBS-0011-5 (Falk 2004), is presented in four general sections—the main body of the report and Attachments A, B and C. The main body of the report contains a detailed description of the following.

- Source term
- Particle size
- Solubility
- In-vitro bioassay methods, minimum detectable activities (MDAs), counting methods, reporting levels, and interferences
- Lung measurements, minimum detectable activities (MDAs), counting methods, reporting levels, and interferences
- Other bioassay data (wound count data, nasal smear and fecal samples)
- Records and reports
- Limited information on the assignment of dose to unmonitored workers

Attachment A describes the minimum detectable activity for urinalysis methods at Rocky Flats. Attachment B describes the minimum detectable activity for in-vivo lung counts at Rocky Flats. Attachment C provides some examples of records and reports used at Rocky Flats.

5.2.1 Implications of High-Fired Plutonium in Bioassay Measurements for Acute and Chronic Intakes

The absorption of the inhaled material to the blood depends on its physical and chemical form. ICRP recommends that material-specific rates of absorption should be used in the model for compounds for which reliable experimental data exist. For other compounds, default values of parameters are recommended. At Rocky Flats, high-fired oxides were generated during the two big fire accidents, and more than likely as a result of smaller plutonium fires and high temperature processes in furnaces, incinerators and production areas.

Because of these facts, an evaluation of the effect in using the high-fired plutonium (Super S) lung retention parameters in the interpretation of bioassay results was carried out using the Type S ^{239}Pu lung retention parameters simulating different scenarios (see Attachment 9). The four simulated scenarios were:

- **Chronic inhalation plutonium compounds of different solubility classes with urinalysis sampling after 20 years.** The total intake was calculated for the ^{239}Pu activity of 1 dpm/24-hour in urine samples taken following a chronic inhalation over 20 years of plutonium Type S at 1 μm and Type M plutonium compounds, respectively. Equivalent doses for the calculated intakes indicates that doses would be higher for the Type M compound compared to the insoluble one, except for the large intestine and respiratory tract, where the high-fired compounds deliver the highest dose.

- **Chronic inhalation of Type S plutonium compound (15Bq/day) plus acute intake of high-fired plutonium oxide with annual urinalysis sampling.** A chronic inhalation of 15 Bq/day of ^{239}Pu Type S, AMAD = 5 μm, through 20 years of exposure with additional acute intakes of 10,000 Bq/year, in the beginning of each year, of high-fired ^{239}Pu compound, AMAD = 1μm. Considering this scenario, it is just possible to detect measurable ^{239}Pu activity in urine samples just after 10 y of chronic and acute exposure.

- **Chronic inhalation of Type S plutonium compound (100 Bq/day) plus acute intake, with quarterly urinalysis sampling.** Chronic inhalation of 100Bq/day of ^{239}Pu Type S, AMAD = 5 μm, through the 20 years of exposure with additional acute intakes of 10,000 Bq/year, in the beginning of each year, of Type S ^{239}Pu compound, AMAD = 1μm (simulating accidental intake of high-fired Pu). Results indicate that the contribution of chronic intake on urinary activity matches and exceeds that from an acute intake of 10,000 Bq during the 6th year of exposure, and makes it increasingly difficult to detect acute intakes thereafter unless the measurement system is very sensitive or the intake is extremely high.

- **Chronic inhalation of Type S plutonium compound (100 Bq/day) plus acute intake, with urinalysis sampling one day after acute intake.** Chronic inhalation of 100Bq/day of ^{239}Pu Type S, AMAD = 5 μm, through the 20 years of exposure with additional acute intakes of 10,000 Bq/year, in the beginning of each year, of Type S ^{239}Pu compound, AMAD = 1μm (simulating accidental intake of high-fired Pu). Results show that total intake (chronic + acute) is higher than chronic intake alone by only a factor of 1.5, which is in the band of normal measurement uncertainty.

This analysis shows that the incidental acute intake of insoluble plutonium compound, in the first 20 years, may be difficult to identify because of several factors, including the relatively high MDA value (0.01 Bq), the low fraction of activity intake excreted through the urine (10^{-6} Bq), and historic delay in or lack of performing post-incident urinalysis or fecal analysis. It was found that the contribution of chronic intake in urinary activity increases over the time of exposure, obviating the detection of incidental intakes, unless the activity is extremely high or the chronic exposure is very low, or undetectable.

5.2.2 Source Term

The TBD, ORAUT-TKBS-0011-2 (Flack and Meyer 2004), states that neptunium, thorium, curium and tritium figured in the operations at Rocky Flats. While it is acknowledged in the TBD, ORAUT-TKBS-0011-5 (Falk 2004, pg. 7) that site-specific internal dosimetry for neptunium, thorium and curium is rare or not available, NIOSH needs to provide some form of guidance for approaching dose reconstruction for these radionuclides either in the TBD or in supporting OTIBs or workbooks.

The TBD (Falk 2004) on page 17 states that the workers were exposed to tritium:

> *Workers were monitored for possible tritium exposures only for special projects or situations, starting in 1973.*

The TBD does not give sufficient information on bioassay measurements for tritium as well as the form of tritium to which workers were exposed.

5.2.3 Particle Size

The TBD (Falk 2004) assumes a 5 *μm* AMAD as the default particle size for Rocky Flats dose reconstructions. Particle sizes and distributions are not available for work areas or incidents, except in limited cases. The TBD states on page 9 that in an incident involving a plutonium fire in Buildings 776 and 777, Mann and Kirchner (1967) measured a mass median diameter of 0.3 μm, similar to that reported for an americium fire incident from the same reference. On page 9, item 5.2.2.2, instructions on assumed particle sizes for exposure to Am in cases of fire are incomplete, in that no value is provided for "x.x."

Based on direction provided by 42 CFR Part 82, a default 5μm AMAD particle size is only applicable in cases where there is no information on particle sizes available. There is some facility-specific particle size information available. SC&A recommends that the particle sizes should be reviewed, and the probability of exposure to particles sizes smaller than or larger than 5μm should be calculated before adopting the default parameter of 5μm AMAD.

In cases where the dose is estimated based on air concentration data, the default 5μm AMAD particle size is not claimant favorable, as shown in Table 1. This table shows the dose coefficients for 1-year equivalent dose, assuming a single intake of 1 Bq of ^{239}Pu by inhalation. The comparison between the solubility Type M and Type S shows that independent of the particle size, the dose coefficients for Type M are always bigger than for Type S. On the other hand, the comparison between the particle sizes AMAD 5 μm and 1 μm shows that independent of the solubility, the dose coefficients for AMAD 1 μm are always bigger than for AMAD 5 μm.

Table 1. Dose Coefficients for 1-Year Equivalent Dose Assuming a Single Intake of 1 Bq of Plutonium-239 by Inhalation

Organs	AMAD 5 μm		AMAD 1 μm		Ratio TypeM/TypeS		Ratio 1μm /5μm	
	Type S	Type M	Type S	Type M	AMAD 5 μm	AMAD 1 μm	Type S	Type M
Adrenals	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Bladder Wall	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Bone Surface	5.17E-07	2.53E-05	8.52E-07	3.35E-05	4.89E+01	3.93E+01	1.65E+00	1.32E+00
Brain	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Breasts	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Esophagus	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
St Wall	1.75E-09	5.87E-08	2.36E-09	7.77E-08	3.35E+01	3.29E+01	1.35E+00	1.32E+00
SI Wall	2.56E-09	5.94E-08	2.88E-09	7.82E-08	2.32E+01	2.72E+01	1.13E+00	1.32E+00
ULI Wall	9.41E-09	6.58E-08	7.28E-09	8.21E-08	6.99E+00	1.13E+01	7.74E-01	1.25E+00
LLI Wall	2.52E-08	8.05E-08	1.75E-08	9.11E-08	3.19E+00	5.21E+00	6.94E-01	1.13E+00
Colon	1.62E-08	7.21E-08	1.17E-08	8.60E-08	4.45E+00	7.35E+00	7.22E-01	1.19E+00
Kidneys	1.17E-08	5.30E-07	1.97E-08	7.18E-07	4.53E+01	3.64E+01	1.68E+00	1.35E+00
Liver	8.60E-08	4.24E-06	1.41E-07	5.59E-06	4.93E+01	3.96E+01	1.64E+00	1.32E+00
Muscle	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Ovaries	5.16E-09	2.54E-07	8.50E-09	3.35E-07	4.92E+01	3.94E+01	1.65E+00	1.32E+00
Pancreas	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Red Marrow	5.25E-08	2.57E-06	8.65E-08	3.40E-06	4.90E+01	3.93E+01	1.65E+00	1.32E+00
ET Airways	2.61E-05	1.16E-05	1.38E-05	6.21E-06	4.44E-01	4.50E-01	5.29E-01	5.35E-01
Lungs	2.65E-05	1.86E-05	3.96E-05	2.69E-05	7.02E-01	6.79E-01	1.49E+00	1.45E+00
Skin	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Spleen	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Testes	5.26E-09	2.58E-07	8.65E-09	3.41E-07	4.90E+01	3.94E+01	1.64E+00	1.32E+00
Thymus	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Thyroid	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00
Uterus	1.21E-09	5.82E-08	2.01E-09	7.74E-08	4.81E+01	3.85E+01	1.66E+00	1.33E+00

5.2.4 Solubility

The TBD recommends that the dose reconstructor should assume that radionuclides are soluble for the purpose of dose assessment of the systemic organs and tissues.

5.2.4.1 Plutonium

The TBD (Falk 2004) states on page 8 that:

> *Plutonium in chemical-processing operations can be either soluble (type M), insoluble (type S), or a mixture of solubilities. A claimant favorable approach is to assume insoluble plutonium if the qualifying cancer is of the respiratory system and to assume soluble plutonium for all other cases. Lung count data in conjunction with urine data may help to determine absorption type.*

The document ORAUT-PROC-0003 (Brackett 2003) states, on page 5, that:

> *Because of these differences, "worst-case" assumptions are not necessarily the same as those that would result in the largest committed effective dose. They will depend on a variety of factors, including radionuclide, organ of interest, and latency period of the cancer. For example, while the assumption of absorption type S material will generally maximize the lung dose, the assumption of type F may result in larger doses to other organs because the material will be removed from the lung more rapidly and distributed throughout the body. The process is to be claimant-favorable whenever there are unknown values.*

In Table 2, and in Figures 1 and 2, an example of 1-year chronic intake of ^{239}Pu is provided. The committed equivalent doses were based on an activity of 1 Bq in a 24-hour urine sample collected in a working day, on the last month of the 1st year of exposure. The committed equivalent doses are significantly higher for most of the gastrointestinal organs for the Type S compounds compared to those of Type M. It indicates that the claimant-favorable approach will depend on the type of cancer, as stated in the document ORAUT-PROC-0003 (Brackett 2003), guidance that is not applied in this TBD.

Table 2. Comparison of Committed Equivalent Doses for Plutonium-239 Type M and Type S Compounds per Bq Plutonium-239 Present in the 24-Hour Working Day Urine Sample, Collected at the End of 1-Year Exposure

Organs	Committed equivalent dose		Ratio TypeM/TypeS
	Inhalation Type M Sv/Bq excreted	Inhalation Type S Sv/Bq excreted	
Adrenals	3.59E-03	2.77E-03	1.29E+00
Bladder Wall	3.59E-03	2.77E-03	1.29E+00
Bone Surface	1.48E+00	1.13E+00	1.31E+00
Brain	3.59E-03	2.77E-03	1.29E+00
Breasts	3.59E-03	2.77E-03	1.29E+00
Esophagus	3.59E-03	2.77E-03	1.29E+00
St Wall	3.65E-03	5.72E-03	6.37E-01
SI Wall	3.74E-03	1.01E-02	3.69E-01
ULI Wall	4.55E-03	4.73E-02	9.62E-02
LLI Wall	6.42E-03	1.33E-01	4.83E-02
Colon	5.33E-03	8.43E-02	6.32E-02
Kidneys	3.72E-02	2.95E-02	1.26E+00
Liver	2.44E-01	1.86E-01	1.31E+00
Muscle	3.59E-03	2.77E-03	1.29E+00
Ovaries	1.47E-02	1.12E-02	1.31E+00
Pancreas	3.59E-03	2.77E-03	1.29E+00
Red Marrow	1.50E-01	1.14E-01	1.31E+00
ET Airways	9.96E-01	7.65E+01	1.30E-02
Lungs	2.10E+00	1.21E+02	1.74E-02
Skin	3.59E-03	2.77E-03	1.29E+00
Spleen	3.59E-03	2.77E-03	1.29E+00
Testes	1.49E-02	1.14E-02	1.31E+00
Thymus	3.59E-03	2.77E-03	1.29E+00
Thyroid	3.59E-03	2.77E-03	1.29E+00
Uterus	3.59E-03	2.77E-03	1.29E+00

Years of Exposure to ^{239}Pu: 1 year
Collection of 24-hr working day urine sample: last month, of the 1st year
Equivalent Doses calculated for the 1st year after the beginning of work
Excretion of ^{239}Pu in urine entirely due to inhalation exposure of Type M material (M) – 5 μm AMAD
Excretion of ^{239}Pu in urine entirely due to inhalation exposure of Type S material (S) – 5 μm AMAD

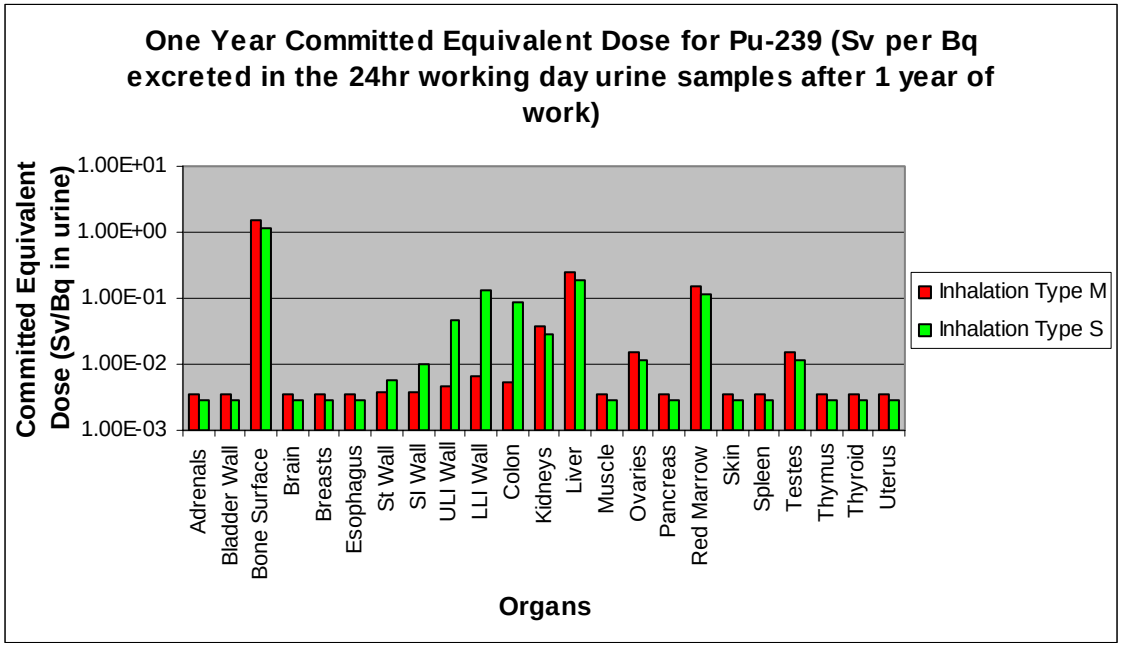

Figure 1. 1-Year Committed Equivalent Dose for All Organs due to 1-Year Chronic Inhalation of Plutonium-239 Type M and Type S Compounds

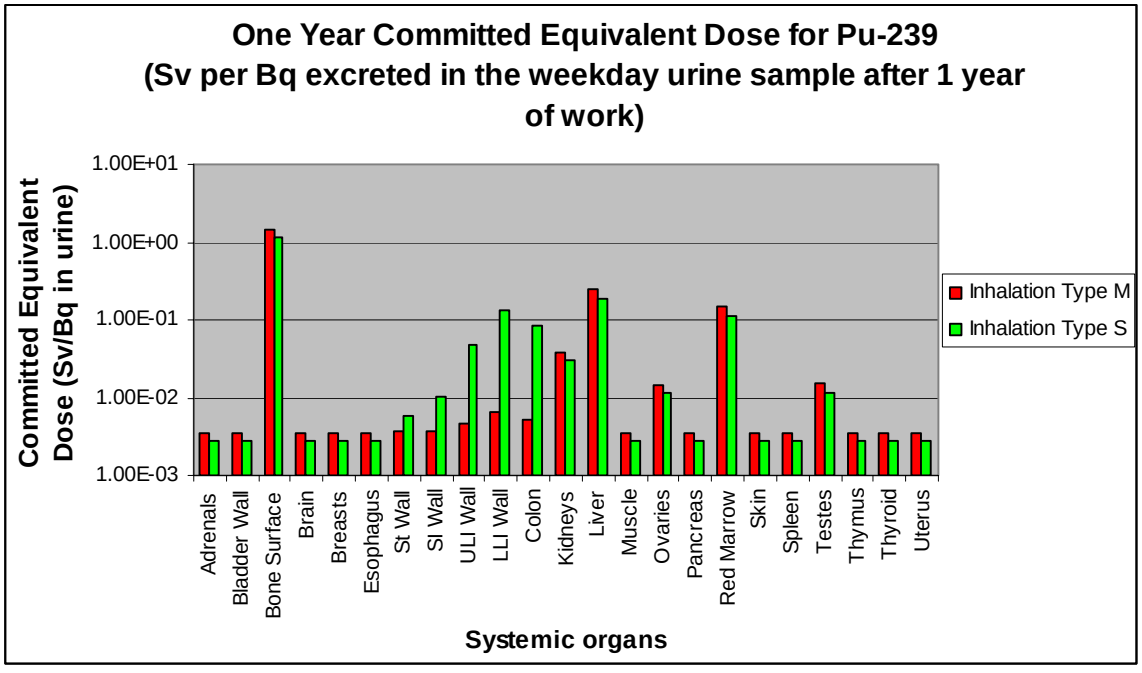

Figure 2. 1-Year Committed Equivalent Dose for Systemic Organs due to 1-Year Chronic Inhalation of Plutonium-239 Type M and Type S Compounds

5.2.4.2 Uranium

There is an uncertainty in the definition of the uranium compound. The TBD (Falk 2004) states that:

> *In many cases, the compound of uranium involved in an intake is not identified. There are no Rocky Flats site-specific data for enriched uranium. In general, intakes in chemical processing areas occurred as type M or as mixtures of type M and type S. Reconstructions should use the most claimant favorable mixture. For intakes that occur in metal-working areas, the claimant favorable assumption is type S if the qualifying cancer site is in the respiratory system. For other cancer sites, the more claimant favorable assumption is type M. Reconstructions should use the default value of 5 µm.*

The values presented in Table 3 illustrate that the committed equivalent doses are significantly higher for most of the gastrointestinal organs for the uranium compounds Type S compared to the Type M. It means that the claimant-favorable approach will depend on the type of cancer as stated on the document ORAUT-PROC-0003 (Brackett 2003), but not applied in this TBD**.** Figures 3 and 4 graphically represent the Table 3 committed equivalent dose.

Table 3. 1-Year Uranium-234 Committed Equivalent Doses per Bq Uranium-234 Present in the 24-Hour Working Day Urine Sample, Collected at the End of 1-Year Exposure

	Type M	Type S	Ratio
	Sv/Bq (excreted)	Sv/Bq (excreted)	TypeM/TypeS
Adrenals	1.79E-05	1.61E-05	1.11E+00
Bladder Wall	1.91E-05	1.71E-05	1.12E+00
Bone Surface	1.99E-03	1.79E-03	1.11E+00
Brain	1.79E-05	1.61E-05	1.11E+00
Breasts	1.79E-05	1.61E-05	1.11E+00
Esophagus	1.79E-05	1.61E-05	1.11E+00
St Wall	2.03E-05	8.49E-05	2.39E-01
SI Wall	2.36E-05	1.88E-04	1.25E-01
ULI Wall	5.25E-05	1.06E-03	4.95E-02
LLI Wall	1.19E-04	3.06E-03	3.88E-02
Colon	8.09E-05	1.92E-03	4.21E-02
Kidneys	1.89E-03	1.71E-03	1.10E+00
Liver	7.98E-05	7.14E-05	1.12E+00
Muscle	1.79E-05	1.62E-05	1.11E+00
Ovaries	1.79E-05	1.62E-05	1.11E+00
Pancreas	1.79E-05	1.61E-05	1.11E+00
Red Marrow	2.09E-04	1.87E-04	1.11E+00
ET Airways	3.69E-02	1.83E+00	2.01E-02
Lungs	7.00E-02	2.59E+00	2.70E-02
Skin	1.79E-05	1.61E-05	1.11E+00
Spleen	1.79E-05	1.61E-05	1.11E+00
Testes	1.79E-05	1.61E-05	1.11E+00
Thymus	1.79E-05	1.61E-05	1.11E+00
Thyroid	1.79E-05	1.61E-05	1.11E+00
Uterus	1.79E-05	1.61E-05	1.11E+00

Years of Exposure to ^{234}U: 1 year
Collection of 24-hr working day urine sample: last month, of the 1st year
Equivalent Doses calculated for the 1st year after the beginning of work

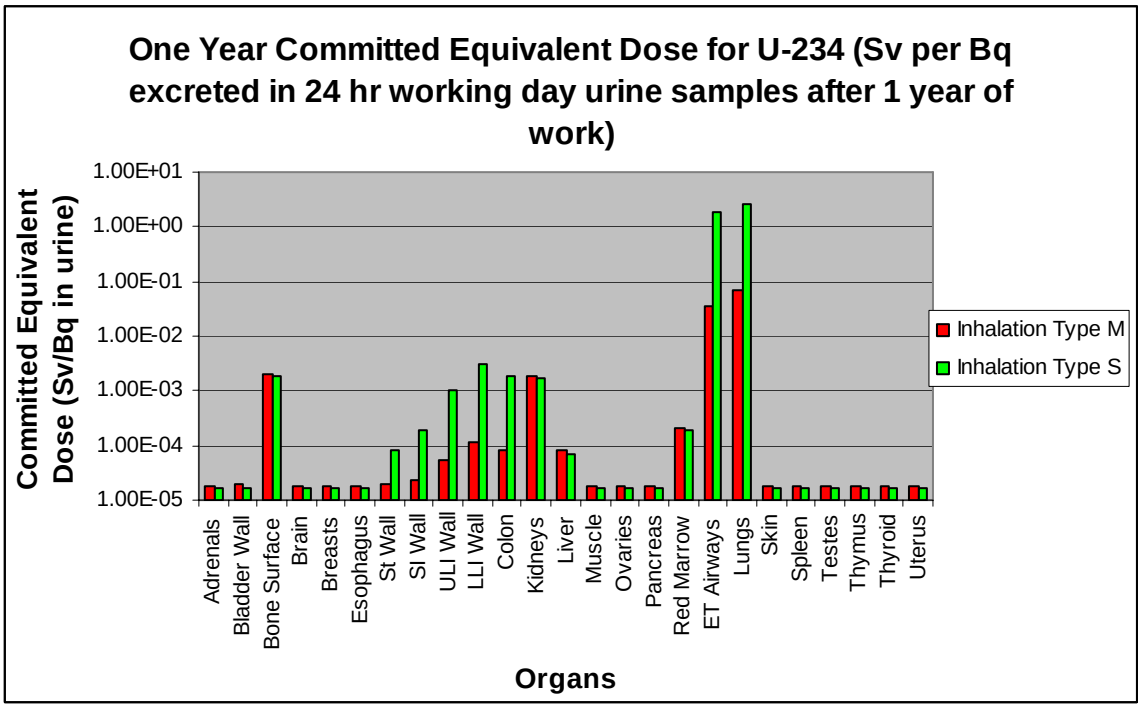

Figure 3. 1-Year Committed Equivalent Dose for All Organs due to 1-Year Chronic Inhalation of Uranium-234 Type S, Type M and Type S Compounds

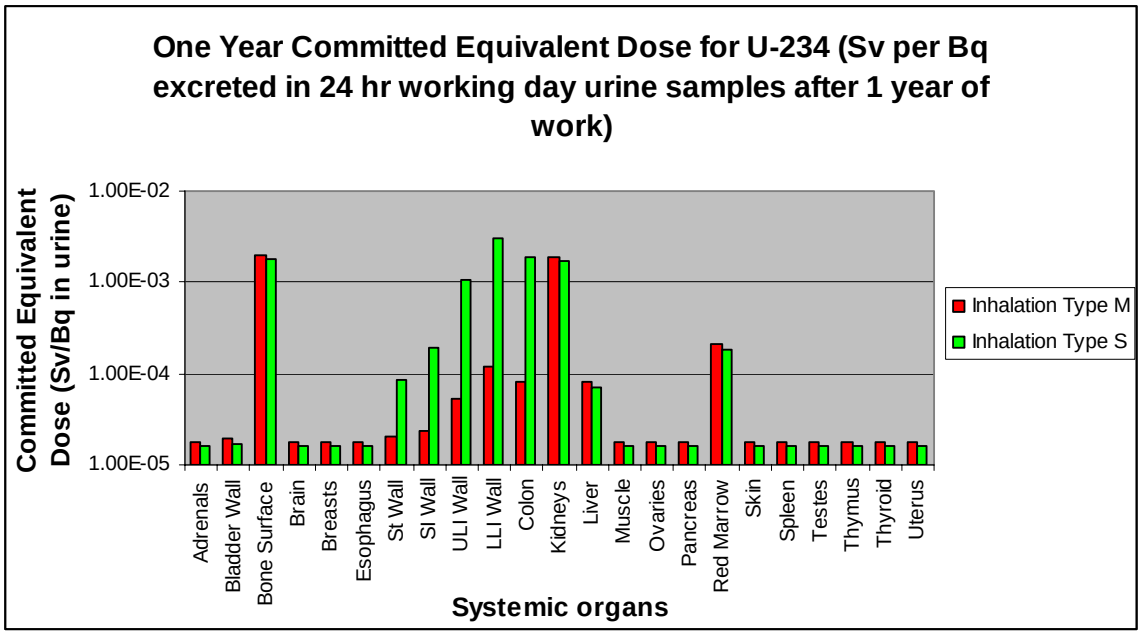

Figure 4. 1-Year Committed Equivalent Dose for Systemic Organs due to 1-Year Chronic Inhalation of Uranium-234 Type S, Type M and Type S Compounds

SC&A finds that solubility should be assigned based on the type of cancer, as recommended in the 42 CFR Part 82, which states the following:

> *…, if the solubility classification of an inhaled material can not be determined, the dose reconstruction would use the classification that results in the largest dose to the organ or tissue relevant to the cancer and that is possible given existing knowledge of the material and process.*

5.2.5 Bioassay Data – Uncertainties and Minimum Detectable Activities

The TBD (Falk 2004) shows that in the earlier times, the median MDA values for determination of Pu and Am in urine samples are about 30 and 20 times higher than the more recent values, as shown in the Tables 5.3.1.1.2-1 and 5.3.1.2.2-1 on pages 12 and 14 (Falk 2004), respectively. The sample-specific MDA may be higher than the generic ones tabulated or described with the results of the urinalyses. This is due to the fact that the recovery strongly influences the MDA and may result in a wide variation. The TBD (Falk 2004), in Attachment A on page 39, states that:

> *Depending on the process, spiked samples, samples to which a known activity of the analyte was added, were generally processed with each batch of samples. The recovery values calculated from the spiked samples were the ratios of the count rate of spiked sample to the average count rate of four to six samples deposited on the planchet or plate with minimal processing.*

On page 52 (Falk 2004), it states that:

> *Not until 1973 were some plutonium samples spiked with an internal tracer (first ^{236}Pu and, later, ^{242}Pu). All plutonium samples were spiked with an internal tracer after 1978. Experience has shown that a significant variability of recovery can exist within a batch of samples. Therefore, the recovery of a batch spike does not necessarily indicate the recovery of each sample in the batch.*

The recovery is strongly dependent on several factors related to the analysis of each sample, such as digestion of organic material of the sample, composition of the samples, reagents, and care in the preparation of the sample. Based on these factors, the specific-sample MDA may be higher than the tabulated values.

The important issue that should be addressed in this TBD (Falk 2004) is the assessment of the missed dose. Table 4 provides an example of the assessment of missed dose considering a 20-year chronic intake of ^{239}Pu, Type S, AMAD = 5 μm, during eight hours per day, 5 days per week. The missed doses for the first 20 consecutive years of exposure was estimated, based on the ½ median MDA value of urinalysis, MDA = 0.57 dpm (0.01Bq). The daily intake and total intake for the years of exposure are shown on Table 4. The values were calculated assuming that the sample was collected in the last day of the year and the result was 0.285 dpm. Table 5 shows that just intakes higher than 10^4 Bq would be detected in the earlier times of Rocky Flats. The

estimated missed equivalent doses are shown on Table 5. SC&A strongly recommends that NIOSH develop guidance for use by the dose reconstructor to assess the missed dose, especially for the insoluble compounds, since a small amount in urine may represent a significant intake and dose. The same applies for uranium; the MDA was considerably high, especially for uranium compounds Type S (UO_2 and U_3O_8).

Table 4. Estimated Intake due to 20-Years Chronic Inhalation of Plutonium-239 (Type S, AMAD 5µm) Based on the ½ Median MDA Value of Urinalysis (0.285 dpm)

Time (years)	Daily intake (Bq)	Total Intake (Bq)
1	9.72E+01	2.43E+04
2	4.85E+01	2.43E+04
3	3.24E+01	2.43E+04
4	2.45E+01	2.45E+04
5	1.99E+01	2.49E+04
6	1.69E+01	2.53E+04
7	1.46E+01	2.56E+04
8	1.31E+01	2.62E+04
9	1.19E+01	2.68E+04
10	1.09E+01	2.72E+04
11	1.02E+01	2.81E+04
12	9.45E+00	2.84E+04
13	8.91E+00	2.90E+04
14	8.46E+00	2.96E+04
15	8.04E+00	3.01E+04
16	7.68E+00	3.07E+04
17	7.38E+00	3.14E+04
18	7.08E+00	3.18E+04
19	6.77E+00	3.21E+04
20	6.58E+00	3.29E+04

Table 5. Missed Doses for the Organs due to Inhalation of Plutonium-239, Based on the ½ Median MDA Value of Urinalysis

Organs	Missed equivalent dose (Sv) x Time of exposure (years)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Adrenals	1.30E-05	3.46E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Bladder Wall	1.30E-05	3.46E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Bone Surface	5.29E-03	1.51E-02	2.83E-02	4.41E-02	6.25E-02	8.30E-02	1.04E-01	1.29E-01	1.55E-01	1.82E-01
Brain	1.30E-05	3.45E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Breasts	1.30E-05	3.46E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Esophagus	1.30E-05	3.45E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
St Wall	2.65E-05	4.82E-05	7.55E-05	1.07E-04	1.42E-04	1.81E-04	2.19E-04	2.63E-04	3.08E-04	3.53E-04
SI Wall	4.68E-05	6.89E-05	9.62E-05	1.28E-04	1.64E-04	2.03E-04	2.41E-04	2.86E-04	3.31E-04	3.77E-04
ULI Wall	2.17E-04	2.41E-04	2.71E-04	3.04E-04	3.44E-04	3.87E-04	4.28E-04	4.77E-04	5.27E-04	5.77E-04
LLI Wall	6.10E-04	6.40E-04	6.74E-04	7.13E-04	7.62E-04	8.13E-04	8.58E-04	9.21E-04	9.82E-04	1.04E-03

Table 5. Missed Doses for the Organs due to Inhalation of Plutonium-239, Based on the ½ Median MDA Value of Urinalysis

Organs	Missed equivalent dose (Sv) x Time of exposure (years)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Colon	3.87E-04	4.12E-04	4.44E-04	4.80E-04	5.23E-04	5.71E-04	6.13E-04	6.68E-04	7.22E-04	7.76E-04
Kidneys	1.37E-04	3.09E-04	4.96E-04	6.93E-04	8.96E-04	1.10E-03	1.30E-03	1.51E-03	1.73E-03	1.93E-03
Liver	8.71E-04	2.56E-03	4.89E-03	7.79E-03	1.12E-02	1.52E-02	1.94E-02	2.44E-02	2.96E-02	3.52E-02
Muscle	1.30E-05	3.46E-05	6.19E-05	9.33E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Ovaries	5.27E-05	1.53E-04	2.91E-04	4.63E-04	6.67E-04	9.02E-04	1.15E-03	1.44E-03	1.76E-03	2.09E-03
Pancreas	1.30E-05	3.45E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Red Marrow	5.37E-04	1.53E-03	2.83E-03	4.34E-03	6.05E-03	7.91E-03	9.77E-03	1.19E-02	1.40E-02	1.62E-02
ET Airways	3.56E-01	6.26E-01	8.42E-01	1.02E+00	1.17E+00	1.30E+00	1.40E+00	1.52E+00	1.62E+00	1.70E+00
Lungs	5.56E-01	6.40E-01	6.97E-01	7.45E-01	7.92E-01	8.38E-01	8.70E-01	9.16E-01	9.57E-01	9.92E-01
Skin	1.30E-05	3.45E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Spleen	1.30E-05	3.46E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Testes	5.36E-05	1.56E-04	2.96E-04	4.70E-04	6.79E-04	9.19E-04	1.17E-03	1.47E-03	1.80E-03	2.13E-03
Thymus	1.30E-05	3.45E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Thyroid	1.30E-05	3.45E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Uterus	1.30E-05	3.45E-05	6.19E-05	9.31E-05	1.28E-04	1.66E-04	2.04E-04	2.48E-04	2.93E-04	3.38E-04
Organs	**Time of exposure (years)**									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Adrenals	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Bladder Wall	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Bone Surface	2.13E-01	2.41E-01	2.74E-01	3.07E-01	3.42E-01	3.78E-01	4.15E-01	4.53E-01	4.89E-01	5.33E-01
Brain	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Breasts	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Esophagus	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
St Wall	4.05E-04	4.51E-04	5.03E-04	5.58E-04	6.13E-04	6.70E-04	7.31E-04	7.93E-04	8.46E-04	9.15E-04
SI Wall	4.29E-04	4.75E-04	5.28E-04	5.85E-04	6.39E-04	6.97E-04	7.60E-04	8.14E-04	8.73E-04	9.41E-04
ULI Wall	6.35E-04	6.84E-04	7.42E-04	8.03E-04	8.60E-04	9.22E-04	9.89E-04	1.05E-03	1.11E-03	1.18E-03
LLI Wall	1.11E-03	1.17E-03	1.24E-03	1.31E-03	1.37E-03	1.45E-03	1.53E-03	1.60E-03	1.67E-03	1.75E-03
Colon	8.40E-04	8.92E-04	9.53E-04	1.02E-03	1.09E-03	1.15E-03	1.22E-03	1.29E-03	1.35E-03	1.43E-03
Kidneys	2.15E-03	2.34E-03	2.57E-03	2.78E-03	3.00E-03	3.22E-03	3.45E-03	3.65E-03	3.85E-03	4.09E-03
Liver	4.16E-02	4.76E-02	5.44E-02	6.18E-02	6.91E-02	7.68E-02	8.49E-02	9.35E-02	1.01E-01	1.11E-01
Muscle	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Ovaries	2.47E-03	2.84E-03	3.24E-03	3.68E-03	4.12E-03	4.58E-03	5.08E-03	5.58E-03	6.05E-03	6.65E-03
Pancreas	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Red Marrow	1.86E-02	2.08E-02	2.32E-02	2.56E-02	2.81E-02	3.06E-02	3.32E-02	3.57E-02	3.80E-02	4.09E-02
ET Airways	1.80E+00	1.86E+00	1.93E+00	2.01E+00	2.07E+00	2.14E+00	2.21E+00	2.27E+00	2.31E+00	2.38E+00
Lungs	1.04E+00	1.07E+00	1.10E+00	1.14E+00	1.17E+00	1.21E+00	1.24E+00	1.27E+00	1.29E+00	1.33E+00
Skin	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Spleen	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Testes	2.52E-03	2.88E-03	3.30E-03	3.75E-03	4.20E-03	4.67E-03	5.18E-03	5.69E-03	6.16E-03	6.78E-03
Thymus	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Thyroid	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04
Uterus	3.89E-04	4.35E-04	4.86E-04	5.41E-04	5.96E-04	6.52E-04	7.12E-04	7.72E-04	8.26E-04	8.95E-04

The TBD (Falk 2004, pg. 16) states that gross alpha urinalysis was used for workers who were potentially exposed to uranium, plutonium, and other alpha emitters in the same monitoring period:

> *Gross alpha measurement is a non-specific analysis used for workers who were potentially exposed to both uranium and plutonium in the same monitoring period. Workers who were potentially exposed to other alpha-emitting radionuclides, such as neptunium and curium, may also have been monitored for gross alpha. Urinalysis methods are discussed in Attachment 5A. The gross alpha method was discontinued in the early 1970s, likely 1973. The results are reported as dpm/24-hr sample of either enriched uranium (the default analyte through 1963) or plutonium (after 1963). Interferences are likely, because the methods were non-specific. Isotopes are all alpha-emitting isotopes of the analyte.*

Since the workers were exposed to other alpha emitters, the TBD should provide some guidance to evaluate the internal dose. There is no bioassay data or air concentration data to allow the dose reconstruction for neptunium, curium and thorium. NIOSH should provide a claimant-favorable guidance document.

5.2.6 Lung Count Data

5.2.6.1 Americium and Plutonium

The TBD (Falk 2004, pg. 18) states that there are two sources of interferences to consider:

> *The first is the 63-keV gamma doublet of ^{234}Th from depleted uranium operations being mistaken for ^{241}Am for lung counts with the NaI or phoswich detector systems. This interference was most troublesome for workers with residual lung depositions of plutonium and americium who subsequently worked in depleted uranium operations. The second interference is the contribution of count from ^{241}Am not in the lungs, for example, contributions from contamination on the skin, from material being cleared from the upper respiratory system, or from ingested material. A positive detection of ^{241}Am did not necessarily indicate an intake of the plutonium/americium mixture, especially for a lung count in response to an incident.*

For the second interference, the skin contamination contribution may be true for accidents or incidents, but not for the material being cleared from the upper respiratory system or from ingested material, since the transit time in the upper compartments of the human alimentary tract is fast. The reference values, for an adult male, of transit time for the luminal contents in the oral cavity is 15 seconds, esophagus is 8 seconds and stomach is 1.5 hr. The contribution of the upper region of the gastrointestinal tract in the lung count should not be considered. If this assumption was true, it was indicative that an inhalation intake occurred indeed. This statement is not correct.

5.2.6.2 Uncertainties

The TBD shows some inconsistencies regarding the assumption of the date of intake to assess the dose from lung count data. In the TBD (Falk 2004, pg. 20), it is stated that:

> *The assumption of the intake date is not straightforward and should balance maximizing the plutonium lung deposition (intake date is close to the date of the lung count) and maximizing the accrued lung dose (intake date is far from the date of the lung count). In addition, the choice of intake date for the lung count data should be coordinated with that for the associated urine data.*

According to the TBD, the in-vivo lung count monitoring was performed for workers who were exposed, or had the potential to be exposed to airborne plutonium. It is not clear if it was applied as part of the routine monitoring program or just as special monitoring applied in incidental intakes. A better guidance document should be established, especially to clarify how to define the date of intake in order to have a claimant-favorable approach. The lung count data associated with urine data is not the best way to evaluate the occurrence of an acute intake. In general, the compounds involved in the incidental intakes were high-fired plutonium or uranium, which are both very insoluble compounds. Unless the intake was very high, it would be very difficult to detect incidental intakes using urine data, since the activity expected to be found in urine excretion is very low, in the order of 10^{-6} (Bq/Bq intake), while the activity expected to be found in feces excretion is in the order of 10^{-2} (Bq/Bq intake), in the first days after intake, as shown on Table 6.

The TBD (Falk 2004, pg. 18) states the following:

> *Reporting levels are not easily defined, because quantification was preceded by verification counts and professional judgments. Before 1974, the practice was not to quantify a positive detection of ^{241}Am unless the deposition could be associated with a known incident with a known ppm ^{241}Am. Affected workers were classified as positive unknowns or some variation. Starting in 1974, the practice was changed to quantify the plutonium depositions for positive unknowns by assuming a default value of 1,000 ppm ^{241}Am on the date of the most likely intake or on the date of the first positive lung count. The ppm ^{241}Am was then calculated for the date of the lung count to account for the ingrowth of ^{241}Am from the nuclear transformation of ^{241}Pu and the radioactive decay of the initial ^{241}Am.*

There is no clear instruction on how the dose reconstructors should choose the appropriate value of ppm ^{241}Am, and also there is no clear explanation of the basis to choose 1,000 ppm as the default value for ppm ^{241}Am.

Table 6. Intake Fraction in Urine and Feces after the Inhalation of 1 Bq of Plutonium-239 Type S Compound (Bq/Bq intake) for 1 µm AMAD

Days after intake	Inhalation ^{239}Pu – Type S -1 µm	
	24-hr Urine (Bq/Bq intake)	24-hr Feces (Bq/Bq intake)
1	2.03E-06	6.10E-02
2	1.23E-06	8.85E-02
3	8.04E-07	4.65E-02
4	6.09E-07	2.01E-02
5	5.02E-07	8.45E-03
6	4.35E-07	3.83E-03
7	3.90E-07	2.05E-03
8	3.59E-07	1.37E-03
9	3.38E-07	1.11E-03
10	3.23E-07	1.00E-03
12	3.05E-07	9.14E-04
14	2.95E-07	8.68E-04
16	2.91E-07	8.30E-04
18	2.88E-07	7.95E-04
20	2.87E-07	7.61E-04
30	2.84E-07	6.14E-04
40	2.84E-07	4.99E-04
50	2.83E-07	4.09E-04
60	2.83E-07	3.37E-04
70	2.83E-07	2.81E-04
80	2.84E-07	2.36E-04
90	2.84E-07	2.00E-04
100	2.85E-07	1.71E-04

Thorium/Depleted Uranium:

The TBD states that one of the methodologies used to assess the internal exposure to depleted uranium was to estimate the ^{238}U activity based on the ^{234}Th measurement in lung, assuming equilibrium. In the TBD (Falk 2004, pg. 21), the following is mentioned:

> *The major uncertainty is the assumption of equilibrium of the ^{234}Th with the ^{238}U before 1990, when depleted uranium was still being processed. Part of the process was to remove decay chain radionuclides, especially thorium, by heating the uranium ingot to drive the smaller atoms of thorium to the surface or top of the ingot, which was then cut off. The result was depleted uranium metal with a deficiency of ^{234}Th for several weeks plus scrap depleted uranium with an excess of ^{234}Th (supe-requilibrium). Super-equilibrium is claimant favorable. The effect of a deficiency of ^{234}Th has not been assessed.*

The assumption of full equilibrium is not necessarily claimant favorable. If the worker is exposed to depleted uranium metal with a deficiency of ^{234}Th, the assumption of equilibrium will underestimate the ^{238}U activity in the lung of the workers exposed to depleted uranium metal with a deficiency of ^{234}Th.

The TBD (Falk 2004) states, on page 21, that the MDA for ^{238}U has not been determined rigorously, and it is based on the ^{241}Am data:

> *The MDA for ^{238}U has not been determined rigorously. However, the ^{238}U worker-specific MDA can reasonably be expected to be a multiple of the ^{241}Am worker-specific MDA because the detected photons (63 keV and 59.5 keV) are very close in energy. As described in Section 5.3.2.2.1 for using the calibration factor for ^{241}Am to determine the ^{238}U activity, the ^{238}U worker-specific MDA can be obtained by multiplying the ^{241}Am worker-specific MDA by 9.4. That result is divided by 0.89 to obtain the worker-specific MDA for depleted uranium. (As noted in Section 5.3.2.1.2 for americium and plutonium, MDA values are reported on report forms 1995 and later, but are not worker-specific. The dose reconstructor should disregard these MDA values.)*

The determination of the MDA is very important since it may be high; the low measurable activity value may represent a significant dose. NIOSH should provide MDA values for ^{238}U and ^{235}U.

The TBD (Falk 2004) does not consider the ^{235}U measurements in lungs to evaluate the enriched uranium exposure for the period before 1995, as stated on page 21.

5.2.7 Other Bioassay Data

5.2.7.1 Wound Count Data

According to the TBD, wound contamination was very likely to happen. Any wound that occurred in a work area involving plutonium was monitored for plutonium contamination, especially after the advent of the wound counter in 1957. The TBD (Falk 2004) states on page 22 that:

> *Wound count information is largely irrelevant to dose reconstruction. The relevant items are the urinalysis data, the identification of the mode and date of intake, and whether there was residual plutonium at the wound site. If there was residual plutonium at the wound site, the dose reconstructor should consider an acute injection into the blood stream plus a possible long-term chronic injection. The profile of the urine data following the date of the wound provides guidance on the proportion of the acute and chronic components. If there was no detected residual plutonium at the wound site, there would have been an acute injection into the blood stream.*

Since no appropriate wound model is available currently, the approach is claimant favorable for most types of cancer. This approach is not appropriate for some special cases like lymph node and skin cancers. For lymph nodes, a special approach should be proposed. It is known that in cases of wound contamination with ^{241}Am, the largest fraction of the Am activity measured in the body is associated with tissues near the puncture wound. Popplewell and Ham (1989) have

described a case of wound contamination 18 years after a puncture wound to the left hand, which had resulted in the deposition of a splinter of plutonium metal. Eighty percent of the measured ^{241}Am activity (a product of ^{241}Pu decay) was associated with the left arm axillary lymph nodes and left hand, 12% was measured in the skeleton, and 1% was measured in the liver. Guilmette and Durbin (2003) have proposed a classification of wound retention for radionuclides. The retention patterns, which are related to the chemical properties of the radionuclides, were grouped empirically into four categories, as shown in Figure 5. The criterion for grouping the radionuclides was based on the fraction of injected activity remaining at the wound site 1 d after deposition, and the rate(s) at which the retained fraction subsequently cleared from the site. The authors have classified Am^{3+} and Pu^{4+} (at doses < 0.2μg) as strongly retained elements. The characteristic of this group is such that these two radioisotopes are slowly cleared from the wound site. Plutonium is classified as an avidly retained element. Besides the chemical properties of the radionuclides, an important variable affecting wound-site retention is the deposited mass. Guilmette and Durbin (2003) have reported an example, at about 1 week after injection, 34% of ^{239}Pu with an initial mass of 11 ng was retained. This can be compared to 51%–66% retention for masses from 0.10 to 1.0 μg, and 96% for a 16 μg mass. At >25 μg, 90% retention was observed at the end of 1 month after injection, and 72% at 2 months. Thus, the pattern of increasing retention with increased injected Pu mass is consistent with the attainment of higher mass concentrations within the wound site. The wound model for strongly and avidly retained elements, like Am and Pu, is not available at the moment, but a draft of the model for wound-site retention of soluble radionuclides has been proposed by Guilmette and Durbin (2003). The wound biokinetic model consists of five compartments comprising the wound site, and **blood** and **lymph node** compartments, which receive radionuclides that are being cleared from the wound site. The compartmental design is based on the physical and chemical properties of the deposited radioactive material, which can be soluble, a mixture of soluble and colloidal material, particulate or fragment, as shown in the Figure 6. All the reported facts show that a claimant-favorable approach needs to be developed for lymph node cancers.

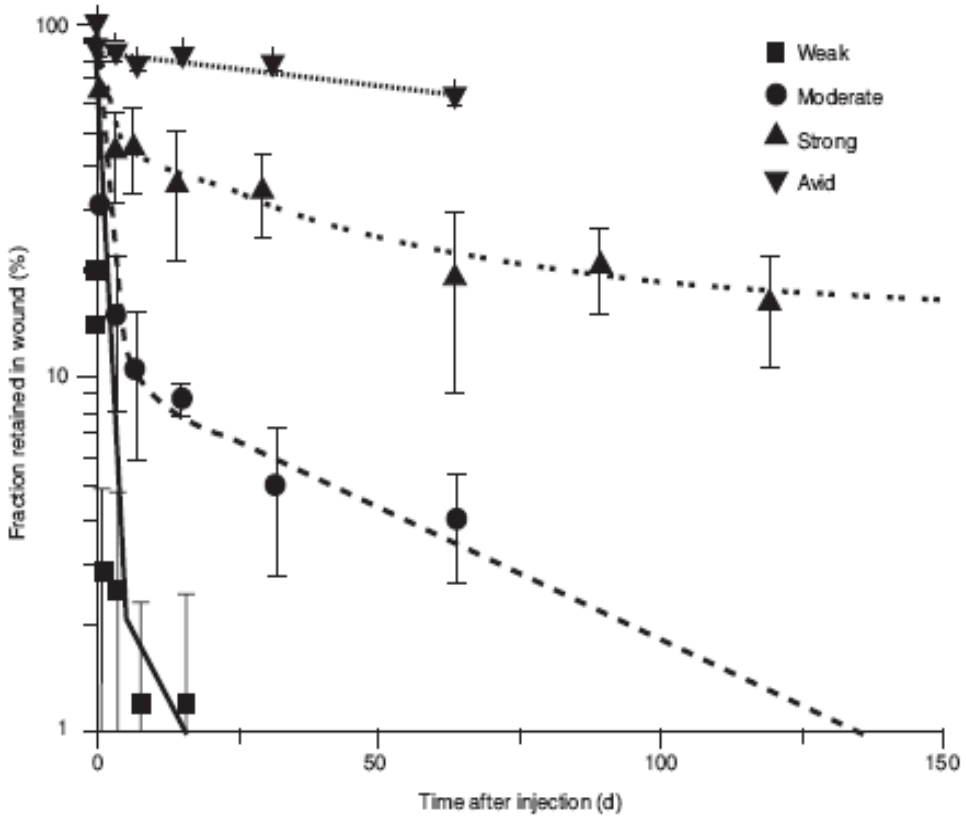

Figure 5. Default Retention Groups (weak, moderate, strong and avid) for Radionuclides Deposited in Intramuscular Wound Sites
(Guilmette and Durbin 2003)

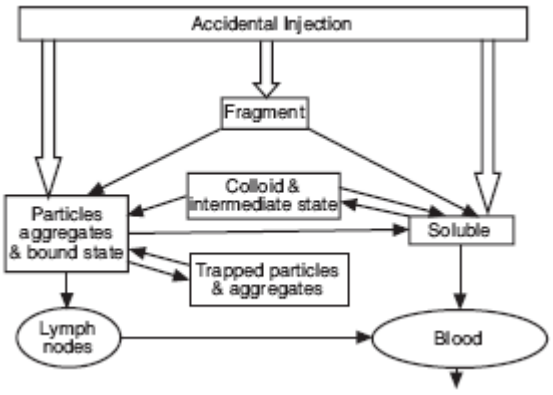

Figure 6. Schematic Compartmental Representation of the Draft NCRP Wound Biokinetic Model
(Guilmette and Durbin 2003)

5.2.7.2 Fecal Samples

Fecal samples were taken when incidents occurred. The fecal data are very important to evaluate any incidental intake of insoluble compounds. As shown in Table 6, it is easier to detect incidental intakes using fecal data rather than urine data. The activity expected to be found in urine excretion is very low; on the order of 10^{-6} (Bq/Bq intake). In contrast, the activity expected to be found in feces excretion is on the order of 10^{-2} (Bq/Bq intake) in the first days after intake.

SC&A suggests that the retrieval and review of fecal measurements (if that data are available in the individual claimant's personal file or in RFP bioassay records) be emphasized for dose reconstruction from episodic exposures.

5.2.8 Co-worker Dose Assignment

ORAUT-TKBS-0011-5 (Falk 2004) does not provide guidance for reconstructing the dose for unmonitored workers. The TBD is incomplete in this regard.

5.3 ISSUE 3: POTENTIAL FOR INGESTION EXPOSURE PATHWAY

The ingestion pathway for internal exposure has not been considered in the TBD. It is well known that although inhalation is, in general, the main pathway of intake, ingestion may occur. SC&A recommends that ingestion of plutonium, americium, and uranium compounds be included as a part of the internal dose for the GI tract.

5.3.1 Plutonium Example

The amount of plutonium that enters through ingestion is more important in terms of bioassay results and doses per Bq excreted than through inhalation. For example, if a worker's exposure had lasted 1 year, the 1-year committed equivalent doses to the different organs, per Bq ^{239}Pu excreted in a 24-hr working day urine sample at the end of the working year, is illustrated in Table 7.

As can be seen from Table 7, doses coming from the ^{239}Pu ingestion pathway should not be ignored, except for the organs related to the respiratory tract. For all others, the doses due to ingestion are higher than the ones due to inhalation. Figures 7 and 8 graphically represent the information provided in Table 7.

Table 7. 1-Year Plutonium-239 Committed Equivalent Doses per Bq Plutonium-239 Present in 24-Hour Working Day Urine Sample, Collected at the End of 1-Year Exposure

	Inhalation Type M	Inhalation Type S	Ingestion f1=0.0005	Ingestion f1=0.0001	Ingestion f1=0.00001
Organs	**Sv/Bq excreted**	**Sv/Bq excreted**	**Sv/Bq excreted**	**Sv/Bq excreted**	**Sv/Bq excreted**
Adrenals	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Bladder Wall	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.19E-03
Bone Surface	1.48E+00	1.13E+00	1.73E+00	1.73E+00	1.73E+00
Brain	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Breasts	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Esophagus	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
St Wall	3.65E-03	5.72E-03	2.03E-02	8.49E-02	8.12E-01
SI Wall	3.74E-03	1.01E-02	4.45E-02	2.06E-01	2.02E+00
ULI Wall	4.55E-03	4.73E-02	2.48E-01	1.23E+00	1.22E+01
LLI Wall	6.42E-03	1.33E-01	7.18E-01	3.56E+00	3.56E+01
Colon	5.33E-03	8.43E-02	4.50E-01	2.23E+00	2.23E+01
Kidneys	3.72E-02	2.95E-02	4.24E-02	4.24E-02	4.24E-02
Liver	2.44E-01	1.86E-01	2.86E-01	2.86E-01	2.86E-01
Muscle	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.19E-03
Ovaries	1.47E-02	1.12E-02	1.72E-02	1.73E-02	1.79E-02
Pancreas	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Red Marrow	1.50E-01	1.14E-01	1.76E-01	1.76E-01	1.76E-01
ET Airways	9.96E-01	7.65E+01	4.17E-03	4.17E-03	4.17E-03
Lungs	2.10E+00	1.21E+02	4.17E-03	4.17E-03	4.17E-03
Skin	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Spleen	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Testes	1.49E-02	1.14E-02	1.76E-02	1.76E-02	1.76E-02
Thymus	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Thyroid	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Uterus	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.22E-03

Years of Exposure to ^{239}Pu: 1 year

Collection of 24-hr working day urine sample: last month, of the 1st year Equivalent Doses calculated for the 1st year after the beginning of work

Excretion of ^{239}Pu in urine entirely due to inhalation exposure of Type M material (M) – 5µm AMAD

Excretion of ^{239}Pu in urine entirely due to inhalation exposure of Type S material (S) – 5µm AMAD

Excretion of ^{239}Pu in urine entirely due to ingestion exposure ($f1 = 5 \times 10^{-4}$)

Excretion of ^{239}Pu in urine entirely due to ingestion exposure ($f1 = 1 \times 10^{-4}$)

Excretion of ^{239}Pu in urine entirely due to ingestion exposure ($f1 = 1 \times 10^{-5}$)

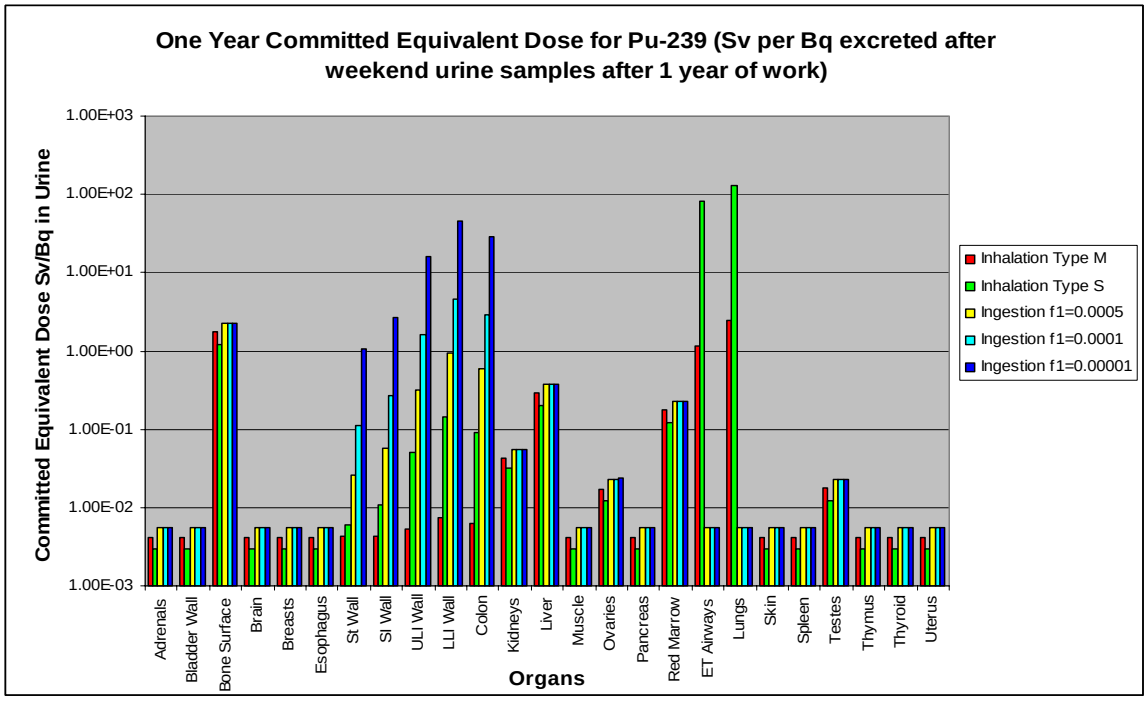

Figure 7. 1-Year Committed Equivalent Dose for Organs due to 1-Year Chronic Intake of Plutonium-239, in Sv per Bq Excreted in 24-Hour Working Day Urine Samples after 1 Year of Work

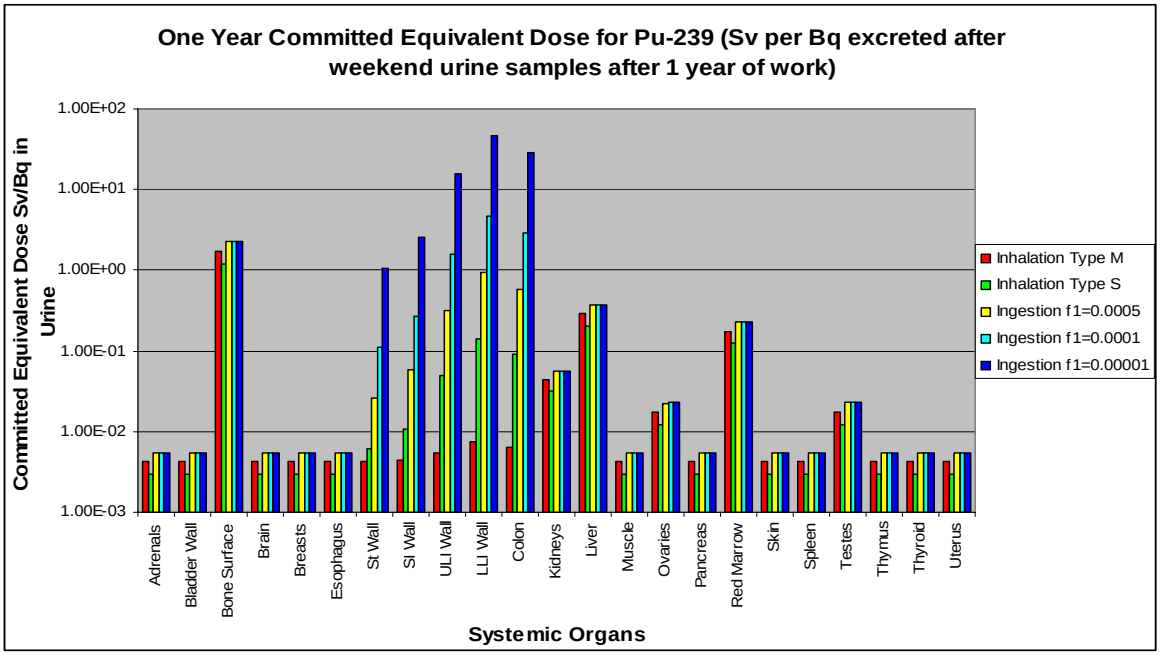

Figure 8. 1-Year Committed Equivalent Dose for Systemic Organs due to 1-Year Chronic Intake of Plutonium-239, in Sv per Bq Excreted in 24-Hour Working Day Urine Samples after 1 Year of Work

5.3.2 Americium Example

For americium, the activity that enters the body via ingestion is more important than the activity that enters the body via inhalation in terms of bioassay results and doses per Bq excreted. For example, if a worker's exposure had lasted 1 year, the 1-year committed equivalent doses to the different organs, per Bq ^{241}Am excreted in the 24-hr working day urine sample at the end of the working year, is illustrated in Table 8.

Table 8. 1-Year Americium-241 Committed Equivalent Doses per Bq Americium-241 Present in 24-Hour Working Day Urine, Collected at the End of 1-Year Exposure

Organs	Inhalation Type M	Ingestion (f1=0.0005)
Adrenals	5.18E-04	5.82E-04
Bladder Wall	5.18E-04	6.33E-04
Bone Surface	3.92E-01	4.50E-01
Brain	5.16E-04	5.75E-04
Breasts	5.16E-04	5.75E-04
Esophagus	5.18E-04	5.75E-04
St Wall	5.43E-04	6.86E-03
SI Wall	5.80E-04	1.63E-02
ULI Wall	9.02E-04	9.50E-02
LLI Wall	1.64E-03	2.77E-01
Colon	1.22E-03	1.73E-01
Kidneys	1.17E-02	1.31E-02
Liver	1.48E-01	1.69E-01
Muscle	5.16E-04	5.95E-04
Ovaries	6.50E-03	7.74E-03
Pancreas	5.18E-04	5.93E-04
Red Marrow	3.28E-02	3.75E-02
ET Airways	3.72E-01	5.75E-04
Lungs	8.72E-01	5.77E-04
Skin	5.16E-04	5.79E-04
Spleen	5.16E-04	5.86E-04
Testes	5.18E-04	5.82E-04
Thymus	5.18E-04	6.33E-04
Thyroid	3.92E-01	4.50E-01
Uterus	5.16E-04	5.75E-04

Years of Exposure to ^{241}Am: 1 year
Collection of the 24-hr working day urine sample: last month, of the 1st year
Equivalent Doses calculated for the 1st year after the beginning of work
Excretion of ^{241}Am in urine entirely due to inhalation exposure of Type M material (M) - 5µm AMAD
Excretion of ^{241}Am in urine entirely due to ingestion exposure (f1 = 5 x10^{-4})

As can be seen from Table 8, doses due to the ^{241}Am ingestion pathway should not be ignored. Figures 9 and 10 graphically represent the information provided in Table 8.

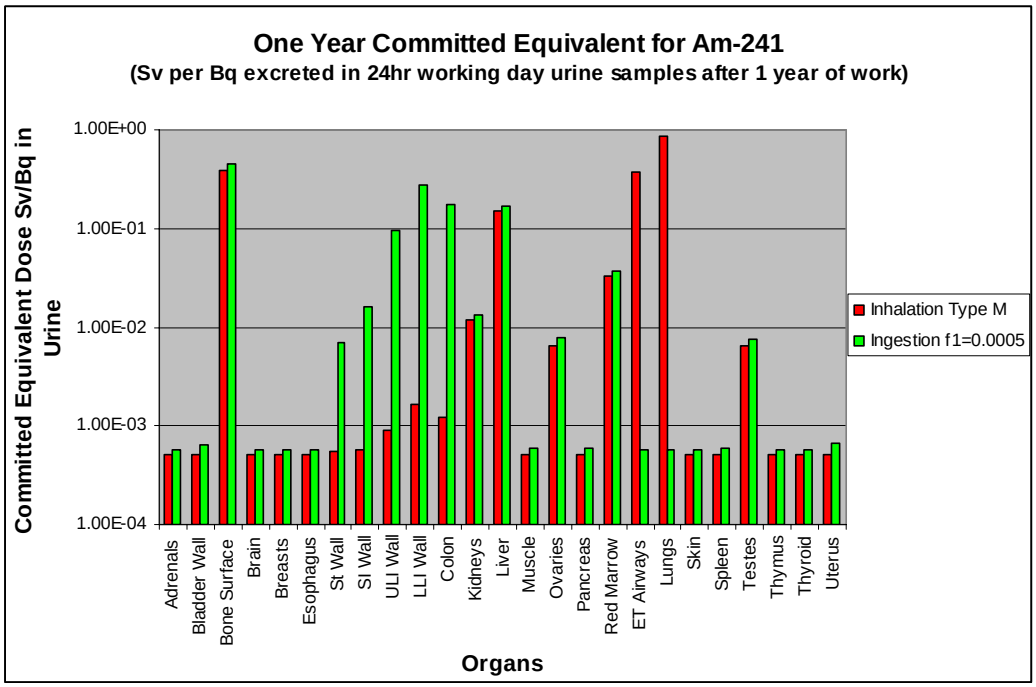

Figure 9. 1-Year Committed Equivalent Dose for Organs due to 1-Year Chronic Intake of Americium-241, in Sv per Bq Excreted in 24-Hour Working Day Urine Samples after 1 Year of Work

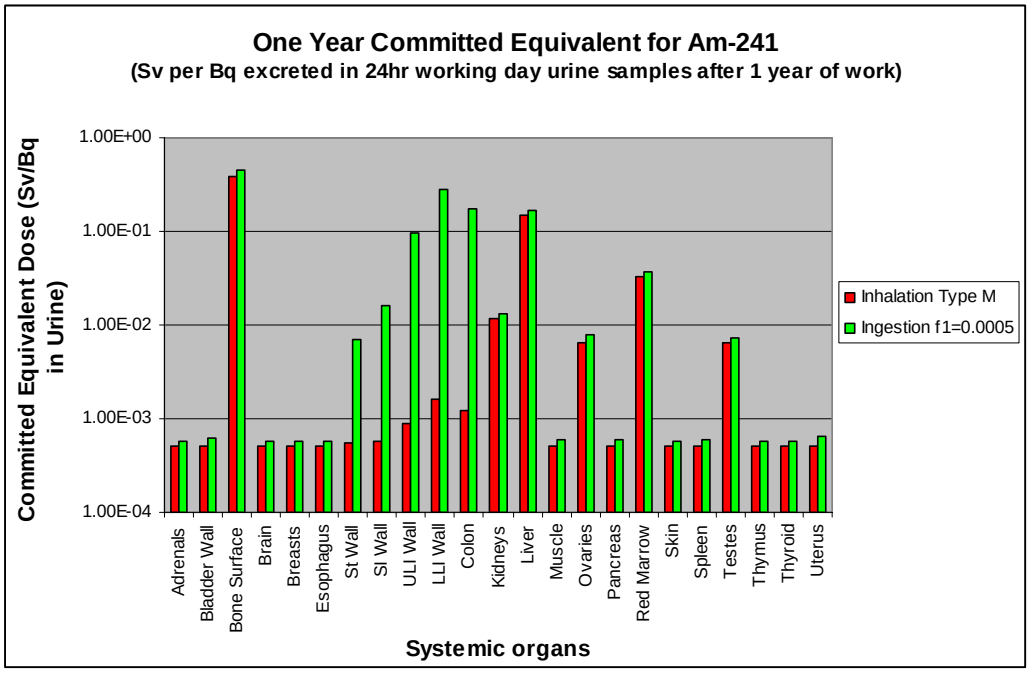

Figure 10. 1-Year Committed Equivalent Dose for Systemic Organs due to 1-Year Chronic Intake of Americium-241, in Sv per Bq Excreted in 24-Hour Working Day Urine Samples after 1 Year of Work

5.3.3 Uranium Example

The amount of uranium that enters through ingestion is important in terms of bioassay results and doses per Bq excreted. For example, if a worker's exposure had lasted 1 year, the 1-year committed equivalent doses to the different organs, per Bq ^{234}U excreted in 24-hr working day urine sample, is illustrated in Table 9.

As can be seen from Table 9, doses coming from the ^{234}U ingestion pathway should not be ignored, especially in the case of cancer to the gastrointestinal (GI) tract. Figures 11 and 12 graphically represent the information provided in Table 9.

Table 9. 1-Year Uranium-234 Committed Equivalent Doses per Bq Uranium-234 Present in 24-Hour Working Day Urine, Collected at the End of 1-Year Exposure

	Inhalation Type M Sv/Bq excreted	Inhalation Type S Sv/Bq excreted	Ingestion f1=0.02 Sv/Bq excreted	Ingestion f1=0.002 Sv/Bq excreted
Adrenals	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Bladder Wall	1.91E-05	1.71E-05	2.05E-05	2.05E-05
Bone Surface	1.99E-03	1.79E-03	2.14E-03	2.14E-03
Brain	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Breasts	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Esophagus	1.79E-05	1.61E-05	1.92E-05	1.92E-05
St Wall	2.03E-05	8.49E-05	3.59E-05	1.86E-04
SI Wall	2.36E-05	1.88E-04	5.98E-05	4.35E-04
ULI Wall	5.25E-05	1.06E-03	2.67E-04	2.54E-03
LLI Wall	1.19E-04	3.06E-03	7.44E-04	7.38E-03
Colon	8.09E-05	1.92E-03	4.71E-04	4.62E-03
Kidneys	1.89E-03	1.71E-03	1.99E-03	1.99E-03
Liver	7.98E-05	7.14E-05	8.72E-05	8.72E-05
Muscle	1.79E-05	1.62E-05	1.92E-05	1.92E-05
Ovaries	1.79E-05	1.62E-05	1.92E-05	1.95E-05
Pancreas	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Red Marrow	2.09E-04	1.87E-04	2.25E-04	2.25E-04
ET Airways	3.69E-02	1.83E+00	1.92E-05	1.92E-05
Lungs	7.00E-02	2.59E+00	1.92E-05	1.92E-05
Skin	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Spleen	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Testes	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Thymus	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Thyroid	1.79E-05	1.61E-05	1.92E-05	1.92E-05
Uterus	1.79E-05	1.61E-05	1.92E-05	1.92E-05

Years of Exposure to ^{234}U: 1 year
Collection of the 24-hr working day urine sample: last month, of the 1st year
Equivalent Doses calculated for the 1st year after the beginning of work
Excretion of ^{234} U in urine entirely due to inhalation exposure of Type M material (M)-5µm AMAD
Excretion of ^{234} U in urine entirely due to inhalation exposure of Type S material (S) - 5µm AMAD
Excretion of ^{234} U in urine entirely due to ingestion of soluble material (f1=0.02)
Excretion of ^{234} U in urine entirely due to ingestion of insoluble material (f1=0.002)

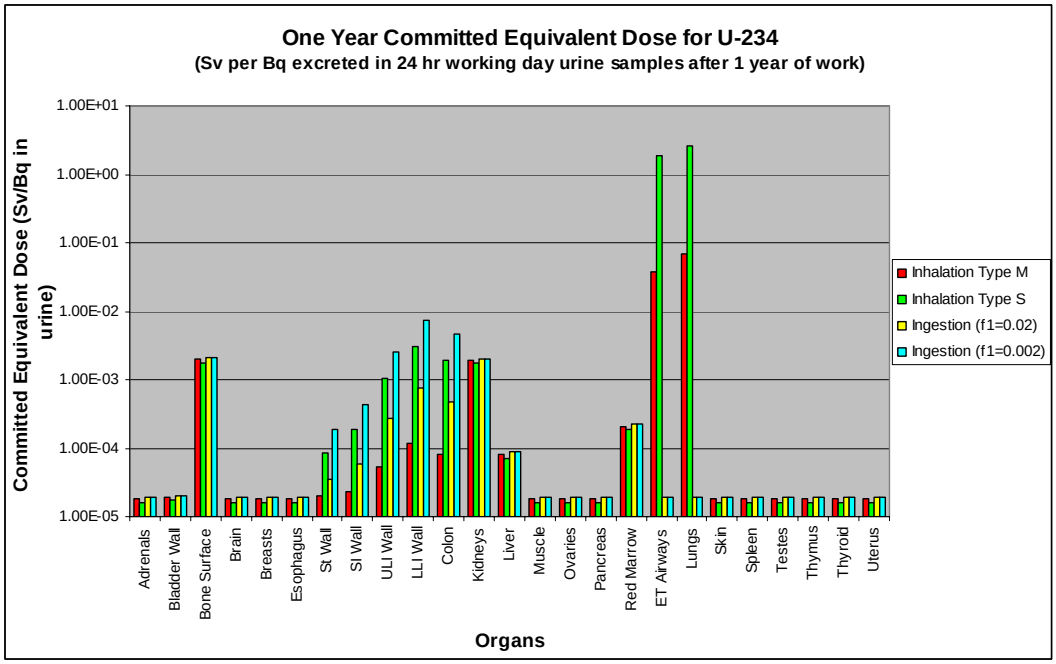

Figure 11. 1-Year Committed Equivalent Dose for Organs due to 1-Year Chronic Intake of Uranium-234, in Sv per Bq Excreted in 24-Hour Working Day Urine Samples after 1 Year of Work

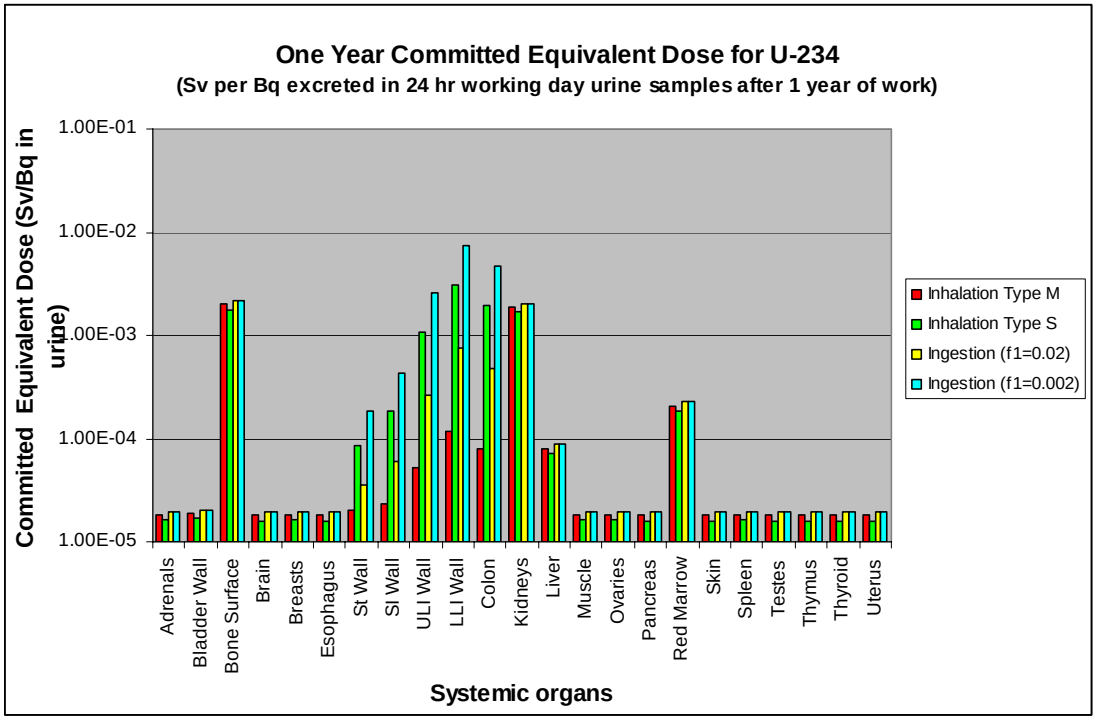

Figure 12. 1-Year Committed Equivalent Dose for Systemic Organs due to 1-Year Chronic Intake of Uranium-234, in Sv per Bq Excreted in 24-Hour Working Day Urine Samples after 1 Year of Work

It is apparent that the ingestion pathway of exposure was not given consideration in the derivation of co-worker data. As demonstrated by the preceding intake scenarios, the amount of plutonium, americium, and uranium that enters through ingestion is very important in terms of interpretation of bioassay results and conversion to organ equivalent doses per Bq excreted. The use of bioassay results to back-calculate intake and doses will produce higher doses for certain organs, if dose contributions from the ingestion pathway of exposure are considered, instead of just the inhalation pathway. SC&A finds that it is not claimant favorable to ignore the ingestion pathway for internal contamination. The ingestion of insoluble compounds should be included as a part of the internal dose, especially in cases of cancer in organs of the gastrointestinal tract.

5.4 ISSUE 4: OTHER RADIONUCLIDES

The TBD is incomplete in its review of the historic dose contribution of radioisotopes other than uranium, plutonium, and americium.

5.4.1 Inadequate Information Regarding Recycled Uranium

The TBD does not provide an adequate assessment of potential doses associated with recycled uranium, which is reflected in the following comment:

> *While TBD reviewer comments indicate that Paducah was processing U beginning in 1953, available Rocky Flats records do not indicate whether fission product or TRU contaminated U was processed at Rocky Flats.* (Flack and Meyer 2004)

Recycled uranium is so called because it is recovered from reprocessing plants after it has already been through a reactor one or more times. This creates uranium that contains radioisotopes not found in virgin uranium, i.e., only ^{238}U, ^{235}U, and ^{234}U. Recycled uranium contains all three of these radioisotopes, as well as other isotopes of uranium, notably ^{236}U, and traces of certain fission products and transuranic radionuclides.

The TBD authors (and SC&A) were unable to find records at Rocky Flats pertaining to recycled uranium. Such information appears to exist based on a review of data provided by the sites that generated this material. For instance, according to a DOE 2000 report, DOE's Idaho National Engineering Laboratory (INEEL) shipped 219 kilograms of ^{236}U recovered from previously irradiated reactor fuel in 1955 to the RFP (DOE 2000). The radiological dangers of ^{236}U can be significant as it "can result in significant gamma fields when secular equilibrium is approached." (DOE 2000, pg. iv).

Furthermore, according to the 2000 report done by INEEL, Rocky Flats shipped 5,403,000 pounds of recycled uranium in the form of billets to INEEL for the manufacture of depleted uranium armament (DOE 2000). In 1999, 60 samples were taken from equal amounts of recycled uranium sent to INEEL from Rocky Flats and Fernald, which found several contaminants, including transuranics and fission products (see Table 10).

Table 10. Radionuclide Contaminants in Depleted Uranium Shipped to INEEL from Rocky Flats and Fernald

Nuclide		pCi/g			g/g	
	maximum	minimum	Average	Maximum	Minimum	Average
Np-237	3.73	1.14	1.82	5.29E-09	1.62E-09	2.58E-09
Pu-238	2.05	0	0.272	1.20E-13	0	1.59E-14
Pu-239/240	2.66	0	0.406	4.28E-11	0	6.55E-12
Am-241	19.24	0	2.78	5.61E-12	0	8.10E-13
Tc-99	537	64	154	3.16E-08	3.78E-09	9.06E-09

In light of the following conclusion reached in a 1985 DOE review, the values in the above table may not be representative of the contaminants in recycled uranium sent to Rocky Flats over the 30-year period in which this material was processed:

> *Informal specifications in the form of "gentlemen's agreements' did evolve and have been used over time… A formal, technically sound, understood and accepted specification for maximum transuranic and fission product contaminants in uranium recycle material has probably never existed either within or between sites….* (DOE 1985)

Documentation or the lack thereof regarding the nature of these informal staff-level "gentlemen's agreements," and their changes over more than 30 years should be addressed by NIOSH. For instance it is quite possible that early staff-level agreements between sites and within the RFP were significantly less stringent than later "gentlemen's agreements."

The absence of data regarding the levels of contaminants in recycled uranium, workplace measurements for contaminants in recycled uranium, and the lack of individual dosimetry for workers processing recycling uranium needs to be addressed by NIOSH.

5.4.2 Inadequate Information Regarding Highly-Enriched Uranium Storage Vulnerabilities

In 1996, the RFP held 7.7 metric tons of Highly-Enriched Uranium (HEU) consisting mostly of metals in the form of pits, parts, samples, and scrap (DOE 1996). According to a 1996 DOE assessment:

> *In addition to the existing facility condition vulnerabilities previously identified in the Plutonium Vulnerability Assessment… the most significant Highly Enriched Uranium Environment, Safety and Health Vulnerabilities involved criticality safety weaknesses, hampered emergency egress conditions, fire protection program weaknesses, authorization basis deficiencies, and institutional weaknesses… Criticality safety vulnerabilities were identified in Buildings 707,*

> *776/777, 881 and 886.. Fissile material and fissile material storage areas were not adequately labeled or lacked any labeling of limits or mass loadings. ..Additionally of the 126 criticality safety limit infractions identified since 1993, only 40 have been closed out... Poor housekeeping, inappropriate drum storage, or improperly roped-off radiation boundaries presented life safety issues….* (DOE 1996, pg. ES-1)

The TBD needs to more completely address this aspect of the operational history of Rocky Flats.

5.4.3 Inadequate Information Regarding the Processing of Uranium-233

The TBD makes only a passing reference to the processing of ^{233}U. From 1945 to the early 1980s, a considerable amount of effort involving several sites in the Federal nuclear complex was made by the Atomic Energy Commission and its successor agencies to produce ^{233}U and to develop military and civilian applications for this fissile material. Between 1965 and the mid 1980s DOE records indicate that the RFP routinely handled kilogram quantities of ^{233}U.

From the mid-1960s to the early 1970s during peak production, hundreds of kilograms of ^{233}U were made into uranyl nitrate solutions at Hanford at a concentration of approximately 300 grams of ^{233}U per liter. Uranium-233 uranyl nitrate solutions were then sent to the Oak Ridge site, at a rate of 20 to 40 kilograms per shipment. Oak Ridge subsequently shipped ^{233}U uranyl nitrate to the RFP in Colorado, and possibly other facilities, for processing (Hanford 1968).

According to a history of ^{233}U processing at Rocky Flats:

> *Processing operations involving ^{233}U were carried out at RF starting in 1965 and ending in 1982. Activities included chemical processing of various uranium compounds, conversion to metal, casting, metal fabrication and waste and residue disposal…* (RFP 1999, pg. 7)

> *^{233}U processing began in Building 771 where the uranyl nitrate solution was transferred to receiving tanks. Fluoride precipitation was then used to remove the 'hot' (highly "radioactive) daughter products (primarily Th-228) and the uranium was converted to peroxide. The peroxide was shipped to Building 881 where it was calcined to an oxide, which in turn was converted to uranium tetrafluoride (UF_4), and reduced to 23% metal using a thermal reaction. The metal was then cast into feed ingots, which were in turn recast into pieces from which the final parts were fabricated. Casting and machining operations took place in Building 881, while other fabrication steps were handled in Building 883. Final component assembly and inspection occurred in Building 777. All wastes and residues were collected, treated, packaged, and shipped to various locations off-site. Uranium oxides and green salt residues were converted to uranyl nitrate solution in Building 771 and returned to OR in the original shipping casks. Some casting skulls and machining chips were burned to oxide in Building 881 and*

> *subsequently converted to a nitrate solution along with the other oxides.* (RFP 1999, pg. 5)

Of particular concern is exposure to ^{232}U contaminants. Uranium-232 is co-produced with ^{233}U by irradiation of thorium and is considerably more radioactive than ^{238}U. This is due to high-energy gamma radiation emitted in the decay scheme of ^{232}U daughter products (^{228}thorium, ^{244}radium, and ^{228}thalium). Typically, ^{233}U currently stored at DOE sites contains 5 to 50 parts per million of ^{232}U (DOE 1996). Although ^{232}U concentrations are small, its gamma radiation constitutes a potentially significant external hazard for ^{233}U handling and processing. For instance, the year following the initiation of large-scale production of ^{233}U at Hanford, the RFP processed ^{233}U in uranyl nitrate and then fabricated ^{233}U metal components in kilogram quantities (DOE 2000a). According to a DOE contractor assessment done in 2000:

> *The first processing operations at the Rocky Flats Plant involving uranium-233 (U-233) occurred in 1965. …The material also contained approximately 50 parts per million (ppm) contaminant …A 50 ppm U-232 content equates to approximately 13R/hr at 1 foot and with extrapolation, a 5 to 10 ppm content would emit approximately 5R/hr [at 1 foot].* (DOE 2000a)

The TBD needs to address the potential exposure history and dose estimation for ^{233}U in RFP operations.

5.5 ISSUE 5: EXTERNAL DOSE CALCULATION AND METHODOLOGIES

Some areas of potential exposures that were not addressed, or were not sufficiently covered, in the RFP TBD, ORAU-TKBS-0011-6 (Langsted 2004) dated January 10, 2004, Rev. 00 (hereafter referred to as the TBD) could lead to underestimated, or missed, external doses to RFP workers in the dose reconstruction (DR) process. According to ORAUT/NIOSH some of these areas will be addressed further in a revised external dosimetry TBD and new OTIBs to be issued in the near future. However, these issues and areas of concern are included in this review for the purpose of completeness.

5.5.1 Areas of Concern in Records and Dose Reconstruction

It was observed that there were a number of areas of concerns when evaluating the information for DR provided in the TBD and OTIB. There appeared to be inconsistencies or gaps in some of the information. Some of these areas of concern are as follows:

5.5.1.1 Dose Reconstruction from Badge Readings versus Historical Documents

The TBD, page 11, and ORAU-OTIB-0027 (Smith 2005), pages 5–7, provide information on skin and penetrating radiation doses. However, this information is not necessarily consistent with the information provided in some of the historical records at the RFP (Owen 1964 and Putzier 1982). In 1964, Owens defines the RFP doses as follows:

Skin dose *= hard gamma dose + soft gamma dose + x-ray dose + beta dose + neutron dose*

Penetrating dose *= hard gamma dose + soft gamma dose + 1/3(x-ray dose) + neutron dose*

Hand dose *= (hard gamma dose + soft gamma dose + x-ray dose) x 2.5 or 5.0 depending on area and chemical form.* (Owen 1964)

ORAU-OTIB-0027 (Smith 2005), pages 5–7, uses the open window (OW), cadmium filter (CD), and brass filter (BR) to define skin and penetrating doses, without relating it to the procedures in place at the time the doses were recorded. In addition, page 10 of the TBD states that further research is necessary to determine which dosimetry method was used to record a worker's dose.

5.5.1.2 Incomplete or Inconsistent Dose Information

Some areas in the TBD where information, which would be useful in DR, seems to be lacking or appears inconsistent are as follows.

- Page 11, Section 6.3.1, states that during the early period (around 1952–1975), the deep gamma dose and the neutron dose were recorded as the total penetrating dose, and not recorded as separate doses in the worker's file. Ruttenber (2003) provides some more details on the subject, stating that only the total penetrating dose (gamma + neutron) was recorded for the time periods of 1952–1958 and 1964–1975, and that for 1976, a large number of neutron and gamma doses were erroneously recorded, apparently due to mistakes made in updating the computer data system. Additionally, Ruttenber (2003, pg. 25) states that there were many problems with the 1970 neutron dosimetry and related records. These items could lead to problems when attempting to separate gamma and neutron doses and performing DR.

- Page 14 of the TBD, Section 6.3.2.2.1, states that from July 1984 to October 1984, some neutron dose was recorded, but the gamma and total dose were zero. This could lead to DR problems if not resolved.

- Page 14 of the TBD, Section 6.3.2.2.2, describes a possible manual correction needed for 1984–1986, where the recorded deep dose was much greater than the neutron plus gamma dose, but ends with the statement that dose components were not provided in the letter and, therefore, were not made. It is unclear what this really means and how it will affect DR.

There was a variety of dosimetry methods, dose notations, and record systems at the RFP throughout its years of operations. In view of this, it is of concern that the information used in dose reconstruction correctly reflects the dose received by the worker. It is not apparent from reading the TBD that the changes that took place during the years in dose determination/recording are adequately tracked and accounted for.

5.5.2 Job Exposure Matrix Study

In Section 6.3.4.3, page 18 of the TBD, it states that DOE funded the Job Exposure Matrix study that was conducted by the University of Colorado-Health Services Center. Based on discussions with NIOSH and ORAU staff, NIOSH has attempted to gain access to this study without success. NIOSH agrees that this document is important to characterizing worker exposures at RFP and will be especially critical to external dose reconstruction, where co-worker assignments will benefit from job-specific exposure data.

5.5.3 Below 10 mrem Dose Reported as Zero

Page 20, Section 6.4.4, states that any dose below 10 mrem was reported as zero dose at the RFP starting in 1993. The DR should take this into account when assigning dose and base it on the appropriate LOD at the time.

5.5.4 Badges Only Calibrated for One Work Location

Individuals sometimes worked on temporary or overtime assignments in other facilities (or at other jobs) in addition to the assignment for which their badge was calibrated (as stated on page 19, Section 6.4.3 of the TBD). The dosimetry department could not detect this change in radiation environment. This may have occurred often enough to create a significant underestimate of dose to workers, because of the change in the dosimetry response. However the TBD (Langsted 2004, Section 6.6.3.4, pg. 27) assumes that each worker stayed in the work area for which the badge was calibrated, and therefore no corrections for photon energy were needed. This could lead to the underestimate of the worker's dose if this was a common practice.

5.5.5 Exposure Geometry

In the dose reconstruction process, the assignment of isotropic (ISO) and rotational (ROT) instead of AP geometry may not reflect the true radiation dose to some workers; such as 100% rotational for site support personnel or 50% for support personnel as given in the TBD (Langsted 2004, Table 6-5, pg. 23). This may not always be claimant favorable in some cases. Further investigation should be done concerning this issue.

In addition, security guards could have received greater exposures than were recorded, because they were responsible for transporting material throughout the site using trucks with cabs and trailers. The radioactive material on the trailers generated a great deal of external radiation exposure at times. Eventually, they had to increase the spacing between the cab and the trailer by 6 feet to reduce exposure. The security guards were receiving posterior-anterior exposures but wore their dosimeters on their chest, which were calibrated for A-P exposure. Calculations show that the worker's dosimeter worn on the chest would have received approximately 50% of the dose incident on the worker's back for photons in the 60 keV to 1 MeV range. This would lead to a two-fold underestimate of dose.

5.5.6 Angular Dependence for Beta/Gamma, NTA Film, and TLDs

In this TBD, and other TBDs as well, the issue of angular dependence for different types of radiation and different dosimetry systems used through the years is not sufficiently addressed. For example, the TBD (Langsted 2004, Section 6.6.4.1, pg. 27) mentions photon angular dependence, but seems somewhat vague about the issue. On page 27 it states that the dosimetry response increases with angle, but on page 28 it states that the Panasonic system response decreased as the angle increased. Page 40, Section 6.8.4.1, addresses beta angular dependence and states that the assembled badge displays severe angular dependence to beta exposure and that for TLD badges, it might record only 36% to 59% of the true beta dose at $\pm$30 degrees (this could result in underestimating the true beta dose, especially to the extremities where the worker's normal movements would not tend to average it out). The Y-12 ORAUT-TKBS-0014-6 (Kerr 2003, pg. 18) states that the recorded dose of record is likely too low at non A-P angles for beta/photon doses. For more uniformity in DR and consistency between sites, NIOSH needs to arrive at a policy to address angular dependence of the different dosimetry systems used at the AEC facilities/labs including (1) NTA film, (2) beta/photon film, (3) TLND neutron, and (4) TLD beta/gamma badges; with modifications for specific locations and time periods. At least some general guidelines for consistency would be helpful.

5.5.7 Use of Dosimeters under Lead Aprons

In some buildings and jobs, workers wore their dosimeters outside their protective lead aprons where the dosimeter would register the exposure dose, but in some buildings/jobs workers wore their dosimeters under their protective lead aprons where the dosimeters would not register the total dose to the head, neck, and to the lower parts of the body (see Attachment 2). This could create a situation where large exposures could accumulate over time without showing up on the dosimetry records. This is especially true for those workers who worked with relatively low-energy photon emitters (such as ^{241}Am) around gloveboxes or assembly lines for extended periods. Using a lead thickness of 0.5mm (the standard lead-apron thickness available), calculations show that only approximately 10% of the 60 keV photons would be transmitted; 27% of 100 keV photons would be transmitted; 70% of 200 keV photons would be transmitted, and 95% of 500 keV photons would be transmitted. Therefore, those working with materials that contained radioisotopes that emitted photons with energies under 100-200 keV and wore their dosimeters under their lead aprons could be at risk of having under-recorded doses to the head, neck, and lower body. A series of studies at the Pantex Plant by Passmore (1995) confirms this in that he showed that single-sided 0.5 mm-lead aprons decreased the photon dose in areas of stored weapon by 57%, but did not significantly impact the neutron dose readings. Therefore, he recommended that the dosimeter be worn outside the lead apron for correct photon dose monitoring.

During dose reconstruction, these individuals could be identified by their job functions and the fact that their dose records should show relatively low skin/shallow dose (because the low-energy photons were absorbed by the lead apron) compared to a relatively larger penetrating photon and neutron dose, because the lead apron would have little affect on the penetrating dose.

This area should be investigated to determine the extent of the possible underreported/missed dose, because of the practice of wearing the dosimeter under the lead apron.

5.5.8 Location of Dosimeters When Working Around Gloveports/boxes

Some tasks required multiple ports of the gloveboxes to be opened (unshielded) during a shift. Workers were generally instructed to wear their dosimeters at chest height. This combination created situations where a worker might receive doses to the head or lower parts of the body that would not be registered by the dosimeter on the chest. For example, if the worker opened the lower gloveport while sitting down, and then stood up and started working in an upper gloveport, the worker would receive unrecorded doses to the lower body. Also, a worker might lean over a glovebox and receive doses to the head and face that would not necessarily be registered by a badge worn on the chest. This issue was not identified or addressed in the TBD and should be investigated because of the possibility of unmonitored doses to gloveport/box workers, especially over extended periods.

5.5.9 Elevated Ambient Levels of External Radiation Affect Net Dose

Elevated ambient levels of external radiation (EALER) may have occurred at the RFP. This could have occurred at locations where radioactive materials were handled, transported, piped, stored, or dispersed into the environment. If the control dosimeter(s) were stored near these locations, this would have created additional exposures to the control dosimeter(s). In these cases, the standard practice of subtracting the reading of the control dosimeter from the worker's dosimeter reading to arrive at a net exposure for the worker would result in value less than the actual worker's exposure being recorded, because the worker was exposed to this elevated radiation field also. This missed dose would not be accounted for in the environmental assessment procedure. Therefore, there is a need to account for EALER as occupational exposures in situations where the control dosimeters were stored in EALER locations.

5.6 ISSUE 6: NEUTRON DOSIMETRY AND EXPOSURES

Neutron dosimetry has historically been more difficult to perform than gamma/beta dosimetry. While the radiation fields at the RFP were perhaps not as complex as at some of the other facilities, they still present a challenge to dose reconstruction. One of the main concerns is the fact that neutron fields were not considered to be a problem in the early days; this could have led to neutron exposures that were not monitored, and resulted in workers being badged after the fact. This brings up the following areas of concern.

5.6.1 The Likelihood of Unmeasured Neutron Exposures

Rocky Flats was a "first of a kind" facility relative to large-scale processing and fabrication of fissile materials for nuclear weapons. For this reason, quantifiable knowledge of neutron hazards in the workplace at Rocky Flats was acquired, on an iterative basis concurrent with large-scale production, and from the experience and experimental evidence from other sites. In addition to the inherent limitations of personnel monitoring for neutrons prior to the development of more

optimal measuring technologies in the early 1970s, it is not at all clear that employees in process areas, particularly those whose jobs required moving in and around different processing areas (i.e., maintenance workers, pipefitters, sheetmetal workers, and electricians) were individually monitored for neutron exposure. The lack of individual monitoring for neutrons is inferred by the authors of a report summarizing data relative to the Former Radiation Worker Medical Surveillance Program at Rocky Flats in 2001:

> *Significant neutron radiation exposure was possible from alpha/neutron reactions with light elements, especially from plutonium tetrafluoride compound.. Neutron exposure was possible from spontaneous fission of ^{240}Pu during handling of large quantities of plutonium as metal, of ^{244}Cm, or of plutonium enriched in ^{240}Pu for special projects conducted at the site.* (Daugherty et al. 2001)

Documentation exists which establishes the considerable uncertainties and primitive nature of neutron measurements in the early years, as evidenced by the incomplete criticality safety program of the era, as outlined in Attachment 10.

5.6.2 Use of Neutron Track Plates and Uncertainties in Dosimetry, 1951–1957

The early history of neutron dosimetry at the RFP is illustrative of these uncertainties:

1952–1956: The occupational external dosimetry TBD, (Langsted 2004, pp. 12 and 32), states that LANL processed neutron track "plates" for the RFP from 1951 to 1956 and that little was known about their performance and calibration. Putzier (1982, pg. 43) mentions that it would be more correct to use the word "film" instead of the word "plates" when referring to the LASL service, but does not explicitly state that it was NTA film. In addition, a paper written in 1963 by Mann and Boss (1963) states, "Since 1952, Eastman NTA (now called Type A) emulsion has been used as a personnel neutron dosimeter."

However, the NDRP (Falk et al. 2005, pg. 2) reports the following:

> *The initial neutron sensitive element was known as a neutron track glass plate. These neutron track glass plates were pieces of glass approximately one-sixteenth inch thick and one inch square with an emulsion coating on one side of the glass*.

And then on page 3, Falk et al. 2005 states that, "From 1952 through 1956, the neutron track plates were supplied, processed, and evaluated by LANL." The NDRP report (Falk et al. 2005, pg. 3) goes on to confirm that the "plates" were not the same as NTA film by stating the following:

> *NTA film was the neutron sensitive element used at Rocky Flats from 1957–1970. Rocky Flats procured their neutron-sensitive films from two separate vendors at different times based on availability and cost. These two vendors were either the DuPont Chemical Company or the Kodak Company. These films were created,*

wrapped in a double-sided paper shield (white on the outside to reflect light and black on the inside to absorb light), packaged in film boxes, and supplied to their customers.

These conflicting statements from presumably reliable sources (some of which were present during the early years) create concern on the reliability of early neutron dosimetry records at the RFP. It is difficult to ensure accurate claimant dose using the details of a given report, if the historical system of dosimetry is not agreed upon.

1956–1957: According to the TBD, (Langsted 2004, pp. 12 and 33), during 1956–1957 an outside source, by the name of HPS, performed the neutron dosimetry using NTA film, but little is known about this process.

1958-: The TBD (Langsted 2004, pg. 33) states that in 1958, personnel at the RFP took over the responsibility of neutron dosimetry using NTA film.

According to the LASL external dosimetry TBD (Widner 2005), LASL only used neutron plates for neutron dosimetry during a short period from August 1949 to April 1951. This would indicate that LASL was not active in the neutron-plate business during the time they were supplying and processing neutron plates for the RFP during 1952–1956.

In view of the uncertainties in the neutron dosimetry processes during the time period 1951 through 1957, it is not apparent that the recorded neutron dose is correct or claimant favorable. More thorough investigation into neutron dosimetry during this period is needed to determine the details of the process. This would enable the DR to more accurately correct for missed and underestimated/unrecorded neutron doses. It should also be determined if neutron track plates were the same as NTA film, and if not, their characteristics. Many of these issues are addressed in the NDRP report (Falk et al. 2005) issued February 7, 2005, but are limited to plutonium workers only. The neutron dose sections in the TBD need to be revised in view of the new information in the NDRP, and extended to include other, non-plutonium workers exposed to neutrons.

5.5.2.1 Use of Neutron/Photon Rations to Generate Correction Factors Needs More Review

The use of neutron/photon ratios and comparing valid overlapping NTA film readings to neutron TLD results, in order to generate correction factors for under-monitored or missed neutron doses, was briefly addressed in the TBD (Langsted 2004, Section 6.7.3.4, pg. 35). It states that the two correction factors (1.99x and 1.13x) provided in Table 6-19 will be used until the NDRP report (Falk et al. 2005) becomes available. It appears from the TBD that this is an interim position on neutron dose, and that the final results will be based on the NDRP report.

However, the NDRP report only addresses neutron doses for plutonium workers. Therefore, a more thorough and detailed analysis of missed or underestimated neutron dose needs to be performed for non-plutonium workers that were exposed to neutrons. The results of the NDRP report cannot be directly applied to other neutron exposures at the RFP, because this report is

especially formulated for a few plutonium neutron spectrum situations with calibration factors (CF) specific for those energy spectra. Therefore, these spectra would not necessarily match other neutron spectra encountered by other workers at the RFP.

In addition, the neutron/photon values changed with location and with time. Initially, the n/p was determined to be around 1:3 in the final-assembly area, but was later found to be 3:1 in the chemical production area. Recent data showed some areas had an n/p value of 12:1 (Bistline 2005). As stated above, the neutron dose sections in the TBD need to be revised in view of the NDRP report, and similar analysis is needed to include other non-plutonium workers exposed to neutrons.

5.6.3 NTA Neutron Energy Threshold May Lead to Missed Dose in RFP Records

NTA film has a 0.8 MeV to 1.0 MeV threshold for neutron-proton recoil created tracks read on a routine, high through-put, basis; even under controlled conditions with good quality control. The shortcomings of past dosimetry methods using NTA film and assuming a neutron energy threshold of 500 keV, or even less (Wilson et al. 1990), has been recognized and has caused some facilities to reevaluate their neutron dosimetry records.

In view of this fact, there is concern that neutron dosimetry at the RFP, especially in the early days, could have missed significant doses of lower energy neutrons, because at the time, it was assumed that the energy level was between 0.25 and 0.4 MeV. They subsequently realized that this energy threshold for neutron detection might be too low and set a sensitivity at 0.48 – 0.75 MeV. Later research shows that this neutron energy threshold was still too low.

A paper written in 1963 by Mann and Boss of the RFP (Mann and Boss 1963) states the following:

> *I. Introduction*
>
> *Since 1952, Eastman NTA (now called Type A) emulsion has been used as a personnel neutron dosimeter. Early calculations of neutron flux from certain plutonium processing vessels and tanks indicated that the film was not seeing all of the fast neutrons present in a given area. Even when the neutron calibration source was changed from PoBe to PuF_4, there was still a large discrepancy between film, calculated, and survey meter dose. Moderated B^{1}° or B'_3 detectors in one form or another have been used for survey work.*
>
> *The effective neutron energy cutoff of Type A emulsion is between 0.25 Mev(1) and 0.4 Mev(2), depending on the track-reading system used and the ability of the reader. The sensitivity of the film thus becomes quite low for neutrons whose average energy is in this range. The sensitivity is 20 mrem/track/10 mm^2 for 0.48-Mev (average) neutrons compared to 6.8 mrem/track/10 mm^2 for 1.4-Mev (average) neutrons from PuF_4. This same situation exists for most proton-recoil chamber instruments, making the use of either device extremely difficult for dose measurements of neutrons below about 0.75 Mev in energy.*

Not only was the NTA film missing doses resulting from lower energy neutrons, but also the proton-recoil survey instruments suffered the same shortcomings as NTA film. Then at the end of the paper, Mann and Boss go on to conclude the following:

> *Type A film can be used as a personnel neutron dosimeter provided calibrations are made with neutron sources having average energies the same as those being measured. Larger field areas must be read for lower energy neutrons to minimize the statistical errors and to reduce the minimum detectable dose.* (Mann and Boss 1963)

5.6.4 NDRP Report Lacks Important Dose Reconstruction Information

The NDRP report (Falk et al. 2005) is a very detailed analysis of neutron dose reconstruction for plutonium workers at the RFP. However, there are limitations to applying the report as follows.

5.6.4.1 NDRP Does Not Cover Non-Plutonium Workers

Some of those neutron dosimetry issues noted above are addressed in the Neutron Dose Reconstruction Protocol (Falk et al. 2005) that covers the period of 1952–1970 when NTA film was used for neutron dosimetry. However, it addresses only workers in the plutonium facilities; it does not cover workers who could have been exposed to other sources of neutron radiation, especially during the early days before some of the sources of neutrons were recognized. Some workers were exposed to uranium and other sources of neutrons such as (alpha, neutron) reactions in UF_4, criticality experiments, calibration sources, etc., besides Pu at the RFP during this time period when NTA film procedures are in doubt.

5.6.4.2 Use of Neutron/Photon Ratios and Film/TLD Comparisons Needed

The use of n/p ratios and comparing valid overlapping NTA film readings to neutron TLD results in order to generate correction factors for under-monitored or missed neutron doses was briefly addressed in the TBD (Langsted 2004, Section 6.7.3.4, pg. 35). It states that the two correction factors (1.99x and 1.13x) provided in Table 6-19 will be used until the NDRP report (Falk et al. 2005) becomes available. It appears from the TBD that this is an interim position on neutron dose, and that the final results will be based on the NDRP report. However, the NDRP report only addresses neutron doses for plutonium workers. Therefore, a more thorough and detailed analysis of missed or underestimated neutron dose needs to be performed for non-plutonium workers that were exposed to neutrons. The results of the NDRP report can not be directly applied to other neutron exposures at the RFP, because it is especially formulated for a few plutonium neutron spectrum situations with specific CF for those energy spectra and would not necessarily match other neutron spectra encountered by other workers at the RFP. As stated above, the neutron dose sections in the TBD need to be revised in view of the NDRP report, and similar analysis is needed to include other non-plutonium workers exposed to neutrons.

5.6.5 Neutron Dose Multiplication Factor

Page 34, Table 6-18, lists the potential missed neutron dose below 800 keV for early NTA film to range from 16% to 60%. However, the text below it selects 56% as the claimant-favorable value with a resulting multiplying factor of 1.79. It would appear that the higher value of 60% missed neutron dose with a resulting multiplying factor of 2.5 should have been selected (i.e., 1/1-0.60) = x2.50). In addition, even if the value of 56% was selected for the percent of neutron dose missed, then the multiplying factor would be 1/(1-0.56) = x2.27 instead of 1.79. This information needs to be corrected.

5.7 OTHER EXTERNAL DOSIMETRY ISSUES

A combination of other factors have been found that SC&A feels complicates and makes difficult the ability to fully characterize the external dose to workers. This may be due to the lack of issued dosimetry in the early days, or missing or incomplete dosimetry. Some aspects of extremity badging may prevent full characterization of extremity dose. The VARSKIN software may miss some of the important radionuclides contributing to skin dose. There is little information in the TBD (Falk 2004) that discusses the possible use of industrial x-ray units, large radioisotope sources, or neutron generators that SC&A feels could be potentially significant contributors to external dose. Neither is the subject of past or recent D&D activities and their unique monitoring requirements addressed. These issues are discussed in the subsequent sections.

5.7.1 Unmonitored Individuals

There is concern that some workers, especially during the early years, may not have been recognized as having the potential of receiving radiation doses from their work at the RFP. The occupational external dosimetry TBD (Langsted 2004, Section 6.9.1, pg. 42), states that in the early 1950s, only groups expected to received doses greater than 10% of the RPG were monitored. However, we find that:

(a) The NDRP report (Falk et al. 2005), page 1, states the following:

> *For some plutonium workers, neutron monitoring was not provided until the early 1960s, and their dose of record may not include significant contributions from neutron exposure received prior to being issued a neutron dosimeter. These workers included most of the employees working in Building 71 (now Building 771). Only a small number (10–18) of these employees were monitored for neutron exposure, and that monitoring was only during the period October 1956 to September 1957.*
>
> *Operations in Building 71 involved chemical processing of plutonium in acid solutions and resulted in significant neutron fields from the alpha-neutron reaction with light elements, especially from the plutonium tetrafluoride compound. No evidence has been found that neutron shielding was present for these operations until the early to mid 1960s.*

(b) Column 2 of Table 2, pages 17 and 18, of the RFP annual radiation exposure report for the year 1984 (RFP 1985) provides the total badged personnel per year for the years 1953–1984. Another RFP document entitled *Film Procedure Timeline* for the Neutron Dose Reconstruction Project 2003 (RFP 2003, pg. 6), provides the number of NTA films processed per month. Analyzing the two tables for the years 1959–1969 shows that for the total number of workers badged, on the average, only approximately 25% were issued NTA film badges (over the 11-year period, it ranged from 9% to 50%). For example, in 1960, a total of 1362 workers were badged throughout the year and approximately 300 NTA films were processed per month (therefore, 300 workers were badged for neutrons throughout that year), this results in a ratio of 300/1362 = 22%.

These facts bring up the question of if the policies and procedures in place during this period at the RFP were adequate to ensure that the workers who were at risk of receiving significant radiation doses (especially neutron doses) were actually, and adequately, badged. The assignment of dosimeters to workers using the "10% of the RPG" policy was apparently based on administrative decisions, not necessarily on actual, well conducted, survey results (if this was not the case, then there would not have been lack of monitoring in certain areas as stated in the NDRP report (Falk et al. 2005) and as indicated in some former worker interview sessions). The basic problem with external radiation monitoring at the RFP for 1951 through the early 1960s was the beginning philosophy that there would not be a great deal of external radiation hazards associated with the operations at the RFP (Putzier 1982). This was coupled with the need to sometimes put production ahead of other issues (as stated during former workers' interviews). This situation led to some after-the-fact badging and catch-up monitoring for some areas and categories of workers. Missed doses caused from these practices were therefore a very real possibility and difficult to compensate for in DR by using co-worker dose or area monitoring information, because these potential areas of exposure were not deemed necessary to monitor at the time.

5.7.2 Photon and Beta Dose Determination

5.7.2.1 Photons with E > 250 keV

Photon exposure spectra are assumed to be mostly in the 30-250 keV range to be claimant favorable (Langsted 2004, Section 6.6.1.1, pg. 24). However, if there are any DR cases where shielding (either external or internal to the body) must be considered, then photons with energies >250 keV may contribute more to the final effective dose because of their greater penetrating power. It needs to be determined if there are cases where this could have an affect on the final assigned dose.

5.7.2.2 Use of VARSKIN Software

Page 42, the last paragraph of Section 6.8.6 recommends using the VARSKIN software to calculate skin dose from contamination. However, the TBD (Langsted 2004, Table 6-26, pg. 43) shows that the VARSKIN Mod 2 only includes one (^{234}Th at 3.40E-07 Ci/gm of DU) of the two

most active beta isotopes [the other being ^{234m}Pa at 3.40E-07 Ci/gm of DU (the third isotope, ^{238}U at 3.40E-07 Ci/gm of DU is not itself an active beta emitter)]. Page 37 states, "Thus, for depleted uranium, one is dealing essentially with 2.29-MeV (Emax) beta particle from ^{234m}Pa, the most energetic contributor to the beta exposure." With the information provided in the TBD, it would appear that VARSKIN should not be used in DR if it leaves out ^{234m}Pa. Including ^{234m}Pa in the DR process is necessary to arrive at correct doses.

5.7.3 Extremity Dose

The TBD addresses extremity dosimetry issues on page 43, Section 6.10. However, there are several items of concern in this section:

5.7.3.1 Use of NTA Film in Wrist Badges

Generally, neutron doses to the extremities are not a large issue, but at the RFP (more so than at most facilities) there appears to have been considerable hands-on work with uranium and plutonium compounds that had the potential to deliver neutron doses to the extremities. Between 1951 and 1970, beta/gamma film was used for extremity dosimetry. However, no mention of NTA film being used for extremity monitoring was mentioned in the TBD or other literature. It appears that the workers who did wear wrist badges were not monitored for extremity neutrons, but only for beta/photon. For those handling neutron-emitting materials, the neutron doses to the extremities could have been greater than the whole-body dose monitored by the regularly issued film badges. Therefore, this is a potential source of worker's missed dose that was not recorded.

5.7.3.2 Extremity Dose Assumed to be Equal to Whole-Body Dose

In some cases, the measured whole-body dose was assigned as the extremity dose of record. This is not claimant favorable. The TBD (Langsted 2004, pg. 43) states the following:

> *Many RFP workers did not receive extremity (wrist) dosimeters. In such cases, the wrist (forearm) dose was assigned as the measured skin (shallow) dose* [as measured by the whole-body badge], *and the hand dose was assigned the same value.*" (Langsted 2004)

NDRP (Falk et al. 2005, pg. 22) lists the average whole-body (WB) photon dose response as only 40% of the wrist photon dose. Additionally, in most cases the dose to the hands would be greater than the dose to the wrist by 2.5x to 5x (Mann 1964). This would mean that the hands could have received 6x to 12x the dose as measured by the WB badge.

The previous procedures at the RFP do not appear to be claimant favorable because the forearm, and certainly the hand, could have received a higher dose than the whole body. If wrist dosimeters were not used, the DR should consider the worker's job description for possible extremity exposures, and calculate an appropriate dose from the whole-body dose information. In these cases, the wrist dose would be greater than the WB and the hand dose would be greater than the wrist dose, as per the applicable hand-to-wrist ratio.

5.7.3.3 Valid Hand-to-Wrist Ratios

It appears that there is a lack of valid information on hand-to-wrist ratios that could seriously affect claimant dose reconstruction at the RFP. For example, Section 6.10, page 43, states that the details on the hand-to-wrist ratios are not available. The last sentence in this section states that additional information on the hand-to-wrist ratios is required before shallow doses to the extremities can be reconstructed. The last paragraph on page 37 states that surface beta dose rates on the order of 1 to 20 rad per hour had been observed, and RFP had problems with elevated beta dose rates from contamination on leather gloves worn during foundry operations. No values for hand-to-wrist ratios are provided in the TBD. The ratios need to be developed and used in the DR, if needed.

5.7.4 Industrial X-ray Units and Neutron Generators

The TBDs (Little and Meyer 2004; Flack and Meyer 2004; Langsted 2004) do not mention any use of industrial x-ray units, large radioisotope sources, or neutron generators for R&D or non-destructive testing (NDT), or any associated radiation exposure or monitoring. However, these units (some in the MeV energy range) were apparently used at the RFP at sometime as referred to in an article by Ruttenber, *Industrial Hygiene Evaluation of Building 444 Exposures* (Ruttenber 1996, pg. 17):

> *The Radiography Laboratory was staffed by NDT Technicians who performed non-destructive testing on the parts after they were finished. They conducted density testing using Freon and determined the oxygen content of beryllium using a **neutron generator**. They also conducted **x-ray** testing to look at welds and performed die penetration testing on the parts. Approximately 10 employees worked in this area of 444.* [Emphases added]

Additionally, in *Industrial Hygiene Evaluation of Building 707 Exposures* (Ruttenber 1996, pg. 4), Ruttenber refers to:

> *After the parts were completely assembled, they would undergo a number of testing operations to determine their suitability. Parts would be **x-rayed** in Module E to identify any structural flaws. A number of chemicals were used in the development of the **x-rays** which was done on site.* [Emphases added]

And in *Industrial Hygiene Evaluation of Building 771 Exposures* (Ruttenber 1996, pg. 35), Ruttenber refers to an X-ray Laboratory**:**

> *The **X-ray Laboratory** was used to determine the amount of plutonium in solid samples received from Production. This laboratory was used when plutonium concentrations were expected to be more than one g/l. Magnesium oxide and ammonium hydroxide were used to suspend the solution so the plutonium concentration could be measured by X-ray fluorescence. The matrix for suspension was mixed every three to six months. Periodically, the odor of*

> *ammonium was present in the air at the beginning of the shift. Prior to the construction of Building 559, the X-ray and Radio Assay laboratories were in separate rooms; now they are located in the same area.* [Emphases added]

In view of the potentially high radiation exposure rates that accompany these units, and the fact that the response of dosimetry systems may be different for these units (high-energy photons and neutrons) from that of the standard calibration for plutonium and uranium isotopes, this is an area that needs to be addressed. The number of units, energies, periods of operations, operating procedures, etc., needs to be determined to assess the potential radiation exposures, and if radiation doses were under-recorded or missed.

5.7.5 Decontamination and Decommissioning Activities Not Addressed

Decontamination and decommissioning (D&D) activities present non-routine situations and unique external and internal monitoring requirements. Considering the many years of operations involving unique materials at the RFP, D&D activities during both the active years of the plant and during recent clean-up activities present radiological conditions not normally encountered. Some of these unique conditions include high-fired Pu and ^{241}Am in ductwork and in building structures, and also a variety of radioisotopes in the soil (some that have been identified are $^{89/90}$Sr, $^{134/137}$Cs, U, ^{238}Pu, ^{239}Pu, ^{208}Tl, ^{212}Pb, ^{214}Pb, and ^{237}Np). If these, and other radiological hazards, associated with D&D activities were not recognized before D&D began, under-recorded and/or missed dose is probable. These issues were not mentioned or addressed in the TBD.

5.8 ISSUE 8: HISTORIC OPERATIONS AND RADIOLOGICAL CONTROLS

5.8.1 Inadequate listing of Radionuclides of Concern

The TBD Site Description provides useful information regarding radionuclides handled in different buildings, but it does not list the general types and quantities of radionuclides to which workers may have been exposed. As Table 11 indicates, such a listing was developed for off-site dose reconstruction studies (ChemRisk 1992).

Table 11. Radioactive Materials at the Rocky Flats Plant

Radioactive Material Handled in Kilogram Quantities	
Americium	^{241}Am
Plutonium	^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu
Thorium	^{232}Th
Uranium	^{233}U, ^{234}U, ^{235}U, ^{236}U*, ^{238}U

Radioactive Materials Handled in Gram Quantities (<1 Kg)			
^{244}Cm	^{3}H (Tritium)	^{237}Np	^{228}Th

Other Sources –
Includes sealed solid sources, plated sources, liquid sources and analytical stock solutions

Actinium	^{228}Ac	Nickel	^{63}Ni
Aluminum	^{26}Al	Plutonium	^{236}Pu, ^{244}Pu
Americium	^{243}Am	Polonium	^{210}Po
Antimony	^{124}Sb, ^{125}Sb	Potassium	^{40}K
Argon	^{39}Ar	Promethium	^{147}Pm
Barium	^{133}Ba	Protactinium	^{231}Pa, ^{234}Pa
Beryllium	^{7}Be	Radium	^{226}Ra
Bismuth	^{207}Bi, ^{210}Bi	Ruthenium	^{106}Ru
Cadmium	^{109}Cd	Selenium	^{75}Se
Californium	^{250}Cf, ^{251}Cf, ^{252}Cf	Silver	^{110}Ag, ^{110m}Ag
Carbon	^{14}C	Sodium	^{22}Na
Cerium	^{139}Ce, ^{144}Ce	Strontium	^{85}Sr. ^{89}Sr, ^{90}Sr
Cesium	^{134}Cs, ^{137}Cs	Technetium	^{99}Tc, ^{99m}Tc
Chlorine	^{36}Cl	Thallium	^{204}Tl
Cobalt	^{57}Co, ^{60}Co	Thorium	^{230}Th, ^{231}Th, ^{234}Th
Curium	^{245}Cm, ^{246}Cm	Tin	^{113}Sn
Europium	^{152}Eu, ^{154}Eu, ^{155}Eu	Uranium	^{232}U, ^{236}U
Holmium	^{166m}Ho	Ytterbium	^{169}Yb
Iridium	^{192}Ir	Yttrium	^{88}Y, ^{90}Y
Iron	^{55}Fe	Zinc	^{65}Zn
Krypton	^{85}Kr		
Manganese	^{54}Mn		
Mercury	^{203}Hg		

Source: ChemRisk 1992, Appendix A (DOE 2000)

5.8.2 The Need for Incident Database Access for Dose Reconstruction

The TBD provides salient details relative to illustrative incidents, which are the most extensive in TBDs reviewed to date by SC&A. This superior approach should be augmented with the inclusion of relevant databases of incidents. NIOSH should not rely on the *a priori* assumption that the files of individual claimants contain all relevant information on incidents involving the claimant. For monitored workers, ORAU and NIOSH rely primarily on the worker dose record and the Computer-Assisted Telephone Interview (CATI) for potential exposure data on radiological incidents. Workers have often complained of poor record keeping and fabrication of records, which have been confirmed in congressional and Tiger Team investigations. The Rocky Flats Site Profile, as it now stands, does not have a dedicated database or assessment for off-

normal exposures and incidents that can guide dose reconstructors as to missed incidents (and hence additional doses) or record keeping practices that might indicate problems with the integrity of individual worker data in some settings and periods. Such data bases exist for Rocky Flats which should be incorporated into dose reconstruction efforts. According to the 1992 public dose reconstruction study done for the State of Colorado:

> *The most complete historical record available of all accidents at Rocky Flats is maintained by the Occurrence Management Department of EG&G Rocky Flats in the form of Summary of Events (SOE) database that covers the period from 1952–1990…At the time of ChemRisks's Review, the database contained approximately 1,767 accident entries.* (ChemRisk 1992, pg. 211)

This concern, particularly over significant exposures due to incidents, is underscored by data collected by the Former Radiation Worker Medical Surveillance Program at Rocky Flats, in which approximately 825 former workers participated from 1992 through December 1999. (Daugherty et al. 2001) According to an analysis of this program:

> *Doses for program participants seen during this period range from near zero to nearly 20 Sv (2,000 rem) TEDE, with about 10% exceeding 1 Sv (100 rem)…for those participants with TEDEs above 1 Sv (100 rem), the majority of the dose typically is from internal depositions of plutonium…Approximately 10% of the participants seen during this period have lung doses of 6 Sv (600 rem or more and the maximum is about 120 Sv (12,000 rem)…Approximately 10% of those bone surface doses are 5 Sv (500 rem) or more, and the maximum is about 320 Sv (32,000 rem)…**The causes of many of the higher internal doses were accidents that generally are well documented.**…* [Emphasis added.] (Daugherty 2001)

5.8.3 Inadequate Description of Post-Production Mission at Rocky Flats

The post-production mission, now in its 16th year, has involved nuclear material storage, nuclear material stabilization and packaging, environmental restoration, waste management, and decontamination and decommissioning. All of these activities have resulted in employees working in various radiation environments, which should be described and characterized relative to radiation exposures and dose reconstruction.

5.8.4 Inadequate Description of Nuclear Plutonium Storage Activities and the Absence of Related Dose Reconstruction Guidance

By 1994, 2 years after production ceased, the RFP was storing metric tons of plutonium in thousands of individual packages—a considerable portion of the entire DOE inventory of excess plutonium at the time. Like other DOE facilities, the RFP had not established storage contingencies to address the end of production (DOE 1994, pg. 18). This resulted in sudden and large inventories of excess nuclear materials, stored under sometimes questionable circumstances from a radiological standpoint. Moreover, post-production fissile material storage problems

posed a much different set of dose reconstruction challenges than encountered during production. For instance:

- NIOSH has not addressed nor provided dose reconstruction guidance relative to the major shift in neutron gamma ratios, associated with large-scale fissile material storage problems during the post-production. According to a 1994 environmental safety and health vulnerability assessment performed by the Energy Department, neutron gamma ratios changed "dramatically and [have] become more variable with the recent consolidation of material…[and]… now typically range anywhere from <1 to 10. Previously the neutron/gamma ratios could be characterized by location due to the type of plutonium operation and material handled. Historically, the typical dose from plutonium metal was 30 percent neutron, 70 percent gamma, while that from liquid plutonium solutions was 70 percent neutrons, 30 percent gamma. **Of particular note for future work is building 317, where the thermal neutron flux has increased dramatically**" [Emphasis added] (DOE 1994, pg. 105). This matter is of concern, because the external dosimetry program algorithm was found by the Defense Nuclear Facilities Safety Board (DNFSB) in 1993 to have "a wrong correction factor [that] may have been applied in the case of the K17 dosimeter chip," potentially impacting the accuracy of neutron dose calculations.

- The TBD does not address the potential for missed doses due to radiological control problems, which resulted in "gross contamination [and] contamination from inactive gloveboxes and tanks; leakage of rainwater through the ceiling in several areas of the building; Solutions in tanks, bottles, and piping …[and] a large number of waste drums in operating areas" (DOE 1994, pg. 70). This concern is underscored by a 1993 review of occupational radiation protection at Rocky Flats by the DNFSB, which reported: "…a potential existed for workers to be exposed to radiation without being monitored…" Subcontractors working at the plant did not appear to be totally integrated into some Radiation Protection Programs. **Currently, their contracts do not require compliance with the RCM** (DOE's Radiation Control Manual), which requires consistent and uniform dosimetry for workers in radiation areas (DNFSB 1993). (At that time Rocky Flats was in compliance with only 22.4% of the requirements in the RCM.)

- "Management of the bioassay program did not appear to be fully developed. RFP personnel noted during briefings that the Radiation Work Permits (RWP) do not stipulate the requirements for bioassay…when asked about other subcontractors, RFP personnel indicated that contractors may come and go and not be bioassayed. A deliberate delinquency tracking system does not exist" (DNFSB 1993).

- "Air monitoring equipment in the workplace at [the Rocky Flats Plant] is not in compliance with the requirements of the RCM." Continuous air monitoring capabilities were found be approximately 7 times less efficient and accurate than required by the DOE (DNFSB 1993).

- Documented respiratory protection was not in compliance with DOE's Radiation Control Manual (DNFSB 1993). This raises important questions about potential missed doses, which NIOSH should address, particularly since in 1994 it was reported that: " many rooms require full face masks due to airborne contamination or undesirable air flow within the room. The former condition is caused by surface contamination becoming loose in the room" (DOE 1994, pg. 38).

Of those, 81 vulnerabilities were identified by the DOE in 1994 as having potential adverse impacts on workers (DOE 1994, pg. 18). According to the assessment:

- *In touring the facilities, several people were very concerned about the potential for plutonium fires from the vibration or movement of packages. However, the concern about the perils associated with package movement restricts the ability to inspect the packages adequately* (DOE 1994, pg. 26).

- *Building 776 also contained…. …near the advanced size reduction room, mixed waste drums are stored. Although all of the drums had labels and travelers and other documents included estimated contents, a number of drums have not been assayed for radioactive material content.* (DOE 1994, pg. 77).

The nature and extent of work necessary to carry out the post-production mission is exemplified in the May 1995 DNFSB Staff report, which noted the following:

> *EG&G stated that there are 17.5 metric tons of combustible residues containing about 0.5 metric tons of plutonium. The total plutonium inventory of all residues at Rocky Flats is 3.1 metric tons. The combustible residues consist primarily of paper, cloth, filters, resins, wood and various plastics along with small amounts of oils, greases and solvent. Potential hazards in the combustibles include radiolytic generation of hydrogen and other flammable gases, nitrated organic compounds which could be flammable or shock sensitive, plutonium metal in contact with chlorinated organic compounds that could result in violent reactions, packaging degradation due to chemical and/or radiolytic effects, and radiation exposure to workers* (DOE 1995).

The risks of the post-production mission at Rocky Flats are underscored by the following:

> *On May 6, 2003, due to the accumulation of combustible material, a fire occurred in the basement of Building 371 at the Rocky Flats Environmental Technology Site (RFETS) as workers were preparing to remove Glovebox 8 from the facility. The fire broke out after operators began cutting a hole near the top of Glovebox 8 to establish a ventilation path for the glovebox. A significant firefighting effort ensued, including the discharge of more than a dozen fire extinguishers and eventual use of a fire hose* (DOE 2003).

As detailed above, the post-production period of the past 18 years created circumstances which required important adjustments to occupational radiation dosimetry, so as to avoid inaccurate or missing external and internal doses. Some of these adjustments may hold implications for the completeness and accuracy of ongoing and future dose reconstructions. NIOSH should accordingly expand the current site profile scope to include the post-production period. This expanded scope should address the preceding issues and provide guidance which takes into account the impact of stored excess fissile materials and the strong potential for missed and/or inaccurate doses due to the documented problems in the overall quality of the Rocky Flats radiation program shortly after the end of production.

5.8.5 The Need to Utilize Job Exposure Matrix Information

The TBD acknowledges that work-related job exposure analyses performed at the University of Colorado would add further insights to the dose reconstruction work at Rocky Flats. The SC&A team was allowed a limited review of working papers relative to job-related exposures to radiological and non-radiological hazards done at the University of Colorado. We find that these analyses provide important knowledge relative to the history and nature of building processes, job titles, and specific activities performed. For instance, in Building 771:

- Radiation exposures to production workers (e.g., Chemical Operators, Process Operators, and Assistant Chemical Operators) influenced the rotation of workers through process areas (Alvarez 2005).
- Radiation Protection Technicians were frequently present in potentially hazardous areas because they were involved in the discovery of and/or response to radiological incidents, as well as subsequent repair activities (Alvarez 2005).
- Pipefitters and Sheetmetal workers were usually in production areas on a daily basis performing piping, glovebox, and duct-work maintenance and repairs. Pipefitters worked on lines carrying liquids in areas and Sheet metal workers worked on ventilation lines. In some instances, Sheetmetal workers were required to enter gloveboxes to perform repairs (Alvarez 2005).
- Maintenance Machinists spent a large portion of their time repairing pumps in gloveboxes and, in some instances, were required to enter the gloveboxes. Maintenance Machinists were also likely to encounter spills during repairs (Alvarez 2005).
- Electricians worked along with Pipefitters, Sheetmetal Workers and Machinists and were likely to receive similar exposures (Alvarez 2005).
- Painters were often present in radiological environments, because a great deal of their time involved scraping contaminated surfaces and decontamination painting of spills (Alvarez 2005).
- Prior to 1972, filter changeouts involving potential exposure to radionuclides were performed by Production Workers and Sheetmetal Workers. This involved changing,

testing, and packaging filters designed to trap radionuclides in plenums and gloveboxes. After 1972, Filter Technician became a separate job category (Alvarez 2005).

- Very little work done by carpenters was done in production areas (Alvarez 2005).
- Janitor, Handyman, and Utility Workers in many instances were not usually found in production areas because most were awaiting clearances. However, some remained in these jobs for several years (Alvarez 2005).
- Work done by Laboratory Workers was not in production areas, but involved glovebox work with smaller quantities plutonium (Alvarez 2005).

This job exposure matrix is important for the dose reconstruction process because it provides a basis for using co-worker data for filling in missing data for unmonitored or inadequately monitored workers. As noted previously, NIOSH recognizes the importance and relevance of this matrix, and has made a concerted effort to obtain it, but to no avail as of the date of this review.

5.9 ISSUE 9: OCCUPATIONAL ENVIRONMENTAL DOSE

The Occupational Environmental Dose TBD, ORAUT-TKBS-0011-3 (McDowell-Boyer and Little 2004) was evaluated to determine if adequate guidance was provided to perform occupational environmental dose reconstruction. SC&A determined that the environmental TBD had several deficiencies, including the following:

(1) Need for source term and exposure pathways re-examination
(2) Need for a timeline for phases of operations, and data availability and types
(3) Data adequacy and completeness
(4) Ambiguous recommendations for particle size
(5) Uncertainty with the RATCHET model

These issues are discussed in the following sections.

5.9.1 Soil Resuspension

The TBD provides the annual inhalation intake for $^{239+240}$Pu and ^{241}Am for atmospheric releases from 1953–2002. It acknowledges that workers were subject to environmental doses from incidents, such as venting of material outside buildings or resuspension of contaminated soil (McDowell-Boyer and Little 2004, pg. 13). The internal dose from resuspension of contaminated soil has not been fully addressed by the TBD. The dose consequences from contaminated soil seem to be limited to external dose. As indicated for the Savannah River Site reviews, there are a couple of methods to estimate inhalation exposure from resuspended radionuclides. These methods include the dust-loading approach and the resuspension-factor approach. The TBD also excludes the impact of resuspension of soil at areas of the site other than the 903 Drum Storage Pad, which may or may not be represented by the air sampling data.

SC&A has not seen any evidence that the resuspension of plutonium and americium was taken into consideration in determining the internal dose values for the pre-1965 period. The occupational environmental dose TBD (McDowell-Boyer and Little 2004, pg. 9) stated that the total routine (non-discrete-event) plutonium emissions from 1953 to 1989 are estimated to be on the order of 0.12 Ci (Voillequé 1999c). This estimate does not include releases due to resuspension of contaminated soil downwind of the 903 Drum Storage Pad. On the same page, the TBD was clear in declaring that there were 24 identified discrete events during the period between 1964 and 1969, and the asphalt pad placed over the 903 Area in 1970, did not stop the resuspension of plutonium-contaminated soil to the air in later years. Releases from the 903 Drum Storage Pad totaled an estimated 3.1 Ci over several years (McDowell-Boyer and Little 2004, pg. 9). Resuspension of soil from this and other surfaces during high winds or soil remediation activities could result in both inhalation and ingestion of radioactive material, and should not be excluded.

With respect to external dose, the TBD focused on the incidental releases at the 903 Area Drum Pad, but did not include other soil contamination areas in its discussion. During a Government Accountability Office (GAO) evaluation of the major problems at RFP (GAO 1988), environmental contamination at RFP was defined as a significant problem. The GAO stated in its report:

> *Inactive waste sites are one of the principal causes of groundwater contamination. A number of such sites were identified at Rocky Flats as potential sources of groundwater and soil contamination.*

Furthermore,

> *A total of 108 inactive sites have been identified at RFP. Some of these sites are considered to be existing or possible sources of significant environmental contamination. Furthermore, some off-site areas have been contaminated with low-levels of plutonium.*
>
> *Of the 108 inactive waste sites identified, RFP officials have given a high priority to 27 sites, which have been grouped together in four areas because of their general proximity. These areas are (1) the 881 Hillside area, (2) the 903 Pad area, (3) the Mound area, and (4) the East trenches.*

Appendix C of the RFP's *Final Buffer Zone Sampling and Analysis Plan* indicates that some samples at the periphery of the site variously contained 2,830 pCi/g ^{137}Cs; 2,610 pCi/g ^{238}Pu; 3,246 pCi/g ^{239}Pu; and 149,060 pCi/g ^{208}Tl. These obviously elevated activity levels in surface soils raise a concern over potential worker contact with radioactively contaminated soils. Some past practices have been identified (and described in Appendix C) that would also add to these concerns.

In 1989, the Environmental Protection Agency and the Federal Bureau of Investigation (FBI) initiated an investigation and regulatory, as well as legal actions, in response to clear

environmental law violations at RFP. Regulatory non-compliance was established under the various environmental statutes, including the Resource Conservation and Recovery Act (RCRA), the Clean Water Act (CWA), and the National Pollutant Discharges Elimination System (NPDES) program (Lipsky 1989). During the investigation, the following areas were identified as outside areas contaminated with mixed waste.

- 750 Pad
- B-series ponds
- Solar ponds
- 904 Pad
- West Spray Field
- East Spray Field
- North Spray Field
- East Trenches

When the 207 Solar Evaporation Ponds were closed, sludge was mixed with concrete to form blocks. The salt brine and evaporator salts from Building 374 were also mixed with cement to produce saltcrete. The 750 and 904 Pad were used to store pondcrete and saltcrete. There were immediate issues with container integrity, sloughing, and runoff to the ponds (Norton et al. 1992).

> *The potential exists for leachate release as sloughing of waste materials could be caused by exposure to precipitation and temperature changes with attendant contamination of the area adjacent to the storage pad…*

Independent inspectors from the Nevada Test Site noted that tarps protecting the concrete were punctured or torn, boxes had suffered significant water damage, and pondcrete boxes were bulging at the sides (Norton et al. 1992). By August 1988, water samples taken around the pads were showing both alpha and beta contamination.

In the 1980s, treated sanitary effluents from the Sewage Treatment Plant (STP) were discharged to B-3 Pond and subsequently spray irrigated onto fields. The sewage sludge was considered to be low-level radioactive waste. As a result, contamination was released into the surrounding soil and groundwater (Norton et al. 1992). It would therefore seem appropriate to consider soil contamination areas other than the 903 Drum Area Pad. Prior to excluding potential exposure from other soil contamination areas, NIOSH should review soil contamination data for the industrial area prior to remediation activities and the potential for exposure from either the areas themselves or the resulting runoff. The high-wind events at RFP can also lead to contamination spread from these areas. The lack of information on these sites in the environmental TBD makes it difficult to determine whether assumptions are bounding. Understanding the extent of soil contamination would lead to a better understanding of environmental exposure and impacts of resuspension on dose to workers.

SC&A also believes that resuspension of $^{239+240}$Pu and ^{241}Am, as well as other radionuclides, throughout the site could be an important contributor to ambient dose for both monitored and unmonitored dose.

5.9.2 Other Radionuclides

The TBD relied on the radionuclides of concern identified during the Historical Public Exposures Studies on Rocky Flats. The TBD states the following (McDowell-Boyer and Little 2004, pg. 8):

> *The Phase I study identified several radionuclides as potentially significant releases – Hydrogen-3, natural thorium, enriched and depleted uranium, $^{239+240}$Pu, ^{241}Pu and ^{241}Am. The results of the Phase I study identified plutonium as the primary material of concern with respect to off-site exposures.*

Although plutonium is considered the primary material of concern, it was noted that some radionuclides present at the site were not considered in the TBD. The TBD did not consider releases from ^{238}Pu, noble gas releases from Building 886, ^{244}Cu, and ^{237}Np (Rope et al. 1999; ChemRisk 1992 and 1994a). As previously mentioned, ^{137}Cs was identified in the Buffer Zone around the industrial area.

The TBD (McDowell-Boyer and Little 2004, pg. 28) indicated that the resuspension of $^{239+240}$Pu deposited in the soil from 903 Drum Storage Area suspension releases was included in the comprehensive evaluation of exposure to $^{239+240}$Pu released from RFP for 1964–1969. A time-dependent factor approach was used to address the resuspension of soil contaminated by released $^{239+240}$Pu and deposited as a result of the continuous and discrete events. The TBD, however, did not indicate that ^{241}Am resuspension was included in calculating the dose, since ^{241}Am is present, on average, at up to 0.30 times the activity of $^{239+240}$Pu. The potential significant contribution of ^{241}Am to the total dose appears contradictory to the TBD conclusion on page 51 that ^{241}Am was an insignificant contributor to inhalation dose and was eliminated from further consideration.

NIOSH should consider internal and external dose impacts from ^{238}Pu, ^{244}Cm, ^{237}Np, ^{137}Cs, and other radionuclides determined to be present in environmental samples. The measurement of ^{137}Cs in the buffer zone indicates that there was an operation onsite releasing this radionuclide. This should be investigated.

5.9.3 Episodic Releases

SC&A has also alerted NIOSH that between 1953 and 1977, five major accidents were identified in Figure 6-1 of the ChemRisk report (ChemRisk 1992). On page 28, the TBD (McDowell-Boyer and Little 2004) listed some events, including the releases from glovebox fires in 1957 and 1969, and suspension of plutonium-contaminated soil from the 903 Area during unusually high-wind events in 1968 and 1969. In that figure, the gross alpha radioactivity emissions from RFP plutonium facilities were shown to range from 500 μCi for the Control Valve Failure in

1974 to 4,000,000 μCi from the 903 Pad Oil Leakage in 1957. In addition, in a memo from Carmine Plott to Larry Goldren from Rocky Flats on July 11, 1986, two explosions (one in 1965 and one in 1969) were identified as two of five major accidents. These accidents are not addressed in the environmental TBD. They are briefly included in the site description TBD in the list of incidents. SC&A recommends that these emissions be reexamined further.

There has been no consideration in the TBD of releases from incinerator fires, ventilation system fires, the 374 fires occurring in the plutonium area between 1955 and 1971, or uranium fires (U.S. DOE Archives). These fires should also be considered in the context of occupational internal dose. The environmental TBD does not adequately consider the impact of episodic releases, including the five major accidents at RFP and the hundreds of small fires involving both uranium and plutonium.

5.9.4 Data Adequacy and Completeness

The environmental TBD relied on atmospheric dispersion modeling to calculate ambient airborne dose. It was stated (McDowell-Boyer and Little 2004, pg. 10):

> *Attachment 4A describes the use of atmospheric dispersion model results from the Phase II study to estimate air concentrations and intake between 1953 and 1964. During this period of time results were not readily available and usually did not allow derivation of ^{239,240}Pu.*

The maximum annual inhalation intake values for $^{239+240}$Pu for the period 1953–1964 range from 5.68E-3 pCi/year to 346 pCi/year (including the 1957 fire). The values for 1965–2002 range from 7.68E-1 pCi/year to 1,320 pCi/year. It is reasonable to believe that routine releases in earlier years were higher than those in later years. In an update on health studies at Rocky Flats, the Colorado Department of Public Health and Environment (CDPHE 1997) stated the following:

> *The largest routine releases from Rocky Flats facilities occurred in the 1950s and 1960s primarily from the Building 771 exhaust stack and Building 776-777 roof vents. These releases were caused primarily from operational problems and faulty air filtration systems, which were improved in the late 1960's.*

Based on CDPHE data, it would seem that the annual inhalation intake values derived by atmospheric modeling may have underestimated actual releases. The TBD should reconsider the inhalation intake values for 1953–1964.

From 1965-2002, the estimate of the average intake of $^{239+240}$Pu and ^{241}Am via inhalation was based on air monitoring data. NIOSH indicates in the TBD that annual intakes derived for these years are biased towards higher concentrations (McDowell-Boyer and Little 2004, pg. 11):

> *Table 4-2 lists estimated annual intakes of ^{239,240}Pu and ^{241}Am between 1965 and 2002. The average values for ^{239,240}Pu in this table are based on measured*

concentrations at samplers across the site, but often biased toward the highest concentrations, typically near the 903 Area after 1970 because concentrations are more often reported for samplers in that area and not for samplers in other RFP areas. Therefore, the average values are inherently claimant-favorable when used as an average for the industrial area.

Following the FBI raid on June 6, 1989, the Department of Energy formed a Special Assessment Team to independently review the operations and practices at RFP. Several deficiencies were identified in the environmental monitoring program, including the ambient air monitoring. In 1989, DOE indicated the following in its own report:

- *Deficiencies in Rocky Flats Plant (RFP) effluent air monitoring program may adversely affect determination of radioactive materials released to the atmosphere* (page 2-7).

- *There are deficiencies in the ambient air monitoring program for radionuclides. As a consequence, the accuracy of measured concentrations of plutonium in ambient air is questionable* (page 2-11).

- *The quality assurance and quality control practices for radiochemistry analyses in the Building 123 HS&E Laboratory do not conform to generally accepted practices. Consequently, the laboratory cannot adequately verify the validity of analytical results* (page 7-9).

- *The quality assurance/quality control practices in the Chemistry Standards Laboratory (CSL) may not be adequate to document the validity of the radiological reference standards prepared by the laboratory. This laboratory prepares reference standards for use by the environmental radiological laboratories, for instrument calibrations, as internal tracers, and for the preparation of control standards* (page 7-13).

- *The quality assurance and quality control practices for radiochemistry analyses in the 881 General Laboratory may not be adequate to document the validity of the analytical data* (page 7-15).

- *Land in the vicinity of and to the east of the 903 Pad is known to be contaminated with low levels of plutonium and americium-241, but the contamination has not been well characterized* (page 7-21).

The report further indicates that ambient air monitoring samples are not analyzed for ^{241}Am and uranium, which can be released independently or in combination with plutonium. With the uncertainty in the environmental monitoring data, and the absence of data at some areas onsite, the NIOSH statement that intake values derived in Table 4-2 are claimant favorable is questionable. Certainly, further investigation into the above issues is needed prior to coming to this conclusion.

NIOSH has assumed that the air sampling locations are representative of the average airborne concentration breathed by a worker. In its assessment of environmental conditions, DOE stated the following (DOE 1989):

> *Samplers may not be properly located. The existing radioactive ambient air monitoring network was established following limited siting criteria which used a Colorado State University wind tunnel study (A-21) as a basis; however, the exact locations of these samplers have not been recently documented to be representative for the Rocky Flats area.*

Further investigation into the representativeness of these air sampling data to the unmonitored workforce should be considered. Also, it is important to note that the air monitors are at a height of 6 feet and may not represent air concentrations from soil resuspension adequately.

Incidental releases determined by the state of Colorado contain a range of release values for the 1957 and 1969 fires that indicate the TBD does not provide a bounding scenario, but instead uses an average value resulting in non-claimant-favorable assumptions. The CDPHE, in its Summary of Findings published in August 1999, indicated that the 1957 fire plutonium releases were between 2.9 and 39 Ci with a median value of 20 Ci. The releases from the 903 Area were estimated to range between 1.8 and 15 Ci with a median value of 3.7 Ci. The releases from the 1969 fire were estimated to be between 10 and 60 mCi, with a median of 20 mCi. (CDPHE 1999). The TBD assumes a release of 21 Ci for the 1957 fire, 37 mCi for the 1969 fire, and 3.1 Ci for the releases from the 903 Drum Storage Pad.

The reliance on the air monitoring system and atmospheric modeling to calculate annual inhalation intakes is questionable. The atmospheric modeling appears to underestimate the releases from the site, as compared to recalculated routine releases by the CDPHE. Deficiencies in the environmental monitoring program may influence the release values derived from ambient air monitors. Methods to effectively ascertain inhalation intake values for radionuclides other than $^{239+240}$Pu should be included in the TBD. Reinvestigation into the annual inhalation intake values is warranted.

5.9.5 Timeline Needed for Phases of Operations, and Data Availability and Types

The RFP TBD for Occupational Environmental Dose (McDowell-Boyer and Little 2004) has attempted to estimate the occupational environmental dose, which is defined as the radiation dose received in the course of work duties, outside plant buildings, but on the RFP site. In Section 4.2.1, two phases of studies, Phase I and Phase II, provided the basis for the analysis of releases of radionuclides from the RFP during its operational period, which ran from 1952 to 1994. The TBD (McDowell-Boyer and Little 2004) indicated that the Phase I study identified several radionuclides as potentially significant releases — tritium, natural thorium, enriched and depleted uranium, $^{239+240}$Pu, ^{241}Pu, and ^{241}Am. The results of the Phase I study identified plutonium as the primary material of concern with **offsite** exposures. However, the references cited on page 19 (ChemRisk 1994a and ChemRisk1994b) have defined Phase I as the operational period between 1952 and 1989.

The TBD (McDowell-Boyer and Little 2004) did not, however, indicate that the reference (ChemRisk 1994b) also provided dose assessment values for the RFP. Phase I is time dependent from the onset of production at the site in 1952 to 1989. Therefore, SC&A would then assume that only 3 years of the production phase plus 8 years of post-production phase are included in Phase II studies.

In Section 4.2.2, the occupational environmental dose TBD (McDowell-Boyer and Little 2004) identified another two phases—the pre-1993 phase, when production activities were ongoing, and the post-1992 phase, when production activities had ceased. Releases were more likely to occur as a result of past contamination or decontamination and decommissioning activities.

The overlap in the definitions of the phases of production and studies requires additional explanation. SC&A, therefore, recommends presenting a timeline of these phases in conjunction with data types and availabilities, as well as data sources used in support of the TDB (McDowell-Boyer and Little 2004). The report was not clear if the definitions of the two phases in Section 4.2.1 are the same as in Section 4.2.2.

In addition, it seems that there is an overlap in the cutoff date (1992 and 1993) between the phases. No explanation was given for the basis of that overlap. In addition, the operational year in Section 4.2.1 was identified to have run until 1994, while Section 4.2.2 indicated that production ceased after 1992. SC&A recommends that these relationships be made clearer through the RFP operational and post-operational years.

5.9.6 Particle Size

The Occupational Environmental Dose TBD, Section 4.2.3 (McDowell-Boyer and Little, pg. 10), indicates that the estimated annual intake of $^{239+240}$Pu between 1953 and 1964 was based on atmospheric modeling described in Attachment 4A. During the period between 1953 and 1964, air monitoring results were not readily available. The report stated that the calculated intakes represented an average from six computational nodes in the industrial area of the site. The 50th and 95th percentile estimates were associated with particles less than 15 μm aerodynamic equivalent diameter (AED), which is an upper limit for respirable particles (Rood and Grogan 1999, pg. iv), as listed in Table 4-1. The report went on to state that this likely includes particles that are larger than those in International Commission on Radiological Protection ICRP 66 (ICRP 1994), which has a default respirable size of 5 μm Activity Median Aerodynamic Diameter (AMAD), and therefore, the use of the intakes in Table 4-1 is likely to be claimant favorable. On pages 37 and 38, Figures 4A-3 and 4A-4 predicted the annual average $^{239+240}$Pu concentrations in air as a function of time for particles less than 30 μm AED in the perimeter area surrounding the site.

The TBD (McDowell-Boyer and Little 2004) did not explain the relationship between the 15 μm AED and the 5 μm AMAD. The predictions and models dealt with particles less than 30 μm AED. The TBD should explain the terminology as it relates to AMAD and the differences in recommended particle sizes. Consideration should be given to the plutonium particle size and solubility as a result of releases from fires.

5.9.7 RATCHET Use is Suspect in the Vicinity of Closely Constructed Buildings

Page 28 of the occupational environmental dose TBD (McDowell-Boyer and Little 2004) explains the reasons for choosing the RATCHET model for deriving outdoor onsite exposures. The model can incorporate spatially varying meteorological and environmental parameters, and includes modules that perform random sampling of the meteorological parameters, allowing for Monte Carlo analysis of uncertainty. SC&A is concerned that the use of RATCHET for the onsite dispersion calculations at the RFP site, which is characterized by closely constructed buildings, would bias the results. The TBD, on page 30, cautioned about the reliability of the method by indicating that predicted average onsite concentrations might not adequately represent actual concentrations of interest, due to the large spatial variation in soil, and thus air contamination at the site.

Examination of Figure 4A-3 on page 37 highlights SC&A's concerns that average onsite monitoring data for the years from 1972 onward were higher than the 95th percentile values estimated using RATCHET. This could be expected because the main goal for RATCHET was offsite dispersion modeling. Near-field application of the code is not verified. Building heights in close proximity could produce an unexpected air flow affecting the results. A wind tunnel experiment to model the building wakes and air flows could be used to correct these problems. However, in the absence of such an experiment, the use of the peak measured value identified in Table 4-2 would be claimant favorable.

SC&A believes that a claimant-favorable approach is to use, in a prorated fashion, the maximum recorded data for the years that there were no data. Applying the maximum intake concentration as given in Table 4-2 in the occupational environmental dose TBD (McDowell-Boyer and Little 2004, pg. 17) to the pre-1965 period would be claimant favorable.

5.9.8 Need to Clarify if Maximum Estimates of Annual Intakes are Applied

It is not clear if the maximum or average estimates of annual intakes were applied in 1965–2002, and if the 50th percentile or the 95th percentile values in Table 4-1 were used for dose reconstruction.

In reference to work recently completed by the National Institute for Occupational Safety and Health (NIOSH) on the revised TBDs for Mallinckrodt and Bethlehem Steel, NIOSH has adopted the 95th percentile value from available data as the basis for filling in missing bioassay, air sampling, and external dosimetry data for claimants with missing data. This strategy represents a revision to previous strategies in which NIOSH often applied the entire distribution as a surrogate for missing data. As we have discussed in the past, we believe the latter approach can be characterized as claimant neutral, while the former approach appears to us to be more claimant favorable and more in keeping with the letter and intent of 42 CFR Part 82. As such, we believe that the "95th percentile" approach be adopted in this TBD (McDowell-Boyer and Little 2004) also.

5.10 ISSUE 10: OCCUPATIONAL MEDICAL DOSE

Section 3 of the RFP TBD for Occupational Medical Dose, ORAUT-TKBS-0011-3 (Furman and Lopez 2004), makes reference and draws rather heavily on prior documents regarding medical exposures at the Savannah River Plant (ORAU 2003), and uses ORAU 2003 and the ORAU-OTIB-0006, *Dose Reconstruction from Occupationally-Related Diagnostic X-ray Procedures* (Kathren and Shockley 2005), as a reasonable basis for assumptions regarding its estimation of worker medical exposures at the RFP. The SC&A review of the TBD recognizes the lack of data and formal protocols through the mid-1980s. One cannot attest to the completeness and accuracy of the data, but rather the review focused on the relevancy of assumptions derived from other site profiles and the TIB.

Preliminary dose estimations for occupational x-rays are derived principally from the research on radiation doses in diagnostic x-ray procedures (Lincoln and Gupton 1958), which evaluated abdominal and spine x-ray dosimetry at the ORNL. Additional calculation of dosimetry to other organs is derived from ICRP Report 34 (ICRP 1982) and NCRP Report 102 (NCRP 1989). This is an important issue in that doses for all sites are based upon this research and not any measurement of dose at the actual site using unknown protocols. NIOSH and its contractor (ORAU) have further assessed medical exposures at other DOE sites, and present their conclusions in summary in ORAUT-OTIB-0006, *Dose Reconstruction from Occupationally-Related Diagnostic X-ray Procedures*, recently published as Revision 3, dated August 2, 2005 (Kathren and Shockley 2005).

The TIB (Kathren and Shockley 2005) reasonably evaluates most parameters involved in assessing the potential medical exposure of DOE site workers. In reviewing the RFP occupational medical dose TBD (Furman and Lopez 2004), it is apparent that little, if any, written records remain to fully document medical exposure of workers during the peak years of 1950 to 1980, when most medical worker exposures occurred. Therefore, in an attempt to fill the gap in assessing medical exposures, the contractor applies the assumption in the TIB (Kathren and Shockley 2005) as its basis documentation.

Additionally, the contractor draws heavily on the NIOSH-OCAS (OCAS 2002a) guidelines to establish its assumptions regarding the magnitude of medical occupational exposures. Review of the subject TBD has resulted in a number of findings and supportive issues that are important for NIOSH to consider in order to ensure that the reconstructed doses are claimant favorable. These findings and issues are discussed below.

5.10.1 Guidelines Needed on What Constitutes Occupational Medical Exposure

The current guidelines, as presented in OCAS 2002a, go a long way in assuring that occupational medical exposures are included in determining the overall dose estimations for claimants. Unfortunately, interpretation of the guidelines has not necessarily been claimant favorable. The occupational medical dose TBD (Furman and Lopez 2004) assumes an interpretation which has been also considered and applied at other sites, such as the Savannah River Plant. To this extent, the assumption that medical procedures are limited to only one pre-employment and other

potential annual chest x-rays, as part of routine physical exams, may substantially underestimate worker medical exposure when evaluating the totality of occupational medical exposure.

In support documentation, ORAU-OTIB-0006, Revision 3, (Kathren and Shockley 2005), it is concluded that other examinations may be included, such as special job exams (e.g., respiratory protection, beryllium workers, asbestos workers, etc.) and termination exams. The occupational medical TBD (Furman and Lopez 2004) does not recognize this change in the TIB, and also incorrectly assumes that special chest radiography for respirator certification, beryllium and asbestos workers, and food handlers are accomplished as part of the annual physical. This is not documented in past medical protocols and often was performed separately at the request of the Health and Safety Department, up through the mid-1980s.

Another factor not discussed in the TBD is the possible use of x-ray procedures for special screenings, evaluating the result of injury and trauma, and the detection of embedded metallic radioactive materials associated with the milling and machining accidents that occurred with reasonable frequency.

The TBD (Furman and Lopez 2004) makes the conclusion that one to two chest exams per year are probably limited to a small fraction of high-risk workers. To the contrary, there is ample evidence that chest x-rays were provided on a voluntary basis to nearly all workers, as part of the annual physical at a minimum. The majority of workers had routine chest x-rays at DOE sites until the mid-1980s, when Federal guidelines warning against routine screening were first being enforced.

Discussions with NIOSH personnel revealed that it was their decision to limit occupational medical exposure to those exams described above, and to assign all other exposures as part of worker background.

SC&A believes that it is not claimant favorable to limit occupational medical exams to one or two chest x-rays annually, unless medical records and protocols clearly limit the use of radiography to a small fraction of workers, which was not the case up to the mid-1980s.

5.10.2 Potential for Other Types of X-ray Exposures

The occupational medical TBD (Furman and Lopez 2004) does not address the potential use of other forms of diagnostic radiography to support medical injury diagnosis. This may involve use of isotopes, sealed sources, etc. The TBD is also deficient in that it does little to catalog the number, types of x-ray equipment, frequency of use, etc. Little information exists regarding protocols to govern the utilization of x-ray units.

The occupational medical TBD (Furman and Lopez 2004) discusses medical x-ray exposure as being chest radiography. In the case of chest radiography, it assumes generally accepted protocols as the norm, with little evidence of rigor or protocols being applied prior to 1985. The TBD provides no documentation to support the assumption that units were routinely calibrated and maintained. The TBD concedes that no attempt to calibrate or measure output of x-ray

equipment occurred prior to 2001. Rather, the protocols to supplant dose calculations are derived from historic and very controlled studies performed to support dosimetry presented in ICRP 34 (1982) and NCRP 102 (1989).

The less than average performance at the RFP to perform routine and preventative maintenance during the 1950 to 1980 timeframe suggests that routine maintenance of x-ray units is not likely, unless performed by an outside contractor. Unfortunately, no records exist to evidence maintenance, calibrations, etc. The lack of defined protocols and basis for approval of radiography procedures suggests that the use of radiography was not closely controlled. The occupational medical TBD (Furman and Lopez 2004) does not discuss the use of portable radiography to perform screenings and the potential for exposure of medical personnel or other workers without dosimetry devices being utilized. This is potentially an issue for the PFG unit, which was often van-mounted at other sites. Additionally, the TBD fails to document that available x-ray units were not operated at greater than 80–90 kVp.

The TBD (Furman and Lopez 2004) does little to document the variety of medical occupational exposures, the type of equipment, and the type of maintenance performed. In light of this, there is a need to reconsider the approach for reconstructing medical radiation exposures.

5.10.3 Frequency and Types of X-ray Exposure is Derived from Other Sites

The occupational medical TBD (Furman and Lopez 2004) relies on assumptions of x-ray frequency derived from other DOE sites. The assumption of one to two chest radiographs per year is not reasonably conservative, in that workers could essentially request an x-ray. The frequency of screenings and the numbers and types of workers receiving x-rays varied from site to site.

The occupational medical TBD (Furman and Lopez 2004) provides no documentation or references to support the assumption that only a limited group of workers received annual x-ray exams. To the contrary, up until about 1985, most DOE sites performed chest x-rays on a voluntary basis. DOE medical program reviews documented during the early 1990s showed many sites still used chest radiography as a general screening exam. Most workers accepted chest x-rays, even though the job did not require it. Also, the assumption that workers in special exposure categories, such as beryllium workers, were given chest x-rays only as part of their annual physical is not documented.

The occupational medical TBD (Furman and Lopez) does document that photofluorography (PFG) units were available from 1953–1968. The presence of PFG units at the RFP for nearly 20 years suggests their potential heavy utilization, far more than any other DOE site. The PFG unit also provides a dose to the worker greater by a factor of 5–6 than that delivered by conventional radiography.

Also, the ORAU-OTIB-0006 (Kathren and Shockley 2005), upon which the TBD relies heavily, uses retake rates that average about 3%. The study referenced was based upon a large metropolitan hospital using highly trained technicians and well-maintained x-ray and processing

units. A comparison review of Federal facilities, such as by the Department of Defense (DOD) during the 1970s using lesser-trained technicians (Federal regulations did not require technician certification), showed that retakes sometimes ran up to 30% for abdominal exams and often over 15% for chest radiography. Although the PFG, by design, is less likely to require retakes, it is inherently much more dose-intensive.

5.10.4 The Determination of Machine and Technician Uncertainties

The occupational medical TBD (Furman and Lopez 2004) provides little documentation to support the assumed techniques and protocols applied to calculate the dose, which is mainly derived from ORAU-OTIB-0006, Revision 3 (Kathren and Shockley 2005). Additionally, the TBD does not address the potential impact of associated uncertainties, nor does it provide documentation to warrant its assumption that multiplication of estimated doses by a factor of 1.3 is claimant favorable.

The occupational medical TBD (Furman and Lopez 2004) is deficient in that little documentation exists to validate x-ray protocols, equipment maintenance and upkeep records prior to 2001. The TBD uses information derived from the Savannah River Site review (ORAU 2003) and from Kathren and Shockley (2005) to estimate dose impacts. Further dose estimations are seemingly derived from a study performed by Lincoln and Gupton (1958) at ORNL. That study was limited to abdominal and spine x-ray procedures, using vastly different x-ray equipment, which could substantially impact dose calculations. Actual organ doses are derived from ICPP 34 (1982) and NCRP 102 (1989), and are not reflective of equipment and protocols used at the RFP during 1950–1975.

The TBD estimates an "uncertainty factor" of 30% to account for variability in machine output, due to fluctuations in voltage, amperage, and timer accuracy; however, other factors that contribute to uncertainty are overlooked. For example, contributions due to technician errors (i.e., wrong techniques, improper machine settings, etc.) all contribute to overall uncertainty related to dose calculations. In an attempt to corroborate, Dr. John Mauro, in a private communication with the New Jersey Department of Radiation Control, found the following information regarding overall uncertainty in x-ray machine output (Mauro 2005). Using established protocols, New Jersey reported that the entry skin exposure (ESE) for chest examinations from nearly 500 units over a 3-year period varied by up to 2 orders of magnitude, and that the standard deviation often exceeded the mean ESE in that study. Given that the New Jersey assessment involved improved technically enhanced x-ray equipment, and followed an established protocol, we believe that application of the 1.3 uncertainty factor in the TBD is not reasonable and does not assure the dose determination is claimant favorable.

The occupational medical TBD (Furman and Lopez 2004) does document that photofluorography (PFG) units were available to be used at that site for nearly 20 years. PFG units were not considered when organ dose calculations were documented in ICRP 34 (1992) and NCRP 102 (1989), which forms the basis for organ dose calculations presented in the TBD document. Kathren in the ORAU-OTIB-0006 does set an exposure of 3 rem per PFG exam,

which is considered reasonable. Therefore, NIOSH should assure that all chest exposures prior to 1964 are based upon a 3 rem estimate.

Also, the occupational medical TBD (Furman and Lopez 2004) does not consider the importance of processor maintenance, and the impact it may have on retake rates and diagnostic quality of the exam. Improper processor maintenance will also appreciably affect the overall dose uncertainty.

5.10.5 Use of Screens, Grids, and Impact of Off-Site Medical X-rays are Not Considered

Finally, the occupational medical TBD (Furman and Lopez 2004) does not consider dose impacts due to less than optimal use of technology, such as using screens, grids, or bucky systems. The TBD does not also consider off-site medical exposure, as part of worker exposure.

The occupational medical TBD (Furman and Lopez 2004) does not show that the RFP applied dose minimization principles to reduce medical exposures. The document also does not assess or consider the likely exposure to workers who are referred to off-site medical facilities for follow-up. The TBD states that review of selected medical records and files did not reasonably show or match expected x-ray exam frequency, and type of exam. Little evidence exists to document the number of x-ray exams provided to the average worker or for special exposure needs.

5.11 ISSUE 11: COMPLETENESS AND ADEQUACY OF DATA FOR DOSE RECONSTRUCTION

A considerable amount of evidence exists that there is a potential for missed occupational external, internal, and environmental dose due to the completeness and quality of data being used in dose reconstruction. These missed doses may have occurred as a result of incomplete monitoring records and inadequate monitoring techniques. There may also be a data integrity issue associated with the external dose record.

5.11.1 General

Based on the conference calls with the TBD authors, NIOSH is in the process of updating their dose reconstruction methodologies and assumptions to address a number of issues, including the following:

(1) Developing a technical information bulletin to provide direction on the use of NDRP data

(2) Acquiring the Rocky Flats Job-Exposure Matrix put together by Dr. Ruttenber for use in determining co-worker doses

(3) Developing a technical information bulletin dealing with dose calculations from high-fired oxides

(4) Considering the inclusion of additional incident reports in the site description

Although these revisions to the TBD are in progress, the following review of the external dosimetry program is included in our review to serve as a baseline against which to evaluate future revisions of the TBD.

5.11.2 Completeness of External Exposure Data

Many of the inadequacies with external radiation monitoring at the RFP in the early years (i.e., 1951 through the early 1960s) was because of the general belief at that time that there would not be a great deal of external radiation hazards associated with the operations at the RFP (Putzier 1982). Based on this belief, external monitoring of workers was limited to workers who were judged to have the potential to experience 10% of the radiation protection guide (RPG) at that time. Furthermore, implementation of this external radiation monitoring strategy was hampered by the inaccuracy of radiation monitoring instruments and the lack of radiation surveys in some areas. The GAO report elaborated on calibration issues at RFP (GAO 1988), as follows:

> *The TSAs found that procedures for calibrating radiation monitoring instruments were weak and poorly documented. The accuracy of instruments is important to ensure that workers and the public are not exposed to unnecessary levels of radiation. Problems included using different calibration techniques in different buildings and not testing instruments with appropriate radiation sources.*

Without appropriately calibrated instrumentation, uncertainty is introduced as to whether the health physics program was effectively identifying those individuals with the potential to experience greater than 10% of the RPG. For example, the plutonium metal (foundry) workers in Building 771 were not monitored for whole body, penetrating gamma radiation and x-ray doses until February 1957. Instead, they were issued only a wrist dosimeter (Falk et al. 2005).

From 1953 to 1970, film dosimeters were used to monitor both whole-body and wrist exposures. Only certain groups of workers were issued dosimeters until 1964. By 1964, dosimeters were incorporated into the security badges of all employees at RFP (Inkret).

The DNFSB has expressed a concern regarding Building 771 that personnel outside the immediate area may have been exposed to radiation without the benefit of monitoring.

> *The staff noted that a potential existed for workers to be exposed to radiation without being monitored in accordance with the Radiological Control Manual (RCM) and DOE Order 5480.11. In discussions with Building 771 personnel, it was noted that the Thermoluminescent Dosimeter (TLD) badge storage rack was being evaluated to determine the amount of radiation the dosimeters were exposed to while hanging on the rack. This evaluation was being accomplished as a result of RFP personnel noting that two TLDs that hung on the rack for six months had received approximately 300 mrem. The DNFSB staff questioned whether any unmonitored workers had spent a significant amount of the workday in the area. RFP personnel noted that a guard station was adjacent to the area, and that the guards were not required to wear dosimeters on a routine basis. The*

> *radiation level in the guard area was not known at the time of the review, and was to be determined. If the radiation level in the guard's post is similar to that at the TLD storage board, exposure of guards to ionizing radiation may exceed the 100 mrem per year limit for those who are not monitored.* (DNFSB 1993)

As a result of the lack of external monitoring in some worker populations, there is a potential for missed beta/gamma dose.

Lack of neutron monitoring also introduced gaps in the monitoring data. Prior to 1957, 10–18 individuals involved in final assembly operations received neutron dosimeters. In 1957, a Los Alamos National Laboratory scientist discovered the substantial neutron exposure associated with the fluorination process. Starting in the period between 1959 and 1960, everyone working in Building 771 was monitored for exposure to neutrons. In other areas at RFP, where the gamma component of external dose equivalent exceeded certain criteria, individuals were also monitored for exposure to neutrons (Inkret). With respect to neutron monitoring, GAO stated the following:

> *When there was initial concern in the mid 1950's that personnel at Rocky Flats were receiving neutron exposure above 10% of the allowable standard (5 rem per year at the time), neutron track plates and/or later NTA film were assigned to some personnel depending on their work locations. These early efforts to identify potential neutron exposure problems were not well explored (Baker 2002).*

Some of the highest exposed individuals were not monitored during their early work in fluorination and metallurgy processes. The Neutron Dose Reconstruction Protocol has reassessed neutron doses (Falk et al. 2005). NIOSH/ORAU has received these data and is in the process of developing a technical information bulletin on how to incorporate these data into the dose reconstruction process.

Even as late as the 1990s, RFP had not established a procedure for identifying the workers that required extremity monitoring. The responsibility for assigning secondary dosimeters, which were not in common use until later, and extremity dosimetry was the responsibility of the field radiological control organization. There were no consistent criteria for determining who received extremity dosimetry (DNFSB 1993). Also, the capability for monitoring neutrons to the extremities was not available until 1972 (Baker 2002).

Where dosimetry data is available, the dose reconstructors used dosimeter measurements. The TBD divides unmonitored workers into production and non-production workers. ORAUT-TKBS-0011-6 (Langsted 2004) instructs the dose reconstructor to assign a missed dose of 600 mrem per year (5% of the annual Radiation Protection Guideline), or 1.2 rem per year at the upper 95% confidence level for unmonitored individuals in the production areas (pg. 42). For those individuals who worked outside the production areas, an environmental dose was assigned (pg. 43). With respect to extremity doses, the TBD states (pg. 43):

> *Additional information on these dosimeters will be required for dose reconstruction for shallow dose to the extremity, if necessary.*

There is no methodology for assigning missed extremity dose. This is especially true when there was no method for neutron extremity monitoring.

In order to assess the methodologies used above, it is necessary to know the job title, work location, and tasks an individual was involved in during a particular year. Those individuals without dosimeter data (i.e., during years when dosimetry was not paired with security badges) must be carefully evaluated to ensure there was not a potential for occupational exposure (e.g., exposure from duct work). For those individuals **not entering any** radiological areas and having no monitoring data, the approach of assigning environmental dose is appropriate assuming these doses take into account all potential modes of exposure and appropriate data.

NIOSH/ORAU indicated that the scope of the NDRP was to reevaluate the available films and reassess the dose for those individuals only. The scope did not include other workers, such as uranium workers and workers who were not monitored with neutron film (see Attachment 4). The NDRP data will allow dose reconstructors to assign missed neutron doses for those workers included in the study; however, no methodology has been developed for uranium workers potentially exposed to neutrons, or production and support personnel who entered the plutonium production area but were not provided neutron monitoring (e.g., company auditors). Missed neutron dose has not been assigned in all non-compensable cases where maximizing assumptions apply. Specifically, a review of a few non-compensable cases on the NIOSH Occupational Claims Tracking System (NOCTS) database indicates that neutron dose was not applied in some cases where claimants worked in plutonium areas. This indicates inadequate guidance in the TBD and other supporting documents for application of missed neutron dose, at least in maximum dose cases that are estimated to be non-compensable. The TBD should investigate the completeness of the NDRP for assignment of missed neutron dose with respect to all potentially exposed workers. Clear direction should be provided on when to assign missed neutron dose.

5.11.3 Completeness of Internal Monitoring Data

The incompleteness of data was not limited to external monitoring. There was some inconsistency in the internal monitoring program as well. In a review of the RFP bioassay program, the DNFSB identified a potential for missed internal dose as a result of not collecting bioassay data, as follows (DNFSB 1994):

> *Additionally, it was not apparent to the DNFSB staff that the program encompasses all applicable personnel. For example, EG&G personnel described that the program's data base is derived from the list of personnel trained on site, and would not track visiting workers. In this case, EG&G personnel explained that it would be a sponsors responsibility to see that the bioassay had been accomplished.*

Even when a routine internal monitoring program was in place, there was no mechanism to ensure that workers and subcontractors were submitting timely bioassay samples. The DNFSB noted the RFP had a significant number of bioassay delinquencies that may have led to missed internal dose.

> *The discussions did not make clear how contractors are included in the bioassay program. For example, when asked about other subcontractors, RFP personnel indicated that contractors may come and go and not be bioassayed. A deliberate delinquency tracking system does not exist, but delinquencies are identified by other means.* (DNFSB 1993)

Furthermore,

> *For example, EG&G personnel identified that the bioassay delinquency rate is 10 to 12 percent, and that some delinquencies durations are at a point where analysis sensitivity may be impacted. EG&G personnel noted that the program has not been fully effective because the procedure has only recently been promulgated. The DNFSB staff believes that these delinquencies may be undermining the effectiveness of the program, and dose may be missed.* (DNFSB 1994)

In the case of an unmonitored worker, there are several techniques used by the TBD to assign dose. To calculate internal dose for workers not involved in an incident, the internal TBD provides the following guidance (Falk 2004):

> *The suggested approach is to estimate the time spent by the worker in a building involved in a radionuclide of interest and credit the worker with a chronic intake at an arbitrary fraction of the inplant guide (or official limit), whichever is more claimant favorable.*

To calculate internal dose for workers involved in an incident, the internal TBD provides the following instructions.

> *Claims files may include event-specific data that should be used to reconstruct internal dose. When such data is not available default assumptions may be made.*

In the case of an unmonitored worker not involved in an incident but having access to radiological areas, it is not clear whether the method outlined is bounding. Information, such as job title, work location, skill or task, time spent in an area, and radionuclides of concern are not readily available and would have to be evaluated for the particular individual. The process for assigning dose to an individual in multiple job locations would further complicate the matter. In the case of an incidental exposure, not collecting samples in a timely manner may prevent dosimetry from collecting needed follow-up samples, or render bioassay techniques ineffective (e.g., insoluble plutonium).

In summary, there is partial or complete absence of records for many former workers, visitors, and subcontractors. As a result, this requires careful consideration of an individual's job title, work location, radionuclides of concern, and acute or chronic exposure potential. These people include those likely exposed to radiation and those who may have no exposure potential.

5.11.4 Dosimetry Files

A review of several Rocky Flats Plant Personnel Dosimetry files has led to some observations related to completeness of records provided to NIOSH/ORAU.

- Although annual summary information is available, the quarterly dosimeter results are absent from each of eight files reviewed for 1970.

- The dosimeter was coupled with the security badge from 1964 through early-1990s (Langsted 2004, Vol. 6, pg. 18). Despite this, blank records were observed in at least two cases for the post-1964 period (see also discussion below).

- If everyone was badged over this period of time, there should not be blank records – that is records containing no data whatsoever, not even a zero—in the file of a monitored worker. It appears to have been the general practice to record a zero when the dose was below the detection limit, for instance. SC&A has found that, in the 1950s, individual dose records entitled *Health Physics External Exposure Activity Run* explicitly explained zeros and blanks as follows:

  > *A zero indicates a "0" dose received.*
  > *A blank indicates that no film badge was worn.*

  If this interpretation is valid for the post-1964 period, the following issues may be raised:

- Blank records for monitored workers appear to be problematic and in need of explicit guidance for interpretation and dose estimation. An inquiry into the reason(s) for the blank records would also appear to be warranted, especially in view of the concerns regarding data integrity discussed below.

- Doses for subcontractors may be incomplete or absent. Interviews indicate that these individuals were monitored; however, no monitoring records were located.

- Gaps exist in individual records, and there is no explanation for the absence of data. This included gaps for the year 1969 when one of the major fires occurred at the site.

- There are records where individuals had positive bioassay samples, yet there was no indication of an incident or personnel contamination in the file.

With single or multiple year gaps occurring in records, especially for support and maintenance personnel, many personnel dosimetry files appear to be incomplete. The absence of these records should be investigated.

Dose reconstruction guidance concerning the handling of contaminated, lost, damaged, or unreturned badges is not addressed in the site profile. When dosimeters became contaminated, they were either decontaminated or replaced with new dosimeters. According to health physics, when a dosimeter was too contaminated to be processed, a dose was estimated based on previous dose history or co-worker data. SC&A has not been able to locate any investigation reports as a result of contaminated badges in Rocky Flats dosimetry files.

5.11.5 Data Integrity Concerns

5.11.5.1 Zero Recorded Doses

When dosimeters were lost or not returned, radiological control was to perform an investigation and assign an estimated dose (see Attachment 2). In testimony to the Congress, the following was stated (HCEC 1994):

> *Mr. Schaefer: If a dosimeter was not returned, should an estimate of the exposure to radiation have been made? What's the result of not making that?*
>
> *Mr. Wells: Well, we think perhaps an estimate that would have been included would have certainly been better than to report zero exposure. And we pointed that out in our most recent report. And DOE is taking a look at that as to ways to correct their existing procedures, and that would include providing better estimates of what might have taken place.*

The assignment of zeros or nothing in lieu of an actual estimated exposure for lost, contaminated, damaged or overexposed film would result in the dose reconstructor assigning a missed dose which may or may not reflect the actual exposure received. In cases where secondary dosimeters were used (not common until later years), this value could provide information on the actual dose. Also, radiological survey data, timekeeping data, and co-worker data can also provide a basis for estimate or validation of the missed dose method.

Workers indicate that the dose reported to them included entries stating "No Current Data Available." Workers receiving this dose notation were commonly in jobs that were associated with higher radiation exposure (e.g., chemical operators, NDA support) (see Attachment 2). A Rockwell memorandum from Roger Falk of the Health Physics Department explaining the annual employees radiation exposure reports, which was apparently an official routine cover memo accompanying workers' dosimetry used for an undetermined period of time, the following statement was made (Falk 1987):

> *A 0 (zero) is recorded for any of the following conditions:*
>
> *1) no exposure received*
> *2) the exposure was so small it cannot be measured by our current methods*
> *3) no data is available to make this assessment.*

An inquiry was made of the author during a conference call with NIOSH in regards to the meaning of "no data is available to make this assessment." Clarification on this issue was not provided (see Attachment 4). Item 3 in the quote above validates the GAO testimony that zeros were entered when no data were available, including the specific instance when the data were lacking because the worker did not turn in the badge.

The practice of recording zeros when badges were not turned in raises questions about the integrity of the external dose record. An analysis of the frequency of this practice and the period(s) over which it occurred is essential. This is especially important since workers report that exceeding the quarterly limit would result in a downgrading of work assignment or even a layoff. This appears to be similar to a problem that existed NTS for some time (Hacker 1994). Under such conditions, it is possible that doses were above the quarterly limit. How frequent such a practice might have been, and its implications for the integrity of the external dose record will take considerable analysis of dose records, job types, and area radiation data, coupled with detailed worker interviews (including retired worker interviews). Since the practice of recording zeros when badges were not turned in was reported by GAO as late as 1994, the entire period of Rocky Flats operation, as well as at least part of the post-production environmental remediation period, should be examined. The records of all or some production workers, guards, maintenance personnel, and other job types with potential for exposure to radiation who were monitored and have zeros in their records may be open to question until this question is resolved.

In the case of a zero dose, the dose reconstructors are to estimate the number of zeros based on the dose level and the exposure limits for the year in question. The missed dose methodology for recorded zero doses assumes that individuals did not exceed the Radiation Protection Guideline. This may not always be a claimant favorable. Dow Chemical (1968) indicated in a report discussing radiation problems with plutonium fabrication operations that eighty-seven of the plant's 1,200 plutonium production workers received penetrating radiation doses exceeding the AEC's 5 rem standard in 1966. Dow traced most of the problems to production changes that enabled the plant to make more nuclear bombs. In 1967, the plant reported eighty-eight worker exposures in excess of 5 rem. Rockwell International (1987) confirmed these numbers in a report on radiation exposures to Rockwell employees. The dose reconstructor should take this possibility into consideration, especially for those working in special projects, such as ^{241}Am purification and ZPPR fuel.

5.11.5.2 Blank Records

The dosimeter was coupled with the security badge from 1964 through early-1990s, according to the TBD:

> *The use of dosimetry expanded to other RFP production operations. In 1964, the security badge was incorporated in the dosimetry badge, which ensured that each individual wore a dosimetry badge* (Langsted 2004, Vol. 6, pg. 18).

If everyone was badged after 1964, there should be no blank records in the files of workers, especially since it was the general practice to record a zero when the dose was below the

detection limit. SC&A has found that blank records may indicate no monitoring at all. In the 1950s, individual dose records entitled *Health Physics External Exposure Activity Run* explicitly explained zeros and blanks as follows:

> *A zero indicates a "0" dose received.*
> *A blank indicates that no film badge was worn.*

It is unclear whether such an explanation would have been retained in the post-1964 period, when all personnel entering the site were provided with an integrated ID-dosimeter. Hence, the existence of blank records for monitored workers appears to be problematic and in need of explicit guidance for interpretation and dose estimation. An inquiry into the reason(s) for the blank records would also appear to be warranted, both as an issue that is relevant for dose reconstruction and for data integrity in the post-1964 period. This inquiry should include the following:

- Whether all personnel wore an integrated ID-dosimeter badge after 1964 and, if not, what the criteria for issuing only an ID badge might have been

- The criteria for and circumstances in which no entry, not even a zero entry, was made into dose record

5.11.6 Additional Issues Pertinent to External and Internal Dose Reconstruction

There are a number of issues associated with the quality of the radiation monitoring and environmental data that may influence dose reconstruction. The issues include the following:

- Dosimetry algorithms, calibrations, and practices were problematic for some periods of operations

- Inadequate bioassay techniques existed for the type of radioactive material present in some facilities

- Inconsistent directions were provided by health physics staff

- Environmental monitoring techniques for airborne releases were questionable

5.11.6.1 External Dose Reconstruction Issues

One of the issues that raise questions about the adequacy of the external dosimetry records at Rocky Flats has to deal with external exposures to the low energy photons associated with ^{241}Am, as evidenced by the following:

> *As I became more aware of radiation properties of plutonium, and also as 241 americium became more prevalent, it became obvious to me that the simple Oak Ridge badge was inadequate* (Putzier 1982).

Even in later years, concerns were expressed regarding the adequacy of the external dosimetry calibration program at the RFP. In testimony to the House Committee on Energy and Commerce (HCEC 1994), the GAO was asked whether there were problems with monitoring at Rocky Flats that could have led to undetected radiation releases. The witness Jim Wells of the GAO stated:

> *Mr. Schaefer: That is very good. I'm glad we did that. You're testimony on page 2 describes problems with monitoring and sampling of air to detect radiation releases at Rocky Flat in 1988. What effect would such problems have had? Could the problem have related to undetected radiation releases?*
>
> *Mr. Wells: I think the answer would be, it's possible, because they were unknown in terms of what actually was out there in the air and how much was being ingested by the workers. The actual dosimetry devices, the program that existed to calibrate equipment to even tell if the correct dose had been received, were not fully functional and operating.*
>
> *And, as the chairman pointed out in his opening statement, they were doing all kinds of mathematical adjustments for the exposure doses, some of which were so artificial it ended up with negative exposure, so the potential is there and they could have but no one knows.*
>
> *Mr. Schaefer: I understand that there were calibration problems. Does that mean that workers could have been exposed to radiation and not realized it?*
>
> *Mr. Wells: What that meant was the device that they had pinned on them, that provided a reading at the end of the day or whenever it was measured, there was no assurance that it was reading high, or low, or reading at all. That's what a lack of calibration program means.*

In a safety audit conducted in 1986, on the external dosimetry program, there were several findings related to quality control procedures and calibrations (Rockwell International 1986).

> *There is no formal verification of accuracy of dosimeter results for field conditions.*
>
> *New instruments and dosimeters are not acceptance tested using beta, photon and neutron radiation sources according to their intended field use.*
>
> *Instrument and dosimeter response is not characterized for radiation types and energies present in the work environment.*

In addition to calibration issues, there were issues associated with dosimeter algorithms. The DNFSB indicated in a 1993 review:

> *RFP personnel noted that the Whole Body Dosimeter Program passed the DOE Laboratory Accreditation Program (DOELAP) in 1990, and that the accreditation certificate was received in October 1991. RFP noted that the program's algorithm has been changed since the last accreditation, and that a wrong correction factor may have been applied in the case of the K17 dosimeter chip.* (DNFSB 1993)

The external TBD indicated that film dosimeters required a work-place specific calibration factor. Since this was the case the Dosimetry Department had to know the facility in which the individual worked (Langsted 2004, pg. 19). This approach to calibration could be problematic for workers whose job took them into various areas of the plant (e.g., security guards, auditors, engineers, maintenance, etc.) Some discussion on the impact of using the incorrect calibration factor should be included and adjustments made to the uncertainty, as necessary.

There is some evidence of unauthorized practices by RFP personnel. Individuals apparently overexposed their badges on purpose (e.g., putting the badge in the glove or on a waste container) to get out of working in a particular area. As a result of this practice, individuals who actually received high doses were accused of overexposing their badges and were in some cases disciplined. In order to protect themselves from disciplinary action and/or ensure they were eligible for overtime, individuals would leave dosimeters in their lockers or put them in their back pockets (see Attachment 2).

In a 1988 review by the GAO, the apparent complacent attitude towards safety was addressed.

> *Worker attention to radiological protection needs to be increased. According to the TSAs, workers have been observed handling contaminated items without surgical gloves, not surveying themselves for contamination, and improperly wearing dosimeters (badges used to measure exposure to radiation.)* (GAO 1988)

Improperly worn dosimeters will affect the dosimeter response. Given that not wearing a dosimeter or wearing it incorrectly (e.g., in back pocket) can influence the response of the dosimeter, the relative difference between default assumptions and actual field conditions should be considered and appropriate correction factors determined. Also, the site profile assumes an exposure geometry based on the fraction of time an individual is working hands-on with material. NIOSH/ORAU need to verify these values with workers and expand the work categories to include all types of workers. During site expert interviews, many of the site experts disagreed with the amount of hands-on time NIOSH/ORAU had assigned to their job title. In other situations it was not clear which category a worker fit into.

In a 1992 draft of the RFP external dosimetry procedure, workers using lead aprons were directed to wear their dosimeters outside and in contact with the apron (RFP 1992). In the Rockwell Health and Safety Manual (RFP 1988), workers were directed to wear their dosimeter under their aprons. The details of which practice was observed could influence the determination of photon dose to exposed portions of the body. The TBD should make a claimant-favorable assumption with regard to dosimeter response and wearing lead aprons.

5.11.6.2 Internal Dose Reconstruction Issues Related to the Inhalation of Plutonium

High-fired plutonium oxide (often referred to as Type Super S) existed in the workplace as a result of both production activities and fires. The early bioassay program utilized urinalysis to detect intakes of plutonium. In 1964, a lung counter was put into operation. Lung counts were initially used in incident response starting in 1964. It was not until the 1970s that production workers were put on a routine lung count. There were some individuals onsite who did not receive a lung count until the 1980s. Fecal sampling was done only if an individual was involved in an incident.

Urinary excretion does not provide an effective method for detecting Type S or Type Super S plutonium using the methodologies employed in the early years of RFP operations. At that time, the lower limits of detection of plutonium in urine were poor, and large quantities of Type S and Type Super S plutonium could have been inhaled (both chronically and acutely) and not have been detected in urine.

If there is sufficient ^{241}Am in-growth in the product inhaled, it is possible that the ^{241}Am can be detected during a lung count and used to derive the amount of plutonium inhaled. However, if the amount of ^{241}Am inhaled, relative to ^{239}Pu, is not known, or if the inhaled plutonium does not contain detectable levels of ^{241}Am, this method of estimating the lung burden of plutonium could be misleading.

With the different forms of plutonium present at the facility, urine, fecal, and lung counts in combination were needed to effectively identify potential intakes. The greatest uncertainty in missed dose is likely for workers who only participated in the urine bioassay program. This was the case for all workers prior to 1964. There are situations where individuals could have received uptakes, but their bioassay results were recorded as background or less than the detection level.

SC&A investigated the potential importance of this issue by back-calculating the doses to the organs of the respiratory tract that might be associated with levels of plutonium in urine that are at the lower limits of detection for plutonium. We have determined that, depending on the assumptions used to model the retention of Type S and Type Super S plutonium in the body, the doses to the respiratory tract could differ by over an order of magnitude. **However, no matter what assumptions are used to derive the doses to the respiratory tract from either Type S or Type Super S plutonium, even at the minimum detectable levels of plutonium in urine, the doses to the respiratory tract are extremely high.** For organs other than those of the respiratory tract, the assumption that the inhaled plutonium is Type S, when in fact it might have been Type Super S, will result in a significant overestimate of the doses to those organs.

As discussed earlier, SC&A has concerns regarding the methods used to derive the MDA for plutonium in urine and the assumptions used by dose reconstructors for deriving doses for workers when the urine bioassay records indicate zero or background. These concerns are important for reconstructing the doses to organs other than the respiratory tract because, depending on the assumptions employed, the doses to those organs can differ by more than an

order of magnitude and in a dose range that could be significant in terms of the associated probability of causation. This issue is not as important when deriving the doses to the respiratory tract based on urine analysis data because, no matter what assumptions are employed regarding the MDA, the doses to the respiratory tract are extremely large and are likely to result in a high probability of causation. We believe that these are important issues that need to be more thoroughly explored and discussed in the TBD.

Many of the issues associated with urine bioassays for plutonium were resolved with the institution of lung counting as a means for estimating the lung burden of plutonium in workers based on the amount of ^{241}Am detected by the lung count. However, there are some issues in regard to the adequacy of the record in relation to the use of ^{241}Am measurements for determining plutonium intake. Weapons grade plutonium, when it is first used to manufacture weapons, inevitably contains a certain amount of ^{241}Pu, with the amount dependent on the irradiation level of the fuel. Over time, the ^{241}Pu decays into ^{241}Am with a half-life of 14.4 years. If the warhead is then dismantled and the plutonium purified to remove ^{241}Am, the workers downstream of that location would have *very different chest or body counts compared to workers upstream for the same level of Pu intake*. Further, even after some time, the levels of ^{241}Am will be low compared to fresh plutonium that has aged, because the amount of ^{241}Pu in plutonium that has been subject to ^{241}Am removal after the return of a weapon would be much lower than in plutonium straight from the reprocessing plant. Hence, estimating worker Pu intake requires not only a measurement of ^{241}Am and knowledge of the age of the plutonium, it also requires a history of how many times the plutonium has been processed for ^{241}Am removal after first fabrication into a weapon.

NIOSH should ensure that the appropriate records are available for determining Pu intake from ^{241}Am whole-body or lung-counting data for the individual worker for whom the dose reconstruction is being done.

Internal Dose Reconstruction Issues Related to Exposures to Radionuclides Other Than Plutonium

With respect to radionuclides of concern, ORAUT-TKBS-0011-5 (Falk 2004, pg. 7) states the following:

> *Workers at Rocky Flats had the potential to receive intakes of plutonium, americium, enriched uranium, depleted uranium, and tritium, as well as other radionuclides. …Site-specific internal dosimetry information for other radionuclides, such as thorium, curium and neptunium, is rare or not available.*

Although thorium, curium, neptunium, ^{233}U, ^{238}Pu, and fission products have been identified as production and/or waste products, there is no method discussed for calculating dose from uptakes of these radionuclides. There is limited information on bioassay techniques for these radionuclides and in some cases no discussion. The TBD does not discuss how potential exposures to these radionuclides are considered in internal dose calculations.

ORAUT-TKBS-0011-4 (McDowell-Boyer and Little 2004, pg. 11) states the following:

> *Table 4-2 lists estimated annual intakes of ^{239,240}Pu and ^{241}Am between 1965-2002. The average values for $^{239/240}$Pu in this table are based on measured concentrations, typically near the 903 Area after 1970 because concentrations are more often reported for samples in that area and not for samplers in other RFP areas. Therefore, the average values are inherently claimant-favorable when used as an average in the industrial area.*

The data collected to monitor airborne environmental releases were deficient. In 1989, DOE conducted an assessment on the environmental conditions at the RFP. The report noted deficiencies in the effluent air monitoring program (DOE 1989).

> *Deficiencies in Rocky Flats Plant (RFP) effluent air monitoring program may adversely affect determination of radioactive materials released to the atmosphere.*
>
> *There are deficiencies in the ambient air monitoring program for radionuclides. As a consequence, the accuracy of measured concentrations of plutonium in ambient air are questionable. These data are reported monthly and annually, and are used in calculating annual radiation dose to the public to confirm dose calculations that are made based on radioactive effluent emission data.*
>
> *The RFP does not analyze ambient air samples for americium-241. For preparing the dose assessments, it is assumed that the americium-241 activity is 20 percent of the alpha-emitting plutonium activity because this is the maximum americium-to-plutonium ratio that may be present in RFP plutonium from the decay of plutonium-241. However, it is not clear that this assumption is valid because some processes at the RFP separate plutonium and americium and the latter may be released independently of the former.*
>
> *The ambient air monitoring samples are not analyzed for uranium.*

Furthermore, DOE performed an assessment on Building 559 indicating that the site continued having problems with ambient air monitoring (DOE 1991).

> *Releases of radionuclides from Building 559 through Building 561 were not measured accurately or with confidence by environmental monitoring personnel. The configuration of sampling equipment and the flow rates through the air sample filter did not permit concentrations of radioactive material in effluent air to be accurately measured. Thus, conformance with appropriate DOE and EPA requirements could not be demonstrated with confidence.*

Since the TBD relies heavily on environmental air monitoring data, the impact of air sample deficiencies on environmental release should be investigated.

5.11.6.3 Summary

In summary, there are a number of issues related to external and internal dosimetry and data integrity that need to be disclosed and more thoroughly explored in the TBD, including the following:

(1) The validity and integrity of external dose records appear to be affected by one or more of the following: inappropriate algorithms, calibration issues, placement of dosimeters in relation to aprons, individuals not wearing and/or improperly wearing their dosimeters, and uncertainty with the conditions under which zero were assigned. In regard to the latter issue, the integrity of records containing zeros may remain open to question until the practice of recording zeros when badges were not returned, along with personnel practices such as disciplining workers who exceeded the quarterly limit, need to be carefully investigated for their implications of the integrity of the dose record. Interviews with the GAO personnel who wrote the 1994 report, the records associated with that report, as well as the people interviewed for its preparation could serve as a valuable guide to gauge the significance and extent of this problem and its practical importance for dose reconstruction. The existence of blank records in the post-1964 period also raise questions about the integrity of data recording practices that need to be explicitly addressed and resolved.

(2) The removal of ^{241}Am from aged Pu when it was reworked to make new pits after obsolete warheads were retired bears further study because the amount of ^{241}Am created by the decay of ^{241}Pu depends on the initial ^{241}Pu concentration. That concentration decreases once a warhead is returned after some years in service for dismantlement and reuse of Pu in new designs. The validity of Pu intake estimates depends on the availability of sufficient data on the ^{241}Pu content and age of the plutonium. Specifically, these records would be needed for plutonium that was recycled from old warheads to fabricate new ones. SC&A expects that this issue will be more important from the mid- to late-1950s to the end of production than in the early years.

(3) With internal dosimetry, there were individuals not monitored, delinquencies in submittal of bioassay samples, and questionable effectiveness in bioassay techniques to detect all chemical forms of radionuclides present at the facility.

(4) The limited information on job titles, skills and tasks, work locations, time spent in the area, and radionuclides of concern further complicate issues, making it difficult to differentiate between radiological and non-radiological workers.

(5) The source data for calculation of airborne environmental dose is questionable, based on effectiveness of environmental air sampling.

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

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

6.1 SATISFYING THE FIVE OBJECTIVES

The SC&A review procedures, as approved by the Advisory Board, require that each site profile be evaluated against five measures of adequacy—completeness of data sources, technical accuracy, adequacy of data, site profile consistency, and regulatory compliance. The SC&A review found that the NIOSH site profile (and its constituent TBDs) for RFP represents an adequate accounting of the "core" plutonium and uranium and dosimetry history of the plant, but falls short in fully characterizing underlying issues that are fundamental to guiding dose reconstruction. In some cases, the issues will impact other site profiles. Many of the issues involve lack of sufficient conservatism in key assumptions or estimation approaches, incomplete site data or incomplete analyses of these data, or incomplete reflection of the operational history. Section 6.0 summarizes the key issues. Detailed evaluation of these issues is provided elsewhere in the report.

6.1.1 Objective 1: Completeness of Data Sources

The breadth of data sources used as a basis for the RFP site profile is evident in the 415 reports available in the Site Profile Research Database. One hundred and nine (109) of these reports were cited in the site profile references, while others served to provide confirmatory information. The ORAU team included health physics personnel with long histories at RFP who have extensive knowledge of key dosimetry historical processes and personnel monitoring data.

However, a number of historical issues and discrepancies cast doubt on the validity, and in some instances, the integrity of dose records being relied upon for EEIOCPA dose reconstruction, ones which are not adequately reflected in the TBDs that make up the site profile. Evidence exists that there is a potential for missed occupational external, internal, and environmental dose due to the incompleteness and questionable quality of data being used in dose reconstruction. These missed doses may have occurred as a result of incomplete monitoring records and inadequate monitoring techniques. There may also be a data integrity issue associated with the external dose record.

In general, the site description TBD (Flack and Meyer 2004) provides an accurate and reasonable characterization of the history and operational activities at the RFP for the period of production, but falls short in doing this for the post-operational decontamination and decommissioning activities. The major functions of many of the production and support buildings were outlined, as well as the major process changes that occurred throughout the years. In addition, accident/incidents, such as fires, were documented in chronological order. The TBD is incomplete in its review of the historic dose contribution of radioisotopes other than uranium, plutonium, and americium.

The TBD Site Description provides useful information regarding radionuclides handled in different buildings. But, it does not provide a comprehensive list of radionuclides and quantities of radionuclides to which workers may have been exposed. For example, a variety of radionuclides ($^{89/90}$Sr, $^{134/137}$Cs, uranium, ^{238}Pu, ^{239}Pu, ^{208}Tl, ^{212}Pb, ^{214}Pb, and ^{237}Np) have been identified in the soil. The TBD does not adequately address potential dose from recycled uranium, highly enriched uranium, and the processing of ^{233}U.

The TBDs do not adequately cover the dose potential from decontamination and decommissioning activities that have been ongoing since the end of the production period in 1989, and processing of special materials such as recycled uranium and special project radionuclides. The occupational environmental dose TBD (McDowell-Boyer and Little 2004) provides limited direction to dose reconstructors on the process and assumptions that should be used to calculate internal dose. The TBD provides limited guidance for the assessment of missed dose for unmonitored workers. NIOSH has indicated that this guidance is provided in supplementary procedures and technical information bulletins (Attachment 4), which is not inherently obvious from the information in the TBD.

For monitored workers, ORAU and NIOSH rely primarily on the worker dose record and the Computer Assisted Telephone Interview (CATI) for potential exposure data on radiological incidents. Workers have often complained of poor record keeping and fabrication of records, which have been confirmed in Congressional and Tiger Team investigations. The Rocky Flats Site Profile, as it now stands, does not have a dedicated database or assessment for off-normal exposures and incidents that can guide dose reconstructors as to missed incidents (and hence additional doses) or record keeping practices that might indicate problems with the integrity of individual worker data in some settings and periods.

The occupational medical TBD (Furman and Lopez 2004) does not show that the RFP applied dose minimization principles to reduce medical exposures. The document also does not assess or consider the likely exposure to workers who are referred to off-site medical facilities for follow-up. The TBD states that review of selected medical records and files did not reasonably show or match expected x-ray exam frequency, and type of exam. Little evidence exists to document the number of x-ray exams provided to the average worker or for special exposure needs.

ORAUT-TKBS-0011-6 (Langsted 2004) describes the default assumptions for occupational external dose at RFP. ORAUT-OTIB-0027, *Supplemental External Dose Information for Rocky Flats Plant* (Smith 2005), provides additional information on the assumptions to be used in dose

reconstruction. The assumptions were derived from historical records relating to the dosimetry program and observations made from the dosimetry report review. The site profile refers the dose reconstructor to the Rocky Flats work history file, the Neutron Dose Reconstruction Protocol (NDRP) file, and a job exposure matrix put together by the University of Colorado Health Sciences Center and the CDPHE for additional information. The job exposure matrix data is unavailable. The NDRP information has only recently become available to NIOSH/ORAU and has not yet been integrated into the site profile.

The TBDs (Little and Meyer 2004, Flack and Meyer 2004, and Langsted 2004) do not mention any use of industrial x-ray units, large radioisotope sources, or neutron generators for R&D or non-destructive testing (NDT), or any associated radiation exposure or monitoring. However, these units (some in the MeV energy range) were apparently used at the RFP.

6.1.2 Objective 2: Technical Accuracy

A number of deficiencies were identified with the internal TBD (Falk 2004). NIOSH's use of median MDA (minimum detectable activity) values for plutonium and americium appear unduly low and likely to yield body burdens or organ doses that would be non-conservative, given the uncertainties involved. The default particle size for dose reconstruction is 5 μm AMAD. Mann and Kirchner (1967) measured a particle size of 0.3 μm mass median diameter (1-2 μm AMAD) during a plutonium fire. Particle sizes and distributions are not available for all work areas or incidents; however, given the production process, the potential exists for smaller particle sizes in work areas. SC&A has been able to identify additional particle size studies conducted at RFP; however, we were not able to obtain copies. These data should be taken into consideration when evaluating the default particle size.

The solubility and particle size should be assigned based on the most claimant-favorable value for the particular type of cancer,

The TBD does not provide adequate guidance for dose reconstruction associated with tritium, neptunium, thorium, curium, noble gases, and fission products. Ingestion exposure pathways were not considered in the TBD in the dose assessment process, especially for cancers of the gastrointestinal tract.

The external dosimetry sections of the TBDs and supporting OTIBs, while providing pertinent historical data and technology information on dosimetry systems and records, fall short in addressing potential missed and unmonitored dose, particularly in the early years of operation (1950s through mid-1960s). The use of neutron track plates and the uncertainties in neutron track counting with these and NTA film indicates there may be important missed dose that was not entered into claimant records. The Neutron Dosimetry Reconstruction Project Protocol (NDRP) was designed to remedy these deficiencies by recounting original tracks and providing a corrected estimated individual neutron dose. However, the recently issued NDRP report does not cover non-Pu workers, nor is it applicable to unmonitored or non-neutron workers. There is a resultant need to use neutron/photon ratios and film/TLD comparisons to correctly determine past neutron doses. The TBD (Langsted 2004) only briefly addressed these two issues, which

could be important in generating correction factors for under-monitored workers or for monitored-worker missed dose.

The RFP occupational medical dose TBD does not adequately address the contribution of historic radiation exposure from occupationally necessitated medical x-ray exposure of workers at Rocky Flats. By narrowly interpreting pre-established NIOSH guidelines (OCAS 2002a) to include only one pre-employment and a chest x-ray annually, it underestimates dose in that it excludes from consideration other special work-required x-ray procedures, e.g., x-rays required for respiratory protection certification, and special exams for asbestosis and beryllium workers (which often occurred at frequent intervals and not as part of an annual physical). Also omitted from consideration are x-rays resulting from work-related injuries. Consequently, by narrowly interpreting what exposure sources should be included and focusing on the relevancy of assumptions derived for other site profiles (e.g., Savannah River occupational medical TBD) rather than on the actual adequacy and accuracy of existing RFP data, the site profile falls considerably short in characterizing this source of occupational exposure.

The RFP environmental TBD excluded internal dose as a result of soil resuspension and focused its efforts on only one soil contamination area without justification. Soil contamination has been found at many areas on the Rocky Flats site, including in the East Spray Fields and the buffer zone. There is no explanation of why dose from radioactive material in soil excluded these other areas. The ambient air monitoring data is of questionable validity for use in assessing onsite worker environmental dose. Annual inhalation intake values developed from atmospheric modeling appear to be underestimated.

6.1.3 Objective 3: Adequacy of Data

A number of historical issues and discrepancies cast doubt on the validity of dose records being relied upon for EEOICPA dose reconstruction, ones which are not adequately reflected in the TBDs that make up the site profile. For external dosimetry, issues include established problems with algorithms, calibrations, dosimeter placement (including in relation to lead aprons), individuals not wearing or improperly wearing dosimeters, and conditions under which zero or null doses were assigned. In some cases, it is clear that zeros were recorded in lieu of more legitimate dose estimates. For internal dosimetry, particularly for the first 20 years of operation, missing dose likely resulted from exposures below the Minimum Detectable Activity (MDA) for plutonium that were recorded as zero or background, inadequate monitoring (urinalysis and fecal) following incidental plutonium exposures, delinquencies in bioassay sample submittals, and questionable capability to detect all chemical forms of radionuclides present. Although the TBDs incorporate methodologies for assigning missed dose, it is not clear that these bound RFP exposure conditions and compensate for errors introduced by calibration and monitoring technology limitations.

The issue of unmonitored workers, particularly from the early 1950s to the early 1960s, is not developed in the TBDs from the standpoint of the extent of the problem and how dose estimation would be handled, particularly the application of co-worker doses. Assignment of dosimeters to workers using the "10% of the radiation protection guide" policy was apparently based on

administrative decisions, not necessarily on actual survey results, and supported by site expert interviews. Although early neutron monitoring data can be supplemented by the NDRP study, this report excludes non-plutonium workers, workers not monitored with NTA film, and non-neutron workers.

6.1.4 Objective 4: Consistency Among Site Profiles

An extensive comparison was performed by SC&A to compare and contrast the methodologies used in the RFP and other site profiles reviewed to date to determine external, internal, medical, and environmental dose. These comparisons focus on the methodologies and assumptions associated with dose assessments and the derivation of values used to obtain a probability of causation for individual claimants. A detailed analysis is provided in Attachment 5 to this report.

The RFP site profile has introduced a few new concepts not previously used in other site profiles. A respirable fraction of 1.0 is applied for environmental dose. This value is claimant favorable. The profile also introduces an inhalation dose factor from ICRP 72, *Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5: Compilation of Ingestion and Inhalation Dose Coefficients* (ICRP 1996) for select radionuclides. An inhalation dose fraction has not been included in other site profiles reviewed to date. It is unclear why this factor would apply to RFP, but not to other DOE and AWE sites.

Site profiles such as Hanford, SRS, and Idaho National Laboratory (INL) have included data for multiple receptor points onsite. The RFP site profile used onsite environmental air sampling data and atmospheric dispersion model estimates based on public dose assessments to determine a single intake quantity per year. Presumably, the assumption here is that the onsite air monitors will provide cumulative release data from all operations of the plant. The site profile has not demonstrated that this single set of intake data represents the highest potential environmental exposure onsite. A similar analysis at multiple receptor points is warranted to determine whether this single intake quality is bounding for all areas onsite.

Environmental occupational dose is typically assigned to those individuals who were not monitored. In the case of the RFP site profile, environmental dose is applied when "a worker was not monitored adequately to develop a reliable individual dose." A worker who was not monitored for either external or internal dose versus a worker that was not adequately monitored constitutes a different set of individuals. Those that were not monitored at all were likely to be in positions where radiation exposure was not an issue. Workers who were monitored inadequately can't be compared to those who may or may not have been exposed to radiation. The terminology used for the application of occupation environmental dose is confusing, and should be more clearly stated to exclude inadequately monitored workers who actually received exposure.

The maximizing approach for missed internal dose to unmonitored workers is determined by using ORAUT-OTIB-0002 (Rollins 2004) or ORAUT-OTIB-0018 (Brackett and Bihl 2005). Although RFP is not a reactor facility, the 28-radionuclide intake scenario for facilities with reactors was used. NIOSH/ORAU has provided no rationale for using the hypothetical intake for a reactor versus non-reactor facility. It is important to note that the internal dosimetry site profile does not mention the use of the above procedures for determining a maximum dose to unmonitored workers. There is also no explanation for when to use which TIB method.

In the RFP site profile, it was assumed that the sample volume represented a 24-hour collection, and no corrections were made to the volume whether they represented an actual 24-hour collection or not. In the Hanford site profile, it is recommended that a urine volume of less than reference man or woman be normalized to these values. A consistent method of addressing sample volume is needed. Ultimately, determining individual 24-hour sample volumes is ideal. In the absence of true 24-hour sample collection, the approach in the Hanford site profile is more claimant favorable.

There has been no consideration of ingestion dose from workers at the RFP facility. The Bethlehem Steel and Mallinckrodt Chemical Works site profiles have included dose from ingestion of radioactive material. Although there may have been more engineering controls at RFP, failure of these engineering controls, internal contamination of respirators, incidents, and allowing food and beverages in specific areas of the plant (e.g., uranium processing area) may have led to ingestion of radioactive material.

Two-element dosimeters did not effectively account for low energy photons present in plutonium facilities. This was recognized by the sites and adjustments were made. For example, SRS used a special x-ray calibration curve for workers involved with handling plutonium. Hanford included 20% of the open window dose in the penetrating dose. Once better designed dosimeters were introduced, this was no longer necessary. RFP also recognized the inadequacies in the two- and three-element dosimeters through 1970 when the TLD was implemented. For the two-element dosimeter, they added 50% of the open window dose to the penetrating dose. For the three-element dosimeter, they added 35% of the open window dose to the penetrating dose. In the RFP TIB, ORAU has backed these correction factors out of the data in order to separate the photons into energy categories. This was not done with data from Hanford and Savannah River Site. The difference in the RFP approach has not been adequately explained.

Some sites such as the Savannah River Site have assigned missed tritium dose. The internal TBD provides no guidance on when and if to assign missed tritium dose. A similar issue occurs with the assignment of missed neutron dose. It is unclear when missed neutron dose should be assigned.

6.1.5 Objective 5: Regulatory Compliance

With one exception, NIOSH has complied with the hierarchy of data required under 42 CFR Part 82 and its implementation guides. 42 CFR Part 82 recommends the use of the default 5μm

particle size only in cases where there is no information on particle sizes. This is not the case with the RFP facility, as stated in ORAUT-TKBS-0014-5 (Falk 2004, pg. 9).

6.2 USABILITY OF SITE PROFILE FOR INTENDED PURPOSE

SC&A has identified seven criteria that reflect the intent of the EEOICPA, the Final Rule, and the regulatory requirements of 42 CFR Part 82 for dose reconstruction. Because the purpose of a site profile is to support the dose reconstruction process, it is critical that the site profile assumptions, analytic approaches, and procedural directions be clear, accurate, complete, and auditable (i.e., sufficiently documented). SC&A used the following seven objectives to guide its review of the RFP Site Profile TBDs to determine whether it meets these criteria:

Objective 1 – Determine the degree to which procedures support a process that is expeditious and timely for dose reconstruction.

Objective 2 – Determine whether procedures provide adequate guidance to be efficient in select instances where a more detailed approach to dose reconstruction would not affect the outcome.

Objective 3 – Assess the extent to which procedures account for all potential exposures and ensure that resultant doses are complete and are based on adequate data.

Objective 4 – Assess procedures for providing a consistent approach to dose reconstruction, regardless of claimants' exposures by time and employment locations.

Objective 5 – Evaluate procedures with regard to fairness and the extent to which the claimant is given the benefit of the doubt when there are unknowns and uncertainties concerning radiation exposures.

Objective 6 – Evaluate procedures for their approach to quantifying the uncertainty distribution of annual dose estimates that is consistent with and supports a DOL probability of causation estimate at the upper 99% confidence level.

Objective 7 – Assess the scientific and technical quality of methods and guidance contained in procedures to ensure that they reflect the proper balance between current/consensus scientific methods and dose reconstruction efficiency.

6.2.1 Ambiguous Dose Reconstruction Direction

In the DR process, the assignment of ISO or ROT instead of AP geometry may not reflect the true radiation dose to some workers; such as 100% rotational for site support personnel or 50% for support personnel as given in the TBD (Langsted 2004, Table 6-5, pg. 23). This may not always be claimant favorable in some cases (i.e., for anterior-seated cancers). Further investigation should be done concerning this issue and revised DR instructions issued.

In this TBD, and other TBDs as well, the issue of angular dependence for different types of radiation and different dosimetry system used through the years is not sufficiently addressed. For example, the TBD (Langsted 2004, Section 6.6.4.1, pg. 27), mentions photon angular dependence, but seems somewhat vague about the issue. On page 27 it states that the dosimetry response increases with angle, but on page 28 it states that the Panasonic system response decreased as the angle increased. Page 40, Section 6.8.4.1, addresses beta angular dependence and states that the assembled badge displays severe angular dependence to beta exposure and that for TLD badges it might record only 36% to 59% of the true beta dose at $\pm$30 degrees (this could result in underestimating the true beta dose, especially to the extremities where the worker's normal movements would not tend to average it out).

The TBD addressed internal dose to unmonitored workers in a limited manner. The reviewer is supposed to infer from the TBD that maximizing internal doses are calculated by using ORAUT-OTIB-0002 (Rollins 2004) or ORAUT-OTIB-0018 (Brackett and Bihl 2005). There is no direction on when which TIB should be used. Also, the assignment of missed tritium dose is absent from the TBD. There is no guidance provided on how to assess internal dose from radionuclides other than plutonium, uranium, tritium, and americium.

6.2.2 Inconsistencies and Editorial Errors in the Site Profiles

SC&A noted some inconsistencies and editorial errors in the site profile TBDs which are included in Attachment 7. In future revisions to the RFP TBDs, these inconsistencies and editorial errors should be corrected.

6.3 UNRESOLVED POLICY OR GENERIC TECHNICAL ISSUES

A number of issues were identified that are common in the RFP and other site profiles reviewed to date and, in some cases, represent potential generic policy issues that transcend any individual site profile. These issues may involve the interpretation of existing standards (e.g., oro-nasal breathing), how certain critical worker populations should be profiled for historic radiation exposure (e.g., construction workers and early workers), and how exposure itself should be analyzed (e.g., treatment of incidents and statistical treatment of dose distributions). NIOSH indicates that it may develop separate TIBs in order to address these more generic issues. The following represents those issues identified in the RFP Site Profile review that, in SC&A's view, represent transcendent issues that need to be considered by NIOSH as unresolved policy or generic technical issues.

(1) Direction on the applicability of the TBD and/or TIBs to individual dose reconstructions is absent.

(2) Mobility of the work force between different areas of the site should be addressed. Site expert testimony that many workers moved from one plant to the next is a complicating factor. Establishment of an accurate worker history is crucial in such cases. This will be especially difficult for family member claimants.

(3) Statistical techniques used in the application of the data to individual workers should be further considered and substantiated.

(4) Dose from impurities and/or daughter products in radioactive material received and processed at sites should be assessed as a contributory exposure source.

(5) The significance of various exposure pathways and the assumptions made that influence dose contributions need to be considered (most notably) for solubility, oro-nasal breathing, and ingestion.

(6) Analysis needs to be performed regarding how "frequent or routine incidents" should be addressed, given the possibility that such "spike" exposures may be often missed by routine monitoring as a function of how often and in what manner it was conducted.

(7) Availability of monitoring records for "transient or outside workers," e.g., subcontractors, construction workers, and visitors who may have potential exposure while working on or visiting a facility should be ascertained.

(8) Dose to decontamination and decommissioning workers should be assessed. Many facilities have large-scale D&D operations, which extend back many years. Decommissioning and decontamination operations often required working in unknown situations, which may provide unique exposure situations.

(9) Dose reconstruction for occupational medical exposures remains incomplete. NIOSH needs to reconsider the definition to include all forms of radiation medical exposure, to ensure its considerations are claimant favorable.

(10) Dose contributions from chemical forms of radionuclides that are not adequately addressed in the ICRP models.

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ATTACHMENT 1: NIOSH TECHNICAL DOCUMENTS CONSIDERED DURING THE REVIEW

Technical Basis Documents

ORAUT-TKBS-0011-1, *Technical Basis Document for the Rocky Flats Plant - Introduction Rev. 00 (*Little and Meyer 2004)

ORAUT-TKBS-0011-2, *Technical Basis Document for the Rocky Flats Plant – Site Description Rev. 00* (Flack and Meyer 2004)

ORAUT-TKBS-0011-3, *Technical Basis Document for the Rocky Flats Plant – Occupational Medical Dose Rev. 00* (Furman and Lopez 2004)

ORAUT-TKBS-0011-4, *Technical Basis Document for the Rocky Flats Plant – Occupational Environmental Dose Rev. 00* (McDowell-Boyer and Little 2004)

ORAUT-TKBS-0011-5, *Technical Basis Document for the Rocky Flats Plant – Occupational Internal Dose Rev. 00* (Falk 2004)

ORAUT-TKBS-0011-6, *Technical Basis Document for the Rocky Flats Plant – Occupational External Dosimetry Rev. 00* (Langsted 2004)

Technical Support Documents

ORAUT-OTIB-0002, Rev. 01 PC-2, (2004), *Technical Information Bulletin, Maximum Internal Dose Estimates for Certain DOE Complex Claims*, Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 7, 2004 (Rollins 2004)

ORAUT-OTIB-0006, (2005), *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, Rev. 03, Oak Ridge Associated Universities, Oak Ridge, Tennessee. August 2, 2005. (Kathren and Shockley 2005)

ORAUT-OTIB-0018, Rev. 01, (2005), *Internal Dose Overestimates for Facilities with Air Sampling Programs,* Oak Ridge Associated Universities, Oak Ridge, Tennessee, August 9, 2005, (Brackett & Bihl 2005)

ORAUT-OTIB-0027, (2005), *Supplementary External Dose Information for Rocky Flats Plant*, Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 15, 2005.(Smith 2005)

ORAUT-PROC-0003, Internal Dose Reconstruction, Rev. 00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 1, 2003 (Brackett 2003)

ATTACHMENT 2: SITE EXPERT INTERVIEW SUMMARY

<RESERVED>

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

SITE DESCRIPTION (ORAUT-TKBS-0014-2)

1. What were the criteria for monitoring workers for external penetrating radiation? How did these criteria evolve over time?

2. What percentage of Rocky Flats Plant (RFP) workers were measured for external radiation over time, including neutrons and photons?

3. How are unmonitored workers addressed, particularly before the 1964 transition to a combined security/dosimetry badge? For example, guards were apparently not routinely monitored, although they were often stationed adjacent to production areas; how would their exposures be characterized?

4. What data did NIOSH/ ORAU obtain regarding the degree and extent of contamination of specific processes that resulted from special projects such as processing/fabricating of ^{233}U and other radioisotopes?

5. How much ^{233}U was handled at Rocky Flats over what periods of time?

6. What were the levels of ^{232}U contaminants present in the ^{233}U processed and handled at Rocky Flats?

7. Why don't the TBDs account for recycled uranium of various assays that were processed at Rocky Flats?

8. What processes at Rocky Flats would have been likely to concentrate contaminants contained in recycled uranium?

9. Were workers who handled and processed recycled uranium measured for exposure to contaminants such as ^{239}Pu, ^{237}Np, and fission products? The TBD appears to have no information about this issue of concern.

10. What radiological controls initially were established at Rocky Flats and how did they subsequently evolve over time?

11. How many workers were exposed unexpectedly to radioisotopes from fires at Rocky Flats? Of this group, how many were not monitored for internal and external exposure? Of those monitored, how many (on a fire-by-fire basis) received doses in excess of prescribed limits?

12. How many workers entered airborne radioactivity areas without respirators and how did they assess or estimate these workers' inhalation dose?

13. How many workers required chelation therapy during the history of the operation of Rocky Flats?

14. What criteria and guidance were used to verify criticality safety relative to drains and overflows that may have evolved over time?

15. What parameter controls (i.e. mass, enrichment, density, concentration, geometry, interaction, reflection, moderation, and neutron absorption) were applied to prevent criticalities at Rocky Flats and how did they evolve?

16. Did Rocky Flats handle or process recycled thorium?

17. What assessments of criticality safety and radiological control at Rocky Flats did ORAU/NIOSH review in the preparation of the TBD?

18. Were there any incidents involving the furnace operations with respect to ignition of combustible gasses, flame flashbacks, etc.?

19. How did NIOSH determine which incidents were to be included in the site profile?

20. What records retrieval efforts were made in support of the site profile review? Were any classification issues encountered during site expert interviews and records retrieval efforts?

21. What worker organizations were contacted to obtain worker input for the site profile? Who are the contacts for these organizations?

22. A "job exposure matrix" was developed as part of a DOE-funded study performed by the University of Colorado Health Sciences Center and the Colorado Department of Public Health and Environment (and cited in ORAUT-TKBS-0011-6), which matches external dosimetry results with year-by-year building assignments and job titles. Has the matrix been obtained by NIOSH for use in DRs?

23. Page 7, Section 2.4.3.1, states that DU is not generally considered a significant external or internal hazard. Why isn't uranium a significant radionuclide with significant external and internal dose potential in the early days when RFP workers performed a lot more operations with uranium (enriched, natural, and depleted?

OCCUPATIONAL MEDICAL DOSE (ORAUT-TKBS-0014-3)

1. The above listed document is dated February 2004. It is noted that a lot of cross referencing is relied upon between various site profiles. What is NIOSH currently doing to provide a revision to this site technical basis document? Is NIOSH currently revising any of the TBD documents for other sites that would require subsequent changes to this document?

2. What does Dr. Furman know about the existence or absence of medical protocols used at RFP to determine the need for radiological exams during his tenure at RFP or prior to his time at RFP?

3. Were x-rays used routinely as part of medical certification for respirator users, food handlers, nurses, etc?

4. Define what is meant by occupational medical radiation exposure? Does it include evaluation of foreign material resulting from machining and milling accidents?

5. Were workers required to have radiography exams as part of a return to work clearance?

6. The TBD suggests all radiography occurred in the diagnostic range of (30-250 kVp). Is NIOSH aware of the acquisition of any x-ray units that were installed at RFP that exceeded 250 kVp?

7. Section 3.2 discusses exam frequency. Is there any physical evidence (by medical record or protocol documents) that show workers were not exposed to voluntary chest x-rays, even when policy did not require them?

8. Is there any physical evidence to show that special surveillance exams for beryllium, asbestosis, and respiratory protection were always scheduled as a part of the annual physical which is an assumption provided in the technical document?

9. Are there any records or studies to document a low retake rate alluded to in the technical document?

10. Are there any records or protocols to demonstrate that radiological processing equipment was properly maintained and serviced to reduce and minimize worker exposure? What records exist for the purchase and maintenance of all x-ray equipment, radiographic processors and supplies for the years 1953–1989?

11. Did the RFP site acquire and use portable x-ray units? Can NIOSH better describe the utilization of photofluorography (PFG) units at RFP? What was the make and model? What was the period of use? How many exams were performed?

12. Many radiographic procedures are performed offsite on a medical referral basis. Does NIOSH have evidence to determine the amount of offsite radiographs performed on workers at the request of the employer and as a condition of employment? An example would be follow-up exposure to evaluate the presence of chronic beryllium disease.

OCCUPATIONAL ENVIRONMENTAL DOSE (ORAUT-TBKS-0014-4)

1. How does the analysis of releases of radionuclides from RFP differ between the Phase I operational period (1952 to 1994) and the Phase II post-1992 phase when production

activities ceased and releases were more likely to occur as result of past contamination and decontamination activities?

2. Please provide a more clear definition of Phase I and Phase II? Why is there a 1-year overlap between the two phases?

3. Describe in more detail how atmospheric dispersion modeling results, from the Phase II study, were used to estimate air concentrations and intakes during the 1953 to 1964 period when air sampling data were not available?

4. Explain why it might not have been better to define the phases by the types and quantity of data available rather than basing and restricting the modeling assumptions and the results on the operational status at RFP?

5. What is the relationship between the 15μm aerodynamic equivalent diameter (AED) and the 5μm activity median aerodynamic diameter (AMAD)? Why is it that the predictions and models dealt with particles < 30μm AED? Would NIOSH describe the rationale for applying these different parameters for particle size?

6. Why does the occupational environmental TBD ignore the potential for ingestion of contaminated soils and other windblown particulates that are larger than normally respirable particles that are traditionally included in dose assessments? What is the basis for not including inadvertent ingestion of radioactively contaminated soil and other finely dispersed radioactive materials?

7. Why is the resuspension of Pu and Am deposited on soil not included in any calculations? Has NIOSH taken into account that the continuous resuspension of deposition during previous years would contribute to the Pu and Am concentration in the air?

8. Why is code RATCHET, which was designed to reconstruct offsite doses from Hanford releases during its early years, used for onsite dose calculations at RFP, which is characterized by several closely constructed buildings? Wouldn't these building wakes prejudice the results?

OCCUPATIONAL INTERNAL DOSE (ORAUT-TKBS-0014-5)

1. Page 84 of the internal dosimetry TBD shows a "Health Sciences Record." On this particular record there is a notation of ppm Am. How was this value determined? How is it used in dose reconstruction?

2. It was noted on some of the records in Attachment C of the internal dosimetry TBD that some bioassay analysis was done offsite. What offsite vendors were involved in bioassay analysis for RFP? For what time period?

3. How do dose reconstructors identify uptakes of Super Type S and other insoluble forms of plutonium, particularly prior to lung counting beginning in 1964? How is the dose reconstruction process modified for these cases? What default solubility values are applied, and on what basis, when solubility is not known?

4. Was any potential exposure from radon and/or thoron? If so, under what circumstances?

5. Section 5.3.1.6, Tritium, did not mention the form of tritium assumed in the dose assessment calculations. What is the default assumption for the form of tritium? Were there other forms of tritium present at the site?

6. What method was used for assignment of internal dose to unmonitored or inadequately monitored individuals?

7. There is no direction for dose reconstruction associated with neptunium, thorium, curium, ^{233}U and ^{238}Pu. Has the potential for intakes from these radionuclides been considered?

8. Which of the DOE complex-wide technical information bulletins were used in dose reconstruction for Rocky Flats claims? Under what conditions were the technical information bulletins used?

9. The TBD recommends that the dose reconstructor assume that radionuclides are soluble for the purpose of dose assessment of the systemic organs and tissues. Is this approach recommended to assess intake and dose for systemic organs when using bioassay and/or air concentration data?

10. The TBD states that particle size and distributions are not available and it recommends the use of the default value of 5 μm AMAD. On what basis is this default value recommended when a range of airborne particle sizes has been confirmed at RFP (i.e., don't measured values take precedence over default values?)? Is this approach recommended to assess intake and dose for systemic organs when using bioassay and/or air concentration data?

11. On page 9 of the TBD in Section 5.2.2.2, it is recommended that the "Dose reconstruction should assume a 5 μm AMAD, except for fires [for which] a X.X μm AMAD should be assumed for consistency with Section 5.2.1.3 above." What did NIOSH intend to convey in Section 5.2.1.3 which does not exist in the TBD? What value corresponds to X.X μm AMAD?

12. In general the values for median MDAs can be considered high, especially for enriched uranium presented in Table 5.3.1.3.2, on page 14 of the TBD. What guidance is given to the dose reconstructor to deal with results below the MDA when assessing the missed dose?

13. In Section 5.3.1.5.1 on page 16, the TBD states that until 1973, gross alpha measurements were applied for analysis of the urine samples of workers potentially exposed to both uranium and plutonium. How dose the dose reconstructor evaluate potential dose contribution from neptunium and curium?

14. In Section 5.3.2.1.1 on page 18, the TBD discusses two sources of interference. The second interference involves the contribution of the count from ^{241}Am not in the lungs but from contributions from contamination on the skin, from material being cleared from the upper respiratory system, or from ingested material. The skin contamination contribution may be true for accident or incident situation, but not for the other examples, since the transit time in the upper compartments of the human alimentary tract is fast. How does NIOSH deal with this contribution?

15. At the end of Section 5.3.2.1.2 on page 20 of the TBD, it states that "An underlying assumption is that americium remains associated with the plutonium particles in the lungs until the particles are dissolved or removed from the lungs." What is the basis for this assumption?

16. The TBD (Section 5.3.2.2.1, pp. 20 and 21) mentions that, "The method to detect depleted uranium was to detect the 63-keV gamma (doublet) photon of ^{234}Th and to calculate the activity of ^{238}U, assuming equilibrium," which was implemented manually for special cases in approximately 1978. How did Rocky Flats Plants dosimetry personnel infer the lung activity of ^{238}U, due to depleted uranium exposure, based on the ^{234}Th measurement?

17. In Section 5.3.3.1 on page 22, the TBD states that "Wound count information is largely irrelevant to dose reconstruction." From other wound decontamination experiences it has been demonstrated that for some radionuclides, even with decontamination treatment, that some wound contamination remains in the scars. In case of skin cancer, does NIOSH use wound contamination measurements for dose reconstruction and how is this accomplished?

18. Figure 5C-16 on page 87, dealing with body counter information, shows that there is no data for the right chest. On page 27, it states that "The dose reconstructor should estimate the contribution for the right chest before using the data from the count because the lung data set generally includes contributions from both right and left lungs." How does NIOSH calculate the total activity in the lung in this situation?

19. Were lung counting measurements a part of the routine monitoring program or was lung counting performed just in case of an accidental intake? On page 27, it mentions that "The dose reconstructor should note of the intake date. If the intake date is different form the date for the Count Started, the intake date is from the file for a worker with a confirmed deposition. Otherwise the date of the lung count is used as the intake data." If it was part of the routine monitoring program, why is the date of the lung count used as the intake date, which does not seem to be the most claimant-favorable approach?

20. On page 30, it mentions that Section 5.5.2 is reserved and yet to be determined. What is NIOSH doing in its revisions to the TBD to expand upon this section? How is NIOSH planning to deal with the assessment of dose based on co-worker data? Will evaluation of air concentration data be a part of this effort?

21. In Attachment A, it is not clear how the volume of urine samples was normalized for 24-hours excretion. Please explain the two different approaches used for uranium and for plutonium and how they were normalized in each situation?

22. In Attachment A on page 39, it states that "Depending on the process, spiked samples, samples to which a known activity of the analyte was added, were generally processed with each batch of samples." On page 52, it states that "Not until 1973 were some plutonium samples spiked with an internal tracer (first ^{236}Pu and, later, ^{242}Pu). All plutonium samples were spiked with an internal tracer after 1978…Whether to use the median value of the MDA or the extreme value depends on the purpose." This seems to suggest that some samples, in the earlier years, may have higher MDA than the ones tabulated or described with the results of the urinalyses, since the recoveries were determined by batch spikes. What is the variability of the recovery?

23. In Attachment A on page 37 in the Analyte/Method Code table on page 37, it is noted that the Method Code B_1 appears both for the analyte "Depleted uranium" and also for the analyte "Enriched uranium". Is it possible for a worker to have been exposed to both depleted and enriched uranium? If so, how does the dose reconstructor distinguish whether it's DU or EU, once the method code (B_1) has been assigned in both situations?

24. In Attachment A, on page 42 under the section entitled "Gross Alpha (1952–1971)" the TBD states that "The default condition, through 1963, was to credit the result to enriched uranium unless the PHA count indicated otherwise…After 1963 (and enriched uranium operations were phased out), the default condition was to credit the result to plutonium." Why does NIOSH feel this is the most claimant-favorable approach?

25. In Section 5.5, *Internal Dosimetry for Unmonitored Workers,* it is indicated that for unmonitored workers "not involved in an incident," use of air concentration limits in effect would be a reasonable approach. However, this section is left "to be determined" given that actual limits applied in the plant are needed, not merely those cited in official requirements. What is the status of obtaining this key information and how are unmonitored internal intakes being modeled in the interim?

OCCUPATIONAL EXTERNAL DOSE (ORAUT-TKBS-0014-6)

Dosimetry Records

1. Page 10 states that further research is necessary to determine which dosimetry method was used to record a worker's dose. Has any progress be made in addressing this area of uncertainty?

2. Why doesn't information in the TBD, page 11 (and also ORAU-OTIB-0027, pp. 5–7), regarding skin and penetrating radiation doses, match that given in some of the historical records for the RFP (Owen 1964 and Putzier 1982)? In 1964, Owens defines the RFP doses as:

   Skin dose = hard gamma dose + soft gamma dose + x-ray dose + beta dose + neutron dose

   Penetrating dose = hard gamma dose + soft gamma dose + 1/3(x-ray dose) + neutron dose

   Hand dose = (hard gamma dose + soft gamma dose + x-ray dose) x 2.5 or 5.0 depending on area and chemical form.

   However, ORAU-OTIB-0027, pages 5–7 uses the open window (OW), cadmium filter (CD), and brass filter (BR) to define skin and penetrating doses, but does not relate them directly to the quantities as listed above which were in place at the time the doses were recorded.

3. How is it intended that the dose reconstructor correlate the methods in TKBS-0011-6 and OTIB-0027 in relationship to the recording methods that were in place during the years they were recorded, and also changed during the years?

4. How is it intended that the dose reconstructor reconstruct the separate doses to arrive at the total dose in these cases? Note on page 11, Section 6.3.1 that it states that during the early period (around 1951–1975) the deep gamma dose and the neutron dose were recorded as the total penetrating dose and not recorded as separate doses in the worker's file.

5. Was the Harshaw TLD 600/700 system used for extremity dosimetry during 1983–1991 when the beta/gamma and neutron dosimetry was being performed using the Panasonic system?

6. Has any more information been found regarding the characteristics, performance and calibration of the LANL processed neutron track "plates" for the RFP from 1951 to 1956? Has the recent Neutron Dose Reconstruction Project Report (NDRP) (Falk et al. 2005) assisted dose reconstruction (DR) during this period?

7. Will the recorded neutron dose be used in dose reconstruction that is discussed on page 14, Section 6.3.2.2.1 where it states that from July 1984 to Oct 1984, some neutron dose was recorded, but the gamma and total dose was zero?

8. How are the dose reconstructors handling the possible manual correction needed and discussed on page 14, Section 6.3.2.2.2, where it describes a possible manual correction, but ends with the statement that dose components were not provided in the letter and, therefore, were not made?

9. Why isn't more information provided besides the exchange history (i.e., quarterly dose history, etc.) that is discussed on page 18, third line list: "1977 – present, dosimeter exchange history?"

10. Why aren't uranium and non radiation workers included on page 18, Section 6.3.4.2, where it states that the NDRP (Falk et al. 2005) will cover 1951–1970 when NTA film was used for neutron dosimetry? How is NIOSH handling dose reconstruction for workers exposed to other neutron sources [(alpha, neutron) reactions such as in UF_4, criticality experiments, calibration sources, etc.] besides PU at the RFP during this time period when NTA film results/procedures are in doubt?

11. Can NIOSH make available to SC&A the DOE-funded Job Exposure Matrix study by University of Colorado-HSC mentioned on page 18, Section 6.3.4.3, that appears to be helpful in dose reconstruction?

12. How has NIOSH dealt with the situation discussed on page 19, Section 6.4.3 that individuals sometimes worked in other facilities (beside the one their badge was calibrated to) on temporary or overtime assignments, which the dosimetry department could not detect? Does NIOSH consider this an occurrence that happened often enough to create a significant underestimate of dose to workers because of the change in the dosimetry response? Does this require some modification to the NIOSH decision stated on page 27, Section 6.6.3.4 that assumes that each worker stayed in the work area where the badge was calibrated and therefore no corrections for photon energy are needed?

13. Why isn't the 10 mrem minimum detectable dose discussed on page 20, Section 6.4.4, used as the dose of record rather than reporting this as a zero dose? Isn't this inconsistent with the other AEC site TBDs and not claimant favorable?

Common Issues

14. Page 21, Section 6.5.2, second paragraph states that "If no activity date is associated with a dose record…" What is an "activity date"? Why would there not be a date associated with a dose record? Also, page 15, Section 6.3.3.1.3, mentions that the Activity Date may be outside the employment period. What does this mean?

15. In the dose reconstruction process discussed on page 23 regarding exposure geometry, why does NIOSH consider the assignment of ISO or ROT instead of AP geometry as always most claimant favorable (i.e., for anterior-seated cancers)?

Photon Dose

16. On page 24, 6th line up from the bottom, shouldn't it read *…the 30-250 keV photon.…*, instead of *…the 30-50 keV photon.…*?

17. Has NIOSH considered the need to take into account during dose reconstruction the effect of shielding where photons with energies >250 keV may contribute more to the final effective dose because of their greater penetrating power? The TBD states on page 24, Section 6.6.1.1, that the photon exposure spectra, assumed to be mostly in the 30–250 keV range, is claimant favorable because of the higher REF for this energy range.

18. Could NIOSH provide more information on how angular dependence has been addressed? On page 27 it states that the dosimetry response increases with angle, but on page 28, it states that the Panasonic system response decreased as the angle increased. The Y-12 ORAUT-TKBS-0014-6, page 18, states that the recorded dose of record is likely too low at non A-P angles for beta/photon doses. What is NIOSH's position on angular dependence for: (1) NTA film, (2) beta/photon film, (3) TLD neutron, and (4) TLD beta/gamma badges?

19. Why is the uncertainty for low doses of 1 and 2 mrem less than for the higher doses of photons (i.e., 1 x1.00 = 1 and 2 x 1.00 = 2, but 10 x 1.23 = 12 and 100 x 1.23 = 123 mrem, etc.) in Table 6-12, page 30? Tables 6-10 and 6-11, page 29, show the opposite characteristics.

20. Please explain how Table 6-3 will be used by the dose reconstructor to amplify what is provided on page 21?

21. In calculating the exposure geometry factors, what dose rate and exposure durations were assumed? From what source was this data derived?

22. Did RFP ever acquire any sealed sources for use in industrial radiography such as ^{226}Ra, ^{137}Cs, or ^{90}Sr?

Neutron Dose

23. Why is there a difference in the limit of detection (LOD) between page 33, Table 6-16, which lists the limit of detection (LOD) for neutron NTA film for 1961 as 96 mrem and Table 6-17 on page 34, where the LOD is listed as 120 mrem?

24. Page 34, Table 6-18 list the potential missed neutron dose below 800 keV for early NTA film to range from 16% to 60%. However, the text below it selects 56% as the claimant-

favorable value with a resulting multiplying factor of 1.79. Why wasn't the higher value of 60% missed neutron dose with a resulting multiplying factor of 2.5 selected (i.e., 1/1-0.60) = x 2.50)? In addition, even if the value of 56% was selected for the percent of neutron dose missed, why wouldn't the multiplying factor be: 1/(1-0.56) = x 2.27 instead of 1.79?

25. Page 35, Section 6.7.3.4 states that other information will be used until the NDRP report is finished. The NDRP report (Falk et al. 2005) was available as of February 7, 2005. Is the NDRP currently being used in dose reconstruction? Has it resulted in any significant changes in the results of past or current dose calculations?

Electron Dose

26. Page 37, next to last sentence states that the RFP had problems with elevated beta dose rates from contamination on leather gloves worn during foundry operations. Did these workers routinely wear wrist badges so that these doses could be accounted for? If not, how will dose reconstruction be performed?

27. Page 40, Section 6.8.4.1, addresses angular dependence and states that the assembled badge displays severe angular dependence to beta exposure and that for TLD badges it might record only 36% to 59% of the true beta dose at $\pm$30 degrees. Wouldn't this need to be addressed, especially in the extremity section where the worker's normal movements would not tend to average it out?

28. Page 41, Table 6-24 footnotes states to multiply any dose greater than 2 mrem by 1.12. However, the forth column contain numbers that do not use this multiplier and do not match Columns 2 and 3. Why is this?

29. How can VARSKIN be used if it leaves out ^{234m}Pa? Page 42, the last paragraph of Section 6.8.6 recommends using the VARSKIN software to calculate skin dose from contamination. However, Table 6-26 on page 43 shows that the VARSKIN Mod 2 only includes one (^{234}Th at 3.40E-07 Ci/gm of DU) of the two most active beta isotopes [the other being ^{234m}Pa at 3.40E-07 Ci/gm of DU (the third isotope, ^{238}U at 3.40E-07 Ci/gm of DU is not itself an active beta emitter)]. Page 37 states "Thus, for depleted uranium, one is dealing essentially with 2.29-MeV (Emax) beta particle from ^{234m}Pa, the most energetic contributor to the beta exposure."

Unmonitored Individuals

30. What other measures, such as the NDRP, are being implemented to identify workers that should have been monitored, but were not? Page 42, Section 6.9.1, states that in the early 1950s the only groups expected to receive doses greater than 10% of the RPG were monitored.

a. The NDRP report (Falk et al. 2005), page 1, states that:

> *For some plutonium workers, neutron monitoring was not provided until the early 1960s, and their dose of record may not include significant contributions from neutron exposure received prior to being issued a neutron dosimeter. These workers included most of the employees working in Building 71 (now Building 771). Only a small number (10–18) of these employees were monitored for neutron exposure, and that monitoring was only during the period October 1956 to September 1957.*
>
> *Operations in Building 71 involved chemical processing of plutonium in acid solutions and resulted in significant neutron fields from the alpha-neutron reaction with light elements, especially from the plutonium tetrafluoride compound. No evidence has been found that neutron shielding was present for these operations until the early to mid 1960s.*

b. Column 2 of Table 2, pages 17 and 18, of the RFP annual radiation exposure report for the year 1984 (RFP 1985) provides the total badged personnel per year for the years 1953–1984. Another RFP document entitled *Film Procedure Timeline* for the Neutron Dose Reconstruction Project 2003 (RFP 2003, pg. 6) provides the number of NTA films processed per month. Analyzing the two tables for the years 1959–1969 show that out of the total workers badged, on the average only approximately 25% were issued NTA film badges (over the 10-year period, it ranged from 9% to 50%). For example, in 1960, a total of 1362 workers were badged throughout the year and approximately 300 NTA films were proceeded per month (therefore, 300 workers were badged for neutrons throughout that year), this results in a ratio of 300/1362 = 22%.

These facts raise the question as to whether the policy and procedures in place during this period at the RFP was adequate to ensure that the workers who were at risk of receiving significant radiation doses (especially neutron doses) were actually, and adequately, badged. It would appear that the "10% of the RPG" policy did not necessarily provide adequate monitoring for all workers that needed it.

Extremity Dosimetry

31. Is NIOSH currently working on TBD changes to make more clear how the following issues are addressed in, Section 6.10, page 43?

    a. **NTA film in wrist badge** - Between 1951 and 1970 film dosimetry was used for extremity dosimetry. Was this only for beta/photon? Was any NTA film used in the wrist dosimeters? If not, how will the extremity dose from neutrons (which could have been greater than the whole-body dose for those workers handing neutron emitting material) be reconstructed?

b. Hand-to-wrist-to-WB ratios – If a worker did not wear a wrist dosimeter, how can it be considered claimant favorable to assign only the whole-body (WB) dose to the hand if he/she was working on a task requiring hands-on work? [The NDRP (Fax 2005), page 22, list the average WB photon dose response as only 40% of the wrist photon dose. Additionally, in most cases the dose to the hands would be greater that the dose to the wrist (Mann 1964).]

c. Valid hand-to-wrist ratios - It states in this section that the details on the hand-to-wrist ratios are not available. In a letter by J.R. Mann (Mann 1964) it is stated that the hand dose is 2.5x or 5x the wrist dose, depending on the work location]. How can it be determined if these ratios represent the working environment at RFP if we do not know their values (none were presented in the TBD) or how they were derived?

d. Addition information - The last sentence in this section states that additional information on the hand-to-wrist ratios is required before shallow doses to the extremities can be reconstructed. The last paragraph on page 37 states that the beta dose to the hands could have been a problem because of considerable hand-on work performed at the RFP. Has any additional information been acquired and is it being used?

SUPPLEMENTARY EXTERNAL DOSE INFORMATION FOR ROCKY FLATS PLANT (ORAUT-OTIB-0027)

1. Page 5, first paragraph, third line: shouldn't this read *Rocky Flats Plant – Occupational **Environmental** Dosimetry (Rev 01).*[2]?

   Page 5, in the pre-1960 section list that skin dose was determined by (OW + CD + BR) and also by (OW + CD). Isn't the BR term in error in this paragraph and shouldn't it be deleted?

ATTACHMENT 4: SUMMARY OF CONFERENCE CALL ON SC&A QUESTIONS PROVIDED TO NIOSH

Dates: September 6, 2005, General Questions and Site Description TBD
September 8, 2005, Occupational Medical Dose TBD
September 6, 2005, Occupational Environmental Dose TBD
September 7, 2005, Occupational Internal TBD
September 7, 2005, Occupational External Dosimetry TBD

RFP General Questions/Site Description TBD Conference Call Summary

Date: September 6, 2005
Time: 10:00 am - 12:30 am EDT

Participants:

ORAU: Bob Meyer, Craig Little, Jim Langsted, Roger Falk, Theresa Lopez, Laura McDowell-Boyer
NIOSH: Brant Ulsh, Greg Macievic, Sam Glover
SC&A: John Mauro, Joe Fitzgerald, and Tom Bell

Additional Participants: Amy Dean (Scribe), Karin Jessen, Al Wolff

Advisory Board – Mike Gibson

Introductory Comments:

NIOSH: We are hoping that we can go through the SC&A questions methodically and deal with them in detail. Some we will be able to answer, some we can perhaps resolve now, and some will need to be resolved later.

General Comments:

SC&A: In the 3 weeks since we started our review of the RFP TBDs, we have boiled down our questions into talking points in a PowerPoint presentation that might help to clarify and elaborate on the questions. We hope everyone has a copy of these. They will form a good basis to review our overall preliminary issues. Joe Fitzgerald has received NIOSH's input on their initial comment resolution which has been placed within a table matrix. This matrix has been very helpful. Realizing there was a holiday during this period, we appreciate you getting this data to us so expeditiously.

DISCUSSION OF THE POWERPOINT SLIDES

SC&A: Slide 2, Bullet (2). The excess Pu and HEU storage vulnerabilities are not addressed in the TBD. However, this was addressed by DOE in the 1990s. Assessments were done in Pu vulnerability and they did assessments as well on where the Pu was being

stored. RFP held 96 MT in form of pits and spares which provides the potential for criticality issues. Also, accumulation of combustibles and potentials for fire were abundant. During the post-1989 cleanup, there was a lot of potential for exposure to workers involved in waste management. What are NIOSH's plans to characterize these exposure histories?

ORAU: We did not address this in the initial go around but now we are trying to go back and see if we can understand if there are any major events that will affect dose. We are buried right now on the Argonne report, but we do plan to go back and address this. We have addressed this from the cleanup program perspective as best as possible; including the D&D effort and this includes what badging was done.

SC&A: Our interest is in the potential exposures.

NIOSH: This will be considered in the TBD Site Description. We realize that the TBD does not characterize this yet.

SC&A: Will the assessments and reviews that were done in the 1990s be reflected eventually in the next round of TBDs?

NIOSH: If you have copies of these assessments and reviews, please provide anything you have that will help us. We will be adding additional information in revisions to the TBD and would be glad to include a summary of what you can provide us.

SC&A: In the evaluation of issues in the SEC, they have asked: "Why are these 1990s reviews not used to the period from 1987 to 1989?" Also we note the occurrence reports were missing.

NIOSH: Some incidents are actually covered in Tasks 5 and 6. After our review of the 1969 fires and what was left over from the Building 903 drum storage area leaks, there is not much new that is important. But we realize that this needs to be extended and anything important addressed. We have found 27,000 pages of records that are a new find. Although we knew they existed, we did not have the time to go through them before this.

ORAU: In the 1980s, nothing of a large scope occurred. In claimant files, there is excruciatingly detailed information about each incident in which they were involved. The claimant's file has an overabundance of data that is helpful in doing dose reconstruction. We did address in the TBD the 1957 Pu fire and the magnitude of their intakes. The only data we have indicate the use of the customary particle size.

SC&A: It sounds like there is a confluence of new data that is relevant to dose reconstruction. With RU you have a potential incident where Np has not been adequately addressed. There appears to be a wealth of new incident data which now enriches the story of the transients in exposure. Some additional radionuclides may be around and could contribute to dose even though their contribution may be low until proven otherwise.

NIOSH: Missed dose for worker intakes is based on what is in the worker's file. The additional files will not affect this data for the individual claimant who has this data. The additional data is just a supplement to what ORAU already has. We do realize that we need to look more at RU. Roger Falk is working on this and what he finds will be captured in the next revision to the TBD. But it is important to point out that only a small part (21 MT) of the total 2373 MT is applicable. Therefore the 25% of Pu that gets into the bone or liver may not be significant. But we realize that an argument should be provided in the TBD revision as to whether this is important or not.

SC&A: Could your current methodologies miss some things that the new records might help to clarify?

NIOSH: We realize that there are other issues to pursue. We need to get more data on how IAEA handles co-worker data. If we find some of this information, we may want to put that in the TIBs. RU will be pursued. Characterization of monitored vs. unmonitored will also be pursued.

SC&A: We need to find a time to get Bob Alvarez on a phone call with you in a small group at a later time to discuss this in more detail. This would be very helpful to Bob Alvarez. This should include further discussion of RU, ^{233}U issues, and how ^{236}U figures into RU operations.

NIOSH: We will send out an e-mail on Thursday or Friday to make this happen.

SC&A: Perhaps we could have Bob Alvarez dial into the end of the last part of the internal dose conference call tomorrow.

NIOSH: That would be even better, as it will be hard to find another time to get these folks together again, and they will all be on the internal dose call tomorrow.

SC&A: We will call Bob Alvarez and try to set this up. I think he may be planning on being a part of that call already.

ORAU General Questions:

SC&A:

1. What were the criteria for monitoring workers for external penetrating radiation? How did these criteria evolve over time?

ORAU: Section 6.9.1 explains that in the early 1950s only groups expected to receive doses greater than 10% of the Radiation Protection Guideline would receive dosimeters. As explained in Section 6.4.1, dosimetry was not universal prior to 1964. In that year, the security badge was incorporated in the dosimetry badge, which ensured that each individual wore a dosimetry badge (Putzier 1982). This design was maintained until the early 1990s, when the

security badge was separated from the dosimeter and individuals unlikely to receive occupational radiation exposure greater than 100 mrem were no longer issued dosimeters.

SC&A: The TBD is a very good product, but we do have some questions. There seem to be important juncture points where policy changed and dosimetry types changed. We would like to better understand how it was decided who the workers were that had the potential to exceed 10% of the guidelines. Who made this decision as to who got badged and who did not?

ORAU: It is difficult to go back that far. That level of detail is hard to come by. We have had to rely on a few pieces of documentation. We don't understand how this documentation was done.

SC&A For a dose reconstruction, how does ORAU do this?

NIOSH: We take a claimant's case. If they have dosimetry, it is easier. If they have no dose, then we have to use co-worker data to determine the individual's dose. We look at the person's job title. If they worked in non-radiation areas, they were given the environmental dose. If they are radiation workers, then we have to rely on co-worker data.

SC&A: We realize the University of Colorado Job Exposure Matrix might be very helpful in this regard. What is the status on NIOSH getting access to the Job Exposure Matrix? We realize there is a problem on who actually owns that data.

NIOSH: We have been working hard to get the University of Colorado Job Exposure Matrix from Dr. Ruttenber and our lawyers are working on it.

SC&A: Are you hampered without it being available to use the Job Exposure Matrix?

NIOSH: Once we get it, we will use it. We have been getting along without it, but when we get it, we believe it will help.

SC&A: So are you just in the minimum/maximum mode now on addressing RFP claimants?

NIOSH: If the claimant's dose puts him over 50% probability of causation (POC), then the minimum/maximum mode makes these easy compensation cases. If they are administrative worker cases, it is likewise easier to determine the potential dose and the POC. When they get to claimant cases where the POC is near the 50%, we are going to make some hefty overestimates.

SC&A: You pointed out in the TBD that those who got badged and those who did not and still worked around radiation in the early 1950s is often uncertain.

NIOSH: There is a TIB on how to use co-worker data. It is OTIB-0020 provides guidelines on how to use co-worker data to determine dose to unmonitored workers. This OTIB provides a lot of information on how to utilize co-worker data.

SC&A: Does OTIB-0020 deal with surrogate data? Do you use the real distribution for people who were not badged and need an environmental dose? Or do you use the 95th percentile rather than the natural distribution for high dose potentials? When you are using your co-worker data as a surrogate for this missed dose, do you use the geometric mean and the geometric SD? Or in other cases, do you use the 95th percentile? When we look at the TBD, it is not always clear which is used.

NIOSH: You would use the known data if you have it. If you do not know the job and they are radiation workers, then we might go to the 95th percentile.

SC&A:

2. What percentage of Rocky Flats Plant (RFP) workers were measured for external radiation over time, including neutrons and photons?

ORAU: The data necessary to develop these statistics have not been located. Based on the previous comment response, it is likely that the overwhelming majority of workers were monitored during the lifetime of the facility.

SC&A: We are trying to get a feel over time, what percentage of workers was monitored over time for neutron and photons. In the NIOSH matrix data that we got on external dosimetry this morning, it is not clear.

NIOSH: The matrix that was completed on Friday, September 2nd, and provided to you is already out of date. We do have for external dose, the years they worked and percent of workers monitored. But for neutrons, this is not as easy to get.

SC&A: You seem to have the information on the claimant population, but this may not be true for the whole work force. What percentage of workers was monitored in the 1950s and 1960s?

ORAU: Workers who were likely to receive 10% of the guidelines were monitored.

SC&A: Based on the 10% rule for badging, how many workers were badged in the mid to late 1950s? What percentage of the workers was monitored? When you look at co-worker data, is it based on a relatively small population? If it is only 5% or 20% of the work force that is different than if it was 60% of the work force.

NIOSH: We don't have those numbers, but we will get them. We think the more important question would be: "Can it be determined if the worker was likely to exceed the 10%". If we can, then this is good. We could then use other co-worker data if that claimant has a likely exposure. But if we don't know who might have exceeded 10% and this was missed during the dose reconstruction, that would not be conservative.

SC&A: Is there a way to look at the percentage of workers who were badged? When the RFP got running, it is likely that the percentage of those workers who were badged were low and that this percentage likely increased with time.

ORAU: The 10% rule was not applied to the individual worker. It was usually applied to worker groups that included the individual. For each of the operations, workers were badged the same way. The rule would apply to the workers in buildings and areas where they are likely to exceed the 10% guideline.

SC&A: But, were they applied very consistently?

ORAU: This evolved over time. In 1958, for Pu workers, badging was done according the 10% rule. It as probably also applied to the EU workers. But this would have been phased out in the mid-1960s. We started to combine the security and FB in 1964, at least for the photon doses. When the TLD came in during 1974, it became even more consistent.

SC&A: In work groups, such at Pu workers, was there this same evolution as with the individual workers mentioned above?

ORAU: For U workers it was consistent from the very beginning. For Pu workers it is not as clear. This is very relevant when you are doing dose reconstruction. Those perspectives are in the TBD, but the distributions over time are important.

NIOSH: We will include whatever data we can develop on this and get it to SC&A.

ORAU: We can't determine the fraction of the work force that is not occupationally exposed. It is not likely that we can get this kind of data for any period of time, especially for the early time.

SC&A: When you do the co-worker analysis, that kind of information over time would be helpful.

NIOSH: The general use OTIB for co-worker external dosimetry dose reconstruction is OTIB-0020. There will likely be a new OTIB developed as well just for RFP that will be even more helpful in doing occupational external dose reconstruction.

ORAU: But, you are missing the point. The unmonitored worker who is not badged is going to be rare. The gap for missed dose will likely be more for administrative people where it is not known or suspected that they did enter an area of potential exposure. But for unmonitored radiation workers who you know are likely to have been in a potential area of exposure, you can rely on the co-worker data when you are doing a dose reconstruction for them.

NIOSH: We might need to use co-worker data even if there is only a possibility of exposure.

SC&A: So there will be a new OTIB, like one done for Y-12 and the analysis will be in that OTIB?

NIOSH: Well, we don't have access to the Job Exposure Matrix yet. If workers are not part of the radiation worker workforce, the co-worker data might still be helpful

SC&A: The general approach is that groups of workers were either in the program or not in the program. If they were in the program, they will have some information and if they are in the 10% group, then they are followed more closely. As time goes on and more and more groups were turned on, it is likely that more workers and groups will be included in the rules for the 10% population. Of course, once the 10% rule was turned on, then everyone would have dose data. If you were missing a dose for a person, then the group dose would be used as the surrogate. But the job exposure matrix might create an incongruity.

NIOSH: Once we get the Job Exposure Matrix, we will assume they are in the group and this will then allow a conservative estimate.

SC&A:

3. How are unmonitored workers addressed, particularly before the 1964 transition to a combined security/dosimetry badge? For example, guards were apparently not routinely monitored, although they were often stationed adjacent to production areas; how would their exposures be characterized?

ORAU: Dose Reconstruction procedures to address unmonitored workers are applied to this situation. It is not clear that guards were not routinely monitored. The dosimetry data file provided by DOE for each claimant does indicate the unmonitored periods. Dose assignment is based on job description, era, dosimeter history, and interview information. Guards that were likely outside of production areas are often assigned ambient per section 6.9.2 of the External dose TBD. Each case is considered separately.

SC&A: Were the guards routinely monitored?

ORAU: No specific information on this has been found, but it is likely that they are not a part of the 10% group. In 1964, they were included in the 10% group, but after that it is not certain.

SC&A: You would then have to assign a co-worker dose from another group. Has this been made clear in the guidelines for Task 5? Who handles unmonitored workers?

NIOSH: They would use ambient dose from the external TBD, but it could also be handled on a case by case basis.

SC&A: If the worker is working in vaults with the pits, this could result in a hefty dose.

NIOSH: We would treat guards as radiation workers, if there is enough information. The guards would have had access to go into various areas of the site. If it is likely their jobs would take them into radiation area, they would be treated as radiation workers.

SC&A: Is co-worker data available by job group?

NIOSH: No, it more often is a summary data for the whole building or site. That data shows the number of badged or unbadged and how it is distributed by different locations. This kind of data does not show it by individual job title. We apply the geometric mean and the geometric SD and apply a 3.0 uncertainty. But it does depend on what kind of data they have. The individual judgments of the dose reconstruction as to whether or not the claimant is working with badged workers or not is important too. When doing a minimum/maximum determination, we would apply the 95th percentile. When applying the OTIB, it is not being used for best estimate dose. The minimum/maximum is just used for overestimates.

SC&A: But you might use the geometric mean?

NIOSH: It depends.

SC&A:

4. What data did NIOSH/ ORAU obtain regarding the degree and extent of contamination of specific processes that resulted from special projects such as processing/fabricating of ^{233}U and other radioisotopes?

ORAU: Roger Falk will have to address this later.

SC&A: Bob Alvarez was interested in this subject, but could not be on the call at this time.

ORAU: There is a Word document that was sent to Bob Meyers that gives Roger Falk's comments. Joe Fitzgerald should have that response.

SC&A: We did not see that particular reference.

ORAU: It should be on the O Drive. If you don't have it, we could provide it.

NIOSH: This is a good document to pull out and review.

SC&A: Maybe we can go over this later. This also applies to the ^{232}U component as well.

ORAU: There is something pertinent to this in our responses to questions 5, 6, 7 and 8 below.

SC&A:

5. How much ^{233}U was handled at Rocky Flats over what periods of time?

ORAU: We have no comprehensive data regarding the amount of U-233 handled. TBD section 2 indicates that small quantities of U-233 were handled in Building 881.

Approximately 20 kg of U-233 was handled as a special project at Rocky Flats in the mid 1960s, according to Ed Putzier in his memoirs, "The Past 30 years at the Rocky Flats Plant," pp. 28–29. This document is in the Site Research Database with the Reference ID 4632.

SC&A:

6. What were the levels of ^{232}U contaminants present in the ^{233}U processed and handled at Rocky Flats?

ORAU: Per the reference cited in Comment 5, approximately 40 ppm U-232 was in the U-233 mixture. A thorium strike was performed after receipt of the material to remove the Th-228 and its daughters, which were troublesome mainly because of their contribution to elevated external doses.

We have performed calculations based on this data to determine the possible internal dose impact of this level of U-232 contaminant with Th-228 and its daughters ingrown at 90 days after the thorium strike. For type M solubility, assessments based on U-233 only will account for 80% or more of committed doses to organs, except for bone surfaces, bone marrow, gonads, and liver.

However, there is no evidence yet found that any worker at Rocky Flats received an intake of this type of material. Ed Putzier cites, "…there were very elaborate precautions made in order to campaign this material. The machine tools which we used were heavily shrouded with plastic to protect them and, as I recall, we had really no trouble in containing the alpha radioactivity. I am not sure why but it seemed like the uranium, maybe it is something about its chemistry, was much easier to contain and clean up as compared to plutonium."

SC&A:

7. Why doesn't the TBDs account for recycled uranium of various assays that were processed at Rocky Flats?

ORAU: Recycled uranium was carefully reviewed by DOE and documented in, "Report on the Flow of Recycled Uranium at the Department of Energy's Rocky Flats Plant, 1953–1993," June 30, 2000. It was determined that a very small fraction (0.03%) of the depleted uranium processed at RFP was known to have resulted from recycled

uranium processing, and this material contained plutonium, neptunium and technetium below *de minimis* levels.

We have performed calculations based on the documented Pu, Np, and Tc levels in recycled DU and HEU at Rocky Flats. For recycled DU and for both Type M and Type S solubilities, committed organ doses assessed based only on non-recycled DU accounted for over 93% of the dose for all organs except bone surfaces (75%), red bone marrow (88%), and liver (79%). Given the minuscule fraction (0.0003) of DU at Rocky Flats of recycled origin and that many DU workers were also monitored for Pu exposures, this is not viewed as a significant internal dosimetry issue. For recycled HEU, the contribution of the recycle contaminants to committed organ doses is less than 0.00000001, again not a significant internal dosimetry issue.

SC&A: Then your bottom line is that there is some interest here.

ORAU: NIOSH had us stop work on that OTIB. Liz Brackett could give us a status.

SC&A: We have a lot of interest in RU. Irradiated rocket fuel was passed through RFP. ^{236}U came out of that. In the 2000 RU report we note that RFP was involved.

SC&A:

8. What processes at Rocky Flats would have been likely to concentrate contaminants contained in recycled uranium?

ORAU: The DOE Recycled Uranium report identified two processes that had the potential for concentrating or releasing transuranics or fission products related to worker exposure. These were the vacuum melting and casting processes for DU. Although information from Fernald indicated this is a potential concentration point, more recent data from the Specific Manufacturing Capability Project indicates that no accumulation occurs. The conversion of DU to oxide in the RFP "chip roaster" was identified as a potential concentration point, but was not supported by associated emissions analysis for transuranic elements.

SC&A: These two processes with RU were cited in the TBD, but we would like to see more on how this is characterized for the dose reconstruction.

SC&A:

9. Were workers who handled and processed recycled uranium measured for exposure to contaminants such as ^{239}Pu, ^{237}Np, and fission products? The TBD appears to have no information about this issue of concern.

ORAU: It is unlikely that special dosimetry was utilized for workers that processed recycled uranium. Based on the low level of contaminates in this material and the lack of knowledge about this at the time, special dosimetry was probably not used. There is no documentation of monitoring for contaminants.

No, uranium workers were not monitored for recycled U contaminants as such. Many uranium workers were monitored for plutonium after 1960 because of possible or actual work assignments in plutonium operations.

NIOSH: For Pu workers, the missed dose would already have been applied by the Task 5 group of people.

SC&A: We feel you should look more into the trace elements. However, the dose contribution from fission and activation products that come along with RU are not likely to be important contributors.

ORAU: We did some of the scoping calculations. It depends on the organ. It makes a 25% difference for the bone and 21% of the liver. Pu and Np are only partially characterized in the worker dosimetry. For Pu and Np, there is a dose contribution, and for the bone it is important and can range up to 25%. For the others organs, it might only make a 2% difference.

NIOSH: We do need to point out what is significant if RU is part of the dose distribution. It should be addressed in the TBD, as it was done in Hanford. We will incorporate Roger Falk's calculations in the TBD and deal with this in the revised TBD.

SC&A:

10. What radiological controls initially were established at Rocky Flats and how did they subsequently evolve over time?

ORAU: We're not sure of the intent of this question. Does the term radiological controls refer to physical barriers, such as gloveboxes and shielding, or monitoring processes? All data available at the time the TBD was written are summarized in the various chapters.

SC&A:

11. How many workers were exposed unexpectedly to radioisotopes from fires at Rocky Flats? Of this group, how many were not monitored for internal and external exposure? Of those monitored, how many (on a fire-by-fire basis) received doses in excess of prescribed limits?

ORAU: Section 2.6 of the RFP Technical Basis Document addresses accidents at RFP, including fires. Section 2.6.2 discusses the 1965 glovebox drain fire and does indicate the number of workers unexpectedly exposed above one lung burden.

Unfortunately, we know of no compilation of this type of information for other fires. Any workers identified as unexpectedly exposed would be subject to non-routine bioassay, which would be recorded in the individual's dosimetry file. The "Possible Inhalation Cases Body-Counted" table included in the Radiation Dosimetry annual reports produced in the mid-1980s (cited elsewhere in these questions) provides these numbers for a limited number of years. No previous or subsequent reports have been found. Roger Falk will see if any additional information can be found.

SC&A: In terms of fires, there is a lot of interest in high-fired oxides. But with so many smaller fires, it will be difficult to determine which of the worker groups were monitored and which were not.

ORAU: All the people affected were monitored for intakes. They were the same people who were monitored for external radiation exposure. This would cover the fire fighters in the first fire in 1957 in Building 71. Internal dose for the support people is characterized, but for the external dose we are not so sure. This, however, is not much of an issue. The important thing is the intake they received by inhalation. All fire fighters were monitored for possible intake.

SC&A: This kind of information is available for big fires. But for the smaller fires, we are concerned that it is not available.

NIOSH: We think we will have to rely on the individual worker files where bioassay data is likely to be recorded for such events like fires.

ORAU: You can also rely on some of the follow-up data as well.

NIOSH: They did not work up a summary report for a whole group in these situations. They put this information in the individual's files.

ORAU: What about the people who were walking by? Only in 1957 and 1969 would this be a problem. In Building 771, however, it all went up the stack. It also occurred off shift in the evening. Most of the release was in the first two hours, and would have blown away at a height that would have precluded having much on an affect on workers near the building. Therefore this is not important. John Till's report in late 1990s provides a lot of information on these fires. It is likely that the onsite air dose would include this in the air calculation. Onsite ambient air concentrations, with or without fires, should account for this. In 1969, the filters stayed in tact and the release, therefore, was much smaller.

SC&A:

12. How many workers entered airborne radioactivity areas without respirators and how did they assess or estimate this worker's inhalation dose?

ORAU: Records summarizing the numbers of such incidences have not been found. If a worker was reported to have entered an airborne radioactivity area, the incident was handled as a "Potential Intake" event, triggering special bioassay, which would be reported in the individual's dosimetry record.

SC&A: Are there procedural records that characterize the wearing of respirators?

NIOSH: We can't answer that. We have never taken into account the wearing of respirators. We just assume they did not use them and did our dose calculations as if they were not wearing respirators.

SC&A: How many cases do you have where surrogate air concentration data was used rather than bioassay co-worker data?

NIOSH: In applying OTIB-0020, we don't remember if this is mentioned. It is possible that Mr. Robinson in Task 5 could answer this. We had asked him to be on line but he apparently was not able to make it.

SC&A:

13. How many workers required chelation therapy during the history of the operation of Rocky Flats?

ORAU: Information on specific workers would be contained in their dosimetry records. Roger Falk and Joe Furman will research this.

SC&A: Let's defer discussion on questions 13, 14 and 15 to a later time when Bob Alvarez can be on a call to discuss these three questions.

SC&A:

14. What criteria and guidance were used to verify criticality safety relative to drains and overflows that may have evolved over time?

ORAU: There is no evidence that an accidental nuclear criticality has ever occurred at RFP. The nature and extent of the criticality safety program was not reviewed in the preparation of the TBD.

SC&A:

15. What parameter controls (i.e. mass, enrichment, density, concentration, geometry, interaction, reflection, moderation, and neutron absorption) were applied to prevent criticalities at Rocky Flats and how did they evolve?

ORAU: There is no evidence that an accidental nuclear criticality has ever occurred at RFP. The nature and extent of the criticality safety program was not reviewed in the preparation of the TBD.

SC&A:

16. Did Rocky Flats handle or process recycled thorium?

ORAU: There is no evidence of recycled thorium. According to Section 2.4.3.1 of Chapter 2, thorium was handled in limited quantities and had several different forms.

SC&A:

17. What assessments of criticality safety and radiological control at Rocky Flats did ORAU/NIOSH review in the preparation of the TBD?

ORAU: There is no evidence that an accidental nuclear criticality has ever occurred at RFP. The nature and extent of the criticality safety program was not reviewed in the preparation of the Technical Basis Documents.

SC&A: Let's defer this one as well until later so that Bob Alvarez can be on the call.

SC&A:

18. Were there any incidents involving the furnace operations with respect to ignition of combustible gasses, flame flashbacks, etc.?

ORAU: Furnace operations at RFP have resulted in accidental airborne releases by a number of mechanisms. Rapid oxidation in a furnace in Building 707 (J-module) did result in an accidental airborne release.

SC&A: At RFP, there is a history of blowbacks. Can you characterize these blowouts for us?

ORAU: We are aware of a blowback in J module in Building 707. There were vacuum furnaces that did have contamination incidents. The workers, however, were monitored and would not likely have exceeded the 10% guideline.

SC&A:

19. How did NIOSH determine which incidents were to be included in the site profile?

ORAU: All the available information was reviewed. Since the original TBD was published, additional information about unusual occurrences has been discovered and will be summarized.

Laura McDowell-Boyer will be adding more information on incidents in the TBD as additional information is found.

NIOSH: We have reviewed the history of the incidents and have gone through them carefully.

ORAU: The document set on incidents contains 27,000 pages of reports. We have gone through all of them. There are a few additional ones where pages are missing. It does not appear that this was caused by not printing them out. Instead, it looks like the pages were missing from the originals. We are trying to track this further. We have found nothing so far that is any thing like the 1957 and 1969 fires. There were some who entered areas where respirators were required without respiratory protection but when they realized it, they left quickly. They, however, did get nasal smears.

NIOSH: They will put whatever they find into a report and will forward the report to the DRs and to SC&A.

SC&A: Was there any involvement of support workers?

ORAU: There were cases of contamination in controlled areas. Reports say the public was not endangered. Generally, they did find contamination, but there was no undue exposure. There was one exception to this which involved a tour group that passed through a contaminated area and 15 people got 10^{-4} mrem.

SC&A: When you have a dose reconstruction process going on for RFP, we feel that these incident reports are important. If a worker's file is lacking any mention of such incidents, then incident reports become important. It is a trigger to begin to look for bioassay data if it is not in the individual's file. If there are 27,000 pages, there may be a lot of information on incidents. So when you are doing an individual's dose reconstruction, it will be important to try to augment the records for individuals from these 27,000 pages.

NIOSH: We agree. If such data is found, it will be placed in the person's file. If it affects dose, ORAU is committed to go back and redo the dose reconstruction. Where the POC is near 50%, this will be even more important.

ORAU: The reports do not identify names, but usually do identify groups. Therefore it may be difficult to identify if a specific individual was involved in one of these groups.

NIOSH: For internal dose, to be more claimant favorable, we do assume a constant chronic intake as long as they were receiving positive bioassay results.

SC&A:

20. What records retrieval efforts were made in support of the site profile review? Were any classification issues encountered during site expert interviews and records retrieval efforts?

ORAU: Information was retrieved from the Denver National Archives, University of Colorado library, Front Range Community College Rocky Flats Reading Room, the site profile research database, the Kaiser-Hill RF records center, and the Rocky Flats Radiological Health group. No classification issues were encountered.

SC&A: The response is fine as is.

ORAU: Roger Falk is working on getting this information.

SC&A:

21. What worker organizations were contacted to obtain worker input for the site profile? Who are the contacts for these organizations?

ORAU: No worker organizations were formally contacted.

SC&A: The response is fine. SC&A has minutes of these meetings.

SC&A:

22. A "job exposure matrix" was developed as part of a DOE-funded study performed by the University of Colorado Health Sciences Center and the Colorado Department of Public Health and Environment (and cited in ORAUT-TKBS-0011-6), which matches external dosimetry results with year-by-year building assignments and job titles. Has the matrix been obtained by NIOSH for use in DRs?

NIOSH: Brandt Ulsh has been working to see if they can be released to ORAU.

ORAU: We are still working on this too.

SITE DESCRIPTION (ORAUT-TKBS-0011-2)

SC&A: Page 7, Section 2.4.3.1, states that DU is not generally considered a significant external or internal hazard. Why isn't uranium a significant radionuclide with significant external and internal dose potential in the early days when RFP workers performed a lot more operations with uranium (enriched, natural, and depleted?

ORAU: Let's defer this until Bob Alvarez can be on the call.

RFP Occupational Medical Dose TBD Conference Call Summary

Date: September 8, 2005
Time: 10:00 am - 11:00 am EDT

Participants:

ORAU: Robert Meyer, Craig Little, Joe Furman, and Theresa Lopex
NIOSH: Brandt Ulsh, Greg Macievic
SC&A: Harry Pettengill, Tom Bell

OCCUPTIONAL MEDICAL DOSE (ORAUT-TKBS-0011-3)

SC&A:

1. The above listed document is dated February 2004. It is noted that a lot of cross referencing is relied upon between various site profiles. What is NIOSH currently doing to provide a revision to this site technical basis document? Is NIOSH currently revising any of the TBD documents for other sites that would require subsequent changes to this document?

ORAU: The Rocky Flats TBD has been reviewed for consistency with all cross-referenced documents, and when we do the update in December 2005, this will be incorporated. We are ensuring that all TBD updates for all sites will be updated to refer to the latest version of ORAU-OTIB-0006. We will also review the SC&A issues and ensure that these are resolved and included in the latest update of the TBD. We will ensure that we use the most up to date references as we issue updates to TBDs.

SC&A:

2. What does Dr. Furman know about the existence or absence of medical protocols used at RFP to determine the need for radiological exams during his tenure at RFP or prior to his time at RFP?

ORAU: All available document sources were searched for RFP protocol. A written protocol was not located but it is the recollection of former employees, including Dr. Furman, that the protocol would have been consistent with other DOE sites. We are certain that lumbar spine x-rays were performed from 1952 through 1974, that chest x-rays were performed annually through 1984 for most workers, and that after the mid-1980s, chest x-rays were performed less frequently and only for certain classes of workers, as described in Section 3. These conclusions were drawn from reviewing worker files as well as the recollection of employees in the medical department.

DR. FURMAN: By radiological exams, do they mean lung counts? If so, I don't remember the frequency (yearly for rad workers?) but someone like Steve Baker, who performed the examinations, would know. If they mean medical examinations for rad workers,

they were required to be yearly, and since 1984 when I first arrived, and even somewhat before, were reliably done on a yearly basis.

SC&A: I should clarify that this question was related to only chest x-rays and does not relate to lung-counts for radiation workers. Also, these are performed annually.

Dr. FURMAN: What we have heard about the possible use of PFGs at RFP seems to be consistent with other sites in terms of protocols?

DR. FURMAN: There were no formal or written protocols until the mid-1980s. We did, however, do a chest x-ray with each exam. Until the mid-1970s,from limited records, it appears that chest x-rays were done sporadically. Most annual chest x-rays were not done by protocol but by tradition. Routine spines were done in the early years as part of the pre–employment medical examination.

SC&A: Were annual spines done separately from medical exams during the period from 1950 to, say, 1975?

DR. FURMAN: No, they were done at the time of employment. No information was found to suggest annual spine exams were performed.

SC&A: Were chest x-ray done up into the mid-1980s as part of the annual medical?

DR. FURMAN: Yes, but in the early days this may not have been done for everyone. We did medical examinations on those workers that presented themselves at the clinic and requested an x-ray. If they chose not to come in, then they would not have had a medical examination every year.

SC&A: We notice that you make reference to Steve Baker in your response. Was he the one who did the whole-body counts (WBC)?

DR. FURMAN: Yes.

SC&A:

3. Were x-rays used routinely as part of medical certification for respirator users, food handlers, nurses, etc?

ORAU: Specific historical protocols have not been located. Therefore, the TBD assumes that all workers received an annual chest x-ray through 1984; lumbar spine x-rays (one set) for all workers hired between 1952 and 1974; and chest x-rays for certain workers from 1985 to the present (see Table 3.2-1). Food handlers and nurses, therefore, would not have necessarily received x-rays if they were employed after 1985 to the present. Prior to that time, the TBD assumes that they would have received one set of lumbar spine x-rays and an annual chest x-ray.

DR. FURMAN: I believe we had presented the required frequency? An Executive Order was published to limit x-rays to those necessary, rather than just annually – wasn't that by President Carter in 1978? We "formalized" the rules for x-ray frequency in the mid-1980s I believe, reducing it to every 5 years if they didn't have a specific requirement such as annually for beryllium workers. Food handlers and nurses were not considered to have a need for periodic chest x-rays since TB became less of a public health problem. I don't know when that was – sometime in the late fifties or early sixties at the latest. Respirator users may have been getting annual chest x-rays through the 1970s, possibly to the mid 1980s, but no later unless they were an asbestos worker who had worked in asbestos at least 10 years or were a beryllium worker.

If a claimant got an annual medical examination, it is assumed that the claimant also got a chest x-ray. Getting annual medical examinations, however, was spotty up until 1979.

NIOSH: In doing dose reconstruction of the claimants, we assume that they got a chest x-ray when they had their annual medical examination. Since many may not have received an annual medical examination in the early days, we are likely overestimating the dose from annual chest x-rays, but we feel this is claimant favorable.

SC&A: From personal experience of folks at SC&A, we realize that respirator users received x-ray examinations in order to receive medical certification to wear the respirator. The health and safety department sent folks to medical to get chest x-ray and sign off on their ability to wear a respirator.

DR. FURMAN: We did certify respirator wearers, but we did this at the time of their annual examinations.

SC&A: But isn't it known that the health and safety department folks had their own tracking system to assure radiation workers had necessary certifications?

DR. FURMAN: That might have been so in the early days, but once medical protocols were in place in the late 1980s, it was done as part of the annual medical examinations.

SC&A: You are correct that regulations began to be enforced after the Executive Order, but implementation was very slow. The Executive Order also provided specific dose guidelines for diagnostic x-ray procedures for the first time. Also, these regulations were not consistently applied at DOE sites until the mid-1980s.

SC&A: What is known about routine x-rays for food handlers?

DR. FURMAN: Routine x-rays for food handlers were not documented in RFP records. We also checked with the State and they did not have a mandatory requirement that we had to do these.

SC&A: In regard to Beryllium workers, we know they were supposed to get an annual chest x-ray, what is the period of time that occurred?

DR. FURMAN: The first Beryllium case we looked at was in 1984. NIOSH came in quickly and ensured that we enforced their standard and that annual exams were more complete in their scope.

SC&A: Did that become part of their annual physical?

DR. FURMAN: Yes.

SC&A:

4. Define what is meant by occupational medical radiation exposure? Does it include evaluation of foreign material resulting from machining and milling accidents?

ORAU: Occupational medical dose is a default estimate of the radiation dose that was potentially received by workers from occupationally required x-rays (i.e. – annual exams, pre-employment physicals, and exit physicals). It does not include medical x-rays arising from injury, accidents, or treatment, as these would vary greatly by individual and should be noted in medical records.

DR. FURMAN: Is that not the exposure from x-rays taken as a result of an occupational injury? I never heard anyone refer to any other work-site exposure as "medical".

SC&A: A lot of accidents and incidents that happened at RFP were due, in part, to the fact that the facility was a large metallurgical facility and workers would need often to be evaluated for the presence of foreign particles or splinters (e.g., Pu) in wounds. The TDB does not address this.

NIOSH: You are correct. This, however, is a generic problem. X-rays resulting from work are part of occupational exposures. They are often just included in worker background statistics and are not part of the occupational medical dose. Dose calculations in the TBD are based on the assumption that there is one pre-employment and one annual examination only, as part of the medical exposure.

SC&A: There is another area where the general rule may not be appropriate for all workers (such as machinists who were in higher number at RFP). Machinists may have received varying levels of exposure. How are you dealing with those who are outside the general rule?

NIOSH: It is handled in the statistics of background exposures for the site. If you were in non-nuclear work classification, a certain percentage of workers are known, in general, to get hurt on the job (whether you were a nuclear worker or a non nuclear worker) and would need an x-ray. This is taken into account in the POC computation in IREP.

Just based on the number of people entering a site, you can statistically evaluate the number of workers that will likely be required to have certain types of x-ray exams. That is different and sporadic and is handled differently in developing the individual claimant's POC. You can't look at every nuclear worker who might get a splinter. That kind of data is not available unless it is in the individual worker's personal file. These become part of the statistics of injuries at a site.

SC&A: We have already gone through a lot of discussion on this issue but I think we have seen that it is handled differently than you describe, based on what we have seen at other sites. Any individual x-ray, for instance if you trip and fall at home and need an x-ray, is not considered a part of the worker's occupational radiation exposure that is used in the input to IREP. Such a dose was something that was just off the table and not considered to be related to what a worker was doing when he was working in a nuclear facility. When we looked at individual cases, using Ron Kathren's ORAU-OTIB-0006, background radiation from these other sources are not included. It is not realistic to do this. Statistically when you get an x-ray like this, it is not a part of the overall process. This is new information that you have just described and I am not aware of this. Please explain this strategy.

NIOSH: You said it correctly. If I said anything above that is contrary to what you have stated, I did not mean to. I agree with what you said.

SC&A: To restate then, from what we have seen, any additional x-ray like the example above is not part of the IREP and is beyond what is used to include annual chest x-rays.

When working at a job, such as doing machining, any x-rays associated with that injury are not captured and used for entry into IREP. Such injuries are handled the same for any machining occupation, regardless of the type of facility involved.

NIOSH: But at RFP, most of what we are talking about for these kinds of injuries do require x-rays. If the claimant's individual file showed that he did have a Pu splinter, we would be interested in this if the claimant has skin cancer, but this would not be of interest for other cancers. So only a few cancers would be involved.

SC&A: NIOSH has gone a long way in assessing dose from x-ray exposures of pre-employment and annuals. These x-rays are important, but they are not unique to just nuclear industries. No one is suggesting that x-rays incidental to work that are seen in off-site hospitals should be included. But when they were machining and got a Pu splinter, it seems this should be treated differently. This should be looked at, since the exposures are at varying levels and could be significant. We note that ORAU-OTIB-0006 Rev. 3 also stresses the importance of including the dose from chest x-rays done during termination exams. The TBD does not include these in the definition of occupational medical examinations. But the workers, as part of their jobs, were also required to have chest x-rays for them to be cleared to go back to

work. This circumstance is also discussed in the TIB, but is not included in the TBD, nor is it covered sufficiently in the OCAS 2002a guidelines.

NIOSH: We will have to give this entire issue further thought as your points are recognized.

SC&A:

5. Were workers required to have radiography exams as part of a return to work clearance?

ORAU: According to Dr. Furman, never. If there were fractures, they were referred to off-site medical facilities and the RFP medical department did not do any procedures to document such x-rays. No radiography was associated with this return to work process. Some could come in as a referral.

SC&A: If an injured worker was referred off-site for treatment and follow-up, did RFP receive diagnosis and prognosis information, including x-ray results, as part of return to work protocols?

Dr. FURMAN: That's possible, but it was not part of the worker's RFP medical record.

SC&A:

6. The TBD suggests all radiography occurred in the diagnostic range of (30-250 kVp). Is NIOSH aware of the acquisition of any x-ray units that were installed at RFP that exceeded 250 kVp?

ORAU: It is the recollection of Dr. Furman and other employees that the voltage of the x-ray units could not be set higher than 250 kVp. Maximum machine settings were presented in Table 3.3-2.

SC&A: Was there any other x-ray generating equipment at RFP?

NIOSH: Yes, but they were all locked up. We have not seen any high doses that came from the vaults. No one seems to remember that.

ORAU: We will do a scan to see if there are any problems with x-ray systems. I would not expect this, since there were no written protocols. In one of the reports, part of report is missing and we will need to follow up on that.

SC&A: Rocky Flats Plant, being a Federal facility and being in the Agreement State of Colorado, would they have had strict procedures when equipment was brought in, for example, an ^{192}Ir NDT source? But this was probably provided and controlled by a private off-site contactor, who may or may not have registered its source properly. How do you consider this?

NIOSH: We will go back and review for this possibility..

SC&A:

7. Section 3.2 discusses exam frequency. Is there any physical evidence (by medical record or protocol documents) that show workers were not exposed to voluntary chest x-rays, even when policy did not require them?

ORAU: Given the legal parameters defining "occupationally required" x-rays, I don't think that voluntary, non-mandatory x-rays should be included in the TBD regardless of whether they may have occurred.

DR. FURMAN: Well, I cannot say that at some time an employee did not convince a clinician that they had a valid reason for having an "off schedule" chest x-ray done. For example, if an employee complained of a cough that had lasted a couple of months, perhaps the clinician would order an x-ray rather than just referring them to their private physician. As Medical Director, I discouraged that, since the DOE did not want us to compete with the private sector. I doubt that anyone would order an x-ray at the whim of the employee; that would be contrary to our training and ethics. That would require a review of many hundreds of charts. But remember, before the 1980s, there still was a tendency to just give everyone getting an examination "everything", thinking we were doing them a favor. Providing examinations tailored to their work-place exposures or, if a voluntary examination, tailored to their age, did not start until the 1980s. At that time, with increased emphasis

SC&A: We have read in the TBD that a lot of chest x-rays were voluntary.

DR. FURMAN: If they were offered the opportunity to receive an annual exam, then they were offered to everyone. They tended to take what was offered.

SC&A: Am I to take it that the TBD's dose calculation is reasonable and that all workers were given an annual chest x-ray?

DR. FURMAN: I don't think you could say that a large number got annual medical examination in the early days.

ORAU: From what we have seen, I would say that a majority of the workers did get their annual examinations which included a chest x-ray. But a lot of workers did not show up for their annual medical examinations. About 50% did get them in the early days. Some got them every couple of years. Generally the workers got a chest x-ray with their annual examination. Accreditations were done up though the 1980s. This was not just done for rad workers, but for all employees.

NIOSH: We don't treat non-radiation workers any differently than radiation workers for purposes of dose estimation for medical exposure.

SC&A:

8. Is there any physical evidence to show that special surveillance exams for beryllium, asbestosis, and respiratory protection were always scheduled as a part of the annual physical which is an assumption provided in the technical document?

DR. FURMAN: In the 1960s and early 1970s there is evidence that an annual physical was not always done. It appears that there was not tracking of this requirement except by the individual supervisors.

SC&A: Supervisors had to ensure tracking of that. In the early days you didn't see any tracking process, but after 1984 as the Federal regulations were implemented and the guidelines started to be followed in 1985 and 1986, then you did start to see compliance in a big hurry.

DR. FURMAN: You're correct. After 1986, it was tracked and the special surveillance was part of the annual exam. Bob Bistline got the computer tracking started and gets a lot of credit for having done so. This prevailed through the mid-1980s. Beryllium propelled us into making sure people were getting their required annual medical examinations.

NIOSH: Prior to the mid-1980s, claimants would they have gotten more dose assigned than they actually may have received because we assumed that everyone had an annual physical, when in fact as many as 50% possibly did not. Even with possible extra x-ray exams for Beryllium and asbestosis, the assumption that everyone got an annual and a pre-employment physical would still be claimant favorable.

SC&A: Is there any evidence of an increase in chest x-ray procedures other than those required on an annual examination?

DR. FURMAN: You never had to send them back for any special x-rays because they were, for example, a beryllium worker. Workers were sent to medical and medical did everything. They would do comprehensive physicals when workers were set up for annual physicals.

NIOSH: Any evidence that a claimant had more than the routine medical x-rays would likely be recorded in the claimant's personal file. If extra exams are found in the file, the DR will take that into consideration and will add the dose into his total medical x-ray exposure history.

SC&A:

9. Are there any records or studies to document a low retake rate alluded to in the technical document?

ORAU: Prior to the 1980s, there is little information. Post-1980, there is data indicating a low re-take rate.{Note: I believe that the Complex-wide TBD values assume a retake rate – I will confirm this)

DR. FURMAN: I found no data on that.

SC&A: ORAU-OTIB-0006 makes reference to rigorous studies performed in large medical research facilities under controlled conditions. It assumes retake rates of 3%. This could be a lot higher and may not be reasonably accurate for medical facilities at RFP.

ORAU: The retake rate is assumed to be 3%, but this in not significant enough to incorporate separately and they just dropped it. Retake rates were assumed to be low in the post-1980s time frame but we don't have documented information for the earlier period. We will look further into this.

NIOSH: ORAU-OTIB-0006 uses a normal distribution with a 30% uncertainty assigned (root mean square of uncertainty). Retake uncertainty is just one of the five or six uncertainties.

SC&A: We still think you may want to take a more rigorous look at retake rates, as you might find they are low, especially for spine x-rays.

NIOSH: We will look at that and follow-up

SC&A:

10. Are there any records or protocols to demonstrate that radiological processing equipment was properly maintained and serviced to reduce and minimize worker exposure? What records exist for the purchase and maintenance of all x-ray equipment, radiographic processors and supplies for the years 1953–1989?

ORAU: Inspection records of the x-ray machines were kept by Radiological Control. These records are now difficult, if not impossible, to find. The records of outside agency inspections and maintenance were kept by Medical since the 1980s. Finding them would be difficult.

DR. FURMAN: Is it true to say that no one could come up with the hard copy?

ORAU: We looked. The State said they did not have them. It is likely a private contractor that did this and it was handled as consults. A member of our team spent a week in Dr. Biseline's office and could not find any medical protocol information.

SC&A: This is not inconsistent with other sites. There is little documentation of maintenance or associated records of machine outputs and calibrations.

DR. FURMAN: State did come on-site and did examine equipment.

SC&A: My point in this question is that many things affect dose beyond the machine output. Principal among these is the processing equipment to make the point that a number of aspects have a bearing on uncertainty.

ORAU: We have a look-up table in ORAU-OTIB-0006 that deals with uncertainty. The general uncertainty is assumed to be 30%, or one sigma.

SC&A: With all the factors that have a play on uncertainty, there should probably be a review and rethink of the validity of the 30%. More needs to be known about the physics of the x-ray unit and the protocols used at the time of the exam. It seems important to come to grips with these additional issues.

NIOSH: We agree. We need to look at ORAU-OTIB-0006 and review the justification of the 30% uncertainty assumption and the retake rate of 3%. We will follow up on this. SC&A should follow up on this too.

SC&A: If you look at it closely, there is a lot of good information on all types of variables that can affect uncertainty in ICRP 34 and NCRP 102. This, however, is early vintage stuff. Even though the dosimetry is good, it still is based on the use of optimized data. Such factors as filtration, voltage output, kVp, buckys and screens, temperature, and quality of the chemicals need to be evaluated..

NIOSH: We agree. We will get back to you with an evaluation of the uncertainties in ORAU-OTIB-0006.

SC&A:

11. Did the RFP site acquire and use portable x-ray units? Can NIOSH better describe the utilization of photofluorography (PFG) units at RFP? What was the make and model? What was the period of use? How many exams were performed?

ORAU: X-ray equipment that was present on-site has been listed in Table 3.3-1. We have no additional data at this time.

DR. FURMAN: Portable medical x-ray units were not used at Rocky Flats. No record has been found indicating how or even if the photofluorography machine was used. I saw no mention or evidence of use in the many charts I had occasion to review over the years. Well into the 1960s we saw the typical 14 x 17 films for the usual x-rays, but I have never seen the smaller PFG x-rays films in the medical records I have reviewed. The PFG unit would have been in the medical department, but it was not used much.

SC&A: Are there no records of how much film was bought?

DR. FURMAN: No evidence of that.

ORAU: We saw and reported removal of the PFG unit in the 1968 (see Table 3.5-2), page 21. It was there in the medical department from 1953 to 1968. But by assuming one PFG exam with each annual physical, this results in a huge overestimate when most workers probably did not have PFG exams.

SC&A: The 3.0 rem estimate per each PFG exam in ORAU-OTIB-0006 is a good and reasonable assumption. A lot of PFGs were placed in vans and became portable screening units on mobile platforms. In the TBD, we note that Ron Kathren got 1.5 rem in his calculations for the dose delivered by each PFG examination and he then doubled it to 3.0 in order to be claimant favorable. This 100% increase is a valid way to deal with this.

NIOSH: There is no evidence whether the PFG was used or not used.

SC&A:

12. Many radiographic procedures are performed offsite on a medical referral basis. Does NIOSH have evidence to determine the amount of offsite radiographs performed on workers at the request of the employer and as a condition of employment? An example would be follow-up exposure to evaluate the presence of chronic beryllium disease.

DR. FURMAN: We treated these all as just an injury or illness. It was all treated the same.

SC&A: Is there a possibility that pre-employment exams were done off-site in the pre-1985's era

DR. FURMAN: There was no evidence that any of this was contracted out up until the year 2000. In 2000 it was all contracted out. Prior to that, if it was contracted out it would have been only for former worker follow-up exams.

Discussion of the PowerPoint Slides

SC&A: Slide on page 26. There is still a need for NIOSH to better define its interpretation of what constitutes occupational medical exposure. NIOSH should update OCAS 2002a guidelines to incorporate what we discussed today. Clearly, the medical exposures from the pre-1985s may be a problem, and the TBD does not cover this uncertainty well.

SC&A: Slide on page 27. The TBD does not address the potential for sealed sources being used in the medial clinic and does not catalog the number and types of x-ray equipment available for use and the conditions of use.

ORAU: We have been hard pressed to come up with documents of when purchases were made and how the equipment was maintained. We have no documents on protocols, processes and procedures.

SC&A: I believe the point we are making is variability is the rule, rather than the exception. You may not want to rely on optimized conditions on protocols and procedures to make estimates when no record exists. For example, there is great variability directed by the physician.

DR. FURMAN: Yes, that is true and it also involved what the doctor preferred. Some doctors like the x-ray dark. With no rigid procedures early on, if a physician wanted to vary the output a little bit he just did it. It depended on the exam.

SC&A: Slide on page 28. RFP did have the PFG unit there in the medical department for nearly 20 years, so the potential existed to use it. These old PFG units had the highest potential dose. Sometimes this was five to six times that of a conventional x-ray.

NIOSH: Yes, the references do grant that.

SC&A: If you assume 3 rem per PFG exam and 1 PFG exam per year, that is a claimant-favorable way to deal with the PFG potential dose. In regards to the retake rate of 3% for routine x-rays post-1968 and spine x-rays, NIOSH needs to look at that. However, it's probably does not need to be increased more than 100% as Ron Kathren did with PFG exams.

SC&A: Slide on page 29. There is a lot of dose impact just due to optimizing the use of bucky systems. It is likely, however, that this information no longer exists.

NIOSH: We will have to look at the ORAU-OTIB-0006 again to see if it does properly lay out these errors and uncertainties. We will have to go back and see how they did it.

SC&A: We would only emphasize that there is a need to go beyond the specific output of the tube and consider all these other potential sources of uncertainty. We appreciate your response and realize that some exposures are hard to get one’s arms around it.

RFP Occupational Environmental Dose TBD Conference Call Summary

Date: September 6, 2005
Time: 3:00 pm - 4:00 pm EDT

Participants:

ORAU: Robert Meyer, Craig Little, Laura McDowell-Boyer
NIOSH: Brandt Ulsh, Greg Macievic, Sam Glover
SC&A: John Mauro, Joe Fitzgerald, Abe Zeitoun, Tom Bell

Additional Participants: Amy Dean (Scribe), Advisory Board (Mike Gibson)

OCCUPATIONAL ENVIRONMENTAL DOSE (ORAUT-TKBS-0011-4) QUESTIONS

SC&A:

1. Could NIOSH provide a time line, which makes a clear distinction between operations, data availability, and types of data?

   There is a lot of good information on operations and availability of data and SC&A gives ORAU and the authors of 0011-4 a lot of credit for what has been done. On the other hand, it would be helpful to have a timeline that describes and distinguishes the types of operations and what data is available during both Phases I and II. The TBD has no references or discussions that help the reader to better understand when Phase II begins. There are the three major accidents. Then there are some 24 to 25 discrete events between 1964 and 1965. The matrix and the interaction of these and the relevance these events have been summarized in the ChemRisk 1992 report. Figure 6-1 has a nice timeline but lacks information on the phases. Five major accidents were identified for RFP. These were the:

   1957 fire
   903 pad
   1965 glovebox fire
   1969 fire
   1974 controlled value failure

ORAU: When you are looking at the ChemRisk report, this is actually Phase I. Phase II was done in more depth in later reports. The 1965 glovebox fire was not as significant as far as release to the environment was concerned. We have the document and we will deal with this in the case of claimants who were involved.

SC&A: It seems easier to find out what was happening during Phase 1. But in Phase II, the studies done do not seem to make it clear which phase you are reading about.

ORAU: John Till's report was for Phase II, so you know when you are in that report you are dealing with Phase II operations. The Rope et al. document (1999) deals with Phase II, as does the Rood and Grogan 1999 document, and these are helpful in understanding Phase II operations. Both these documents are referenced in the TBD reference list. But SC&A makes a good point and we will do a better job to make sure that this transition between phases along with timelines is more evident during revisions to the TBD.

SC&A: The authors do no seem to refer to Phase II. For instance on page 8 in Section 4.2.1, the TBD does not refer to what phase. It is important that this is made clear to the reader so that he knows which phase they were a part of.

SC&A

2. Table 4-1 of the TBD presents the estimated 50th percentile and 95th percentile annual plutonium intakes from 1953 to 1964. It is our understanding that these values are based on reconstructed radionuclide source terms and atmospheric dispersion models employing Monte Carlo techniques. For the purpose of dose reconstruction, is NIOSH recommending that the 50th percentile or the 95th percentile values be used? Similarly, in Table 4-2, does NIOSH recommend that the average or maximum estimates of annual intakes be used for the years 1965–2002?

   In regard to Pu intakes from 1953 to 1964, it is not clear what values are being used and the reasons for choosing either the 50th or the 95th percentile. As noted in the question, in Table 4.2 on page 17, it is not clear if NIOSH is recommending that the average or maximum estimates of annual intakes are to be used for the years 1965 and 2002.

NIOSH: Task 5 may be better able to address this. When we are overestimating dose in a claimant dose reconstruction, we use the 95th percentile in most cases. Normally our response would be that NIOSH uses the geometric mean of the lognormal distribution with a geometric SD of 3.0. Usually we use the 50th percentile. Of course, if the claimant has bioassay data in his record we use that.

SC&A:

3. What is the relationship between the 15μm aerodynamic equivalent diameter (AED) and the 5μm activity median aerodynamic diameter (AMAD)? Why is it that the predictions and models dealt with particles < 30μm AED? Would NIOSH describe the rationale for applying these different parameters for particle size?

   The TBD appears to move from 5 um to 15 um in different places. If you go the graphs, you see the use of 30 um. SC&A would like to see more commonality for whoever is reading document, so that it is clear to the reader when there is a transition or a change from one diameter to another. SC&A does not disagree with what is done; it is just hard

to follow. A transition is needed to allow the reader to better understand why various diameters are being used.

ORAU: We will go back and try to make these changes more apparent. When using the aerodynamic equivalent diameter (AED), the highest value used is 15 um. But with the AMAD, we have to figure what fraction is relative to this. The ICRP AMAD of 5 is only applicable for about 15% of the cases whereas an AMAD larger than 15 um is more appropriate in 80% of the cases. For instance, in the 1969 fire it is possible they do not know the AMAD – it might be 1 um.

SC&A: Normal PuO_2 behavior may not the behavior of the PU after the fire. If the physics and solubility is changing, then the stay time of Pu inside the body may be longer that they thought. Later as more Pu changes to Am, it stays even longer and a matrix of changes is occurring. Another issue is when to use 1 um.

NIOSH: This will be discussed at length in the internal dosimetry discussion tomorrow, so let's defer this until tomorrow.

SC&A: The results of tomorrow's discussion should be considered in assessing environmental dose.

ORAU: You may not even know what the solubility is.

SC&A:

4. Why does the occupational environmental TBD ignore the potential for ingestion of contaminated soils and other windblown particulates that are larger than normally respirable particles that are traditionally included in dose assessments? What is the basis for not including inadvertent ingestion of radioactively contaminated soil and other finely dispersed radioactive materials?

   Ingestion needs to be taken into account in the equation of the dose. Environmental dose may not contribute the higher portion of dose, but the reliability of what portion of the dose that comes from ingestion is important for the reader to understand as one of the possible contributors. These should be taken into account in dose reconstruction. Somehow the TBD should deal with how much internal intake is from ingestion and how much is from inhalation, how much will stay in body in the various organ systems, and the proper dose for those environmental factors.

ORAU: When we started writing the RFP TBD, we were not looking at potential dose from ingestion originally. But OTIB-0009 was later developed by NIOSH and this TIB does deal with ingestion from soil contamination. I looked at their method used in OTIB-0009 and found that there were two modes. One was from airborne contaminants deposited on food or drink and the second was from resuspension of airborne contaminants that had deposited on surfaces and was later transferred to the

worker's face. When they look at the 50th percentile dose, only 0.1% of the dose was from soil contamination.

SC&A: Do you use 100 mg/day as the default assumption for the potential ingestion of contaminants. NIOSH is using this default assumption in revisions to the Bethlehem Steel TBD.

ORAU: We don't know what they would use in OTIB-0009. I just realized that OTIB-0009 was applicable. I did look at EPA for more information on potential daily ingestion of contaminants. There are only a few studies on this; EPA recommends that if the person is digging in the soil and transferring contaminationed soil to their face that 50 mg/year be used. The 903e area is the area with the highest contamination at RFP. But it didn't make sense to use 50 mg/year. They did not define the mode of entry and their analysis was not based on actual data.

NIOSH: ORAU has done an analysis in order to attempt to address this issue and will put something in the TBD to close the loop on this issue.

SC&A: We would like to see why you do not use 100 mg/day. I remember that some of the assumptions in the TBD were low, so there may be merit in reviewing the use of this default assumption. This has been an ongoing dialogue with NIOSH and is a more generic issue that SC&A has been talking to NIOSH about.

SC&A:

5. For the pre-1965 time period, has NIOSH taken into account that the continuous resuspension of Pu and Am?

   There appear to be two dimensions here. We have discussed the particle size of the Pu, but should also consider the physical dimension.

   SC&A has recently discovered a report entitled "The Final Buffer Zone Sampling and Analysis Plan of 2002" which we will be glad to share with NIOSH. Appendix B deals not with the industrial area, but instead with the buffer zone outside the industrial area. The report deals with a lot of calculations of the contamination in soil. Appendix E shows that for ^{238}Pu monitoring, they collected 656 samples. The maximum result was 2,610 pCi/gm. They also looked at Sr. The U values were not really that high. The Cs maximum result was 2,830 Ci/g.

   Also SC&A understands there are "DOE Close Out Reports" that include good data on soil contamination in the industrial area and in the buffer area. If these reports give us a good idea of the levels of contamination, then resuspension can be better understood as well as the doses that are occurring. This is an important issue as SC&A believes this can lead to high numbers. DOE collected all the samples and made a deal with EPA regarding the use of this data.

NIOSH: We have been using air samples data and some of the particles will be re-suspended. Therefore air data is better than soil contamination.

SC&A: In Table 4.2, it appears the intake from 1965 to 1972 releases are higher by a factor of 2.

ORAU: The RATCHET code does include this. The resuspension factor was developed by them as their own factor. ORAU will go back and look at this more closely. In the Appendix of the TBD, it does mention that resuspension was used. Rood and Grogen et al. explained this and what factors they used for resuspension.

SC&A: There was an example of a waste treatment plant where the waste water was used to spread over the soil to control wind spread of contamination. The DOE close out report may cover this. The TBD on page 9 explain that an estimated 3.1 curies (50^{th} percentile) of Pu (<30 um size fraction) were released from the 903 pad over several users, mainly as a result of mechanical disturbance and wind action (Weber et al. 1999). And yet on page 14 of the TBD according to Weber et al. (1999), the highest release estimate for ^{239}Pu in the 903 storage area was on the order of 1000 g, which corresponds to 62 Ci. The discrepancy between these two statements needs to be explored. How much really did leak out of the drums and did ORAU assume that some of the PU was converted to Am.

ORAU: On page 9, 3.1 curies related to a discrete release event. It does not take into account all of the resuspension that occurred later. The page 14 statement comes from the John Till RAC report, which discusses this. In the Till report, they were able to capture data down field and were able to figure resuspension during all high wind events, so that the resuspension estimates become pretty awful. Those estimates were compared with actual Pu release and corrected. 3.1 Ci was dominated by 9 events, which were observed and quantified on the 903 pad. Americium was taken into account and the activity shows about 30% of Am in the airborne Pu releases.

SC&A:

6. Has NIOSH evaluated the degree to which RATCHET can be used to reliably simulate the atmospheric dispersion factors onsite, in the immediate vicinity of the releases, which is characterized by several closely constructed buildings? Wouldn't these building wakes prejudice the results?

   SC&A has a concern that RATCHET (an offsite model) may not be accurate enough for areas with buildings. Has ORAU made any adjustments to account for onsite building?

   The second point – if used during period with no data prior to the early 1960s, Figure 4-A-3, why is there no data goes beyond the 50^{th} percentile – you would think that the 95^{th} percentile should have been modeled too. In 1969 the 50^{th} is measured. If you compare that with the 1957, it is 10x higher in 1969 than in 1957. We realize the RATCHET code

is the best we have. But if you use the average (50th percentile) value in Table 4.1 for 1957 of 3.3 pCi/year, it would seem you should multiple this by 10, so that the 3.3 pCi/year for 1957 becomes 33 pCi/year. This 10X factor should also be applied to the years before 1957 as well, since there were no laws in the 1950s on this. Therefore the 1952 to 1964 gaps should use the 10X value

ORAU: A lot of this was modeled on the 903 pad releases which would skew results. ORAU will have to look at what other claimant-favorable things were used in the 1957 fire, and what other conservative estimates were used. If you keep adding factors of 10 on top of other factors of 10, the values can become unrealistic.

SC&A: There will need to more follow up and explanations of these margins of conservatism in regard to the 1957 fire to see if the conservative assumptions are logical and then it will be possible to determine if the X10 is needed. How RATCHET applies is one we have dealt with before.

ORAU: We use RATCHET because it had source terms for the RFP site and the results could be compared with the 30 um data. RATCHET was only used for the period of 1953 to 1957. One of the major events had a release from a stack that was 53 meters high. However others say that 47 meters is more accurate for the stack height. Even with these variations, stacks of this height would tend to rule out that buildings which are not this high would have a big input. They are looking at the average concentrations and the average (50th percentile) is probably OK.

RFP Occupational Internal Dose TBD Conference Call Summary

Date: September 7, 2005
Time: 10:00 am- 12:30 pm EDT

Participants:

ORAU: Robert Meyer, Craig Little, Roger Falk, Jan Johnson, Liz Brackett, Karen Jessen, Tim Vitkus, Al Wolff
NIOSH: Brandt Ulsh, Sam Glover
SC&A: Joe Fitzgerald, Dunstana Melo, Tom Bell, Bob Alvarez, and Kathy Robertson DeMers

Additional Participants: Amy Dean (Scribe), Muddy Sharkey, Advisory Board, Mark Griffin

Introductory Comments:

We will let Joe Fitzgerald walk us through the questions as we did yesterday. Jim Langsted sent out a revised Section 6 on external dosimetry.

SC&A General Comments:

Dunstana Melo provided corrections to the titles of two tables in the previously provided PowerPoint presentation on preliminary talking points for the RFP conference call. It was pointed out that on page 17 of that PowerPoint presentation (see Attachment 6), the titles of the two tables should read "Intake Retention Fractions for Pu-239 Inhalation" instead of "Dose Coefficients for Pu-239 Inhalation."

The PowerPoint slides were done later and provide some perceptions as to where we are now as to preliminary issues that were done 3-4 weeks ago. The internal dose discussion begins on page 12 of the viewgraphs.

The talking points are where we are and will likely change as we discuss all these questions and issues.

Let's have Dunstana Melo comment as to whether the response in the matrix table is OK or needs further clarification. We may not need to discuss the questions if it is answered OK.

ORAU General Comments:

Could we make sure that each new iteration of the ORAU matrix has an update date and version?

OCCUPATIONAL INTERNAL DOSE (ORAUT-TKBS-0011-5)

SC&A:

1. Page 84 of the internal dosimetry TBD shows a "Health Sciences Record." On this particular record there is a notation of ppm Am. How was this value determined? How is it used in dose reconstruction?

ORAU: Figure C-13 was presented in the Appendix as an example of a data report that the DR might encounter in a claimant's file. In this example, the parts per million by weight of the americium-241 (ppm Am) was calculated and recorded for the fecal and nose smear samples. The value of the ppm Am is calculated by converting the dpm (activity) values of the Pu and Am to mass by dividing by the appropriate specific activity (for Pu, weighted for the relative isotopic abundance for weapons grade Pu). The ppm Am is then the ratio, [mass Am/ (mass Pu + mass Am)] x 1, 000,000. The ppm Am value was used in real time by the dosimetrist who was managing the case data for the worker who was involved in a possible inhalation incident in order to interpret the Pu lung deposition from the lung count results, which were americium measurements. The project DR may or may not decide to use this type of supplemental information

SC&A: The response in the Matrix table is OK.

SC&A:

2. It was noted on some of the records in Attachment C of the internal dosimetry TBD that some bioassay analysis was done offsite. What offsite vendors were involved in bioassay analysis for RFP? For what time period?

ORAU: Use of offsite laboratories to analyze bioassay samples started circa 1993, starting with IT Analytical Services, Richland, WA, later named Quanterra, and, circa 1998, with General Engineering Laboratories, Inc, Charleston, SC. Some bioassay samples were processed by other laboratories as backup to the primary lab.

SC&A: The response in the Matrix table is okay.

SC&A:

3. How do dose reconstructors identify uptakes of Super Type S and other insoluble forms of plutonium, particularly prior to lung counting, beginning in 1964? How is the dose reconstruction process modified for these cases? What default solubility values are applied, and on what basis, when solubility is not known?

ORAU: These issues are being addressed in a project technical information bulletin, ORAUT-OTIB-0049, which is currently in review. The implementation, when the TIB is

approved, will apply to the RFP in the same manner as for all the other sites with plutonium inhalation exposures. In general, when the solubility type is not known, the DR will use the type which results in the most claimant-favorable outcome.

SC&A: We are interested in learning more about how you are including dose from the high-fired PuO_2. Are you following the approach in OTIB-0029 that was used for Y-12? If you consider the high-fired PuO_2 as Type S, we agree that is acceptable for all cancers except for lung cancers. What solubility class are you using for high-fired PuO_2?

NIOSH: For cancers other than lung cancers, Type M is appropriate. A new OTIB is in review on high-fired oxides that has been sent to NIOSH for review, and it should be available soon. If you get a non compensation when determining the POC, where the Type S issue might be important, we will hold the claim until the OTIB is issued. But very few are being held for this consideration. The OTIB should also be out in two weeks. It covers high-fired PuO_2, but not high-fired uranium oxides. It does discuss it, but we don't think that high-fired PuO_2 will affect the dose.

ORAU: We focused on the Pu in the OTIB. In our experience, they have not observed any long-term retention of uranium.

SC&A: Then you are saying that there are no claimants with lung burdens of DU?

ORAU: For Pu, we see workers who have Am showing up in their lung counts and this is stable over 30–40 years.

SC&A: Yes, Pu does stay in the body for a very long time. But U does not. How about RU and its trace daughters? It's hard to know how the processes have concentrated them. At Hanford, the bag workers got high doses of Np.

ORAU: At RFP, we did not have a fission product problem.

SC&A: Did RFP process recycled uranium?

ORAU: Only 2 tons out of approx 8,000 tons might have had RU. This is discussed as part of study done and published in the year 2000.

SC&A: But there is some data regarding ingots that indicates this could be as high as 2500 metric tons and they did find fission products. It would be useful to know more about this. Yesterday it was agreed this would be addressed perhaps as a broader issue. Does OTIB-0049 address any potential for high-fired oxides?

ORAU: Yes, it will. If it can't be determined, the DR should make that assumption.

NIOSH: There will be guidelines on how to determine dose that is not currently in the TBD.

SC&A: What is the document?

ORAU: There is currently a TIB on how to fill in for missed dose, but there are also guidelines for each site (not formal documents). These informal guidelines are written and distributed to the dose reconstructors.

NIOSH: Filling in missed dose comes from a compendium of information. Task 5 comes up with specifics as to how do dose reconstruction. We will be glad to provide them if you have not seen them.

SC&A: Are you using OTIB-0029 that you developed for Y-12 for internal dose estimates at RFP, or are you holding all but minimum/maximum compensation decisions until the OTIB 49 comes out?

NIOSH: These questions won't be clearly addressed until later.

SC&A:

4. Was any potential exposure from radon and/or thoron? If so, under what circumstances?

ORAU: None that we know of. High ventilation rates in the processes and other populated areas would have precluded buildup of radon and thoron.

SC&A: The response provided by ORAU addresses our question, but we are seeing lead peaks on lung counts. Were any workers monitored for ^{24}Na?

ORAU: We did not look for fission products since we feel they were not there.

NIOSH: ^{226}Ra would not be there.

SC&A: Did it occur naturally and is that why we are seeing lead peaks?

NIOSH: Radon is an issue with Gravel Gertie's, but this was not so at RFP.

ORAU: We are not acquainted with that.

SC&A:

5. Section 5.3.1.6, Tritium, did not mention the form of tritium assumed in the dose assessment calculations. What is the default assumption for the form of tritium? Were there other forms of tritium present at the site?

ORAU: The default assumption is tritiated water, HTO, formed from tritium gas released to the atmosphere. There is no evidence of other forms of tritium at RFP which would constitute a significant source of exposure.

SC&A: The response in the Matrix table is OK.

SC&A:

6. What method was used for assignment of internal dose to unmonitored or inadequately monitored individuals?

ORAU: The DR has generic procedures and instructions to deal with these circumstances. As appropriate, internal dose is assigned using claimant-favorable methods provided in OTIB-2, OTIB-14, and OTIB-18. EEs with specific partial bioassay may also be assigned internal dose based on IBMA runs if it is needed to refine the estimate or determine dose from positive bioassay results. Maximizing or minimizing assumptions are made depending on whether the case is compensable or non-compensable.

SC&A: If you have an unmonitored individual, are you defaulting to OTIB-0002?

ORAU: If the claim is currently in processing, we would use OTIB-0002 or OTIB 0018, both of which would result in an overestimate of dose. We might use OTIB-0014 if it involves environmental dose reconstruction.

SC&A: Is the environmental dose what you would consider to be that which occurs outside?

NIOSH: If you have a secretary or cook, you might give them an environmental internal dose, even though they were inside and more in a sheltered setting.

SC&A: Will you be mentioning OTIB-0049 in the TBD?

ORAU: It is not possible to have all OTIBs mentioned in the TBDs. They are coming out all the time and may come out after we issue a revision of the TBD. The TBD is designed to provide the basic data. For instance, some TIBs are directed to a specific site such as what was discussed in the Hanford TBD. In the early 1943 – 1945, there is a special TIB that is cited for use that is specific to that issue at Hanford. It is not applicable to other sites.

SC&A:

7. There is no direction for dose reconstruction associated with neptunium, thorium, curium, ^{233}U and ^{238}Pu. Has the potential for intakes from these radionuclides been considered?

ORAU: There is no record of intakes by RFP workers to pure forms of these radionuclides. ^{238}Pu is included in the weapons grade plutonium mixture. Contaminants in recycled U at RFP were not a significant internal dose issue.

SC&A: We note that you do address ^{238}Pu, but you indicate that you do not see the other internal contaminants.

ORAU: Roger Falk would be the best person to address this, but he is not on the conference call at this point.

SC&A: It is important to note that there were no technical limits until 1985, and things widely varied from site to site. We feel there is a commitment to provide a strong rationale for some of the potentially dominant radioisotopes. The TBD seems not to address these. We also wonder what you are doing about dose for Am.

ORAU: All lung counts, of course, are picking up the Am. If they worked with Am, then it is easy to include a dose for this. The urine program started in 1964, as discussed in Appendix A. We did not have a program to monitor for curium, but if we suspected it was there, we would look for it. But the handling of curium was a small effort at RFP.

SC&A: How do you deal with the purification issue with Am, and can you be sure there is enough Am in the lung counts?

ORAU: Am decays at rate of 20 ppm per month. With the recently purified Pu, and if it was less than 200 ppm, then that person was recounted once a quarter for the following year. There was that kind of follow-up for freshly purified Pu.

SC&A: Did you have any individuals who may not have been involved where you picked up uptakes of Pu or U?

ORAU: When we went to using germanium detectors and switched from NaI detectors, we saw more.

SC&A: The lack of good radiological control procedures at these uranium foundries is an important issue. In 1994, DOE did an assessment and RFP had serious problems in their radiation control procedures.

ORAU: We had very sensitive counting systems and urine bioassay at that time, but I am not aware of the operational aspects.

SC&A: We are not sure how long this went on. In the post-1989 period and after shutdown in 1994, there were lots of materials sitting around that were either leaking or had loose surface contamination. We are trying to understand how they handled missed dose in such instances.

ORAU: It certainly was true that things were left in disarray. But if there is the need to do a dose reconstruction for an unmonitored worker during this post-1989 period, this would be calculated using available bioassay data. Things were not just sitting in the

lines. After the RFP was shut down in 1989, there was a flurry of activity to get things cleaned up in 1992 and 1993 in anticipation of a restart. It wasn't until 1993 that DOE decided they were not going to go back into production. Then radiation monitoring programs were established that were based on work permits, fecal and nasal smears, reentry criteria, and respiratory protection. These were all state-of-the-art RadCon procedures. The primary data for any dose reconstruction is the bioassay data as the highest tier and the bioassay was very sensitive.

SC&A:

8. Which of the DOE complex-wide technical information bulletins were used in dose reconstruction for Rocky Flats claims? Under what conditions were the technical information bulletins used?

ORAU: All of the complex-wide bulletins are used as needed to provide general guidance on implementation of TBD information and/or to provide a maximizing or minimizing estimate if the TBD does not cover a topic of interest.

SC&A: The response in the Matrix table is OK.

SC&A:

9. The TBD recommends that the dose reconstructor assume that radionuclides are soluble for the purpose of dose assessment of the systemic organs and tissues. Is this approach recommended to assess intake and dose for systemic organs when using bioassay and/or air concentration data?

ORAU: The DR generally uses the solubility that gives the best outcome to the claimant if the solubility is not known, so the TBD no longer needs to give that recommendation.

NIOSH: That will be taken out of the TBD.

SC&A: The response in the Matrix table is OK.

SC&A:

10. The TBD states that particle size and distributions are not available and it recommends the use of the default value of 5 μm AMAD. On what basis is this default value recommended when a range of airborne particle sizes has been confirmed at RFP (i.e., don't measured values take precedence over default values)? Is this approach recommended to assess intake and dose for systemic organs when using bioassay and/or air concentration data?

ORAU: Although there is a smattering of particle sizes measured for certain processes and time at Rocky Flats, the particles inhaled by a worker are situation-specific and are

unknown. Therefore, a default value is recommended. Note also that the RFP particle size data are generally stated in terms of mass median diameter (MMD) and not activity median aerodynamic diameter (AMAD). For plutonium oxide, the AMAD is approximately three times greater than the MMD. Also, use of 5 µm AMAD results in a neutral or slightly more claimant-favorable outcome than using a smaller particle size, when assessing doses from urine or lung data (the predominant situation for RFP workers).

The only situation for which there is a measured particle size associated with an airborne contamination incident is the 1965 Pu fire, for which the measured particle size is recommended instead of the default value. The default value of 5 µm AMAD is recommended for all other situations, consistent with the project wide approach.

Advisory Board: Mark Griffin joined the call at this point.

SC&A: The response by ORAU is OK as long as the DRs base their dose reconstruction on bioassay data. The dose reconstruction would not be as good if it was based on air sampling data.

SC&A: Do you have a sense of the amount of measured vs. estimated data that is used?

ORAU: Approximately 92% of claims have some internal dosimetry associated with them. This was based on the urine bioassay program until 1989 for systemic organs. DRs in Task 5 do not use any of that anyway. Therefore it is not used in the TBD. If they have a positive result on their lung count or on their urine bioassay, of course, that data is used in the dose reconstruction. Lung counts intakes can be used in conjunction with bioassay results. Internal doses below the MDA are covered in the missed dose assessment.

We look at as those above the MDA. Some intakes are pre-assigned based on what is known about typical doses, like those at the Hanford reactors.

SC&A: Big incidents occurred at times when pressure on production was high. As a result, people might not have been measured or monitored.

ORAU: If you have a Pu uptake, it could still be seen months later, so it might have been analyzed later and, therefore, not have been missed. If a person was unmonitored then OTIB-0002 or OTIB-0018 would be used.

NIOSH: It was not unusual to not see some internal dose monitoring.

SC&A: We wonder how well they monitored short-term workers. We have interviewed a millwright who had a Q clearance and was sent into the area were Pu work was ongoing. He reported that there was no internal dose assigned that was recorded in his personal file. Where would records like this be stored?

ORAU: There was an effort to consolidate these within the last year.

SC&A: Were any of these records taken away in the FBI raid?

ORAU: No, none of the records were taken away in the FBI raid.

NIOSH: We use all records we can find. If you think there are others and you have copies, we certainly would be interested to review them.

SC&A: In the process of transition to a more temporary workforce in the post-production period, it seems likely that some folks could be missed.

ORAU: In the post-production period, only certified radiation workers were permitted to enter the area, and they would have been badged.

SC&A:

11. On page 9 of the TBD in Section 5.2.2.2, it is recommended that the "Dose reconstruction should assume a 5 µm AMAD, except for fires [for which] a X.X µm AMAD should be assumed for consistency with Section 5.2.1.3 above." What did NIOSH intend to convey in Section 5.2.1.3 which does not exist in the TBD? What value corresponds to X.X µm AMAD?

ORAU: When this section was written, the value of 0.3 µm MMD had not been converted to AMAD. The conversion has been calculated, and the value is 1 µm AMAD. This value will be inserted in the X.X at the next revision of the TBD section

SC&A: It looks like the 1 µm AMAD is going to be the space holder for the XX µm value.

SC&A:

12. In general the values for median MDAs can be considered high, especially for enriched uranium presented in Table 5.3.1.3.2, on page 14 of the TBD. What guidance is given to the dose reconstructor to deal with results below the MDA when assessing the missed dose?

ORAU: Task 5 dose reconstructors have general guidance on how to handle less-than-MDA values of data. No special instructions are warranted for this TBD.

Missed dose is assessed by the DR by censoring the data to ½ the median MDA unless the actual MDA is available, in which case the missed dose is assessed using ½ of the reported MDA.

SC&A: The MDA is important in developing a missed dose. The MDA for Pu and U was very high. How do you deal with results that are below the MDA? Is there a specific document for this?

NIOSH: We use ½ of the MDA to do an assessment. The last bioassay measurement is used and a chronic intake is assumed for the entire period with the minimum being zero and the maximum at the MDA. We use a triangular distribution. There is not a specific document, but there are guidelines to the DRs and we have weekly discussions with the DRs to point out new guidelines. Missed dose is calculated by running positive readings to determine a chronic dose. We use whichever is larger (Calculated vs. measured).

SC&A: It would be helpful to see what instructions that you follow. This would help us.

SC&A:

13. In Section 5.3.1.5.1 on page 16, the TBD states that until 1973, gross alpha measurements were applied for analysis of the urine samples of workers potentially exposed to both uranium and plutonium. How does the dose reconstructor evaluate potential dose contribution from neptunium and curium?

ORAU: If there is evidence in a claimant's file that the worker was involved in a neptunium or curium project, the DR may interpret the gross alpha urine in terms of that radionuclide if that results in a more claimant-favorable outcome.

Problem with these questions involved Pu and curium. But until 1963, all results applied to U and after that to Pu. But there may be some combined that could be seen by alpha counts and this could lead to missed dose.

SC&A: Would you have looked at the individual case to see if you should look at more than U before 1963 and Pu after 1963?

ORAU: In the TBD, we tried to describe how the data was used at the time. The DR can re-interpret that as they see fit. There is more information to assess than the description of the program at RFP in the TBD.

SC&A: Nonetheless, it would be good to clarify this in the next TBD.

SC&A:

14. In Section 5.3.2.1.1 on page 18, the TBD discusses two sources of interference. The second interference involves the contribution of the count from ^{241}Am not in the lungs, but from contributions from contamination on the skin, from material being cleared from the upper respiratory system, or from ingested material. The skin contamination contribution may be true for accident or incident situation, but not for the other examples,

since the transit time in the upper compartments of the human alimentary tract is fast. How does NIOSH deal with this contribution?

ORAU: All of the interferences, if operative, are claimant favorable when the DR uses the recorded lung count data at face value.

SC&A: The response in the Matrix table is OK

SC&A:

15. At the end of Section 5.3.2.1.2 on page 20 of the TBD, it states that "An underlying assumption is that americium remains associated with the plutonium particles in the lungs until the particles are dissolved or removed from the lungs." What is the basis for this assumption?

ORAU: The basis for the assumption is the observation that americium lung count measurements for many RFP workers with confirmed, medium-to-high levels of Pu and Am lung depositions remained constant or slightly increased (from Am ingrowth) for over 30 or more years post-intake. In addition, recent USTUR data for autopsy cases of RFP workers indicate that the ratio of measured Pu and Am activities in the lungs at autopsy is consistent with that calculated based on the underlying assumption.

SC&A: The response in the Matrix table is OK.

SC&A:

16. The TBD mentions in Section 5.3.2.2.1 on pages 20 and 21 that "The method to detect depleted uranium was to detect the 63-keV gamma (doublet) photon of ^{234}Th and to calculate the activity of ^{238}U, assuming equilibrium" which was implemented manually for special cases in approximately 1978. How did Rocky Flats Plants dosimetry personnel infer the lung activity of ^{238}U, due to depleted uranium exposure, based on the ^{234}Th measurement?

SC&A: We would like to get a clarification of who was likely to be exposed to uranium and who had the potential to be exposed to ^{234}Th?

ORAU: During the operation period, the situation was probably super U. The thorium would come to surface. If you assumed equilibrium and the lung counter saw Th, then you would tend to overstate the ^{238}U if there was super equilibrium. If you have very freshly purified DU then we also assume equilibrium.

ORAU: The activity of the DU was calculated from the ^{234}Th measurement as described in the third paragraph of Section 5.3.2.2.1. When ^{234}Th is in equilibrium with its parent

^{238}U, the activity of the ^{234}Th is equal to the activity of the ^{238}U (Section 5.3.2, 2nd paragraph).

SC&A:

17. In section 5.3.3.1 on page 22, the TBD states that "Wound count information is largely irrelevant to dose reconstruction." From other wound decontamination experiences it has been demonstrated that for some radionuclides, even with decontamination treatment, that some wound contamination remains in the scars. In case of skin cancer, does NIOSH use wound contamination measurements for dose reconstruction and how is this accomplished?

ORAU: The TBD author is not aware of any RFP worker who has had a skin cancer at the site of a wound with residual plutonium. If such a case were to happen, the DR would have available wound count and skin contamination data in the claimant's file.

Wound count information is largely irrelevant to dose reconstruction. This guidance directs the attention of the DR away from the clutter of count data on wound count reports to the much more relevant information on the wound count reports or associated with the wound.

SC&A: The reasons and approach in the TBD are OK for the cancers in the systemic organs. We agree with the answer, if we are discussing skin cancers. But for lymphomas, it is known that residual contamination, for some radionuclides like Am and Pu, can be retained in the scars and lymph nodes. A special procedure is needed for dose reconstruction for cases of lymphomas.

ORAU: We have a TIB in OCAS that deals with wounds. It does not address lymph nodes cancers, but it does state that it should be looked at for specific claimant cases.

NIOSH: The wound TIB that we are preparing, and that is in OCAS for review, will address lymphoma cancers. I can provide copies of this when it is released.

SC&A:

18. Figure 5C-16 on page 87, dealing with body counter information, shows that there is no data for the right chest. On page 27, it states that "The dose reconstructor should estimate the contribution for the right chest before using the data from the count because the lung data set generally includes contributions from both right and left lungs." How does NIOSH calculate the total activity in the lung in this situation?

ORAU: The DR would refer to Appendix B, equation 5B-6 to get the calibration for that period for two detectors and then multiply that calibration factor by 0.43, per the following sentence. The net c/m data for the left chest divided by the adjusted

calibration factor gives the total americium activity for that count. The DR is directed to Appendix B in the third paragraph of Section 5.3.2, for "more detail."

SC&A: The response in the Matrix table is OK.

SC&A:

19. Were lung counting measurements a part of the routine monitoring program, or was lung counting performed just in case of an accidental intake? On page 27, it mentions that "The dose reconstructor should note of the intake date. If the intake date is different from the date for the Count Started, the intake date is from the file for a worker with a confirmed deposition. Otherwise the date of the lung count is used as the intake data." If it was part of the routine monitoring program, why is the date of the lung count used as the intake date? This does not seem to be the most claimant-favorable approach.

ORAU: Lung counting measurements were performed both routinely and for possible inhalation incidents.

The cited paragraph on page 29 pertains to lung count reports generated by the ABACOS-PLUS© software, which calculated uranium, plutonium, and americium activities for every lung count, regardless of the detection of the radionuclide. The guidance to the DR was to look at the date to discern whether the computer's calculation was based on a "real" and confirmed intake or just on the count data for that date. Indeed, if a routine count gave a "positive" indication, the internal dosimetrist would have conducted a follow-up investigation.

SC&A: The response in the Matrix table is OK. One question we have is related to the bioassay program. How was fecal analysis done?

ORAU: For the entire operational period, it seems this kind of data was only recorded for the accidents. The claimant's file will likely include it. RFP tried to implement a fecal program and it was not well received by the workers. Also, it was difficult to get consistent results using the chemical analysis they were using. Therefore, they backed off of it. There is fecal data for some of the accidents and some data in the mid-1990s. Missed dose, when assuming constant chronic intake, is more favorable than looking a bunch of small incidents.

SC&A: Fecal bioassay programs need to be enhanced in the TBD in order to provide more information about fecal analysis. In cases of incidental intakes of insoluble compounds, it is very unlikely that these insoluble forms would have been detected using urine data since the activity expected to be found is very low. The more appropriate method is to use fecal data associated with lung count data.

NIOSH or ORAU: It is agreed that this section should be enhanced including the methods, uncertainties and MDAs.

SC&A:

20. On page 30, it mentions that Section 5.5.2 is reserved and yet to be determined. What is NIOSH doing in its revisions to the TBD to expand upon this section? How is NIOSH planning to deal with the assessment of dose based on co-worker data? Will evaluation of air concentration data be a part of this effort?

ORAU: These issues are still to be determined. It is likely that each case, if any arise, will need to be researched on a case-specific basis, using whatever data are appropriate and available. The next revision may say just that.

SC&A: The response in the Matrix table is okay.

ORAU: Co-worker data is all being analyzed. The work on the wound OTIB got postponed by work on recent Mallinckrodt Chemical Works reports and research, but the OTIB is pretty far along. The co-worker data will not be addressed in the TBD, but will be in the new TIB. There is an OTIB-0019 that discusses internal dose. Three TIBs have been issued for internal dose and the process recommended takes the data sets and does an analysis of them. Values are put in the OTIBs and the DR then decides if those intakes are applicable. There is a Rocky Flats internal dose OTIB in development. This has not gone to OCAS for review. It will be OTIB-0038 when it is released.

SC&A:

21. In Attachment A, it is not clear how the volume of urine samples was normalized for 24-hours excretion. Please explain the two different approaches used for uranium and for plutonium and how they were normalized in each situation?

ORAU: In general, routine urine bioassay samples were <u>not</u> normalized to a 24-hour excretion, i.e., a standard volume such as 1400 mL. Instead, the worker was instructed to collect all his urine excreted over a continuous 24-hour period or two 12-hour overnight periods, and the worker was expected and assumed to have complied with the instructions. The median volume of 1350 mL, presented on page 43 and obtained from urine data logs for samples submitted 1952–1955 and 1960–1971, verifies the validity of that assumption (ICRP-23 Reference Man daily urine volume = 1400 mL). It was noted (p.40) that volumes less than 1000 mL for Pu routine samples were normalized to 1200 mL and, for routine DU samples (p.41), volumes less than 1000 mL were set equal to 1000 mL. For EU samples, no such volume adjustment was made, since only 50 mL of the sample was analyzed. This information was presented to describe the method that was used.

SC&A: We still have a question. Will the values in the claimant files be normalized?

ORAU: All values are taken as if they were 24-hour samples. If samples were less, then there is a description of what they did in early years to adjust for this. This will not be applicable to more current times. They were usually handled as 24-hours samples, but you would use ICRP 23 if you needed to normalize.

SC&A:

22. In Attachment A on page 39, it states that "Depending on the process, spiked samples, samples to which a known activity of the analyte was added, were generally processed with each batch of samples." On page 52, it states that "Not until 1973 were some plutonium samples spiked with an internal tracer (first ^{236}Pu and, later, ^{242}Pu). All plutonium samples were spiked with an internal tracer after 1978…Whether to use the median value of the MDA or the extreme value depends on the purpose." This seems to suggest that some samples, in the earlier years, may have higher MDA than the ones tabulated or described with the results of the urinalyses, since the recoveries were determined by batch spikes. What is the variability of the recovery?

ORAU: Indeed, 50% of samples have a sample-specific MDA higher than the median MDA for the process. The table on the bottom of page 44 gives the median and 5th percentile values of recoveries. The 5th percentile values of recoveries are an indicator of the variability at the worst-case end of the distribution.

SC&A: The response in the Matrix table is okay.

SC&A:

23. In Attachment A on page 37 in the Analyte/Method Code table on page 37, it is noted that the Method Code B_1 appears both for the analyte "Depleted uranium" and also for the analyte "Enriched uranium." Is it possible for a worker to have been exposed to both depleted and enriched uranium? If so, how does the dose reconstructor distinguish whether it's DU or EU, once the method code (B_1) has been assigned in both situations?

ORAU: The B_1 method was used for DU starting 5/1/64, coinciding with the wind-down of EU operations at RFP, which ended in 1967. Even though it is not likely that one worker would be exposed to both DU and EU in this period, the DR always has the option to assign the analyte that results in the more claimant-favorable outcome, when the DR does not have adequate information in the claimant's file. Note that the building number is recorded on the bottom of the Urinalysis Record Card: Building 44 = DU; Building 81 = EU, which can help the DR to make a correct judgment concerning the analyte.

SC&A: The response in the Matrix table is okay.

SC&A:

24. In Attachment A, on page 42 under the section entitled "Gross Alpha (1952–1971)," the TBD states that "The default condition, through 1963, was to credit the result to enriched uranium unless the PHA count indicated otherwise…After 1963 (and enriched uranium operations were phased out), the default condition was to credit the result to plutonium." Why does NIOSH feel this is the most claimant-favorable approach?

ORAU: The information in Attachment A describes the program as it was conducted in real time at RFP. For any given case, the DR may choose a different approach if needed to achieve a correct compensation decision.

SC&A: The response in the Matrix table is okay.

SC&A:

25. In Section 5.5, *Internal Dosimetry for Unmonitored Workers,* it is indicated that for unmonitored workers "not involved in an incident," use of air concentration limits in effect would be a reasonable approach. However, this section is left "to be determined" given that actual limits applied in the plant are needed, not merely those cited in official requirements. What is the status of obtaining this key information and how are unmonitored internal intakes being modeled in the interim?

ORAU: Much of that research has been done and will be incorporated in the next revision of the TBD. Although it is not clear whether the DR has yet encountered such a case for RFP, the DR has generic tools to assess this situation—use of environmental exposures, use of MDA values at the end of employment or risk, and co-worker bioassay data. Each case is individual-specific, but unmonitored workers' internal dose is generally assessed through use of maximum and minimum assumptions based on generic guidelines such as OTIB-2, OTIB-14, and OTIB-18 and, in some cases, data from other sites (e.g., for tritium).

SC&A: The response in the Matrix table is okay.

POWERPOINT VIEWGRAPHS

Slide 12

SC&A: There is limited direction to the dose reconstructor on the process and assumptions that should be used to calculate the internal dose; for example, missed dose, solubility and particle size, and incidental intakes.

Slide 13

SC&A: The TBD needs better guidance for ^{3}H, and Np, Th, curium and fission product. This may represent no appreciable dose, but it should be addressed... The TBD does not address exposure from the processing of recycled uranium.

ORAU: There is no available information.

Slide 15

SC&A: 5 μm is acceptable for bioassay, but not for air sample data.

NIOSH The only time that air data is used is for environmental dose reconstruction. For all others, we use bioassay or missed dose procedures.

Slide 16

SC&A: The TBD assumption for solubility of the compounds is not claimant favorable, especially for cancers in the gastrointestinal organs. The graph shows that for stomach, small intestine and large intestine (colon) the assumption of Type S compound arises with higher doses. So, the solubility should be assigned based on the type of cancer.

ORAU: We would deal with this in our guidelines to the DRs and it will be taken out of the TBD. We use Type S for colon and digestive tract. We will take this out of the next TBD and specific DR instructions will be followed. The solubility should be done based on the specific cancer.

Slide 17

SC&A: We have provided a table that shows the values of the intake retention fractions (IRF) for urine and feces for Type S and high-fired Pu compounds following a single inhalation of ^{239}Pu. Urinalysis seems to be inappropriate for the detection of intakes of either high-fired Pu or Type S, unless there was a really high intake. The fecal data are more appropriate for the detection of incidental intakes of insoluble compounds, in the first days after the accident. The activity expected to be found in feces is about 4 orders of magnitude higher than urine.

ORAU: We can't go back and get fecal samples, so we have to work with what we have. By using bioassay, the values will be higher and more claimant favorable.

NIOSH: In the TBD, fecal analysis results are discussed in a short paragraph. We realize that this needs enhancement as to what fecal data is available and how much it was used.

ORAU: Fecal data is rare and difficult to use. Did the fecal sample capture the bolus coming through the GI tract? If you don't capture the bolus, then it's not claimant favorable.

NIOSH: We will summarize this, although it might be better to do this in a generic document.

SC&A: Are you using AMAD of 1 μm when dealing with high-fired oxides?

NIOSH: We generally use Type M and 5 μm for most organs other than lung. We are looking into what is best with high-fired oxides and we will deal with this in the new OTIB.

SC&A: It is but a fraction of a 1 Bq intake that is expected to be found in urine and feces after the inhalation of ^{239}Pu Type S and high-fired compound, and an AMAD of 1 μm would be more appropriate.

NIOSH: There is not going to be a very large difference. It is better to go from bioassay data and determine what gets into the organs. The TIB for high-fired oxides will discuss this. We use type M for most organs and Super Type S for lung.

Slide 19:

SC&A: Slide 19 points out the uncertainties related to using urinalysis. High uncertainties are associated with estimates of the high blank, recovery, 24-hour urine volume, and the estimate of the median MDA values. Therefore, the TBD presents an evaluation of the extreme conditions for the variables, but does not provide a clear guidance on how to apply them.

NIOSH: The DRs are using a chronic intake with ½ MDA. This is a much bigger number and is more conservative. It is not claimant favorable to do individual accident analysis. So we feel no action is needed.

Slide 20

SC&A: This has already been discussed.

Slide 21, 22, and 23

SC&A: This has already been discussed as well.

Slide 24

SC&A: Ingestion pathway of exposure was not considered on the dose assessment; it is important especially in cases of cancer in organs of the gastrointestinal tract.

Slide 25

SC&A: This has already been discussed.

SC&A: We would recommend to the TBD authors that they include in the TBD an example of a dose reconstruction. This could be placed in the Attachment. This is very helpful and should be used in other TBDs.

SUM UP

NIOSH will send the lymphoma and wound TIB to SC&A as soon as it is released.

NIOSH will go through and compare the entire body of TIBs and will send them to SC&A on a CD.

SC&A will get the online TIBs to Dunstana Melo.

Unanswered internal dosimetry questions will go to Roger Falk who missed most of the first part of the call.

SC&A: A memorandum titled *Personal Radiation Exposure Summary* was issued to the workers along with annual exposure summary. The memo stated the following:

> *A 0 (zero) is recorded for any of the following conditions:*
>
> 1) *no exposure received*
> 2) *the exposure was so small it cannot be measured by our current methods*
> 3) *no data is available to make this assessment.*

What does no data is available to make this assessment mean?

NIOSH/ORAU: The annual report card was a computer generated summary of exposure. If an individual was not monitored during the year, the computer would put a place holder zero in the report. The description of a zero covered all the possibilities as far as the computer generated report. It really didn't mean much. It was just a clarification to the worker of all the possibilities for zero.

RFP Occupational External Dosimetry TBD Conference Call Summary

Date: September 7, 2005
Time: 1:30- 4:00 pm EDT

Participants:

ORAU: Robert Meyer, Craig Little, Jim Langsted
NIOSH: Brandt Ulsh, Greg Macievic
SC&A: John Mauro, Joe Fitzgerald, Ron Buchanan, Tom Bell and Kathy Robertson DeMers

Additional Participants: Amy Dean (Scribe), Advisory Board, Mark Griffin, All Wolff

SC&A General Comments:

Let's just go to the questions and state if the answer on the matrix is satisfactory – then we will proceed. If there are any additional questions –then we will discuss these issues as we get to them.

ORAU General Comments:

We have used this process previously and this is a good way to proceed.

OCCUPATIONAL EXTERNAL DOSE (ORAUT-TKBS-0011-6)

Dosimetry Records

SC&A:

1. Page 10 states that further research is necessary to determine which dosimetry method was used to record a worker's dose. Has any progress be made in addressing this area of uncertainty?

ORAU: The statement, "Further research is necessary to identify exact dates for each dosimeter type," still stands. Dosimeter types were typically phased in over a period of time (sometimes as much as 2 years). The methods of recording worker doses sometimes indicated which dosimeter was used, but sometimes this cannot be determined. Where possible this information has been included in the TBD or passed on to the Dose Reconstruction group. No further data is available about exactly when specific dosimeters were used.

SC&A:

2. Why doesn't information in the TBD, page 11 (and also ORAU-OTIB-0027, pp. 5–7), regarding skin and penetrating radiation doses, match that given in some of the historical

records for the RFP (Owen 1964 and Putzier 1982)? In 1964, Owens defines the RFP doses as:

Skin dose = hard gamma dose + soft gamma dose + x-ray dose + beta dose + neutron dose

Penetrating dose = hard gamma dose + soft gamma dose + 1/3(x-ray dose) + neutron dose

Hand dose = (hard gamma dose + soft gamma dose + x-ray dose) x 2.5 or 5.0 depending on area and chemical form.

However, ORAU-OTIB-0027 (pp. 5–7) uses the open window (OW), cadmium filter (CD), and brass filter (BR) to define skin and penetrating doses, but does not relate them directly to the quantities as listed above which were in place at the time the doses were recorded.

ORAU: This will take some additional work to complete.

SC&A:

3. How is it intended that the dose reconstructor correlate the methods in TKBS-0011-6 and OTIB-0027 in relationship to the recording methods that were in place during the years they were recorded, and also changed during the years?

   In regards to questions number 1-3 above, our interest here deals more with the consistency of use and approach that is used by the dose reconstructor and how the DR reconciles this with relevant historical documents. The consistency of the TBD and the TIB are OK as written.

ORAU: OTIB-27 is a clarification, interpretation, and documentation of selected issues and information in Rev 0 and draft Rev 1 TKBS-0011-6. There are no known inconsistencies. OTIB-27 represents the approach agreed to by OCAS to implement the external dose TBD.

In regards to these issues (Questions 1-3), this area needs more attention. It will be necessary to determine the dosimetry/records methods used over the years and their changes. Page 11 of the present TBD needs further expansion and this information will be included in the revised TBD.

SC&A:

4. How is it intended that the dose reconstructor reconstruct the separate doses to arrive at the total dose in these cases? Note on page 11, Section 6.3.1, that it states that during the early period (around 1951–1975) the deep gamma dose and the neutron dose were

recorded as the total penetrating dose, and not recorded as separate doses in the worker's file.

Our concern is that if the deep gamma dose and the neutron dose were combined into a total penetrating dose and that separate doses were not placed in the worker's file, this may not be as claimant favorable as calculating the dose that was neutron if that was applicable, and then do a separate calculation for all dose that was gamma.

ORAU: If we need to overestimate the dose in cases where the claimant is approaching the 50% POC, then we will determine the penetrating dose, which will include the application of all neutrons or all gammas to make it as claimant favorable as possible.

SC&A:

5. Was the Harshaw TLD 600/700 system used for extremity dosimetry during 1983–1991 when the beta/gamma and neutron dosimetry was being performed using the Panasonic system?

   Response is okay

ORAU: This is correct, as indicated in Table 6-1.

SC&A:

6. Has any more information been found regarding the characteristics, performance and calibration of the LANL processed neutron track "plates" for the RFP from 1951 to 1956? Has the recent Neutron Dose Reconstruction Project Report (NDRP) (Falk et al. 2005) assisted dose reconstruction (DR) during this period?

   SC&A has reviewed several historical documents looking for information on the LANL neutron track glass dosimeter and there is not much that can be found. Has NIOSH done much work on this? Do the neutron track glass plates provide similar dose determination as would TLDs, or is there a difference?

ORAU: We have found a lot of new data on these neutron track glass plate dosimeters. There is information on the neutron track plates in the LANL TBD for external dosimetry. There is a different calibration factor for the track plates and these have been reread and doses changes have been made if we find it is needed. This information will be included in the revised TBD. The schedule for the revised TBD is still not certain but when it is published, we will incorporate information about these issues that have come up and we will address SC&A issues. The TBD reissue is operating in concert with the SEC petition. Both will come out in December before the board meeting in January 2006. So it will be important to ensure these issues are incorporated into the TBD by then.

SC&A: The NDRP indicates that these plates have been read. How fragile are the plates and is there a problem with physical fading?

NIOSH: NIOSH does not know of any problems with fading. If there is fading in field and that same fading is included in the calibration, then there should be no great effect and it will likely cancel out any effect. As they re-read the plates they do use calibration sets that were used to read them back in those days. This process was done manually over 2–3 years. They had good quality assurance procedures in place.

SC&A: What sort of error margins did you establish for the overall assessment?

ORAU: Roger Falk would be the better person to provide you an answer to this, but he was unable to be on the call this afternoon. You may want to contact him on this.

SC&A: Does your data tell you by building number what n/p ratios were used? For instance, we have read that the n/p ratio is 30/70 for Pu and for metals it's just the reverse 70/30.

ORAU: We do not have that kind of specific data by building location. RFP only recorded where workers worked. For instance, in Building 771 they were doing wet chemistries and in Building 776 and 777 they were working with metal.

SC&A: In the DOE 1994 vulnerability study, it was noted that in the post-operational era that thermal neutrons became a problem. Have you found this to be true in your reviews?

ORAU: There are some n/p ratios in the NDRP. For the post-1969 period up to 1970, we have to be careful how we use the n/p ratios. We can also back extrapolate to determine neutron dose for the 1969 to 1970 time period.

SC&A: Have criticality control program accidents been reviewed? Incidents that involve alpha/neutron reactions such as perimeter controls on drains are an issue that bears closer looking at.

NIOSH: If you have a solutions near critical, you would see a lot of higher energy photons affecting the film badges. You would then likely see a characteristic neutron or photon pattern.

SC&A: Wasn't there a criticality control group?

ORAU: Yes, there was a criticality control group that was assigned for the majority of the time. Section 2, page 15, discussed criticality accidents.

SC&A: Are you aware of criticality experiments that were done at RFP?

NIOSH: Yes, we are aware of these experiments and they are covered in the TBD. In terms of the NDRP, quality control is covered in the appendices, as well as how they did their statistical analysis. NDRP has n/p rations for different buildings. We are working on OTIB-50 that will go over the ways DRs will use NDRP. We have looked over all our data and have n/p ratios from 1970 to current times. The numbers are stable over the years. In more recent times, the n/p ratios have been conjoined, but in the earlier days they were separated.

SC&A:

7. Will the recorded neutron dose be used in DR that is discussed on page 14, Section 6.3.2.2.1, where it states that from July 1984 to October 1984, some neutron dose was recorded, but the gamma and total dose was zero?

ORAU: Yes, we will include that neutron in the total dose. Typically it won't matter, but we still will include it so as to err on the side of claimant favorability.

SC&A: Have you looked at what happened when the badge was contaminated and no dose was found in the records associated with such contamination?

ORAU: In such a case we would rely on co-worker or other dose reconstruction processes. When such procedures are used, there is a write-up that goes into the individual's file on how the dose was assigned.

SC&A: In the DOE dosimetry file do you have both measured and calculated dose?

ORAU: Yes, the file would include any pertinent dose data...

SC&A: We have heard recently during our site expert interviews that a number of workers shucked the badge and didn't even use the film badge. Worker interviewees seem to indicate that this could be a problem that will create gaps in their records.

ORAU: In such cases, if they are identified by the claimant, we use n/p ratios and/or back extrapolate to get a dose. We also look at claimant interview and then we compare what they are telling us with the dosimetry file.

SC&A:

8. How are the dose reconstructors handling the possible manual correction needed and discussed on page 14, Section 6.3.2.2.2, where it describes a possible manual correction, but ends with the statement that dose components were not provided in the letter and, therefore, were not made?

   It is unclear what is meant by possible manual corrections. If such manual corrections were done were they placed in the person's record?

ORAU: The deep dose would be used and applied to compute the most favorable dose. The dose would be used unless there was information to the contrary in the file. Applying the dose in 1976 would be claimant favorable if the dose was really incurred in 1984 through 1986 and appropriate, given lack of contrary information.

SC&A: Do you have any other information on why that occurred or what was supposed to be put into the file?

ORAU: No, we just found these files, but they do not provide what the correction factor was.

SC&A:

9. Why isn't more information provided besides the exchange history (i.e., quarterly dose history, etc.) that is discussed on page 18, third line list: "1977-present, dosimeter exchange history?"

   This is okay – no further questions.

ORAU: The wording in the text is unclear. What is intended is that for 1977 onward, the dosimeter-by-dosimeter record is available for the dose reconstructor.

SC&A:

10. Why aren't uranium and non-radiation workers included on page 18, Section 6.3.4.2, where it states that the NDRP (Falk et al. 2005) will cover 1951–1970 when NTA film was used for neutron dosimetry? How is NIOSH handling dose reconstruction for workers exposed to other neutron sources [(alpha, neutron) reactions such as in UF_4, criticality experiments, calibration sources, etc.] besides PU at the RFP during this time period when NTA film results/procedures are in doubt?

ORAU: Uranium workers and non-radiation workers were not monitored with neutron film. The scope of the NDRP is to reevaluate the available films and reassess the dose for those individuals only. The scope did not include other workers, unfortunately.

Early neutron film response correction (Table 6-18) does include a range of neutron spectra (metal, waste, salts, and PuF_4). In the later years neutron dosimetry systems were calibrated with a variety of neutron spectra.

SC&A:

11. Can NIOSH make available to SC&A the DOE-funded *Job Exposure Matrix* study by University of Colorado-HSC mentioned on page 18, Section 6.3.4.3, that appears to be helpful in DR?

    Have you received the job exposure matrix?

ORAU: We do have copy of the report that Dr. Ruttenber prepared. We are trying to get a copy of the job exposure matrix, but this is currently in the hands of our lawyers. It might have pertinent information and we are committed to go back and make changes, and will provide SC&A a copy when we get it. Dr. Ruttenber did some work in the mid-90s, but NIOSH does not have this either.

SC&A:

12. How has NIOSH dealt with the situation discussed on page 19, Section 6.4.3, that individuals sometimes worked in other facilities (beside the one their badge was calibrated to) on temporary or overtime assignments, which the dosimetry department could not detect? Does NIOSH consider this an occurrence that happened often enough to create a significant underestimate of dose to workers because of the change in the dosimetry response? Does this require some modification to the NIOSH decision stated on page 27, Section 6.6.3.4, that assumes that each worker stayed in the work area where the badge was calibrated and therefore no corrections for photon energy are needed?

    During site expert interviews there have been discussions of people working part-time in another work area or working after-hour duties so that their badge might not be properly calibrated for these non-routine work locations.

NIOSH: It seems unlikely this could have any significant effect on total dose.

SC&A: Would records help on this?

NIOSH: We tend to work more with general work assignment rather than day by day changes. We understand that part of what Dr. Ruttenber did may have included such data and that is why we are interested.

SC&A: We are hearing that there is about a 50/50 split. Some workers work all over the plant and others work more in stationary locations. For instance, machinists often stayed in one area due to special training needed.

ORAU: We have found that in general, lower-level workers stayed put, but the upper-level workers moved around. Everyone had a badge. Therefore this is not a problem in determining dose. Most workers spent their time in areas in which their badging was appropriate. Work in other buildings on a temporary or overtime basis is likely to result in dose which is a fraction of the dose received from the routine work assignment. Given the number of claimant-favorable assumptions in the dosimetry records, it seems unlikely that large underestimations of dose occurred.

SC&A:

13. Why isn't the 10 mrem minimum detectable dose discussed on page 20, Section 6.4.4, used as the dose of record rather than reporting this as a zero dose? Isn't this inconsistent with the other AEC site TBDs and not claimant favorable?

ORAU: It was RFP's policy was to record 10 mrem as zero. Zero is a potential missed dose and NIOSH would assign dose based on the MDA at the time. For missed dose we assign the LOD/2 and a geometric SD of 1.52. The dose of record is the dose reported in the worker's dosimetry file, not the TBD. The TBD reports the practices of the time.

Common Issues

SC&A:

14. Page 21, Section 6.5.2, second paragraph states that "If no activity date is associated with a dose record…" What is an "activity date"? Why would there not be a date associated with a dose record? Also, page 15, Section 6.3.3.1.3, mentions that the Activity Date may be outside the employment period. What does this mean?

ORAU: "Activity Date" is the nominal date on which the badge wear-period ended. This does not account for weekend days or holidays, which delayed the badge pickup. This is discussed (somewhat vaguely) in Section 6.3.3.1. Later when "start date" and "end date" were incorporated into the new database, it was necessary to synthesize these dates from the activity date and the exchange period. Thus, it was possible to have a "start date" before the hire date or an "end date" after the termination date. The addition of "correction" record to the file may not have had a date associated with it (sometimes just a year). Hire dates were sometimes corrected because of prior service and termination dates corrected to allow use of remaining vacation or sick leave. These and other exceptions (which are not well understood) result in date discrepancies in many of the dosimetry records.

SC&A: There is a concern that dose is not assigned when they got their dose. It appears that it could vary from 30 to 90 days. The beginning date could go back a number of years.

ORAU: For example, if the activity date was something like August 31st, the badge might be picked up on August 29th and processed a week or so later. The next badge would pick up for the remaining days of August.

If a person started part way through the quarter, they would only have a partial dose for the quarter and they might have to continue to wear their badge into the middle of the next month.

There are situations where RFP recorded previous dose and give it a date prior to hire date so that they could see they came from somewhere else. Typically we put in the earliest date it was recorded and this could be different from the actual date. That dose is included even if it's outside the date of employment. If a previous dose that is not acquired at the RFP is found, it's unclear how this would be handled. If it is in the RFP employment period, it would be used. It depends on the specific case and scrutinized and included in some fashion.

There was one working activity date assigned in 1986, but they really could have been received as early as 1976. It is best if the dose they received is recorded in the period it was received. However, if pops up in 1986, they would then apply it in 1976 when it was reported. This would be most claimant favorable.

SC&A:

15. In the DR process discussed on page 23 regarding exposure geometry, why does NIOSH consider the assignment of ISO or ROT instead of AP geometry as always most claimant favorable (i.e., for anterior-seated cancers)?

    It is realized that some claimants could be exposed from back when their cancers might be due to higher front-sided orientation. So their dose would be greater if it were a 100% A-P exposure.

NIOSH: We have looked into the geometry effect of using frontal A-P and it is not always favorable. Tim Taulbee is working on a draft TIB that will address this issue. This is a hot issue and will be addressed generically. We are working on finalizing the TIB soon. The addition will also go into the IG for use by all DRs.

Photon Dose

SC&A:

16. On page 24, 6th line up from the bottom, shouldn't it read *…the 30-**2**50 keV photon.…*, instead of *…the 30-50 keV photon.…*?

ORAU: This is a typographical error that will be corrected.

SC&A:

17. Has NIOSH considered the need to take into account during DR the effect of shielding where photons with energies >250 keV may contribute more to the final effective dose because of their greater penetrating power? The TBD states on page 24, Section 6.6.1.1, that the photon exposure spectra, assumed to be mostly in the 30–250 keV range, is claimant favorable because of the higher REF for this energy range.

SC&A: The REF reference came from a HPS Journal article of July 2005, pages 3–32, that looks at the radiological effectiveness factor for 30 keV photon and higher. Would it be more claimant favorable to assign the higher of the two?

ORAU: Photon dose correction factor is used for 30–250 keV spectra in most cases. This is considered claimant favorable. There is about a 15%–20% difference where the 250 keV peak occurs. Generally this is not large problem and the 30–250 keV is most claimant favorable. The energy distribution for plutonium (shown in Table 6-6) does include the effect of spectrum hardening. Glovebox material shielding was considered. Uranium was typically processed outside of gloveboxes and was not subject to this effect.

It is not clear where the referenced text, "…higher REF for this energy range," is located. The most claimant-favorable photon-energy range is used in DR.

SC&A:

18. Could NIOSH provide more information on how angular dependence has been addressed? On page 27 it states that the dosimetry response increases with angle, but on page 28 it states that the Panasonic system response decreased as the angle increased. The Y-12 ORAUT-TKBS-0014-6, page 18, states that the recorded dose of record is likely too low at non A-P angles for beta/photon doses. What is NIOSH's position on angular dependence for: (1) NTA film, (2) beta/photon film, (3) TLD neutron, and (4) TLD beta/gamma badges?

ORAU: The TBD's position on angular dependence is stated in Section 6.6.4.1, "There is insufficient data to identify an angular dependence correction to apply to any of the dosimeters. Because any correction would reduce the dose or, in the case of the Panasonic dosimeter, increase the dose only slightly, not including this correction factor is generally claimant favorable." The statement on page 27 (response increases with angle) is for the film badge, while the statement on page 28 is for the Panasonic badge. This data is relevant to the RFP badges, while the Y-12 Plant data is relevant to their badge. The TBD's analysis of angular dependence is presented in Sections 6.6.4.1, 6.7.4.1, and 6.8.4.1. With little data on the effect of angular dependence, especially in the early days, probably no one knows for sure.

SC&A: We would like to recommend that NIOSH develop some internal guidelines on angular dependence and the impact that has on gamma, beta, and NTA neutron dosimetry response. This could be an important factor.

NIOSH: This is a generic problem that we intend to handle on an overall basis. NIOSH will check on this and let SC&A know about the time line for how and when we will address this.

SC&A:

19. Why is the uncertainty for low doses of 1 and 2 mrem less than for the higher doses of photons (i.e., 1 x1.00 = 1 and 2 x 1.00 = 2, but 10 x 1.23 = 12 and 100 x 1.23 = 123 mrem, etc.) in Table 6-12, page 30? Tables 6-10 and 6-11, page 29, show the opposite characteristics.

ORAU: This is a result of rounding the result to the nearest mrem value (consistent with RFP dosimetry data). The actual multipliers are:

Dose (mrem)	1983–1989	1990–1998	1999-present
1	1.27	1.27	1.23
2	1.24	1.24	1.19
5	1.23	1.23	1.18

SC&A:

20. Please explain how Table 6-3 will be used by the dose reconstructor to amplify what is provided on page 21?

ORAU: Table 6-3 can be used in determining the maximum number of zeros to assign a non-comp case with only summary data.

SC&A:

21. In calculating the exposure geometry factors, what dose rate and exposure durations were assumed? From what source was this data derived?

ORAU: Since the results are presented in fraction of the dose received via each geometry, the dose rate is irrelevant. Likewise, the hands-on work time is presented as fraction of the total work time; thus, the actual exposure time is irrelevant. What is important here is the relative ratio between the hands-on dose rate (AP geometry) and the other dose rate (ISO or ROT). This ratio (AP/ISO or ROT) is 4 for the line source and 16 for the plane and point source geometries.

SC&A:

22. Did RFP ever acquire any sealed sources for use in industrial radiography such as ^{226}Ra, ^{137}Cs, or ^{90}Sr?

ORAU: From the information we have found, industrial radiography appears to have been performed by outside contractors. RFP-owned sources may have been possible, but we have no such documentation. As far as we are aware of there was an NDT plant.

There were very large MeV x-ray units used to x-ray pits, but this was done in a vault where no one entered.

SC&A: Are you aware of how many of these MeV x-ray units there were and what their milliamp output was? Is there any documentation on this?

NIOSH: No summary documents have been found, but we can look at this in more detail as well as look in the incident records. This has not been done yet. As far as neutron generator(s), we know it existed but we don't know applications.

Neutron Dose

SC&A:

23. Why is there a difference in the limit of detection (LOD) between page 33, Table 6-16, which lists the limit of detection (LOD) for neutron NTA film for 1961 as 96 mrem and Table 6-17 on page 34, where the LOD is listed as 120 mrem?

ORAU: Table 6-16 reports the values determined by the NDRP. The paragraph immediately following the table sites a study performed at that time. The more claimant-favorable value was selected. Table 6-17 summarizes values that should be used by the DR and takes into account this more claimant-favorable selection.

SC&A:

24. Page 34, Table 6-18 lists the potential missed neutron dose below 800 keV for early NTA film to range from 16% to 60%. However, the text below it selects 56% as the claimant-favorable value with a resulting multiplying factor of 1.79. Why wasn't the higher value of 60% missed neutron dose with a resulting multiplying factor of 2.5 selected (i.e., 1/1-0.60) = x 2.50)? In addition, even if the value of 56% was selected for the percent of neutron dose missed, why wouldn't the multiplying factor be: 1/(1-0.56) = x 2.27 instead of 1.79?

ORAU: This is an error. The commenter is correct that the maximum value in the table is 60% and the multiplier should be 2.5. This will be corrected.

SC&A:

25. Page 35, Section 6.7.3.4, states that other information will be used until the NDRP report is finished. The NDRP report (Falk et al. 2005) was available as of February 7, 2005. Is the NDRP currently being used in DR? Has it resulted in any significant changes in the results of past or current dose calculations?

    This question ties together with Question #10. The NDRP addressed mainly the Pu workers. Therefore, it is not helpful for non-Pu workers and U workers. Is there

anything in the works to extend this to other areas where there might be significant changes in results of past or current dose calculations?

NIOSH: DOE did not release the NDRP data to NIOSH until sometime in June 2005. The NDRP data has been used for selected cases since it was issued, and final implementation issues are being addressed. Past cases were worked with highly minimizing (for compensable cases) or maximizing (for non-compensable cases), and thus are not expected to have a major impact on past dose reconstructions. A number of cases that could not be worked with maximizing or minimizing assumptions will now be able to be worked as a result of the NDRP data. DOE has not and likely will not fund such additional studies. On DU, we did take estimates at Fernald and apply those estimates to workers. We used 10% of gamma dose and applied that. We do need to look at EU to estimate neutrons there which is an analogous process. Advice to the DRs will be given as our efforts progress.

Electron Dose

SC&A:

26. Page 37, next to last sentence states that the RFP had problems with elevated beta dose rates from contamination on leather gloves worn during foundry operations. Did these workers routinely wear wrist badges so that these doses could be accounted for? If not, how will DR be performed?

    This is related to extremity dose as well.

ORAU: It is unlikely that wrist dosimeters would measure the dose resulting from contaminated gloves. This issue must be addressed for those relatively few claims resulting from extremity or skin cancers originating on the hands.

SC&A:

27. Page 40, Section 6.8.4.1, addresses angular dependence and states that the assembled badge displays severe angular dependence to beta exposure and that for TLD badges it might record only 36% to 59% of the true beta dose at $\pm$30 degrees. Wouldn't this need to be addressed, especially in the extremity section where the worker's normal movements would not tend to average it out?

    This is related to extremity dose as well.

ORAU: It is relevant to address this issue with extremity dosimetry. Based on DOE Good Practices (DOE 2001) it was determined to be inappropriate to use a correction factor for body dosimeters.

SC&A:

28. Page 41, Table 6-24 footnotes state to multiply any dose greater than 2 mrem by 1.12. However, the fourth column contains numbers that do not use this multiplier and do not match Columns 2 and 3. Why is this?

ORAU: This is a function of rounding. At 2000 mrem the factors are actually 1.1215, 1.1215, and 1.1156. These sections should probably be rewritten to correctly show the multipliers as reasonable approximations based on these tables. Since the multipliers are used in the DR process, they are the result of interest. It is inappropriate to use more than three significant figures, however.

SC&A:

29. How can VARSKIN be used if it leaves out ^{234m}Pa? Page 42, the last paragraph of Section 6.8.6 recommends using the VARSKIN software to calculate skin dose from contamination. However, Table 6-26 on page 43 shows that the VARSKIN Mod 2 only includes one (^{234}Th at 3.40E-07 Ci/gm of DU) of the two most active beta isotopes [the other being ^{234m}Pa at 3.40E-07 Ci/gm of DU (the third isotope, ^{238}U at 3.40E-07 Ci/gm of DU is not itself an active beta emitter)]. Page 37 states "*Thus, for depleted uranium, one is dealing essentially with 2.29-MeV (Emax) beta particle from ^{234m}Pa, the most energetic contributor to the beta exposure.*"

ORAU: The commenter brings up a very good point. It is necessary to include ^{234m}Pa in any skin dose calculation that is performed. It will be necessary to implement an updated version of VARSKIN, modify the code to include this isotope, or use a different code to estimate skin dose from skin contamination. The code package VARSKIN 2 includes VARSKIN Mod 2 and SADDE Mod 2. The latter code allows the user to input pertinent information for beta-emitting radionuclides that are not in the VARSKIN library. Dose reconstructors who process RFP cases will be made aware of this issue through Task 5 meetings, and the next revision of ORAUT-OTIB-0017 will include a reminder to dose reconstructors that all significant radionuclides must be included in dose calculations from skin contamination.

Unmonitored Individuals

SC&A:

30. What other measures, such as the NDRP, are being implemented to identify workers that should have been monitored, but were not? Page 42, Section 6.9.1, states that in the early 1950s, the only groups expected to receive doses greater than 10% of the RPG were monitored.

a. The NDRP report (Falk et al. 2005), page 1, states that:

For some plutonium workers, neutron monitoring was not provided until the early 1960s, and their dose of record may not include significant contributions from neutron exposure received prior to being issued a neutron dosimeter. These workers included most of the employees working in Building 71 (now Building 771). Only a small number (10–18) of these employees were monitored for neutron exposure, and that monitoring was only during the period October 1956 to September 1957."

Operations in Building 71 involved chemical processing of plutonium in acid solutions and resulted in significant neutron fields from the alpha-neutron reaction with light elements, especially from the plutonium tetrafluoride compound. No evidence has been found that neutron shielding was present for these operations until the early to mid 1960s.

b. Column 2 of Table 2, pages 17 and 18, of the RFP annual radiation exposure report for the year 1984 (Radiation 1984) provides the total badged personnel per year for the years 1953–1984. Another RFP document entitled "Film Procedure Timeline" for the Neutron Dose Reconstruction Project 2003 (Rocky 2003, pg. 6), provides the number of NTA films processed per month. Analyzing the two tables for the years 1959–1969 show that out of the total workers badged, on the average only approximately 25% were issued NTA film badges (over the 10-year period, it ranged from 9% to 50%). For example, in 1960, a total of 1362 workers were badged throughout the year and approximately 300 NTA films were processed per month (therefore, 300 workers were badged for neutrons throughout that year); this results in a ratio of 300/1362 = 22%.

These facts raise the question as to whether the policy and procedures in place during this period at the RFP were adequate to ensure that the workers who were at risk of receiving significant radiation doses (especially neutron doses) were actually, and adequately, badged. It would appear that the "10% of the RPG" policy did not necessarily provide adequate monitoring for all workers that needed it.

ORAU: The statement as quoted is correct, and applies today for many sites—workers not expected to receive more that 10% of the occupational limit are not required to be monitored. The co-worker dose estimation process is under development to address this issue. If the EE job description and/or work or dose history in later years indicated potential dose during this time, the EE would be assigned either the 600 mrem indicated in the TBD Section 6.9.1 or other appropriate dose, such as the maximum dose for later years. If later years/work history/dose history indicated that

no dose was likely and the EE was not in a production area, then the EE is routinely assigned ambient dose per the guidance in section 6.9.2.

The NDRP has addressed neutron dosimetry gaps in the application of their protocol, and the co-worker process will provide some additional input. For the early days with limited dosimetry, it will be necessary to apply a co-worker process. Prior to the NDRP data, claimant-favorable estimates of neutron dose (for non-compensable cases) were used. The NDRP data not only included the measured neutron dose, if any, but also estimated claimant-favorable doses based on location, job, and gamma dose. For those few cases that are not in the NDRP but were in neutron buildings with jobs that may have involved exposure, the neutron to photon ratios or other method is used to estimate neutron dose.

It is not clear from the numbers provided in this comment that the conclusion ("…did not necessarily provide adequate monitoring…") follows. This is, however, the history that we are faced with. It will be necessary for the co-worker process to provide claimant-favorable dose reconstructions for unmonitored individuals. Application of neutron dose is based on job description, NDRP data, building, and era, as appropriate. Neutron dose assignments are made based on multiple lines of evaluation and are thought to be claimant favorable.

SC&A: There is a concern that some workers may not have been adequately badged or worked in areas where later it was found that there really was some dose and they had not been badged. Also we are interested to know if you assigned missed dose if they lost badge. What is your comment about people in buildings where it was originally thought that there was no dose?

NIOSH: Our Task 5 efforts have been trying to address this, and co-worker data and additional external data are just coming online. We often will use maximum dose for later years if it looks like they were doing this work in the earlier years. Or we will assign the administrative limit in cases where there is no other data.

At Y-12 - Only 13%–15% were badged.

Based on the claimant populations at RFP (not plant as whole) – external gamma started in 1952
By 1953, 1/3 of the workers were badged
By 1964, +95% were badged with a combined film/security badge.

Dr. Ruttenber might have this information. Dr. Ruttenber concentrated on those workers with a 1 rem total dose, however. So he might not have all the data. The NDRP gives some reconstructed gamma dose – wrist to WB – that will help to determine which value is used.

Co-worker study – we are at a state where we have 52 thru 78 and now it is being validated. This is coming on line.

SC&A: If there were situations where there is no co-worker data, but later it was found that there were radiation fields – how will that be handled?

NIOSH: If we don't have it, we hold up doing the claimant's dose reconstruction until more data comes in. It's hard to comment until we see that the co-worker data is validated.

SC&A: Who is generating the data?

NIOSH: This is being developed as a joint effort between Task 5 and Task 3 (site profile folks). In Area 38 n/p ratio is used to estimate dose. The present TBD does not focus on n/p ratio, however, and more work will be done. For the most part when we cannot use the NDRP data, they will call out individual timeline presentation to show when they apply n/p ratios (1979–1976). OTIB-50 will have this information, and this can also be summarized in TBD revision in December 2005.

Extremity Dosimetry

SC&A:

31. Is NIOSH currently working on TBD changes to make more clear how the following issues are addressed in, Section 6.10, page 43?

    a. NTA film in wrist badge - Between 1951 and 1970, film dosimetry was used for extremity dosimetry. Was this only for beta/photon? Was any NTA film used in the wrist dosimeters? If not, how will the extremity dose from neutrons (which could have been greater than the whole-body dose for those workers handing neutron emitting material) be reconstructed?

    b. Hand-to-wrist-to-WB ratios – If a worker did not wear a wrist dosimeter, how can it be considered claimant favorable to assign only the whole-body (WB) dose to the hand if he/she was working on a task requiring hands-on work? [The NDRP (Falk et al. 2005), page 22, list the average WB photon dose response as only 40% of the wrist photon dose. Additionally, in most cases the dose to the hands would be greater that the dose to the wrist (Mann 1964).]

    c. Valid hand-to-wrist ratios - It states in this section that the details on the hand-to-wrist ratios are not available. In a letter by J.R. Mann (1964), it is stated that the hand dose is 2.5x or 5x the wrist dose, depending on the work location. How can it be determined if these ratios represent the working environment at RFP if we do not know their values (none were presented in the TBD) or how they were derived?

d. Additional information - The last sentence in this section states that additional information on the hand-to-wrist ratios is required before shallow doses to the extremities can be reconstructed. The last paragraph on page 37 states that the beta dose to the hands could have been a problem because of considerable hands-on work performed at the RFP. Has any additional information been acquired and is it being used?

ORAU: It is not clear how many claimant cases will require careful extremity dose reconstruction. It may be possible to use maximizing and minimizing assumptions to address the appropriate cases. If additional information is required, this will be developed and documented. Detailed analysis of extremity dose is a concern. We will do a maximum/minimum and if no one falls into the middle category, then they don't pursue it any further. If neutron film was used in extremity dosimeters, then these results will be evaluated. If not, it will be necessary to develop and apply neutron to gamma ratios appropriate for extremity dose at RFP.

The assignment of body dose to the wrist for those not monitored with extremity dosimeters was the policy at RFP. We cannot change this fact; only develop dose reconstruction bias correction factors appropriate to provide the best estimation of the extremity dose. If hand-to-wrist measurement studies conducted at RFP cannot be located, it will be necessary to use studies performed elsewhere in the industry. We must assess the appropriateness of these studies to the exposure conditions at RFP and consider the data that is included in the documentation cited in this comment. To date, no additional information has been acquired relative to extremity dosimetry.

SC&A: But isn't it more likely that there will be hands on work at RFP so extremity dose could be more of a problem?

NIOSH: Hand-to-wrist ratios have been seen but we have not distilled them down to put in the TBD. This could be done. The body-to-wrist ratio would come from claimant data we have to date. If the worker did not wear wrist badges and had a body skin dose, we would have to review and evaluate that closely. But we do not assign whole-body dose as the wrist dose if the wrist is expected to be higher.

SUPPLEMENTARY EXTERNAL DOSE INFORMATION FOR ROCKY FLATS PLANT (ORAUT-OTIB-0027)

SC&A:

1. Page 5, first paragraph, third line: shouldn't this read *Rocky Flats Plant – Occupational **Environmental** Dosimetry (Rev 01).*[2]?

ORAU: Yes, this appears to be a typographical error. It was a typo but should not have been the Environmental Dosimetry TBD; it should have been Rev. 01-A, March 3, 2004, of the Technical Basis Document for Rocky Flats Plant-Occupational External Dosimetry. The purpose was to document unpublished changes in Rev. 1 of the External TBD.

SC&A:

2. Page 5, in the pre-1960 section lists that skin dose was determined by (OW + CD + BR) and also by (OW + CD). Isn't the BR term in error in this paragraph and shouldn't it be deleted?

ORAU: Yes, this appears to be a typographical error. Error has been noted and has not affected dose reconstruction. BR will be deleted in next revision.

POWERPOINT SLIDES REVIEW

We have covered most of these

Slide 3 Issue: Potential external doses from RU not considered.

ORAU: We do look at the potential external dose from RU, but we don't consider it to be an internal problem. The potential for possible external dose is not covered in the TBD. The only case where RU would be involved is in operations with any significant concentration of RU. This would be possible for operations, such as vacuum melting, and then this will be addressed.

SC&A: In the Ruttenber 2003 doc, there was a discussion about a large number of neutron and gamma doses in 1976 that were erroneously entered. Do you know anything about this?

ORAU: Al – when the switch-over occurred, there may have been some who did not work in 1976 but got a dose. But we use it as if it were real. This has only happened in a couple of cases and the incidence is very small. It may be more a case of effective dose rather than a missing dose.

Slide 7

SC&A: The NDRP report shows that the later neutron threshold was 0.48 to 0.75 keV. How will this affect the neutron dose (got these from historical literature – Mann and Boss in 1963)? However, the early threshold was from 0.25 and 0.4 keV.

NIOSH: I think they used a threshold of 800 keV and did not use the lower ones.

SUM UP

(1) Related to Q1 – Further research will be done on date-of-use of each dosimeter system. This information will be put in the revised TBD.

(2) Questions 1, 2, and 5 will be reviewed.

(3) Related to Q6 - More information on neutron track plates from LANL will be included in the revised TBD.

(4) Related to Q18 - Angular dependence – General guidelines on this issue are being worked on and they will let SC&A know when the OTIB or other studies will be done.

(5) Related to Slide #3 – We will look at Y-12 for EU data and use in RFP TBD if appropriate.

(6) Related to Slide #3 – More information on RU and processes that concentrated it will go into the revised TBD

(7) We will include any information found on industrial x-ray units, radiographic sources, and neutron generator in the revised TBD, and send to SCA.

(8) TLDs worn under the lead apron - This has not been addressed in the TBD. Pantex data supported the wearing of TLDs under the lead aprons. Determine if it is applicable to RFP? It came up with Iowa as data coming out of Pantex.

ATTACHMENT 5: CONSISTENCY BETWEEN SITE PROFILES

The default site profile assumptions and methodologies were reviewed for the Rocky Flat Plant and other site profiles reviewed to date are described below. Site profiles completed to date by the SC&A team include Bethlehem Steel, Mallinckrodt Chemical Works (MCW), Iowa Army Ammunition Plant (IAAP). Hanford, Savannah River Site (SRS), the Y-12 National Security Complex (Y-12 Plant), and Idaho National Engineering and Environmental Laboratory (INEEL). An additional site profile in the process of review is the Nevada Test Site (NTS).

Occupational Medical Exposure

The basis for occupational medical exposure for the RFP site profile and other site profiles is ORAUT-OTIB-0006, *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*. In the absence of site specific x-ray data, the RFP site profile relied on values provided in this document for chest x-rays. For guidance on lumbar spine exams, the RFP relied on *Radiation Doses in Diagnostic X-ray Procedures* (Lincoln and Gupton 1958). Lumbar spine x-ray dose has been integrated into the latest revision of ORAUT-OTIB-0006 (Kathren 2005). This information should be considered in subsequent revisions of the RFP TBD. The differences identified between the RFP site profile and other site profiles include the following.

- The RFP site profile did not include lateral chest x-rays. Since there were not lateral x-rays considered, there was also no correction for lateral chest x-rays.

- The Rocky Flats TBD assumed an anterior-posterior and lateral lumber spine x-ray from1952–1974 upon first hire (Furman and Lopez 2004, pg. 9).

- Annual photofluorography examines were applied to workers at RFP from 1953–1968 (Furman and Lopez 2004, pg.13).

- X-ray machine records for equipment were not readily available prior to 2001. As a result, the RFP site profile assumed the default assumptions outlined in ORAUT-OTIB-0006, Revision 2 (Kathren 2003). The assumption was also made that technique factors at RFP were similar to those at other DOE sites (Furman and Lopez 2004, pg. 9).

- For spinal x-rays, a 1.8 multiplication factor is applied to convert air kerma from a single-phase unit to a three-phase unit (Furman and Lopez 2004, pg. 10).

To date, the records reviewed and site expert interviews only indicate standard posterior-anterior chest x-rays. Excluding lateral chest x-rays assumed in other site profiles is reasonable for cases where there is no indication of such an exam in the medical records.

Lumber spine x-rays were included at RFP based on information indicating anterior-posterior and lateral x-rays were performed at the initial employment medical examination. Ultimately, occupational medical x-ray dose should be determined based on the individual's medical record.

This evaluation should consider special and/or incident related x-ray exams. This has not been considered in the RFP site profile or other site profiles reviewed to date. In the absence of additional information, assuming each employee had lumber spine x-rays upon hire from 1952–1974 is acceptable.

Information on x-ray machine equipment and techniques employed at RFP is unavailable until 2001. As a result, the RFP site profile assumed the default assumptions outlined in ORAUT-OTIB-0006, Revision 2 (Kathren 2003). The assumption was also made that technique factors at RFP were similar to those at other DOE sites (Furman and Lopez 2004, pg. 9). In order to appreciate the dose received from an x-ray, it is important to know the type of equipment, the output, the beam hardness, the techniques used, and the processing equipment parameters. It is uncertain whether the assumption made in the RFP site profile is bounding for this particular site.

The application of the 1.8 multiplication factor between single- and three-phase units is a factor not used in other site profiles reviewed. Without information on the equipment and techniques at RFP, this factor cannot be effectively evaluated.

The IREP input criteria for occupational medical exposure was consistent between site profiles. The radiation rate was assumed to be acute, the radiation type was 30-250 keV photons, the dose distribution was constant, and the dose was multiplied by a factor of 1.3 to account for a 30% uncertainty. The basis for the organ dose conversion factors, the substitution dose conversion factors, and the analogue organs assumed in the RFP site profile were consistent with other TBDs. RFP assumed the same chest wall thickness as that used in ORAUT-TIB-0006 (Kathren 2003) and the Savannah River Site TBD. Although the site profile does not specifically give the backscatter factor for skin dose, it does refer to Table B-8 in NCRP 102 (1989), *Medical X-ray, Electron Beam, and Gamma-Ray Protection for Energies up to 50 MeV (Equipment Design, Performance and Use).* Presumably the RFP value is 1.35 as with other TBDs.

Overall, the default values assigned for determining occupational medical exposure are relatively consistent. Deviations from the techniques used in other TBDs are based on site specific information.

Occupational Environmental Exposure

ORAUT-TKBS-0011-4 (McDowell-Boyer and Little 2004) describes the default assumptions for occupational environmental dose at RFP. The profile depends substantially on work performed by ChemRisk (1994a, 1994b) and Radiological Assessment Corporation (RAC) (Rope et al. 1999; Rood and Grogan 1999; Voillequé 1999a, 1999b, and 1999c; Weber et al. 1999). The purpose of these assessments was to calculate dose to members of the public, and not environmental dose to workers onsite. The RFP environmental site profile differs from other site profiles in the following ways (McDowell-Boyer and Little 2004).

- An environmental dose is applied when "a worker was not monitored adequately to develop a reliable individual dose"(pg.7).

- The elements considered for internal environmental exposure include routine ambient airborne releases, airborne releases from the 1957 and 1969 fires, and soil resuspension from contamination around the 903 Pad (pg. 9).

- A respirable fraction of 1.0 is applied for soil resuspension calculations (pg. 11).

- The particle size is assumed to be 15 micron Activity Equivalent Diameter (AED). Values adopted from atmospheric modeling assumed < 30 micron AED (pg. 9-10).

- The site profile provides a single set of dose values based on an average of onsite air sampling data.

- There is no consideration of submersion dose.

- Doses are multiplied by an inhalation dose factor from ICRP 72, *Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5: Compilation of Ingestion and Inhalation Dose Coefficients* for select radionuclides.

- ^{238}Pu, ^{241}Am, ^{235}U, ^{238}U, and ^{3}H are not considered substantial contributors to the environmental dose, although they are known to be present at the site. There is no mention of whether $^{233/234}U$ and curium releases contributed to the dose.

- Insoluble plutonium (Type S) is used for respiratory system cancers, while soluble plutonium (Type M) is used for all other cases.

Environmental occupational dose is typically assigned to those individuals who were not monitored. In the case of the RFP site profile, environmental dose is applied when "a worker was not monitored adequately to develop a reliable individual dose." A worker who was not monitored for either external or internal dose versus a worker that was not adequately monitored constitutes a different set of individuals. Those that were not monitored at all were likely to be in positions where radiation exposure was not an issue. Workers who were monitored inadequately can't be compared to those who may or may not have been exposed to radiation. For example, if a subcontractor worked in the production area where there was a potential for exposure, and no dosimetry data is located for the individual, it is not appropriate to assign the individual an environmental dose. The terminology used for the application of occupation environmental dose is confusing, and should be more clearly stated to exclude inadequately monitored workers who actually received exposure.

Review of the site profiles to date indicates that NIOSH has not come to a consensus on what components should be considered in the environmental dose. RFP had included dose from ambient airborne releases from routine and "nonroutine incidents." The site profile considered only the 1957 and 1969 fires under "nonroutine incidents." The RFP environmental site profile includes only potential exposure from soil resuspension at the 903 Pad. There are other outside areas onsite that have soil contamination levels. In fact, the Savannah River Site (SRS) site profile indicates that plutonium was detected at several locations near the release points in both the F and H areas (Scalsky 2004, pg. 58). Soil contamination has been found at many areas on

the Rocky Flats site, including in the East Spray Fields and the buffer zone. There is no explanation of why dose from radioactive material in soil excluded these other areas. SC&A was unable to obtain soil sample data to determine whether the 903 Pad had the highest soil contamination levels onsite. If this is the assumption made in the TBD, this should be clearly stated.

$^{239+240}$Pu was considered the only significant source of exposure from airborne exposure in the environment at RFP. Other radionuclides such as ^{238}Pu, ^{241}Am, ^{235}U, ^{238}U, ^{3}H, $^{233/234}$U, and curium were not considered in the assessment of internal environmental dose. This included tritium exposure from the large tritium release in 1973. It is interesting to note that Table 4B-1 shows no elevated tritium release during 1973. These radionuclides should be reconsidered, since many were purified and not merely an impurity. An evaluation of episodic releases of these radionuclides should be completed to verify releases from these radionuclides remain inconsequential.

Site profiles such as Hanford, SRS, and INEEL have included data for multiple receptor points onsite. The RFP site profile used onsite environmental air sampling data and atmospheric dispersion model estimates based on public dose assessments to determine a single intake quantity per year. Presumably, the assumption here is that the onsite air monitors will provide cumulative release data from all operations of the plant. The site profile has not demonstrated that this single set of intake data represents the highest potential environmental exposure onsite. A similar analysis at multiple receptor points is warranted to determine whether this single intake quality is bounding for all areas onsite.

There is no submersion dose assigned at RFP from noble gas releases. There has been no data on large particle releases discovered to date, as with INEEL and Hanford. As a result, it is reasonable to exclude these components from the environmental dose. As with other site profiles reviewed to date, there is no discussion of the liquid effluent streams. The RFP site profile also does not consider uptake from ingestion of materials (e.g., dirt, game, vegetation, etc.).

The RFP site profile has introduced a few new concepts not previously used in other site profiles. A respirable fraction of 1.0 is applied for environmental dose. This value is claimant favorable. The site profile used two particles sizes: < 30 micron AED for modeled intakes and 15 micron AED for intakes calculated from air sampling data. Other site profiles typically provide particle size in terms of AMAD, as does the RFP internal site profile. There is not direction to the dose reconstructor on how to convert AED to AMAD, which is the unit used within the IMBA software. The environmental site profile indicates that the AED values may exceed the 5 micron AMAD required under 42 CFR Part 82, unless other particle size data are available. The site profile has not presented any data to demonstrate that an alternate particle size is more appropriate.

The RFP site profile introduces an inhalation dose factor from ICRP 72, *Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5: Compilation of Ingestion and Inhalation Dose Coefficients* (ICRP 1996) for select radionuclides. An inhalation dose fraction has not been included in other site profiles reviewed to date. It is unclear why this factor would apply to RFP, but not to other DOE and AWE sites.

The solubility assumed for the calculation of internal dose was based on the type of cancer and the type that would result in the highest dose to the organ. There is no mention of whether Super Type S was an issue in environmental exposure scenarios. The solubility for SRS was based on the known material in the facility. For Hanford, the solubility for plutonium was assumed to be Type S. Using the most claimant-favorable solubility class under unknown conditions is claimant favorable as was done with RFP. The RFP environmental site profile, however, did not consider the presence of Super Type S material from releases to the environment. The potential for this material in the environment should be investigated to ensure current methodology bounds environmental internal doses.

The assumptions made with respect to ventilation rate and exposure time are consistent with other site profiles. There is a caveat allowing the dose reconstructor to scale numbers based on the work level and actual length of exposure during the year. Where available, site profiles to date have consistently used environmental dosimeters to ascertain external dose. The IREP input for radiation rate, radiation type, and dose distribution types are consistent with the radionuclides considered and the assumptions from other site profiles.

External Exposure

ORAUT-TKBS-0011-6 (Langsted 2004) describes the default assumptions for occupational external dose at RFP. ORAUT-OTIB-0027, *Supplemental External Dose Information for Rocky Flats Plant* (Smith 2005), provides additional information on the assumptions to be used in dose reconstruction. The assumptions were derived from historical records relating to the dosimetry program and observations made from dosimetry report review. The site profile refers the dose reconstructor to the Rocky Flats work history file, the Neutron Dose Reconstruction Protocol (NDRP) file, and a job exposure matrix put together by the University of Colorado Health Sciences Center and the Colorado Department of Public Health and Environment for additional information. The job exposure matrix data is unavailable. The NDRP information has only recently become available to NIOSH/ORAU and has not yet been integrated into the site profile. The RFP external dose site profile differs from other site profiles in the following ways:

Beta/Photon

- There are two default radiation types used for plutonium exposure. ORAUT-OTIB-0027 indicates default radiation types for plutonium of 25% photons < 30 keV and 75% 30-250 keV photons (Smith 2005, pg. 5). ORAUT-TKBS-0011-6 indicated the default radiation type for plutonium of 100% 30–250 keV (Langsted 2004, pg. 25).

- Available dosimetry records do not provide individual dosimeter results for 1951–1976. The exchange frequency is determined by job title. If the job title is unknown, the most frequent exchange frequency is used. The number of zero doses is estimated based on the dose level, the monthly, quarterly, or annual limits, and the number of possible zero monitoring intervals (Langsted 2004, pg. 20).

- The default exposure geometry is based on eight major job categories and the relative time spent performing hands-on work for that particular job (Langsted 2004, pg. 23).

- For dosimetry records with missing entries, dose is assigned based on the preceding and following period (Langsted 2004, pg. 23).

- For years prior to 1960, estimation of low-energy photon dose for plutonium workers, intermediate/high-energy photon for plutonium workers, and > 15 keV electrons for uranium workers is calculated with the following formulas (Smith 2005, pg. 6):

  Electrons $_{>15\ keV}$ or photon $_{<30\ keV}$ = [skin-pen]/0.50 = Open Window (OW)

  Photon $_{30\text{-}250\ keV}$ + photon $_{>250\ keV}$ = pen* = Cadmium (CD) + 50%*OW
  * pen = penetrating radiation dose

- From 1960–1970, estimation of low-energy photon dose for plutonium workers, intermediate/high-energy photon for plutonium workers, and > 15 keV electrons for uranium workers is calculated with the following formulas (Smith 2005, pg. 6):

  Electrons $_{>15\ keV}$ or photon $_{<30\ keV}$ = [skin-pen]/0.65 = Open Window (OW)

  Photon $_{30\text{-}250\ keV}$ + photon $_{>250\ keV}$ = pen = CD + Brass(BR)

- From 1970-present, estimation of low-energy photon dose for plutonium workers, intermediate/high-energy photon for plutonium workers, and > 15 keV electrons for uranium workers is calculated with the following formulas (Smith 2005, pg. 6-7):

  Electrons $_{>15\ keV}$ or photon $_{<30\ keV}$ = Skin - Pen

  Photon $_{30\text{-}250\ keV}$ + photon $_{>250\ keV}$ = Pen

- Electron and photon dosimetry uncertainty values are based on the building and dosimeter result range (mrem). The reported dose is multiplied by the appropriate factor to obtain the upper 95% confidence level (Smith 2005, pg. 7).

- For skin contamination, the location and count are obtained from personnel contamination reports. Prior to 1970, the exposure length is 8 hours. From 1970 forward, the exposure length is 4 hours. The GM probe is assumed to be 33.3% efficient. Depleted uranium is aged 1 year. VARSKIN is used to calculate a dose (Langstad 2004, pg. 42).

- The reconstructed dose for unmonitored individuals in the production area is 600 mrem per year (5% of the annual Radiation Protection Guideline), or 1.2 rem per year at the upper 95% confidence level.

Neutron

- The neutron energy distribution is based on location and includes areas in Buildings 771, 776, and 707.

- A correction multiplier and uncertainty factor are multiplied by the dosimeter result based on location and dosimeter result range (Smith 2005, pg. 7).

- The sensitive energy range of the NTA film is assumed to be > 800 keV. There is no correction factor for unmonitored energies in film after 1963. The TIB (Smith 2005, pg. 7) recommends a 2.5 correction multiplier, while the site profile recommends a value of 1.79.

- The default exposure geometry is based on eight major job categories and the relative time spent performing hands-on work for that particular job (Langstad 2004, pg. 23).

- There is no instruction for when to assign missed neutron dose for unmonitored workers. Based on review of several dose reconstructions, a missed neutron dose is not assigned to all claimants. The dose reconstructor is referred to the NDRP for supplemental data on neutron exposure. These records have recently become available, but the dose has not been included in many denied claims.

The default radiation type for plutonium is stated as 25% photons < 30 keV and 75% 30-250 keV photons in ORAUT-OTIB-0027 (Smith 2005). The default assumption in the external dosimetry site profile is 100% 30-250 keV. There is no explanation as to why this difference exists between the two Rocky Flats documents. This discrepancy needs to be resolved. In general, the radiation types are consistent with those used in other site profiles.

Missed dose for beta, photon, and neutron dose is calculated using Limit of Detection (LOD)/2 times the number of zero readings. A lognormal distribution with an uncertainty of 1.52 is applied. The difference between RFP and other sites is that the number of zeros has to be estimated, since only summary reports are available. This estimation is based on the annual dose received, the exchange frequency for a particular job, and the annual regulatory limit. This approach is reasonable, assuming the job titles are categorized correctly.

The major job titles are listed in Attachment B (Langsted 2004, pg. 67). It is evident from worker interviews that some jobs have not been adequately characterized (see Attachment 2). For example, Clerk Packers are listed under support personnel, when their job involved handling plutonium on a routine bases. Prior to assuming which jobs fit into which category and how much hands-on work was conducted by particular jobs, NIOSH/ORAU should obtain input on the tasks associated with these jobs. Not only may this impact the number of zeros calculated for missed dose, but it will also affect exposure geometry selections. The MCW site profile based exposure geometry on job title as with RFP; however, the list of job titles was much more extensive. Hanford and SRS based their default geometry on the compensability of the claimant. Where possible, use of individual specific geometry factors is acceptable; however, there has to be a clear understanding of the tasks performed.

RFP is the first site profile reviewed where the dose reconstructor is directed to use the preceding and following periods to assign dose for gaps in the record. In previous site profiles, an unmonitored individual would receive a dose based on the LOD and the exchange frequency. Use of the higher of the two methods is claimant favorable and should be considered. Another option for determining a bounding dose for a particular missing year is to use secondary dosimetry data.

Two-element dosimeters did not effectively account for low-energy photons present in plutonium facilities. This was recognized by the sites and adjustments were made. For example, SRS used a special x-ray calibration curve for workers involved with handling plutonium. Hanford included 20% of the open window dose in the penetrating dose. Once better designed dosimeters were introduced, this was no longer necessary. RFP also recognized the inadequacies in the two- and three-element dosimeters through 1970, when the TLD was implemented. For the two-element dosimeter, they added 50% of the open window dose to the penetrating dose. For the three-element dosimeter, they added 35% of the open window dose to the penetrating dose. In the RFP TIB, ORAU has backed these correction factors out of the data in order to separate the photons into energy categories. This was not done with data from Hanford and Savannah River Site. The difference in the RFP approach has not been adequately explained.

Electron and photon dosimetry uncertainty values are based on location and dosimeter result range (mrem). The reported dose is multiplied by the appropriate uncertainty factor to obtain the upper 95% confidence level dose (Smith 2005, pg. 7). The consideration of dosimeter range in the uncertainty is important, as the closer the dosimeter is to the LOD, the higher the percentage of error would be.

The inclusion of a methodology for skin contamination was a positive addition to the site profile. This is especially important in facilities which had routine personnel contamination incidents. A similar section should be included in other site profiles.

The reconstructed dose for unmonitored individuals in the production area is 600 mrem per year (5% of the annual Radiation Protection Guideline), or 1.2 rem per year at the upper 95% confidence level. This varies from the LOD/2 times the number of zeros used in other site profiles. The method employed for unmonitored workers at RFP should be compared to the previous approach of estimating missed dose based on the LOD to ensure the most claimant-favorable methodology is used.

The neutron energy distribution was limited to Buildings 771, 776, and 707. There was no specific mention of areas handling uranium, storage areas, or areas where neutron sources were used. These areas should also be considered when determining neutron energy distributions. Also, the neutron energy distribution may change when the site installed Benelex impregnated with boron in the glove boxes to provide additional shielding.

In order to calculate a neutron dose based on monitoring data, the neutron dose was separated into energy ranges and an ICRP 60 radiation weighting factor was applied. This is the same

methodology used in other site profiles. The default IREP input for neutron exposure is also consistent with other site profiles (e.g., a chronic exposure of 100 – 2,000 keV neutrons).

The sensitive energy range of the NTA film is assumed to be > 800 keV. This value is consistent with the minimum neutron energy adopted in other site profiles. There is a discrepancy in the correction multiplier for the neutron film reading. The TIB (Smith 2005, pg. 7) recommends a 2.5 correction multiplier for neutron film from 1951–1963 while the site profile recommends a value of 1.79 (Langstad 2004, pg. 34). NIOSH/ORAU has indicated that this will be corrected in the next revision of the site profile (see Attachment 4). No correction factor for energy under response is applied after 1963, although TLNDs were not implemented until 1971.

The NDRP offers a unique opportunity for NIOSH/ORAU to determine who had a missed neutron dose for a subset of Rocky Flats workers. The reevaluation of NTA film for plutonium workers serves as the basis for this. This information needs to be integrated into a revision of the site profile. Since not all workers were included in the study, the methodology used to assign missed neutron dose to workers should be maintained as a part of the site profile. Clear instructions on when to include missed neutron dose is necessary, as there seems to be a discrepancy as to when it is included in a particular worker's dose reconstruction.

Internal Exposure

ORAUT-TKBS-0011-5 (Falk 2004) describes the default assumptions for occupational internal dose at RFP. The assumptions were derived from historical records relating to the in-vivo and in-vitro monitoring programs. The procedures used for assignment of missed internal dose are derived from ORAUT-OTIB-0002, *Technical Information Bulletin, Maximum Internal Dose Estimates for Certain DOE Complex Claims* (Rollins 2004) and ORAUT-OTIB-0018, *Internal Dose Overestimates for Facilities with Air Sampling Programs* (Brackett and Bihl 2005), as indicated in a conference call with NIOSH/ORAU (see Attachment 4). Revision 0 of the internal dosimetry site profile is incomplete with respect to internal dosimetry for unmonitored workers. The RFP internal dose site profile (Falk 2004) differs from other site profiles in the following ways:

- The default solubility for plutonium, enriched uranium, and depleted uranium is type S for all cancers of the respiratory system and type M for all other cancers. Individuals involved in the October 1965 fire in Buildings 776 and 777 may exhibit super type S characteristics (Falk 2004, pg. 8).

- The default particle size is 5 micron AMAD. Assume 0.3 micron AMAD for all plutonium fires unless the qualifying cancer involves tissues of the extrathoracic regions (Falk 2004, pg. 9).

- The default isotopic composition is weapons grade plutonium. There is a separate isotopic composition for Zero-Power Physics Reactor (ZPPR) fuel (Falk 2004, pg. 8).

- Assume dpm/24-hours through 1989 and dpm/sample after 1989, regardless of the volume. Excretion period can be modified based on actual excretion period documented in the records (Falk 2004, pg. 11).

- Uncertainty is estimated by dividing the median Minimum Detectable Activity (MDA) value by 3.3 (pp. 13–16).

- The plutonium urine data, instead of the ^{241}Am urine data, is used to assess intakes of weapons grade plutonium. The ^{241}Am dose is calculated based on a measured or assumed ^{241}Am concentration for the plutonium mixture (pg. 13). The initial ^{241}Pu mass fraction for the 1950s through 1976 was 0.005. July 1976–1989, the ^{241}Pu mass fraction is 0.0036 (Falk 2004, pg. 20).

- For the purposes of lung counts, assume an initial concentration of 100 ppm ^{241}Am (Falk 2004, pg. 20).

- An index of 1.35 should be assumed to determine the MDA for lung counting, if the worker height and weight are unavailable (Falk 2004, pg. 19).

- If there is residual plutonium at a wound site, an acute injection plus a possible long-term chronic injection should be considered. For uranium contaminated wounds, consider an acute injection (Falk 2004, pg. 22).

- A hypothetical intake can be calculated using ORAUT-OTIB-0002 or ORAUT-OTIB-0018 where there was an established air monitoring program. When using the ORAUT-OTIB-0002 methodology, the 28-radionuclide scenario is used.

- No missed tritium dose is assigned.

- There is no consideration for ingestion dose in monitored workers.

The default solubility for plutonium, enriched uranium, and depleted uranium is type S for all cancers of the respiratory system and type M for all other cancers. Individuals involved in the October 1965 fire in Buildings 776 and 777 may exhibit super type S characteristics (pg. 8). Assigning the most claimant-favorable solubility for a particular radionuclide and cancer type is appropriate. Super Type S should not be limited to the 1965 fires, but the dose reconstructor should consider operations and incidental fires that may have heated plutonium to temperatures in excess of 600 degree Celsius. High-fired uranium oxide and associated particle sizes should also be addressed.

The default particle size is 5 micron AMAD. The site profile indicates that a 0.3 micron AMAD for all plutonium fires may be considered unless the qualifying cancer involves tissues of the extrathoracic regions (pg. 9). NIOSH/ORAU has been hesitant to integrate facility-specific particle size studies into a number of site profiles. RFP is no exception. There have been particle size studies completed at Rocky Flats that indicate particle sizes on the order of 1–

2 micron AMAD. NIOSH/ORAU is obligated to consider these studies in their analyses when the values are more claimant favorable than the default assumptions.

The default isotopic composition is weapons grade plutonium. There is a separate isotopic composition for ZPPR plutonium (pg. 8). It is appropriate to consider alternate isotopic compositions that workers may have encountered at the facility. The default isotopic composition for enriched uranium and depleted uranium is consistent with other sites handling uranium of this type.

In the RFP site profile, it was assumed that the sample volume represented a 24-hour collection and no corrections were made to the volume, whether they represented an actual 24-hour collection or not. In the Hanford site profile, it is recommended that a urine volume of less than reference man or woman be normalized to these values. A consistent method of addressing sample volume is needed. Ultimately, determining individual 24-hour sample volumes is ideal. In the absence of true 24-hour sample collection, the approach in the Hanford site profile is more claimant favorable.

Per the *Internal Dose Reconstruction Implementation Guide* (OCAS 2002b), a standard deviation of 0.3 times the MDA or reporting level, is adequate except for chest counts for which 0.5 times the MDA should be used. Dividing the MDA by 3.3 essentially gives the same value. The actual standard deviation or error is preferable where available, if it exceeds the value calculated above.

The RFP assumes $^{239+240}$Pu as the radionuclide of concern for nonspecific plutonium urine data. If ^{238}Pu is not recorded separately, multiply the $^{239+240}$Pu result by 1.0264 (pg.11). This is similar to methodologies used in other site profiles to ascertain dose contribution for those radionuclides not routinely evaluated in the bioassay program.

Although internal uptakes by wounds have been an issue at other sites, the RFP site profile is the only site profile reviewed to date that provides direction on assessing uptakes via a wound site. Consideration is given to acute and long-term chronic injection as a mode of intake.

For the purposes of lung counts, assume an initial concentration of 100 ppm ^{241}Am (pg. 20). This is a reasonable assumption, as long as records don't indicate material had a lower concentration of ^{241}Am.

An index of 1.35 is assumed to determine the MDA for lung counting, if the worker's height and weight are unavailable (pg. 19). Where height and weight are available, the index can be calculated and the most appropriate MDA applied to the particular person. As a best estimate approach, using 1.35 is reasonable; however, if this data is used to calculate a maximizing dose, the index giving the highest MDA for a detection system should be used to be claimant favorable. The application of the index in conjunction with the MDA provides a more individualized MDA.

In a conference call with TBD authors (Attachment 4), it was indicated that the maximizing approach for missed internal dose to unmonitored workers is determined by using ORAUT-OTIB-0002 (Rollins 2004) or ORAUT-OTIB-0018 (Brackett and Bihl 2005). Although RFP is not a reactor facility, the 28-radionuclide intake scenario for facilities with reactors was used. NIOSH/ORAU has provided no rationale for using the hypothetical intake for a reactor versus non-reactor facility. It is important to note that the internal dosimetry site profile does not mention the use of the above procedures for determining a maximum dose to unmonitored workers. There is also no explanation for when to use which TIB method.

There has been no consideration of ingestion dose from workers at the RFP facility. The Bethlehem Steel and Mallinckrodt Chemical Works site profiles have included dose from ingestion of radioactive material. Although there may have been more engineering controls at RFP, failure of these engineering controls, internal contamination of respirators, incidents, and allowing food and beverages in specific areas of the plant (e.g., uranium processing area) may have led to ingestion of radioactive material.

The inputs to IREP include radiation rate, radiation type, and dose distribution type. The RFP inputs into IREP are consistent with the other DOE sites reviewed so far. The maximizing approach assumes an uptake of 28 radionuclides as defined in ORAUT-OTIB-0002 (Rollins 2004). The exposure rate is inputted as a chronic intake. The radiation types include photons (>250 keV), electrons (> 15 keV), and alpha. These values are entered as a constant and encompass the uncertainty related to the dose estimation. The input for the best estimate internal dose is dependent on the individual's internal exposure history, but will default to a chronic intake. It is noted in compensable cases that dose reconstructors are using a triangular distribution.

Although radionuclides such as ^{237}Np, ^{238}Pu, ^{244}Cm, ^{233}U, and thorium are mentioned as either trace radionuclides or purified radionuclides, there has been no consideration of potential intakes from these radionuclides. There is also no mention of whether missed tritium dose should be assigned under any conditions. The site profile indicates that dosimetry data for these radionuclides is rare or not available. There is no clear conclusion on whether the gross alpha analysis of urine included these radionuclides. The relative contribution of the radionuclides to internal dose is not adequately discussed.

The Rocky Flats site profile has included example dosimetry records and detailed explanation of these records in both the internal and external site profiles. This is extremely helpful to the dose reconstructor in the interpretation of records and thus in the dose reconstruction effort. To date, other site profiles have not included this type of discussion; however, SC&A would strongly recommend that this information be included in other site profiles.

ATTACHMENT 6: PRELIMINARY TALKING POINTS FOR CONFERENCE CALL – SEPTEMBER 6–8, 2005

Review of the NIOSH Site Profile for the Rocky Flats Site

Preliminary Talking Points for
Conference Call – September 6-8, 2005

SC&A Review Team

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Site Description: Issues and findings

Overall, the Site Description provides a reasonable characterization of the history of production. (1951-89). However there remain important gaps:

- (1) Cleanup mission, now in its 15th year at Rocky Flats, is not included in the TBD.
- (2) Excess PU and HEU Storage vulnerabilities are not addressed.
- (3) Missing and incomplete information relative to extensive processing of recycled uranium.
- (4) Inadequate description of U-233 processing activities

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External Dose TBD: Findings and Issues

Records/Methodology

- Dose reconstruction from badge readings versus historical documents:
  - The TBD does not clearly relate the use of OW, CD, and BR to the historical records' definitions of skin, penetrating, and hand dose.
  - Dosimetry method at time of records are not always identifiable.

- Incomplete or inconsistent information:
  - 1952-1975 -> the deep gamma dose and the neutron dose were recorded as the total penetrating dose and not recorded as separate doses in the worker's file.
  - Potential external doses from recycled uranium not considered.
  - 1976, a large number of neutron and gamma doses were erroneously recorded.
  - July 1984 to Oct 1984, some neutron dose was recorded, but the gamma and total dose was zero.
  - 1984-1986 Possible manual corrections were needed, but the information was not provided to make these corrections.

External Dose TBD

Dose Calculations

- Job exposure matrix study should be available and used.
- Doses <10 mrem counted as zero dose is inconsistent.
- Use of "activity date" is uncertain.
- Worker's badge calibrated for one work location. However,
  - Workers worked at temporary sites.
  - Workers worked at other sites on overtime assignments.

  This could lead to under-recorded doses.
- Exposure Geometry – The assignment of ISO or ROT instead of AP geometry may not always be claimant favorable.
- NIOSH needs a consistent approach for angular dependence of beta/gamma film, NTA Film, and TLDs.

External Dose TBD

External Photon and Beta Dose

- Photons with E > 250 keV:
  - Penetrating power of photons w/ E>250 KeV may off set the REF of lower energy photons.

- Use of VARSKIN Software:
  - It is not apparent that this program includes one of the predominate beta emitter, *Pa-234m*, that was present at RFP.

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External Dose TBD

Extremity Dose

- Considerable hands-on work at RFP
  - No apparent extremity neutron monitoring.
  - Extremity dose should not be assumed to be equal to whole body dose:
    - ✓ Extremity dose may be 6x to 12x WB dose.
  - No valid hand-to-wrist ratios provided:
    - ✓ Surface beta dose rates on the order of 1 to 20 rad per hours in some locations.

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External Dose TBD

Neutron Exposures and Dosimetry

- Use of neutron track plates and uncertainties in neutron dosimetry 1951-1957 leads to areas of concern in correct DR:
  - Relationship of "plates" to NTA film not known
  - Characteristics/calibration of plates unknown.
  - Details of 1956-57 out-source to HPS are not known.

- NTA film neutron energy threshold may have lead to missed dose in RFP records:
  - Early threshold of 0.25 -0.4 MeV is too low.
  - Later threshold of 0.48 – 0.75 MeV is also too low.

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External Dose TBD

Neutron Exposures and Dosimetry

- The NDRP report is limited:
  - NDRP does not cover non-Pu workers.
  - Is not directly applicable to non-Pu workers.
- Because the NDRP report does not include non-Pu workers:
  - More work is needed on the use of neutron/photon ratios and film/TLD comparisons to correctly determine past neutron doses.
  - More robust neutron dose multiplication factors are needed.
  - Shift in neutron/photon ratios after production period not addressed

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External Dose TBD

Unmonitored Individuals

- Early radiation hazards may not have been recognized before exposures occurred:
  - Policy of badging only those expected to receive >10% of RPG may have left some radiation workers unbadged.
  - Lack of information on criticality parameter controls which evolved over time.
  - The NDRP (Falk 2005) reports that:
    - ✓ *There were significant neutron fields* from the *alpha-neutron reaction with light elements, especially from the plutonium tetrafluoride compounds.*
    - ✓ *Pu workers were not routinely monitored for neutron exposures until the 1960s.*

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External Dose TBD

Unmonitored Individuals

- 1959-1969 -> RFP 1984 annual report and NDRP 2003 shows that:
  - ✓ Average of only 25% of workers badged received NTA film during this 11-year period.
  - ✓ Range of 9% - 50% over the 11-year period.

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External Dose TBD

Industrial X-ray Units and Neutron Generators

- Radiographic X-ray units and neutron generator units were apparently used for NDT at the RFP
  - Units were not addressed in TBDs.
  - Energy/current/type, periods of operation, and SOPs, of these units need to be determined.
  - Dosimetry systems' response to these different radiation sources needs addressed.
  - Possible accidents/incidents need to be investigated.

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Internal Dose TBD: Findings and Issues

- The internal dosimetry TBD is incomplete:
  - There is limited direction to the dose reconstructor on the process and assumptions that should be used to calculate internal dose.
  - TBD does not provide guidance for assessment of missed dose and unmonitored workers.
  - The approaches regarding to solubility and particle size need to be reviewed.
  - TBD does not provide guidance for assessment of dose in accident case.

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Internal Dose TBD

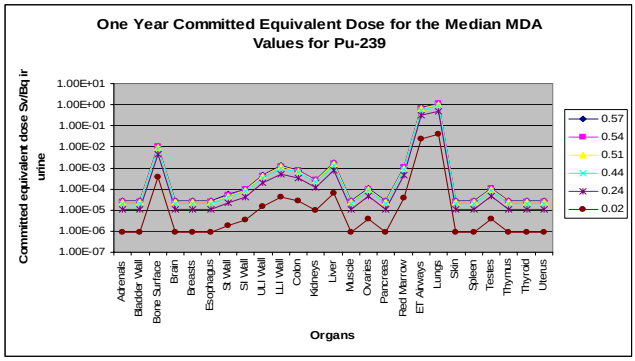
Source term:

- The TBD does not present a guidance for dose reconstruction to associated with tritium, neptunium, thorium, curium and fission products.
- The TBD does not address exposures from the processing of recycled uranium.

Internal Dose TBD

MDA of bioassay data:

- The MDA values for urinalysis are high, especially in the early years.
- The TBD does not present a guidance to assess the missed dose. The graphic below illustrates an example of missed dose for one year inhalation Pu-239, Type S, based on the different values of median MDA for plutonium in urine.



Internal Dose TBD

- Particle size:
  - The TBD does not present a complete analysis of the particle sizes. It adopts the default parameter of 5µm AMAD.
  - In the fire accidents the AMAD values were evaluated as 0.12 - 0.30 µm.

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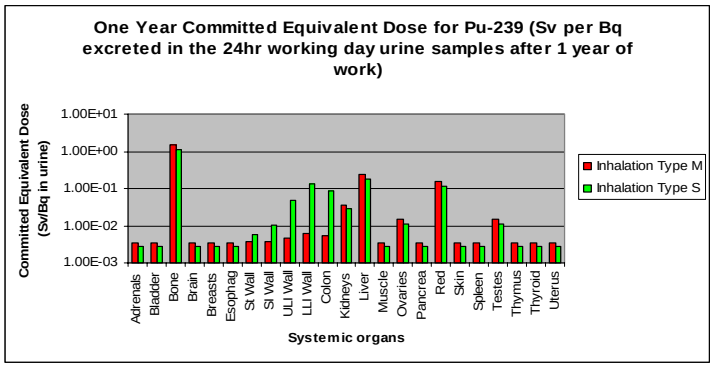
]

Internal Dose TBD

- Solubility:
  - The TBD assumption for the solubility of the compounds is not claimant favorable, especially for the cancers in the gastrointestinal organs. The solubility should be assigned based on the type of cancer as recommended in the 42CFR Part 82.



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Internal Dose TBD

- Fire accidents:
  - The Table shows the similarity of the values of the IRF for urine and feces for Type S and high fired Pu compounds. It can be considered as Type S compound.
  - The urinalysis were probably inappropriate to detect the intakes of either high-fired Pu or Type S Pu, unless there was a very high intake.
  - Feces analysis seems to be the more appropriate to evaluate accidental intakes.

Dose coefficients for Pu-239 inhalation

	24 hr Urine (Bq/Bq intake)				24 hr feces (Bq/Bq intake)			
days after intake	0.12 um Type S	0.12 um High fired	0.3 um Type S	0.3 um High fired	0.12 um Type S	0.12 um High fired	0.3 um Type S	0.3 um High fired
1	2.96E-06	5.05E-06	1.83E-06	2.84E-06	1.33E-02	1.33E-02	1.84E-02	1.84E-02
2	1.90E-06	7.77E-06	1.15E-06	4.37E-06	2.66E-02	2.66E-02	3.01E-02	3.01E-02
3	1.33E-06	5.99E-06	7.99E-07	3.37E-06	1.82E-02	1.82E-02	1.77E-02	1.77E-02
4	1.07E-06	4.18E-06	6.37E-07	2.35E-06	9.91E-03	9.91E-03	8.63E-03	8.63E-03
5	9.35E-07	2.91E-06	5.50E-07	1.64E-06	5.60E-03	5.59E-03	4.31E-03	4.31E-03
6	8.49E-07	2.07E-06	4.95E-07	1.17E-06	3.72E-03	3.71E-03	2.52E-03	2.51E-03
7	7.92E-07	1.53E-06	4.59E-07	8.60E-07	2.94E-03	2.94E-03	1.80E-03	1.80E-03
8	7.53E-07	1.16E-06	4.34E-07	6.54E-07	2.61E-03	2.61E-03	1.52E-03	1.51E-03
9	7.26E-07	9.12E-07	4.17E-07	5.13E-07	2.46E-03	2.45E-03	1.39E-03	1.39E-03
10	7.07E-07	7.39E-07	4.05E-07	4.16E-07	2.37E-03	2.36E-03	1.33E-03	1.32E-03
30	6.61E-07	3.02E-07	3.76E-07	1.70E-07	1.52E-03	1.52E-03	8.47E-04	8.46E-04
90	6.74E-07	2.20E-07	3.83E-07	1.24E-07	4.93E-04	4.94E-04	2.77E-04	2.78E-04

Internal Dose TBD

- Fire accidents:
  - The Table shows the similarity of the dose coefficients for Type S and high fired Pu compounds.

Dose coefficients for Pu-239 inhalation

	0.12 µm		0.3 µm	
Organs	Type S	High fired	Type S	High fired
Adrenals	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Bladder Wall	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Bone Surface	1.96E-06	9.70E-07	1.12E-06	5.47E-07
Brain	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Breasts	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Esophagus	4.65E-09	2.22E-09	2.65E-09	1.25E-09
St Wall	4.92E-09	2.50E-09	2.85E-09	1.45E-09
SI Wall	5.33E-09	2.91E-09	3.15E-09	1.75E-09
Colon	1.22E-08	9.81E-09	8.18E-09	6.79E-09
Kidneys	4.58E-08	2.00E-08	2.61E-08	1.13E-08
Liver	3.26E-07	1.62E-07	1.86E-07	9.16E-08
Muscle	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Ovaries	1.96E-08	9.73E-09	1.12E-08	5.48E-09
Pancreas	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Red Marrow	1.99E-07	9.86E-08	1.14E-07	5.55E-08
ET Airways	2.20E-06	2.22E-06	3.81E-06	3.86E-06
Lungs	9.93E-05	9.95E-05	5.42E-05	5.44E-05
Skin	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Spleen	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Testes	1.99E-08	9.90E-09	1.14E-08	5.58E-09
Thymus	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Thyroid	4.65E-09	2.22E-09	2.65E-09	1.25E-09
Uterus	4.65E-09	2.22E-09	2.65E-09	1.25E-09

Internal Dose TBD

Internal Dosimetry Records/Methodology
Urinalysis

- Gross alpha urinalysis was used for workers who were potentially exposed to uranium, plutonium and other alpha emitters in the same monitoring period. Until 1963, the results were assigned to EU. After 1963 (and EU operations were phased out), the results were assigned to plutonium. It is not a claimant favorable approach since the dose for plutonium is higher than the ones for uranium.

- High uncertainties on estimates of the: high blank, recovery, 24 hours urine volume, and consequently on the estimate of the median MDA values. The TBD presents the MDA for extreme condition, but it does not provide information on how to apply them.

Internal Dose TBD

Internal Dosimetry Records/Methodology
Urinalysis

- Urinalysis results less than 10% of the tolerance level were recorded and reported as background (BK on the Urinalysis Record Card) or zero – it is inconsistent and critical, especially for alpha emitters.
- There is no clear guidance on how to normalize the urine sample volume for 24 hours urine volume.

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Internal Dose TBD

Internal Dosimetry Records/Methodology
***In Vivo* Lung Count**

- Assignment of the date of intake – source of uncertainty.
- It is not clear if *in vivo* lung count was used as a routine monitoring program or just in special monitoring.
- No information about measurement of fission products.
- A positive detection of Am-241 did not necessarily indicate an intake of the plutonium/americium mixture, especially for a lung count in response to an incident – it is not a claimant favorable approach.
- Consider super-equilibrium of the Th-234 with the U-238 is not necessarily claimant favorable approach, especially for the workers exposed to depleted uranium metal with a deficiency of Th-234.

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Internal Dose TBD

Internal Dosimetry Records/Methodology
***In Vivo* Lung Count**

- The assumption of the similar behavior of americium associated with the plutonium particles in the lungs until the particles are dissolved or removed from the lungs – it need to be evaluated in order to avoid the underestimation of plutonium activity.
- When there is no measurement in one of the chest side, it is stated that the dose reconstructor should estimate the contribution for the other chest side before using data from the count – no guidance for this calculation.

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Internal Dose TBD

Other Bioassay Data

- Wound count information is largely irrelevant to dose reconstruction:
  - Although no appropriate wound model is available currently, the approach is claimant favorable for most types of cancer, unless for lymph node cancers – special approach need to be presented, since there are available information about a signiticant fraction of intake retained in the lymph nodes.
- Fecal analysis:
  - The available data should be used as much as possible to evaluate the intakes of radionuclides Type S compounds.

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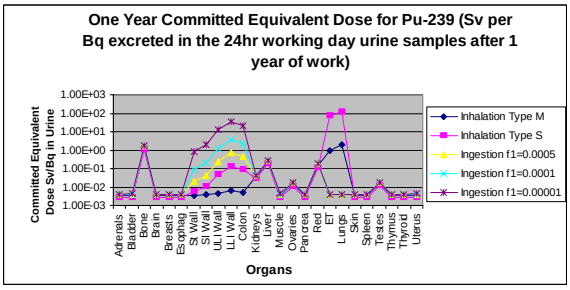
Internal Dose TBD: *Dose Assessment*

- Potential for Ingestion Exposure Pathways:
  - Ingestion pathway of exposure was not considered on the dose assessment. The ingestion of insoluble compounds should be included as a part of the internal dose assessment, especially in cases of cancer in organs of the gastrointestinal tract.



Internal Dose TBD: *Dose Assessment*

- **Coworker Dose Assignment:**
  - The TBD does not present any guidance to calculate the dose for unmonitored workers.

Occupational Medical Exposure TBD: Findings and Issues

- NIOSH needs to better define its interpretation of what constitutes medical exposure.
  - NIOSH does not provide clarity or interpretation of included exposures in OCAS (2002) guidelines.
  - ORAUT-TKBS-0011-3 interprets NIOSH guidelines as including pre-employment and annual routine exams.
  - Special x-rays (e.g., respiratory certification) are presumed to have occurred at time of annual medical exam, which is not demonstrated by records.
  - ORAUT-OTIB-0006 recently revised (Revision 3) suggests that all exposure incidental to employment should be included. TIB also suggests inclusion of termination x-rays be included.
  - TBD does not discuss impacts of special exams and x-rays resulting from work related injury or illness, and routine-to-work exams.

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Occupational Medical Exposure TBD

- The TBD does not address the potential for sealed sources being used in the medical clinic. The TBD does not catalog the number and types of x-ray equipment available for use and the conditions of use.
  - The TBD provides little or no information on types of procedures used on workers or protocols for use beyond chest x-rays.
  - The TBD does not detail the protocols used to assure workers did not receive x-ray exams without approvals or received unwarranted screening exams.
  - The TBD does not document that x-ray equipment did not exceed the diagnostic range or greater than 80 kVp.

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Occupational Medical Exposure TBD

- The TBD uses assumptions drawn from other site reviews to address exam frequencies. The TBD assumes only 1-2 exams per year. This is a very speculative assumption for many workers without proper documentation.
  - There is no documentation to show that most workers did not receive voluntary annual chest x-rays.
  - There is no documentation to show that special worker categories (e.g., asbestos and beryllium workers) did not receive multiple chest x-rays.
  - The RFP utilized the PFG unit for nearly 20 years (~1950-1970) which have the highest exposure rates.
  - The TIB suggests that a retake rate of 3% was used. The use of Type II machines in industrial environments may easily run an order of magnitude higher (up to 30%).

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Occupational Medical Exposure TBD

- There is little documentation to support the assumption on equipment and x-ray exam techniques which appear to be derived mainly from TIB-0006.
  - There is no documentation on x-ray protocols or machine calibration requirements prior to 2001.
  - Their assumptions rely heavily on ORAU 2003a and b from the SRS.
  - Their dose to abdominal and spinal areas are derived from Lincoln and Gupton (~1958).
  - The RFP relied heavily on the PFG unit for routine chest radiography. Doses to workers could have been easily 5-6 times as great as other sites from chest x-rays alone.
  - The TBD does not address the importance of processors which impact dose and retakes.

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Occupational Medical Exposure TBD

- The TBD does not evaluate the dose impact due to proper use of screens or grids, as it assumes that equipment output would not vary or impact off-site exposures.
  - There is no documentation to show that the RFP assessed its techniques and protocols to minimize dose.
  - The RFP TBD does not address off-site medical exposures that may have been prescribed by physicians at RFP.
  - There are no records to show that physicians reviewed the frequency, type or need for x-ray exams on a routine basis.

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Occupational Environmental TBD: Findings and Issues

- Values applied in 1965–2002 dose reconstruction.
  - Identify if the 50th or 95th percentile values were used to determine dose
- The relationship and relevance of particle sizes need to be explained
  - Many particle sizes were used in the text and relevance to dose was not clear
- Inadvertent ingestion of radioactive materials
  - Why ingestion of Pu and Am was not included in the dose calculations
- Continuous resuspension of plutonium and americium
  - Resuspension seemed ignored in calculating the dose
- Adequacy of RATCHET to simulate the atmospheric dispersion factors on site
  - Code was originally designed for off-site calculations
- Delineate phases of operations, data availability, and types of data.
  - Several Phases were being identified and time-line is needed to emphasize relevance

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ATTACHMENT 7: EDITORIAL ERRORS IN THE TECHNICAL BASIS DOCUMENTS

The following items are those that need to be explained or addressed further in order to provide clarity and/or completeness in the TBD.

Observation 1: Errors or Confusing Statements in TBD-0011-6

Missing Information

ORAU-TKBS-0011-6 (Langsted 2004, pg. 18), 3rd line, lists, "1977-present, dosimeter exchange history." Shouldn't there be more information provided besides the exchange history (i.e., quarterly dose history, etc.)?

Energy Range Error

ORAU-TKBS-0011-6 (Langsted 2004, pg. 24), 6th line up from the bottom, should read …*the 30-**2**50 keV photon…*, not …*the 30-50 keV photon….*

Table 6-18 Clarification

ORAU-TKBS-0011-6 (Langsted 2004, pg. 31) Table 6-18, Column 2 heading, should read "Fraction of dose using NCRP38 flux-to-dose conversion factors." This would clarify how the information in the column was derived. Also, potential missed neutron dose based on accompanying text should be 60% with a multiplying factor of 2.5 rather than 56% and 1.79 from the standpoint of claimant favorability.

Table 6-24 Clarification

ORAU-TKBS-0011-6 (Langsted 2004, pg. 41) Table 6-24 footnotes state to multiply any dose greater than 2 mrem by 1.12. However, the fourth column contains numbers that do not use this multiplier and do not match Columns 2 and 3.

Observation 2: Errors or Confusing Statements in OTIB-0027

Reference Error

ORAU-OTIB-0027 (Smith 2005), Page 5, 1st paragraph, 3rd hird line, should read, *Rocky Flats Plant – Occupational **Environmental** Dosimetry (Rev 01).*[2] [Emphasis added.]

Error in Calculating Skin and Penetrating Doses

ORAU-OTIB-0027 (Smith 2005), page 5, in the Pre-1960 section list that skin dose was determined by (OW + CD + BR) and also by (OW + CD). The BR term is apparently in error in this paragraph and should be deleted.

Beta/gamma only in OTIB-0027

ORAU-OTIB-0027 (Smith 2005) provides supplemental DR information for beta and gamma doses only. It would be helpful to provide in the document title the fact that it is only for beta/gamma (i.e., it does not apply to neutron dose reconstruction). This would clarify its

purpose, because it does mention neutrons in the uncertainty factors listed in Table 4-1 and Table 4-2 on pages 7 and 8.

Error in Table 4-2

ORAU-OTIB-0027 (Smith 2005), page 8; in Table 4-2 it would appear that the third entry in Column 2 should read 1983-2003 instead of 1983–1998.

ATTACHMENT 8: RECORDS REQUESTED FROM ROCKY FLATS

Rocky Flats records personnel performed a keyword search of their site records database for the SC&A team. The list of records under each keyword was reviewed for technical reports and other records pertinent to the SC&A review. The following records were requested from RFP via email on September 9, 2005. Records have not been provided to date.

(1) *Investigation Team Report: Investigating the Source of Potential Internal Radiological Exposures Involving Eleven Personnel in Building 771*, Rocky Flats Environmental Technology Site, March 15, 2001.

(2) Sullivan, M.T., *Lifetime Dose Limitation and Neutron Dose Reconstruction*, Letter, July 26, 1994.

(3) Tontodonato, R.E., *Trip to Review Feed Characterization for RFP Building 707 Thermal Stabilization Process, January 20, 1994*, Letter, February 8, 1994.

(4) *A Report on Radiation Problems Related to Plutonium Fabrication Operations at the Rocky Flats Plant*, Dow Chemical, Rocky Flats Division, January 1968.

(5) *Safety Considerations in the Operations of the Rocky Flats Plutonium Processing Plant,* Atomic Energy Commission, March 1970.

(6) Putzier, Edward, 1970, *A Summary of On-site Radioactive Waste Disposal*, April, 1970.

(7) Putzier, Edward, *Past Thirty Years*,

(8) Barrick, C.W., 1981, *Past Accidental Releases of Radioactivity from the Rocky Flats Plant*, January 14, 1981.

(9) Putzier, Edward, *Internal Letter to Medical File*, March 8, 1976.

(10) *An Aerial Radiological Survey of the United States Department of Energy's Rocky Flats Plant*, DOE, August 1981.

(11) *An Aerial Radiological Survey of the United States Department of Energy's Rocky Flats Plant*, DOE, July 1979.

(12) *Environmental Safety and Health Progress Assessment of the Rocky Flats Plant*, DOE, May 1993.

(13) Measurements of Plutonium-238, 1967.

(14) In-vivo Measurements of Plutonium-238, 1967 (Bistline, pg. 6).

(15) 2002-03-12 – Report DOE/IG-0544: Report on "Inspection of the Accountability and Control of Sealed Radioactive Sources at Selected Department of Energy Sites."

(16) 1996-09-19 – Report WR-L-96-03: Audit of the Environmental Restoration of the 903 Pad, Mound, and East Trenches at the Rocky Flats Environmental Technology Site.

(17) 1995-03-15 – Report WR-L-95-22: Assessment of EG&G Rocky Flats, Inc., Internal Audit Function.

(18) List of Site Closure Reports in the RFP Records System.

ATTACHMENT 9: EVALUATION OF INHALATION SUPER S VS. TYPE S AND TYPE M

The absorption of the inhaled material to the blood depends on its physical and chemical form. ICRP recommends that material-specific rates of absorption should be used in the model for compounds for which reliable experimental data exist. For other compounds, default values of parameters are recommended. In Rocky Flats, high-fired oxides were generated during the two big fire accidents. It is clear that other potential sources of such oxides are the more numerous smaller fires that have occurred, and multiple high temperature processes in furnaces, incinerators, and production process areas used in multiple plutonium buildings.

In order to evaluate the effectiveness of bioassay methods, which were applied during the early years in Rocky Flats, to detect ^{239}Pu activity in urinary samples from accidental intakes, some simulations of different scenarios for ^{239}Pu inhalation were done. As ICRP has not recommended specific values for lung retention parameters for high-fired plutonium, the Type S parameters were used for these simulations. The Type S plutonium compounds are less insoluble than high-fired plutonium, so if it is not possible to detect measurable activity for ^{239}Pu Type S in urinary samples due to the high MDA values it will be unlikely to measure any activity in urinary samples due to acute intake of high-fired plutonium.

Scenario 1 - Chronic inhalation different compounds: For the ^{239}Pu activity of 1 dpm/24-hr in urine samples taken at the end of the 20 years of exposure, assuming that the total activity is due to the inhalation of Type S compound (AMAD = 1μm), the total intake was calculated to be 6.42E+04 Bq. Assuming that the total activity was due to the inhalation of Type M compound (AMAD = 1μm), the total intake was calculated to be 6.68E+03. The equivalent doses are presented in Table 1, which shows that the doses are higher for Type M compound compared to the insoluble ones, except where the critical organs are the large intestine and respiratory tract, where the high-fired compound delivers the highest doses.

Table 1. Equivalent Dose due to a Chronic Inhalation of Plutonium-239 for Type S and Type M Compounds, Estimated by Urinalysis

Organs	Equivalent dose for 20 y chronic exposure (Sv)		
	Type S	Type M	TypeM/TypeS
Adrenals	3.28E-03	4.15E-03	1.27E+00
Bladder Wall	3.28E-03	4.15E-03	1.27E+00
Bone Surface	1.95E+00	2.52E+00	1.29E+00
Brain	3.28E-03	4.15E-03	1.27E+00
Breasts	3.28E-03	4.15E-03	1.27E+00
Esophagus	3.28E-03	4.15E-03	1.27E+00
St Wall	3.30E-03	4.17E-03	1.26E+00
SI Wall	3.34E-03	4.17E-03	1.25E+00
ULI Wall	3.66E-03	4.19E-03	1.14E+00
LLI Wall	4.43E-03	4.26E-03	9.62E-01
Colon	3.99E-03	4.22E-03	1.06E+00
Kidneys	1.50E-02	1.82E-02	1.21E+00

Table 1. Equivalent Dose due to a Chronic Inhalation of Plutonium-239 for Type S and Type M Compounds, Estimated by Urinalysis

Organs	Equivalent dose for 20 y chronic exposure (Sv)		
	Type S	Type M	TypeM/TypeS
Liver	4.04E-01	5.28E-01	1.31E+00
Muscle	3.28E-03	4.15E-03	1.27E+00
Ovaries	2.42E-02	3.16E-02	1.31E+00
Pancreas	3.28E-03	4.15E-03	1.27E+00
Red Marrow	1.50E-01	1.88E-01	1.25E+00
ET Airways	2.44E+00	5.13E-02	2.10E-02
Lungs	4.29E+00	1.94E-01	4.52E-02
Skin	3.28E-03	4.15E-03	1.27E+00
Spleen	3.28E-03	4.15E-03	1.27E+00
Testes	2.47E-02	3.23E-02	1.31E+00
Thymus	3.28E-03	4.15E-03	1.27E+00
Thyroid	3.28E-03	4.15E-03	1.27E+00
Uterus	3.28E-03	4.15E-03	1.27E+00

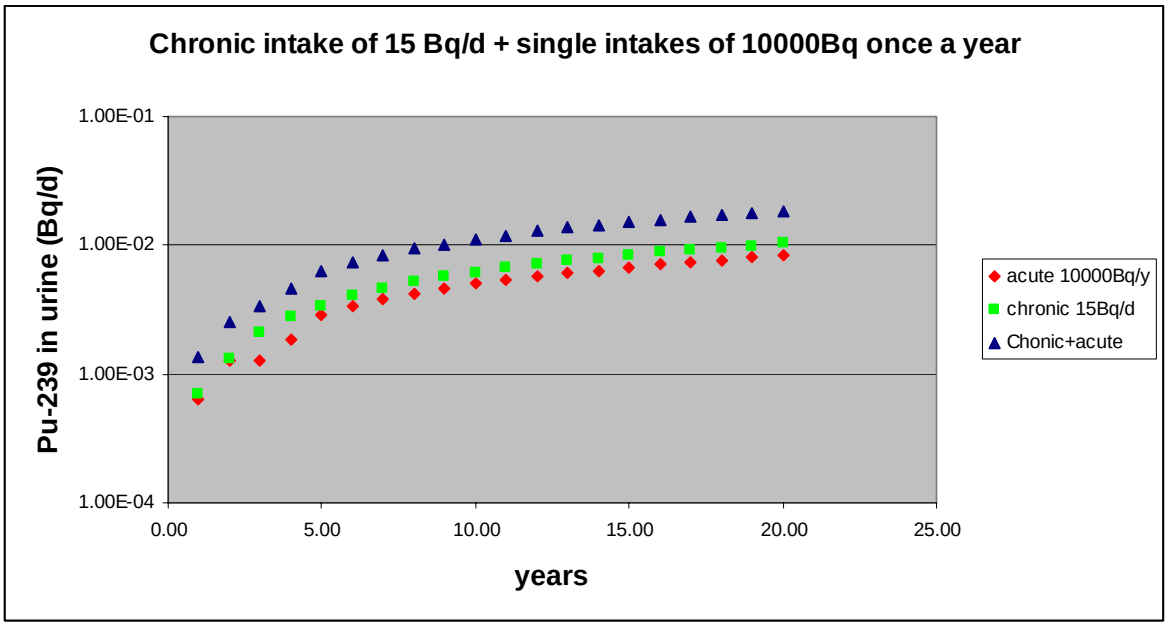
Scenario 2 – Chronic inhalation of 15Bq/day of ^{239}Pu Type S + acute intake of 10E+03 Bq: The second scenario modeled was a chronic inhalation of 15Bq/day of ^{239}Pu Type S, AMAD = 5 μm, through the 20 years of exposure with additional acute intakes of 10,000 Bq/year, in the beginning of each year, of Type S ^{239}Pu compound, AMAD = 1μm. The annual intake due to chronic exposure was 3.75 E+03 Bq, assuming that the worker was exposed 250 days per year, and due to acute intake was 10E+03 Bq. If the procedure to estimate the missed dose was applied, the calculated intake would be 2.72E+04 Bq for the whole period of employment, instead of real one that was 7.5E+04 Bq for chronic plus 2E+05 Bq for acute intakes. Since it is not significant chronic exposure, the worker could probably be monitored just once a year. Taking into account that the MDA value for the early 20 years, 0.57–0.51 dpm (0.01 Bq), ^{239}Pu in urine would be detected just after 10 years of exposure, as seen in Table 2. The table also shows that whether the urine sample is collected in the end of the year the acute intake is not detected. As the contribution of chronic intake is not significant, the activities in urine due to acute intakes are very similar to the chronic intake of 15Bq/d. A graph below represents the data on Table 2.

Table 2. Predicted Activity in Daily Urinary Excretion due to 20-Year Chronic Intake of 15 Bq/day Plus One Acute Intake of 10E+03 Bq Each Year

Years	^{239}Pu in urinary excretion (Bq/d)		
	Acute 10,000Bq/y	Chronic 15 Bq/d	Chronic+acute
1.00	6.43E-04	6.92E-04	1.33E-03
2.00	1.26E-03	1.30E-03	2.55E-03
3.00	1.26E-03	2.07E-03	3.33E-03
4.00	1.83E-03	2.76E-03	4.59E-03
5.00	2.87E-03	3.42E-03	6.29E-03
6.00	3.34E-03	4.01E-03	7.35E-03
7.00	3.79E-03	4.64E-03	8.42E-03

Table 2. Predicted Activity in Daily Urinary Excretion due to 20-Year Chronic Intake of 15 Bq/day Plus One Acute Intake of 10E+03 Bq Each Year

Years	^{239}Pu in urinary excretion (Bq/d)		
	Acute 10,000Bq/y	Chronic 15 Bq/d	Chronic+acute
8.00	4.21E-03	5.15E-03	9.35E-03
9.00	4.60E-03	5.66E-03	1.03E-02
10.00	4.99E-03	6.20E-03	1.12E-02
11.00	5.36E-03	6.62E-03	1.20E-02
12.00	5.72E-03	7.13E-03	1.28E-02
13.00	6.07E-03	7.58E-03	1.36E-02
14.00	6.41E-03	7.94E-03	1.43E-02
15.00	6.74E-03	8.37E-03	1.51E-02
16.00	7.06E-03	8.78E-03	1.58E-02
17.00	7.38E-03	9.21E-03	1.66E-02
18.00	7.69E-03	9.59E-03	1.73E-02
19.00	8.00E-03	9.95E-03	1.79E-02
20.00	8.30E-03	1.03E-02	1.86E-02



Scenario 3 – Chronic inhalation of 100 Bq/day of ^{239}Pu Type S + acute intake of 10E+03 Bq: The third scenario modeled was a chronic inhalation of 100 Bq/day of ^{239}Pu Type S, AMAD = 5 µm, through the 20 years of exposure, with additional acute intakes of 10,000 Bq/year, in the beginning of each year, of Type S ^{239}Pu compound, AMAD = 1µm. The annual intake due to chronic exposure was 2.5E+04 Bq, assuming that the worker was exposed 250 days per year, and due to acute intake was 10+03 Bq, assuming that the worker was being monitored each 3 months. The calculated intake for the whole period of employment, was 5E+05 Bq for

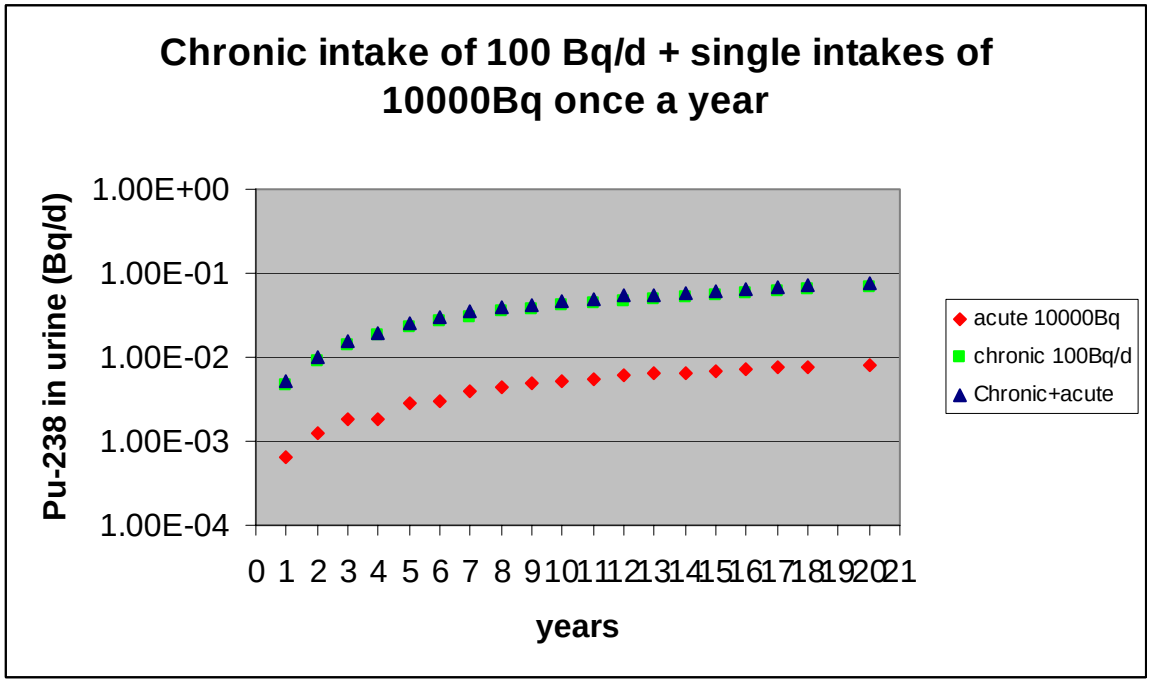
chronic plus 2E+05 Bq for acute intakes. Table 3 shows that after the 2nd year of exposure, the urinary activity due to chronic intake is similar to the one in the first day after the acute intake of 10+03 Bq. It means that any acute intake in the order of 10^4 Bq may be confounded with chronic intake. In the 6th year of exposure, the contribution of chronic intake on the urinary activity is higher than the one due to acute intake of 10+03 Bq. As the urinary activity due to chronic intake is increasing over the years of exposure, it becomes difficult to detect acute intakes unless the measurement system is very sensitive or the intake is extremely high. The value of daily intake taken to simulate chronic exposure is just 25% higher than the one calculated based on the MDA value of 0.01 Bq (0.57dpm). In terms of dose, it is important for respiratory and gastrointestinal tract. A graph below represents the data on Table 3.

Table 3. Predicted Activity in Daily Urinary Excretion due to 20-Year Chronic Intake of 100Bq/day Plus One Acute Intake of 10E+03 Bq Each Year

Years	^{239}Pu in urinary excretion (Bq/d)			Years	^{239}Pu in urinary excretion (Bq/d)		
	Acute 10,000Bq	Chronic 100Bq/d	Chronic+acute		Acute 10,000Bq	Chronic 100Bq/d	Chronic+acute
0.003	2.11E-02	2.02E-04	2.13E-02	8	4.38E-03	3.44E-02	3.88E-02
0.25	8.92E-04	1.43E-03	2.32E-03	0.003	2.55E-02	3.44E-02	5.99E-02
0.5	7.12E-04	2.48E-03	3.19E-03	0.5	4.98E-03	3.59E-02	4.09E-02
0.75	6.60E-04	3.36E-03	4.02E-03	9	4.83E-03	3.78E-02	4.26E-02
1	6.43E-04	4.61E-03	5.25E-03	0.003	2.59E-02	3.78E-02	6.37E-02
0.003	2.17E-02	4.61E-03	2.64E-02	0.5	5.38E-03	4.13E-02	4.67E-02
0.25	1.53E-03	5.68E-03	7.21E-03	10	5.25E-03	4.12E-02	4.64E-02
0.5	1.34E-03	6.67E-03	8.01E-03	0.003	2.63E-02	4.12E-02	6.75E-02
0.75	1.28E-03	7.83E-03	9.11E-03	0.5	5.79E-03	4.29E-02	4.87E-02
2	1.25E-03	8.96E-03	1.02E-02	11	5.60E-03	4.45E-02	5.01E-02
0.003	2.24E-02	8.96E-03	3.13E-02	0.003	2.67E-02	4.45E-02	7.12E-02
0.25	2.13E-03	1.02E-02	1.23E-02	0.5	6.16E-03	4.56E-02	5.18E-02
0.5	1.93E-03	1.13E-02	1.32E-02	12	5.96E-03	4.74E-02	5.34E-02
0.75	1.86E-03	1.25E-02	1.44E-02	0.003	2.70E-02	4.74E-02	7.44E-02
3	1.83E-03	1.37E-02	1.55E-02	0.5	6.47E-03	4.85E-02	5.50E-02
0.003	2.24E-02	1.37E-02	3.61E-02	13	6.28E-03	4.99E-02	5.62E-02
0.25	2.13E-03	1.45E-02	1.66E-02	0.003	2.73E-02	4.99E-02	7.72E-02
0.5	1.93E-03	1.58E-02	1.77E-02	0.5	6.79E-03	5.15E-02	5.83E-02
0.75	1.86E-03	1.68E-02	1.87E-02	14	6.61E-03	5.27E-02	5.93E-02
4	1.83E-03	1.80E-02	1.98E-02	0.003	2.76E-02	5.27E-02	8.03E-02
0.003	2.35E-02	1.80E-02	4.15E-02	0.5	7.08E-03	5.42E-02	6.13E-02
0.25	3.23E-03	1.93E-02	2.25E-02	15	6.91E-03	5.55E-02	6.24E-02
0.5	3.01E-03	2.03E-02	2.33E-02	0.003	2.79E-02	5.55E-02	8.34E-02
0.75	2.92E-03	2.13E-02	2.42E-02	0.5	7.38E-03	5.73E-02	6.47E-02
5	2.87E-03	2.25E-02	2.54E-02	16	7.20E-03	5.85E-02	6.57E-02
0.003	2.35E-02	2.25E-02	4.60E-02	0.003	2.82E-02	5.85E-02	8.67E-02
25	3.23E-03	2.33E-02	2.65E-02	0.5	7.68E-03	5.95E-02	6.72E-02
75	3.01E-03	2.45E-02	2.75E-02	17	7.50E-03	6.09E-02	6.84E-02
6	2.92E-03	2.67E-02	2.96E-02	0.003	2.85E-02	6.09E-02	8.94E-02
0.003	2.44E-02	2.67E-02	5.11E-02	0.5	7.97E-03	6.24E-02	7.04E-02
0.5	4.04E-03	2.90E-02	3.30E-02	18	7.79E-03	6.38E-02	7.16E-02

Table 3. Predicted Activity in Daily Urinary Excretion due to 20-Year Chronic Intake of 100Bq/day Plus One Acute Intake of 10E+03 Bq Each Year

Years	^{239}Pu in urinary excretion (Bq/d)			Years	^{239}Pu in urinary excretion (Bq/d)		
	Acute 10,000Bq	Chronic 100Bq/d	Chronic+acute		Acute 10,000Bq	Chronic 100Bq/d	Chronic+acute
7	3.92E-03	3.06E-02	3.45E-02	0.003	2.88E-02	6.54E-02	9.42E-02
0.003	2.50E-02	3.06E-02	5.56E-02	20	8.25E-03	6.89E-02	7.72E-02
0.5	4.50E-03	3.26E-02	3.71E-02				

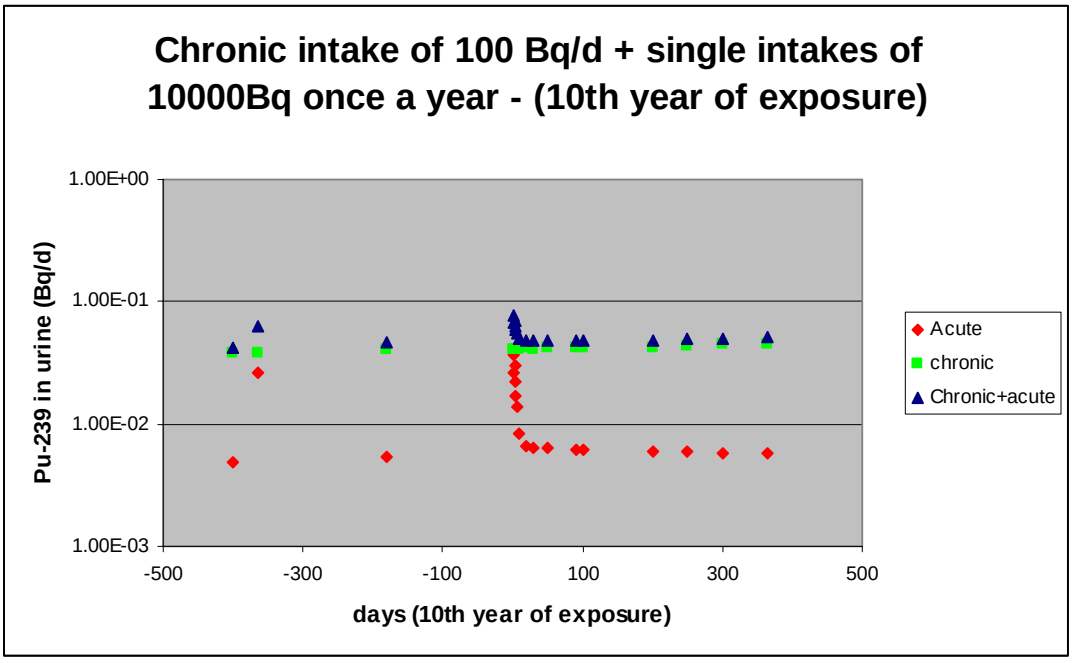


Scenario 4 – Chronic inhalation of 100 Bq/day of ^{239}Pu Type S + acute intake of 10E+03 Bq - sequential measurements after the acute intake in the 10th year of exposure:

The fourth scenario modeled was a chronic inhalation of 100 Bq/day of ^{239}Pu Type S, AMAD = 5 µm, through the 20 years of exposure, with additional acute intakes of 10,000 Bq/year, in the beginning of each year, of Type S ^{239}Pu compound, AMAD = 1µm. Sequential urinary measurements were performed one day after the acute intake. Table 4 shows that the values of urinary excretion due to total intake are higher than the chronic just by a factor of 1.5 (maximum). Depending on the recovery and measurement system, it may be part of the uncertainty of the measurement.

Table 4. Predicted Activity in Daily Urinary Excretion After an Acute Intake of 10E+03 Bq of Plutonium-239 in the Beginning of the 10th-Year Chronic Intake of 100 Bq/day Plus Annual Acute Intakes of 10E+03 Bq

Days	^{239}Pu in urinary excretion (Bq/d)		
	Acute 10,000 Bq/y	Chronic 100 Bq/d	Chronic+acute
-730	2.55E-02	3.44E-02	5.99E-02
-545	4.98E-03	3.59E-02	4.09E-02
-400	4.83E-03	3.78E-02	4.26E-02
-365	2.59E-02	3.78E-02	6.37E-02
-180	5.38E-03	4.13E-02	4.67E-02
1	2.63E-02	4.11E-02	6.74E-02
2	3.70E-02	4.12E-02	7.82E-02
3	2.97E-02	4.11E-02	7.08E-02
4	2.23E-02	4.10E-02	6.33E-02
5	1.71E-02	4.09E-02	5.80E-02
6	1.37E-02	4.13E-02	5.50E-02
10	8.27E-03	4.11E-02	4.94E-02
20	6.62E-03	4.15E-02	4.81E-02
30	6.49E-03	4.13E-02	4.78E-02
50	6.34E-03	4.17E-02	4.80E-02
90	6.15E-03	4.18E-02	4.79E-02
100	6.11E-03	4.18E-02	4.79E-02
200	6.05E-03	4.25E-02	4.85E-02
250	5.95E-03	4.35E-02	4.94E-02
300	5.85E-03	4.43E-02	5.01E-02
365	5.80E-03	4.53E-02	5.11E-02



CONCLUSION:

The incidental acute intake of high-fired ^{239}Pu, in the first 20 years, may be difficult to identify because of several factors:

- High MDA value (0.01Bq)
- Urinalysis applied to evaluate incidental intake
- Low fraction of activity intake excreted through urine (10^{-6} Bq)

According to workers' interview, the urinalysis or other type of measurement was not performed following the accidents; in some cases after a considerable time after intake
Fecal excretion associated with lung count is the best methodology to evaluate incidental intake, but it was not performed.

The contribution of chronic intake in urinary activity increases over the time of exposure, obviating the detection of incidental intakes, unless the activity is extremely high or the chronic exposure is very low, or undetectable

These scenarios show it would be unlikely that an acute intake of Type S ^{239}Pu would be detectable, with the implication that it would be even more difficult to detect acute intakes of high-fired ^{239}Pu due to the lack of sensitivity of conventional urinalysis methods.

ATTACHMENT 10: LIKELIHOOD OF UNMEASURED NEUTRON EXPOSURES

Rocky Flats was a "first of a kind" facility relative to large-scale processing and fabrication of fissile materials for nuclear weapons. For this reason, quantifiable knowledge of neutron hazards in the workplace at Rocky Flats was acquired, on an iterative basis concurrent with large-scale production and from the experience and experimental evidence from other sites.

By virtue of the steep build-up and routine turnover of nuclear weapons and the constant and active experimentation with new weapons designs, the establishment of threshold values to prevent criticalities and limit neutron exposures to workers during the 1950s and 1960s were largely derived from a "learn by doing" process. Such a process, by its very nature would very likely result in missing neutron doses to a potentially significant number of workers. This is indicated by recent history of the Rocky Flats criticality laboratory. From the inception of operations, Rocky Flats had a Nuclear Safety Group which:

- *…was divided into two groups: the criticality mass laboratory, where experiments were conducted, and criticality engineering. The principal functions of criticality engineering included writing criticality limits and procedures for the safe handling of fissile materials, implementing the limits and procedures in all areas that handled fissile materials, training and indoctrinating personnel who handled fissile materials, and performing auditing operations.* (Rothe 2005, pg. 45)

- *Until the early 1960s, criticality testing was done after-hours in the production glove boxes. Experiments were only allowed to go towards criticality, but not allowed to go critical. Values were then extrapolated. The need to obtain more actual values was recognized and in 1964, ground was broken on a state-of-the-art criticality mass laboratory.* (Rothe 2005, pg. 45)

- *Investigators would set up the production materials in various arrays to perform neutron multiplication experiments and make predictions with respect to safe geometries for various kinds of production vessels, spacing parameters, shipping containers, and other items. These in situ experiments conducted outside Building 886 were always subcritical.* (Rothe 2005, pg. 45)

- *Prior to constructing the [*Critical Mass Laboratory in 1965], *persons performing in situ experiments were the same ones evaluating criticality safety throughout the plant. The Nuclear Safety Group was small; but everyone wore many hats. The division of manpower between experiments and plant safety only evolved during the late-1960s. …At first, even this distinction was a little vague. Evaluators participated in a few experiments; and, to a lesser extent, experimenters became involved in plant-wide criticality safety. That distinction became much clearer during the early 1970s when the AEC introduced the requirement that people performing critical experiments should somehow be "certified."* (Rothe 2005, pg. 55)

Unlike current criticality safety and neutron exposure protection regimes at DOE sites, during the period of peak production between 1955 and 1965, the system that was in place at the Rocky Flats Plant had a small staff and was not formalized relative to postings, the formalization of binding operating limits in different process areas, and strict compliance with requirements.

- ***For many years, the entire Nuclear Safety Group consisted of only 14 persons.*** [emphasis added]*This included three hired to perform experiments at the CML and one who served as a technical/mechanical/electronic support person. [the Nuclear Safety Group manager] had one secretary for the whole group and an Administrative Assistant. The remainder, always the larger group, worked closely with all buildings on plant site housing fissile materials to ensure nuclear criticality safety.* (Rothe 2005, pg. 55)

- *Early criticality safety advice did not possess the significance it now carries.* ***Managers of various plant operations sought advice and guidance from [the Nuclear Safety Program director] and his team; but that input was neither considered binding nor limiting.*** *Important safety information bore the innocent heading: "Nuclear Safety Recommendation." That such important safety documents should ever have been relegated to the status of recommendation is somewhat surprising* [Emphasis added] (Rothe 2005, pg. 56)

- *This author also recalls once finding an ancient and long-lost hidden sign suspended from some seldom-used equipment in a deep, never-visited, recess of one of the plant's more-remote production areas.* ***This sign, discovered over 30 years ago, contained small hand-written black letters on a simple, white-painted, rectangle of metal. The text was headed simply: 'Crit Recommendation;' and this was followed by a few terse words of advice.*** [Emphasis added] *Had this been saved, it would have made an interesting comparison against modern postings.* (Rothe 2005, pg. 56)

- ***As late as the mid-1960s, some limits were still issued verbally.*** *Though not usually the case, last-minute changes in planned operations sometimes called for the Operations Manager to seek verbal modification of a written limit. This was occasionally given. Verbal criticality approvals were prohibited by later that decade.* [Emphasis added.] (Rothe 2005, pg. 58)

- *…the entire Nuclear Safety Group consisted of only 14 persons….. The division of manpower between experiments and plant safety only evolved during the late-1960s.* (Rothe 2005, pg.55)

In addition to the inherent limitations of personnel monitoring for neutrons prior to the development of more optimal measuring technologies in the early 1970s, it is not at all clear that employees in process areas, particularly those whose jobs required moving in and around different processing areas (i.e., maintenance workers, pipefitters, sheetmetal workers, and electricians) were individually monitored for neutron exposure. The lack of individual monitoring for neutrons is inferred by the authors from a report summarizing data relative to the Former Radiation Worker Medical Surveillance Program at Rocky Flats in 2001:

Significant neutron radiation exposure was possible from alpha/neutron reactions with light elements, especially from plutonium tetrafluoride compound. Neutron exposure was possible from spontaneous fission of 240Pu during handling of large quantities of plutonium as metal, of 244Cm, or of plutonium enriched in 240Pu for special projects conducted at the site. (Daugherty 2001)