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Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

**A Review of NIOSH’s Program Evaluation Report
DCAS-PER-083, “Weldon Spring Plant TBD Revision”**

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SC&A, Inc. technical support for the Advisory Board on Radiation and Worker Health’s review of NIOSH dose reconstruction program

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
Bq	becquerel
Bq/g	becquerel per gram
DCAS	Division of Compensation Analysis and Support
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DR	dose reconstruction
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
EU	enriched uranium
IREP	Interactive RadioEpidemiological Program
Np	neptunium
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Claims Tracking System
ORAUT	Oak Ridge Associated Universities Team
PER	program evaluation report
pCi/mg	picocurie per milligram
pCi/μg	picocurie per microgram
POC	probability of causation
Pu	plutonium
Ra	radium
Rn	radon
RU	recycled uranium
SEC	Special Exposure Cohort
TBD	technical basis document
Tc	technetium
Th	thorium
U	uranium
WSP	Weldon Spring Plant
WSRP	Weldon Spring Raffinate Pits
WSQ	Weldon Spring Quarry

1 Statement of Purpose

To support dose reconstruction (DR), the National Institute for Occupational Safety and Health (NIOSH) and the Oak Ridge Associated Universities Team (ORAUT) assembled a large body of guidance documents, workbooks, computer codes, and tools. In recognition of the fact that all of these supporting elements in DR may be subject to revisions, provisions exist for evaluating the effect of such programmatic revisions on the outcome of previously completed DRs. Such revisions may be prompted by document revisions due to new information, misinterpretation of guidance, changes in policy, and/or programmatic improvements.

A program evaluation report (PER) provides a critical evaluation of the effects that a given issue or programmatic change may have on previously completed DRs. This includes a qualitative and quantitative assessment of potential impacts. Most important in this assessment is the potential impact on the probability of causation (POC) of previously completed DRs with POCs less than 50 percent.

On February 16, 2023, the Advisory Board on Radiation and Worker Health (Board) tasked SC&A to review DCAS-PER-083, “Weldon Spring Plant TBD Revision” (NIOSH, 2019; “PER-083”). In conducting a PER review, SC&A is committed to perform the following five subtasks, each of which is discussed in this report:

- **Subtask 1:** Assess NIOSH’s evaluation and characterization of the issue addressed in the PER and its potential impacts on DR. Our assessment intends to ensure that the issue was fully understood and characterized in the PER.
- **Subtask 2:** Assess NIOSH’s specific methods for corrective action. When the PER involves a technical issue that is supported by documents (e.g., white papers, technical information bulletins, procedures) that have not yet been subjected to a formal SC&A review, subtask 2 will include a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science. Conversely, if such technical documentation has been formalized and previously subjected to a review by SC&A, subtask 2 will simply provide a brief summary and conclusion of this review process.
- **Subtask 3:** Evaluate the PER’s stated approach for identifying the universe of potentially affected DRs and assess the criteria by which a subset of potentially affected DRs was selected for reevaluation. The second step may have important implications where the universe of previously denied DRs is very large and, for reasons of practicality, NIOSH’s reevaluation is confined to a subset of DRs that, based on their scientific judgment, have the potential to be significantly affected by the PER. In behalf of subtask 3, SC&A will also evaluate the timeliness of the completion of the PER.
- **Subtask 4:** Conduct audits of DRs affected by the PER under review. The number of DRs selected for audit for a given PER will vary. (It is assumed that the Board will select the DRs and the total number of DR audits for each PER.)
- **Subtask 5:** Prepare a written report that contains the results of DR audits under subtask 4, along with our review conclusions.

2 Relevant Background Information Pertaining to Facility Operations, Potential Source Terms, and Worker Monitoring Protocols

The following information was obtained from the most current revisions of the Weldon Spring technical basis documents (TBDs) to present the relevant background for this report. Older versions of the TBDs will be referred to as applicable in the appropriate sections for PER-083.

2.1 Facility operations

The facilities covered under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) are the Weldon Spring Plant (WSP), Weldon Spring Quarry (WSQ), and the Weldon Spring Raffinate Pits (WSRP). In this document, the term “WSP site” is used where it is unnecessary to distinguish between the plant, the quarry, and the raffinate pits. The WSP site was operated for the U.S. Atomic Energy Commission (AEC) as a feed materials plant to process uranium and thorium ore by the Uranium Division of Mallinckrodt Chemical Works.

There were four periods for the WSP site:

1. Site acquisition and development, 1954–1957
2. Operational, 1957–1966
3. The U.S. Department of Energy (DOE) did not control WSP during the period 1967–1985 and WSRP and WSQ during the period 1967–1974. The U.S. Department of Defense (DoD) had control of those Weldon Spring facilities during these periods.
4. Remediation, 1985–2002

WSP employment is covered under EEOICPA only during the operational (1957–1966) and remediation (1985–2002) periods when the AEC, U.S. Energy Research and Development Administration, and DOE had contractors and radioactive materials at WSP.

WSQ and WSRP employment is covered during the operational period (1957–1966), the period 1975–1984, and the remediation period (1985–2002).

2.2 Source terms

The radionuclides of concern are those that make up 95 percent of the potential internal dose. According to the TBD for internal dose, ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017c; also “TBD-5, revision 04”), the radionuclides of concern at the WSP site for DR are the naturally occurring isotopes of uranium (U-234, U-235, and U-238), their decay products (primarily thorium (Th)-230 and radium (Ra)-226), isotopes of natural thorium (Th-228 and Th-232) and their decay products, and recycled uranium (RU).

2.2.1 Uranium

ORAUT-TKBS-0028-5 (ORAUT, 2017c) recommends that for the purposes of DR, the assumption be made that all uranium processed at the WSP site was natural uranium from 1957 through 1962, with a specific activity of 683 picocuries per milligram (pCi/mg). After 1962, all uranium is assumed to be enriched to 1 percent, with a specific activity of 973 pCi/mg.

2.2.2 Radon

The three radon isotopes that are generated during the decay of U-235, U-238, and Th-232 are Radon (Rn)-219, Rn-222, and Rn-220, respectively. Due to the limited amount of enriched uranium (EU), which contains U-235, processed at the WSP site, there was no large source of Ra-223 and, in turn, Rn-219. The risks associated with Rn-219 were insignificant due to its extremely short half-life (4 seconds) and small source term. Therefore, TBD-5, revision 04 (ORAUT, 2017c), considers only the inhalation intakes for Rn-222 and Rn-220 to be potentially significant.

2.2.3 Natural thorium

The conservative (favorable to claimant) assumption for natural thorium (Th-232) is that the decay products have built up to equilibrium. Thorium in the workplace at the WSP site was monitored by air concentration (section 5.2.3 of TBD-5, revision 04 (ORAUT, 2017c)). Thoron from Th-232 was present and a portion was released during the processing and storage of thorium at WSP and the associated waste storage locations. The thoron, with its subsequent progeny, would act as a potential source of internal exposure in the thorium process buildings and at waste storage locations. Although not measured directly, thoron exposures were determined and controlled by measuring thorium concentrations.

2.2.4 Recycled uranium

It should be assumed that all of the uranium that the WSP site processed beginning in 1961 was RU. For the periods that include RU (i.e., after 1960), RU contaminant mass concentrations are provided in section 5.6.1.3.3 of TBD-5, revision 04 (ORAUT, 2017c).

2.3 Internal monitoring

The following summarizes the internal intake monitoring at the WSP site. SC&A obtained this information from ORAUT-TKBS-0028-4, revision 04 (ORAUT, 2020; also “TBD-4, revision 04”), and ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017c).

2.3.1 Operational period, 1957–1966

Urine bioassay was the primary method of determining uranium intakes during the production phase. There has been no indication so far that a routine urine sampling program was implemented for thorium. No urine bioassay data for thorium have been found in the worker files. Air monitoring results were used to derive potential WSP workers intakes (TBD-5, revision 04, section 5.5), and environmental intakes (TBD-4, revision 04, section 4.2.3) of various radionuclides, including thorium and radon, for which energy employees were not directly monitored.

2.3.2 DoD period, 1967–1985

There did not appear to be DOE contractor personnel present at the WSP during the DoD period, and no bioassay monitoring records have been located for this period.

The WSQ and WSRP were under DoD control during the period 1967–1974 and under DOE control during the period 1975–1985. However, there did not appear to be DOE contractor

personnel present at the WSQ or the WSRP during the DOE control period 1975–1985 period, and no bioassay monitoring records have been located for this period.

2.3.3 Remediation period, 1985–2002

An extensive bioassay monitoring program was conducted from 1991 to 2001 to detect intakes greater than 100 millirem committed effective dose equivalent.

2.4 External and ambient monitoring

The following summarizes external monitoring methods at the WSP site. SC&A obtained this information from TBD-4, revision 04 (ORAUT, 2020), and ORAUT-TKBS-0028-6, revision 01 (ORAUT, 2013c).

2.4.1 Operational period, 1957–1966

Employees who worked in radiological areas were monitored, and their exposures should be accounted for in their dosimetry results. Documents obtained to date do not contain monitoring data that describe the ambient exposure rate at the WSP site during the operational period.

2.4.2 DoD period, 1967–1985

There did not appear to be DOE contractor personnel present during the DoD period, and no external monitoring records have been located for this period. There are no records of site surveys being conducted until 1982, except for a 1975 aerial radiological survey.

2.4.3 Remediation period, 1985–2002

Personnel external monitoring was provided as needed during the remediation period. Site external ambient exposure monitoring began in 1982.

3 Subtask 1: Identify the Circumstances that Necessitated DCAS-PER-083

3.1 Chronology of events that necessitated PER-083

3.1.1 RU beginning in 1961

The revisions in TBD-4, revision 03 (ORAUT, 2017a), and TBD-5, revision 04 (ORAUT, 2017c), consisted of recommending that the dose reconstructor use RU intakes beginning in 1961. This corrected some language in the previous TBDs where it was stated that RU intakes be assessed after 1961.

3.1.2 RU contaminant radionuclides

The revisions in TBD-4, revision 02 (ORAUT, 2017b), consisted of recommending that the dose reconstructor use RU contaminate intakes as provided in table 4-1 (page 19), which was an expanded list of radionuclides compared to the previous guidance.

The revisions in TBD-5, revision 03 (ORAUT, 2017d), recommended that the dose reconstructor use RU contaminate intakes as provided in table 5-23 and table 5-24 (page 46), which consisted of an expanded list of radionuclides compared to the previous guidance.

3.1.3 Uranium specific activity

The revisions in TBD-4, revision 02 (ORAUT, 2017b), consisted of recommending that the dose reconstructor use an enriched uranium specific activity of 973 pCi/mg after 1962 (page 19).

The revisions in TBD-5, revision 03 (ORAUT, 2017d), consisted of recommending that the dose reconstructor use an enriched uranium specific activity of 0.973 picocurie per microgram (pCi/μg) after 1962 (pages 15 and 47) instead of 0.783 pCi/μg as previously recommended (ORAUT, 2013b, p. 13).

3.1.4 DCAS-PER-083

On January 7, 2019, NIOSH issued DCAS-PER-083 (NIOSH, 2019) for the WSP site, which addressed changes in DR procedures using the latest revisions (as of 2019) of the Weldon Spring TBDs: ORAUT-TKBS-0028-4, revision 03 (ORAUT, 2017a), and ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017c).

3.2 SC&A's comments

SC&A reviewed the sequence of revisions of the Weldon Spring TBDs and PER-083. SC&A found that PER-083 addressed the pertinent changes in TBD-4 and TBD-5 that could potentially result in increases in internal or external doses.

SC&A reviewed the changes in TBD-4, revision 03 (ORAUT, 2017a), and revision 02 (ORAUT, 2017b) compared to revision 01 (ORAUT, 2013a). SC&A also reviewed the changes in TBD-5, revision 04 (ORAUT, 2017c), and revision 03 (ORAUT, 2017d) compared to revision 02 (ORAUT, 2013b).

The following is a summary of the changes that have the potential to increase assigned dose.

3.2.1 ***ORAUT-TKBS-0028-4: Occupational environmental dose***

Revision 03 of ORAUT-TKBS-0028-4 (ORAUT, 2017a) included the following changes that may increase assigned occupational environmental dose:

- **RU beginning in 1961:** Section 4.2.2.1 of revision 03 stated that the DR should assume, as favorable to claimants, that all of the uranium WSP processed **beginning** in 1961 was RU (ORAUT, 2017a, p. 11). Revision 02 of TKBS-0028-4, section 4.2.2.1, had stated that the DR should assume as favorable to claimants that all of the uranium WSP processed **after** 1961 was RU (ORAUT, 2017b, p. 11).
- **RU contaminants:** Section 4.2.4 of revision 03 contained table 4-1, “RU contaminant intakes per unit activity of uranium, Bq/Bq U” (ORAUT, 2017a, p. 19), which provided an expanded list of RU contaminants compared to section 4.2.2.1 of revision 01 (ORAUT, 2013a, p. 11), which only included plutonium (Pu)-239, neptunium (Np)-237, and technetium (Tc)-99.
- **Specific activity of enriched uranium:** Section 4.2.4 of revision 03 stated that after 1962, all uranium was assumed to be enriched to 1 percent, with a specific activity of 973 pCi/mg (ORAUT, 2017a, p. 19), whereas revision 01 (ORAUT, 2013a) did not contain a section on radionuclide intake derivation.

SC&A did not identify any findings or observations in this review of revision 03 of TBD-4 (ORAUT, 2017a).

3.2.2 ***ORAUT-TKBS-0028-5: Occupational internal dose***

Revision 04 of ORAUT-TKBS-0028-5 (ORAUT, 2017c) includes the following changes that may increase assigned occupational internal dose:

- **RU beginning in 1961:** NIOSH states in section 5.2.4 of revision 04 that the DR should assume that all of the uranium processed at WSP **beginning** in 1961 was RU and that this is favorable to claimants (ORAUT, 2017c, p. 18). NIOSH stated in revision 03, section 5.2.4, that the DR should assume that all of the uranium processed at WSP **after** 1961 was RU and that this is favorable to claimants (ORAUT, 2017d, p. 18).
- **RU contaminants:** Section 5.6.1.3.3 of revision 04 contains table 5-23, “RU contaminant intakes per unit activity of uranium, Bq/g U,” and table 5-24, “RU contaminant intakes per unit activity of uranium, Bq/Bq U” (ORAUT, 2017c, pp. 45–46), which provide an expanded list of RU contaminants compared to section 5.2.4 of revision 02 (ORAUT, 2013b, p. 16) that only included Pu-239, Np-237, and Tc-99.
- **Specific activity of enriched uranium:** Section 5.2.1 of revision 04 states that it is reasonable to assume that the EU at Weldon Spring was 1 percent enriched with a specific activity of 0.973 pCi/μg after 1962 (ORAUT, 2017c, pp. 15 and 47), whereas revision 02, section 5.2.1 (ORAUT, 2013b, p. 13), stated that it is reasonable to assume that the slightly enriched uranium processed at Weldon Spring was 1 percent enriched with a specific activity of 0.783 pCi/μg.

SC&A did not identify any findings or observations in their review of revision 04 of TBD-5 (ORAUT, 2017c).

4 Subtask 2: Assess NIOSH's Specific Methods for Corrective Action

NIOSH released revision 00 of TBD-4 in June 2005 (ORAUT, 2005a), revision 01 in May 2013 (ORAUT, 2013a), revision 02 in March 2017 (ORAUT, 2017b), and revision 03 in September 2017 (ORAUT, 2017a). NIOSH released revision 00 of TBD-5 in June 2005 (ORAUT, 2005b), revision 01 in March 2013 (ORAUT, 2013d), revision 02 in May 2013 (ORAUT, 2013b), revision 03 in March 2017 (ORAUT, 2017d), and revision 04 in August 2017 (ORAUT, 2017c).

SC&A had previously reviewed revision 00 of TBD-4 and TBD-5 in 2009 (SC&A, 2009). Additionally, SC&A reviewed revision 01 of TBD-4 and revisions 01 and 02 of TBD-5 in subtask 2 of our review of DCAS-PER-051 (SC&A, 2023). However, revision 02 and revision 03 of TBD-4 and revisions 03 and 04 of TBD-5 had not been reviewed by SC&A. Therefore, subtask 2 of PER-083 included a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science as described in the following section.

The 2017 revisions to TBD-4 and TBD-5 included several changes that could cause an increase in calculated doses, as described in section 3 of this report. NIOSH's corrective actions in PER-083 are described in section 3.0 of PER-083 and section 5 of this report.

4.1 Overview of SC&A's review of Weldon Spring site profile

For PER-083, SC&A reviewed TBD-4, revisions 02 and 03 (ORAUT, 2017b, 2017a), to determine if it contained technically correct methodology and information and referred to appropriate references as needed. SC&A analyzed changes that could decrease or increase assigned dose; we had no findings or observations concerning TBD-4. Additionally, SC&A reviewed TBD-5, revisions 03 and 04 (ORAUT, 2017d, 2017c), to determine if it contained technically correct methodology and information and referred to appropriate references as needed. SC&A analyzed changes that could decrease or increase assigned dose; we had no findings or observations concerning TBD-5. SC&A summarized the changes that have the potential to increase assigned dose in sections 3.2.1 and 3.2.2 of this report for TBD-4 and TBD-5, respectively, and had no findings or observations concerning the TBDs or PER-083.

4.2 SC&A's comments

SC&A confirmed that the revisions incorporated into Weldon Spring TBD-4, revisions 02 and 03, and TBD-5, revisions 03 and 04, were scientifically sound. Since NIOSH reevaluated all applicable Weldon Spring claims and reworked the appropriate claims using the revised TBDs, SC&A finds NIOSH's corrective actions to be appropriate.

SC&A has no findings associated with subtask 2.

5 Subtask 3: Evaluate the PER's Stated Approach for Identifying the Number of DRs Requiring Reevaluation of Dose

5.1 NIOSH's selection criteria

- **RU beginning in 1961:** According to section 3.0 of PER-083, NIOSH reviewed all Weldon Spring Plant claims completed between March 2017 and September 2017 and found that only one had employment in 1961. NIOSH reviewed the claim and found that recycled uranium intakes were assigned in 1961. Therefore, no further consideration for this issue was necessary.
- **RU contaminants and specific activity of enriched uranium:** According to section 3.0 of PER-083, NIOSH reevaluated all Weldon Spring claims and reworked the applicable claims using the latest version of the TBDs as of 2019: ORAUT-TKBS-0028-4, revision 03 (ORAUT, 2017a), and ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017c).

NIOSH searched for and evaluated all claims with employment at any one of the three Weldon Spring facilities in the NIOSH claims tracking system (NOCTS). Additionally, a keyword search was conducted on DR reports for the word "Weldon." These searches resulted in 330 unique claims being identified. The following is a summary of the results of NIOSH's search.

- Three claims were identified as being completed with the current TBD.
- 126 claims were identified as having a POC greater than 50 percent.
- 51 claims had been pulled from DR (primarily due to inclusion in the Mallinckrodt Special Exposure Cohort (SEC)).
- Seven claims were active at NIOSH at the time of the search and would be completed using the current TBDs.
- Two claims were determined not to have employment at Weldon Spring. They had been identified because the DR report mentioned Weldon Spring but actually had no employment there, and the Weldon Spring TBD was not used to estimate the dose.
- One claim met the criteria for the Mallinckrodt SEC and the DR was done prior to the designation of that SEC class. Therefore, it was removed from evaluation under PER-083.

The remaining 140 claims were to be reevaluated under this PER as follows:

- Two of the claims were returned to NIOSH for a new DR (for other reasons) before the evaluation occurred. A new DR for these two claims would be completed using the current revisions of the TBD. Therefore, the two claims were removed from further consideration under PER-083.
- 138 claims were evaluated using the current revisions of the TBD and all other applicable procedures, with results as follows:
 - 129 claims had POC values that remained below 45 percent.

- Four claims resulted in a POC between 45 percent and 52 percent. For those claims, the Interactive RadioEpidemiological Program (IREP) was run 30 times at 10,000 iterations per NIOSH procedures. The resulting POC was less than 50 percent for all four claims.
- Five claims resulted in a POC greater than 50 percent.

NIOSH will provide the U.S. Department of Labor (DOL) with the list of all the claims evaluated under this PER. Further, NIOSH will request that DOL return the five claims that would now result in a POC greater than 50 percent.

5.2 SC&A's comments

The selection criteria used by NIOSH for previously completed DRs that required reevaluation under PER-083 are valid. SC&A had no findings or observations associated with subtask 3.

6 Subtask 4: Conduct Audits of a Sample Set of Reevaluated DRs Mandated by DCAS-PER-083

Previous sections of this report describe changes introduced in revisions of WSP TBDs that could increase the dose assigned for the periods covered for the WSP site.

For SC&A to satisfy its commitment under subtask 4, SC&A suggests that two or three DR claims be selected for a focused review from the WSP site during the covered period. SC&A suggest that the claims selected should attempt to include the following criteria to address some of the major changes in the TBDs:

1. Environmental intakes consisting of exposure to EU (1963–1966) and RU (1961–2001) contaminants
2. Internal intakes consisting of exposure to EU (1963–1966) and RU contaminants (1961–2002)

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