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**ISSUES MATRIX FOR THE WELDON SPRING SITE SPECIAL
EXPOSURE COHORT PETITION AND NIOSH EVALUATION REPORT,
AND SC&A'S REVIEW OF THE WELDON SPRING SITE PROFILE**

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Disclaimer

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This matrix contains a list of the issues SC&A has identified in the Weldon Spring Site (WSS) SEC Petition with a proposed class from January 1, 1957, through December 31, 1966, and NIOSH's Evaluation Report (ER) of April 16, 2010, for the period of January 1, 1957, through December 31, 1967. This matrix also includes SC&A's findings from their review of the Weldon Spring site profile Technical Basis Documents (TBDs), as well as NIOSH's responses to those findings.

This combined issues matrix is based on assessments of the following:

- The WSS Petition SEC-00143, September 2009 (NIOSH 2009)
- The NIOSH Evaluation Report dated April 16, 2010 (NIOSH 2010a)
- SC&A's review matrix of the WSS SEC petition and NIOSH's ER (SC&A 2010)
- WS site profile TBDs (ORAUT-TKBS-0028-1 through ORAUT-TKBS-0028-6)
- SC&A's Site Profile Review (SC&A 2009)
- Former worker interviews (SC&A 2009)
- SC&A's review of WSS-related documents
- The NIOSH Response to SC&A Comments on Weldon Spring Profile (NIOSH 2010b)
- NIOSH's responses contained in the April 21, 2011, e-mail, with six attachments (NIOSH 2011a)
- NIOSH's responses to the recycled uranium (RU) issue (NIOSH 2011b)
- NIOSH's responses to the blunders in AWE data (NIOSH 2011c)
- SC&A's updated matrix (SC&A 2011a), reply to RU issue (SC&A 2011b), and reply to NIOSH's 4/21/2011 report (SC&A 2011c)
- SC&A's WSS initial data completeness test (SC&A 2011d)
- SC&A's reply to WSS neutron issue (SC&A 2011e)
- SC&A's reply to NIOSH's evaluation of AWE blunders (SC&A 2011f)
- The results of four WSS work group (WG) meetings held October 19, 2011; January 25, 2011; May 9, 2011, and September 13, 2011.

NIOSH has proposed that the classes of workers to be evaluated cover the period of January 1, 1957, to December 31, 1967, and finds that monitoring data are available to estimate exposures with sufficient accuracy for all workers employed during that period.

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SC&A SEC Issue No.	SCA TBD Finding No. Primary Findings 21 and 27	NIOSH TBD Reply No. 7 and 10	Issue ORAUT-TKBS-0028-5 and ORAUT-TKBS-0028-6: Accuracy of Records not Sufficiently Verified
1a	NIOSH ER Position (SC&A reading)		
	a) Internal – NIOSH presents the availability of bioassay records on page 35 of the ER and a comparison of WSS hardcopy uranium urinalysis data to the Center for Epidemiologic Research (CER) database on page 49 of the ER, and concludes that the bioassay is accurate for 1957–1967.		
	SC&A Initial Review		
	a) Internal – SC&A did not find that NIOSH’s comparison was sufficient to establish the accuracy of the internal dose of record. Comparison of hardcopies to the CER database does not provide sufficient evidence that the records used by the dose reconstructor are adequate and have accurately survived the transfer of data over the years. Hardcopies compared to the files that would be provided to the dose reconstructor are necessary for validation. The sequence of databases and the verification of accurate transfer of data between these databases are necessary to demonstrate that the data received by the dose reconstructor are traceable to the original data.		
1a	NIOSH Reply to SC&A Finding		
	a) Internal – NIOSH verified that only photocopies of the original datasheets are being used for dose reconstruction (DR) purposes; the CER database is not being used for DR. Therefore, accuracy is not an issue.		
	SC&A Response		
a) Internal – SC&A finds the photocopies of the datasheets from the WSS legible and useful for DR purposes; therefore, accuracy does not appear to be an issue at this time. However, SC&A recommended to the WG that an initial data completeness test be performed to determine if there are any indications that the dose records are not complete. A plan to perform this initial test was submitted to the WG on May 13, 2011, by SC&A. SC&A completed the initial data completeness test and provided the WG a report (SC&A 2011d) titled, <i>SC&A’S Initial Test of External and Bioassay Data Completeness for the Weldon Spring Site</i> , on August 15, 2011. This report was presented by SC&A to the WSS WG for consideration at the September 13, 2011, WG meeting.			
1b	NIOSH ER Position (SC&A reading)		
	b) Air data – The ER provides breathing zone (BZ) and area air sampling data sources on page 40 for uranium (1958–1966) and pages 41–45 for thorium (1963–1966), and recommends using Battelle-TIB-5000 and Battelle-TBD-6001, but no specific intake values are provided in the ER.		
	SC&A Initial Review		
	b) Air data – SC&A reviewed the data sources and found that they do contain periodic air sampling data for uranium and thorium as stated in the ER. However, the ER does not provide any further evaluation of adequacy or accuracy of this data, nor justification for using Daily Weighted Average (DWA) values, or application details for dose reconstruction purposes.		
NIOSH Response			
b) Air data – NIOSH provided a revised version of their use of the DWE method in November 2010.			
SC&A Review			
b) Air data – SC&A evaluated the DWE issue in conjunction with the Fernald site and generally accepts the use of DWA for DR purposes, but would like NIOSH to evaluate the effects of errors in the datasheets (“blunders”) on the outcome of dose assignments.			

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	<p>NIOSH Reply to SC&A Finding</p> <p>b) Air data – NIOSH will provide an analysis of the effects of errors in the datasheets (“blunders”) on the outcome of dose assignments as per 5/9/2011 WG meeting. NIOSH provided this report (NIOSH 2011c), titled “Evaluation of Blunders Associated with DWA,” on September 7, 2011.</p>
	<p>SC&A Review</p> <p>b) Air data – SC&A evaluated NIOSH’s report and issued a reply (SC&A 2011f) on September 27, 2011, titled <i>SC&A’s Evaluation of NIOSH’s Response of September 7, 2011, to Daily Weighted Exposure Blunders in Weldon Spring Data</i>. In this reply, SC&A recommended that NIOSH address the representativeness of the limited DWE data and a method of incorporating the results during dose reconstruction.</p>
1c	<p>NIOSH ER Position (SC&A reading)</p> <p>c) External – NIOSH briefly addresses the availability of external dosimetry results on pages 46 and 52 of the ER, and concludes that the available external dosimetry monitoring data are available in sufficient quantity and quality to adequately represent external beta and photon dose for the Weldon Spring Plant class under evaluation for the period from January 1, 1957, through December 31, 1967.</p>
	<p>SC&A Initial Review</p> <p>c) External – While the number of badges and the average gamma/beta doses are listed, there is no verification of external dose of records provided. Additionally, there are no data present for 1967, as will be detailed in a following SEC issue.</p>
	<p>NIOSH Reply to SC&A Finding</p> <p>c) External –See SEC Issue #1a above.</p>
	<p>SC&A Response</p> <p>c) External –See SEC Issue #1a above.</p>
1d	<p>NIOSH ER Position (SC&A reading)</p> <p>d) Coworker – NIOSH does not discuss coworker models for the WSS in the ER or the technical basis documents (TBDs); however, it is stated on pages 63 and 67 of the ER that exposures for unmonitored workers can be bound by using the monitored workers’ data for both external and internal exposures. The issue of the representativeness of cohort bioassays for groups is not addressed, or how these data would be used in a coworker model.</p>
	<p>SC&A Initial Review</p> <p>d) Coworker – There appears to a large amount of both bioassay and external dose data; however, until the accuracy of the data can be determined, it is not applicable for the creation of an external dose or internal intake coworker database for unmonitored workers. Additionally, the proposed structure of the database and its applicability need to be addressed, including how the cohort bioassays would be used.</p>
	<p>NIOSH Reply to SC&A TBD Finding</p> <p>d) Coworker - The SEC Evaluation Report for Petition SEC-00143 identified approximately 8,000 external monitoring records in the ORAU CER database representing approximately 1,850 employees during the period 1957 through 1967. A coworker model for external dose at the Weldon Spring Plant is not deemed to be necessary.</p>

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<p>SC&A Response</p> <p>d) Coworker - SC&A finds that the validity of using the recorded data for a coworker model will be determined from the results of the data completeness as outlined in SEC Issue #1a & 1c above. However, SC&A found that NIOSH has proposed several coworker models, or advocated that one is not needed; SC&A would like for NIOSH to state a definite recommendation on a coworker model for both internal and external doses.</p>			
<p>NIOSH</p> <p>d) Coworker – As the results of the September 13, 2011, WG meeting, NIOSH is to (1) provide the method that will be used to assign doses to unmonitored workers that should have been monitored and bridge gaps in dose records for monitored workers, and (2) evaluate petitioner’s concern of unmonitored workers access to operating plant area.</p>			
<p>SC&A SEC Issue No. 2</p>	<p>SCA TBD Finding No. Primary Finding 1</p>	<p>NIOSH TBD Reply No. Yet to be determined</p>	<p>Issue ORAUT-TKBS-0028-4, ORAUT-TKBS-0028-5, and ORAUT-TKBS-0028-6: Lack of Personnel Contamination and Egress Monitoring</p>
<p>NIOSH ER Position (SC&A reading)</p> <p>NIOSH states in the ER, on page 67, that the petitioner’s concern of a lack of routine personnel contamination monitoring was one among several broad statements that were the basis for qualifying the petition. These concerns resulted in the evaluation of the petition for the Weldon Spring Plant and the responses to these concerns are encompassed in the ER.</p>			
<p>SC&A Initial Review</p> <p>Workers were apparently allowed to leave the controlled areas and the WSS without confirmation that they were not contaminated. This could have spread contamination to non-controlled areas at the site, creating chronic exposure (internal and external) to unmonitored workers, as well as leaving contamination on the workers that could lead to chronic beta exposure to the skin (especially in the folds of the skin) and internal exposure through ingestion and resuspension/inhalation. Personnel badges worn during working hours would not have picked up beta exposures from contamination on the skin that could have irradiated local skin areas for extended periods, especially in the folds of the skin around the ears, nose, neck, and arms. Additionally, because workers only periodically submitted urine samples, as described in ORAUT-TKBS-0028-5, some of these individual internal intakes through this pathway could have been missed. Even with good dosimetry and records, there would be no records of these missed exposures for dose reconstruction purposes. Contrary to the ER statement, the ER (nor ORAUT-TKBS-0028-6) specifically addressed the personnel contamination issue.</p>			
<p>NIOSH Reply to SC&A Finding</p> <p>NIOSH’s investigation of this issue found that the contamination situations at the WSS were not unique compared to those at other similar AEC facilities during that time period. Contamination issues can be addressed on a case-by-case basis, and there are various programs available to assist in skin dose assignments.</p>			
<p>SC&A Response</p> <p>This issue was brought before the WSS WG at the May 9, 2011, meeting and the WG recommended that this issue be closed.</p>			

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SC&A SEC Issue No.	SCA TBD Finding No.	NIOSH TBD Reply No.	Issue
3	Primary Finding 2 and Secondary Finding 13	Yet to be determined	ORAUT-TKBS-0028-4, ORAUT-TKBS-0028-5, and ORAUT-TKBS-0028-6: Lack of Information for Workers During 1967
NIOSH ER Position (SC&A reading)			
NIOSH included the year 1967 in the ER for the WSS SEC-00143.			
SC&A Initial Review			
The inclusion of the year 1967 in NIOSH’s ER extends the evaluation of the original SEC-00143 petition for the WSS to an era unlike the production era of the original SEC petition, because the production facility was completely shut down during 1967. Examples have been given where workers were handling uranium by hand while digging up the floors to convert the building for a different use. There was no apparent local MCW and/or DOE administration oversight, health and safety organization, documentation, etc., to direct work practices, control exposures, and to keep records. Therefore, exposure records, bioassays, and environmental data do not appear to be sufficiently available for dose reconstruction purposes for the year 1967. SC&A found no monitoring data during the review of several claims that covered the 1967 period, and the ER does not include 1967 in any of the data provided. Neither production workers’ data nor environmental data from the production era (1957–1966) can be applied to the 1967 time period, because the working conditions, exposure pathways, and potential intakes/external doses were completely different.			
NIOSH Reply to SC&A Finding			
NIOSH’s investigation of this issue found that 1967 appears to have been a transition year that consisted transferring the shut-down plant to the Dept. of the Army. The renovation activities appear to have begun in 1968; therefore, operational period dose data would be bounding for the year 1967, for which year no dose records have been found.			
SC&A Response			
This issue was brought before the WSS WG at the May 9, 2011, meeting and the WG recommended that this issue be closed pending any further information being brought forward.			

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SC&A SEC Issue No. 4	SCA TBD Finding No. Primary Finding 19	NIOSH TBD Reply No. 5	Issue ORAUT-TKBS-0028-5: Inadequate Radon and Thoron Determination for Monitored and Unmonitored Workers
<p>NIOSH ER Position (SC&A reading)</p> <p>a) NIOSH investigated the ability to assess radon (a decay product of uranium) concentrations during the operational period. As described in Section 5.1.1, page 17, of the ER, the materials processed at Weldon Spring did not include radium-bearing “raw” ores, and thus did not produce significant amounts of radon relative to unprocessed uranium ore. Section 5.2.1.5, page 27, of the ER provides details concerning radon-generating materials and their disposition at the site. NIOSH claims to be able to conservatively estimate the maximum radon released given the uranium source term, as described in Section 7.2.3, page 64, of the ER.</p> <p>b) NIOSH addressed thoron (a decay product of thorium with a 55-sec half-life) on pages 28 and 57 of the ER and concludes that, given the specific activity of thoron in thorium feed materials and assuming the feed materials were received with at least a 1-year delay since processing, it is possible to calculate the amount of thoron in process per day (approximately 0.3 Ci thoron) during the period of the maximum production rate. By assuming a conservative equilibrium factor for a plant configuration with large buildings and engineered ventilation (0.02), it is possible to determine the concentration of thoron and its daughters to achieve 1 Work Level. The release fraction (RF) can be calculated by measuring the particulate thorium in the working environment of the process equipment, compared to the inventory amounts in process. The thoron releases are expected to be less than the particulate materials, since the gaseous state will be more easily captured by the ventilation systems. Maximizing assumptions can be applied on a case-by-case basis to occupancy factors, RFs, and diffusion rates.</p>			
<p>SC&A Initial Review</p> <p>a) The outdoor environmental radon concentration was calculated, not measured. Additionally, the assumption of equal radon concentration in the indoor areas compared to the outdoor areas, as recommended in NIOSH’s ER and ORAUT-TKBS-0028-5, is not supported by actual measurements. These are potential SEC issues for both non-production and production workers, unless NIOSH can propose a more reliable and claimant-favorable approach to assess the radon exposure, especially for indoor operations areas for the WSS.</p> <p>b) There were no specific measurements for thoron decay products made at the WSS. Therefore, NIOSH recommends a modeling method based on certain assumptions. However, this method is not detailed concerning the procedure to be used and how the values of the variables are tied to the WSS during the operational period. Additionally, there are no provisions for the intake of thoron decay products if thorium was stored on site before 1963, from the raffinate pits, or from the disposal of thorium in the quarry, since the recommended method would only apply to processed thorium. NIOSH states on page 67 of the ER that there are DWA concentration air monitoring data from the years 1957 through 1966, and that the data (1957–1966) encompass the span of thorium processing at the site. However, the thorium data on page 41 of the ER only cover the period 1963–1966.</p>			
<p>NIOSH Reply to SC&A Finding</p> <p>This comment refers to Section 5.2.2. Th-234 was present in equilibrium concentrations during the initial processing in Bldg. 101, but it contributes only slightly to internal dose. For all but a few organs, the Th-234 dose, which includes all of the progeny that decay in the body, is <1% of the U-238 dose for an equal activity. NIOSH dose reconstruction methodologies account for dose from progeny by crediting all uranium internal exposures to U-234, since this provides for the highest internal dose for the isotopes most likely to be encountered. NIOSH intends to revise the TBD to include the contributions of Th-230 and Th-232 and their decay products, which are much more important for internal dose. MK-Ferguson 1989, pp. 72–75, will be used to determine the ratios to Th-230, with the conservative assumption that Th-230 will be in equilibrium with U-234. These changes will only be applicable to intakes before initial processing.</p>			

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NIOSH Additional Response			
NIOSH provided additional analyses of the environmental air concentrations and proposed indoor radon model in an attachment to an e-mail of April 21, 2011.			
SC&A Response			
SC&A analyzed NIOSH proposed indoor radon model and found it to be a simple air concentration model, which is generally conservative, and useful for DR purposes. However, SC&A has found in the past that the AB did not accept indoor radon model for other AEC/DOE site.			
SC&A SEC Issue No.	SC&A TBD Finding No.	NIOSH TBD Reply No.	Issue
5	Secondary Finding 4.	Yet to be determined	ORAUT-TKBS-0028-4, ORAUT-TKBS-0028-5, and ORAUT-TKBS-0028-6: Inadequate Recommendations for assigning Recycled Uranium (RU) Dose
NIOSH ER Position (SC&A reading)			
NIOSH's ER states that NIOSH investigated the receipts and processing of recycled uranium (RU) at the Weldon Spring site, and acknowledges that limited quantities of RU were received at Weldon Spring for processing. The fact that the quantities of RU are unknown led DOE to assume, as a worst case, that all uranium received after 1962 was RU. DOE acknowledges that this assumption leads to the worst-case quantities of transuranic elements. These quantities do not represent what was actually processed and, in fact, DOE estimates these quantities to be significantly less (0.0 grams of plutonium-239, 12.3 to 15.3 grams of neptunium-237, and 4.9 to 6.1 grams of technetium-99, as compared to the worst case 2.4 grams, 330 grams, and 7,200 grams of plutonium, neptunium, and technetium, respectively). For the purpose of defining the ability to bound dose for the evaluated class in this report, the maximum quantities have been considered as the source term for this evaluation. Additionally, NIOSH states that for the periods that included RU, Table 5-6 of the ER contains maximum values for the RU contaminants as a fraction of uranium intake based on material that is likely to have been received by Weldon Spring (DOE 2000, p. 1,140).			
SC&A Initial Review			
SC&A found the year that the dose reconstructor is to start assigning all RU doses from the uranium analysis is not consistent within the documents quoted above. If materials potentially containing RU started to be processed in 1961 at the WSS, then the dates should be consistently stated as "prior to 1961" and "1961 and after," not "after 1961" or "after 1962." Additionally, it has not been verified that the WSS did not receive RU before 1961.			
SC&A found that WSS ORAUT-TKBS-0028-5, page 15, recommends that 100 ppb Pu-239, 3,500 ppb Np-237, and 9,000 ppb Tc-99 be added to the intake, based on the uranium intake value. SC&A deciphered the contents of Fernald ORAUT-TKBS-0017-5, Table 5-11, conversion factors as follows:			
$\#pCi\ Pu-239 = (100\ ppb-Pu/U) \times (62.89\ pCi-Pu/gm-U\ per\ 1\ ppb-Pu/U) \times (\#gm-U\ in\ bioassay)$			
This is not made very clear in the WSS ORAUT-TKBS-0028-5, page 15, or the Fernald ORAUT-TKBS-0017-5, page 17, but is applicable if used correctly. The same analysis applies to Np-257 and Tc-99. SC&A's review of WSS claims indicates that this method was correctly applied in one of the full dose reconstruction, best-estimate, cases SC&A analyzed. However, in several of the dose reconstruction cases, where the probability of causation was <50% and a full dose reconstruction should have been performed, and the EE worked during the 1961–1966 time period, no internal intakes from RU were assigned. This is technically a dose reconstruction issue and not an SEC issue, but the oversight during dose reconstruction may have resulted from lack of clarity in ORAUT-TKBS-0028-5.			
Additionally, NIOSH's ER, Table 5-6, page 27, lists values not found elsewhere in the documents quoted above; hence, there does not appear to be consistency between the ER and the TBDs. It is not obvious how the values listed in Table 5-6 of the ER were derived from DOE 2000; why they are lower than the recommended values found in the WSS TBD, and how they are to be applied in the dose reconstruction process. The reference provided in the ER was DOE 2000, page 1,140; however, there is no indication in the ER how the data in Table 1 on page 1,140 and following pages generated the values listed in Table 5-6 of the ER.			

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<p>Even if the concentration values of 100 ppb Pu-239, 3,500 ppb Np-237, and 9,000 ppb Tc-99 are used, it has not been documented that these values are necessarily correct or bounding. SC&A reviewed the source of these concentration values, which is a document entitled, <i>DOE Ohio Field Office Recycled Uranium Project Report</i> (DOE 2000), as referenced in the ER. However, this document does not provide defined sources for its recommended values of the radionuclide concentrations; therefore, these concentration values appear to be estimates or assumptions, rather than measured values. Because both the WSS TBD and the ER base the RU composition and throughput at the WSS on Fernald RU data, then the Fernald issues are relevant to the WSS issues, and as SC&A has pointed out in their review of the Fernald SEC (SC&A 2007), there are contradictions within the Fernald TBDs, the DOE 2000 document, and the DOE 2003 document; and hence, “it is likely that the DOE 2000, which is the basis for the data on RU, is incorrect even for the basic value relating to uranium receipts at Fernald” (SC&A 2007, page 35).</p>			
<p>NIOSH Reply to SC&A Finding</p> <p>As per the September 13, 2011, WSS WG meeting, NIOSH will evaluate the need for, and the implementation of, a PER for the consistent assignment of 100 ppb Pu/U in WSS DR cases.</p>			
<p>SC&A SEC Issue No. 6</p>	<p>SCA TBD Finding No. Secondary Finding 28</p>	<p>NIOSH TBD Reply No. Yet to be determined</p>	<p>Issue ORAUT-TKBS-0028-6: Neutron Dosimetry Records not Available</p>
<p>NIOSH ER Position (SC&A reading)</p> <p>NIOSH states on page 33 of the ER that those employees that processed the slightly enriched uranium were assigned special neutron dosimeter badges to be worn in conjunction with their regular film badge dosimeters. Neutron dose results for these Weldon Spring employees have not been located, plausibly because there was no measured neutron dose. NIOSH concludes on page 61 that in the absence of measured dosimeter doses, the primary method for assigning potential neutron dose is in the determination of missed neutron dose, as described in the NIOSH document, <i>External Dose Reconstruction Implementation Guideline</i> (OCAS-IG-001).</p>			
<p>SC&A Initial Review</p> <p>SC&A did not agree in the WSS site profile review with the recommended method in the WSS ORAUT-TKBS-0028-6 concerning using a one-time measurement at Fernald to assign neutron doses at the WSS. Additionally, SC&A does not find that assigning neutron dose based on missed dose is technically correct, because missed dose can only be assigned if the badge reading is available and the recorded reading was less than ½ the lower limits of detection. This is a situation where exposure could have occurred, but no recorded dose data are available.</p>			
<p>NIOSH Reply to SC&A Finding</p> <p>NIOSH maintains that there is no neutron issue for DR at the WSS, because it used the same methodology as used for Fernald.</p>			
<p>SC&A Response</p> <p>SC&A performed a further review of the use of n/p values at the Fernald site (which are being used at the WSS) and maintain that the method of determining the n/p values is not scientifically sound; i.e., the neutron doses were measure in 1995 on canisters and the gamma dose was measured in 2001 on drum, therefore, the results are not correlated.</p>			
<p>NIOSH Response</p> <p>This issue was discussed at length at the September 13, 2011, WG meeting and it was found that NIOSH recommendations and SC&A’s modeling results were similar. NIOSH will review SC&A’s MCNP spreadsheet and provide SC&A a reply. SC&A received a response from NIOSH on September 19, 2011.</p>			
<p>SC&A Response</p> <p>SC&A finds that SC&A’s modeled n/p values and NIOSH’s recommended values to be approximately the same. SC&A issued an e-mail on September 20, 2011, that this issue may be considered for closure by the WSS WG (SC&A 2011e).</p>			

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SC&A SEC Issue No.	SCA TBD Finding No.	NIOSH TBD Reply No.	Issue
7	Not applicable	Yet to be determined	ORAUT-TKBS-0028-4, ORAUT-TKBS-0028-5, and ORAUT-TKBS-0028-6: Quarry and Raffinate Pits Exposures Inadequately Addressed
NIOSH ER Position (SC&A reading)			
<p>NIOSH states on page 28 of the ER that measurements in the quarry area in the late 1970s and early 1980s (before remediation) averaged 0.65 ± 0.41 pCi/L, indicating that the quarry was not a major source of radon... and that as in the case of the raffinate pits, this value would be limiting for the operational period. NIOSH assumes that measurements made in later years would bound the operational years, because the ingrowth of decay products would be greater as time progressed.</p>			
SC&A Initial Review			
<p>SC&A agrees that the ingrowth of decay products would increase as a function of time. However, the exposure conditions were not necessarily the same during the operational phase as during the later years at the WSS. The quarry and raffinate pits were actively being used during the operational period, with radioactive materials being dumped into them, but were idle during the following years when the measurements of constituents, air samples, and external doses were performed. The difference in physical and chemical compositions and usage negates the extrapolation of the later measurements to the operational era without at least some minimal comparison measurements to validate such extrapolations. While the intakes and external exposures for unmonitored workers may be bound by the data from monitored workers in the plant, workers exposed to the raffinate pits and quarry have no counter part for dose assignment, if they were not monitored for external exposures or bioassayed for the specific radionuclides present in these locations.</p>			
NIOSH Reply to SC&A Finding			
<p>In NIOSH's April 21, 2011, attachment, they presented indications that the conditions, and therefore the exposure potentials, at the quarry and raffinate pits remained approximately the same during the operation and the later period when measurements were made. Therefore, the results of later measurements can be used to bound exposures during the operating period.</p>			
SC&A Response			
<p>This issue was discussed at the May 9, 2011, WG meeting and the WG recommended that this issue be closed.</p>			
SC&A SEC Issue No.	SCA TBD Finding No.	NIOSH TBD Reply No.	Issue
8	Secondary Findings 5 and 17	Yet to be determined	ORAUT-TKBS-0028-4, ORAUT-TKBS-0028-5, and ORAUT-TKBS-0028-6: Insufficient Investigation and Documentation of Off-normal Situations and Accidents/Incidents
NIOSH ER Position (SC&A reading)			
<p>NIOSH states on page 33 of the ER that the Health and Safety Division maintained annual logbooks of forms and memos for employees with high urinary uranium concentrations. Investigation reports were also included in the logs (for Action Level 2 exposures and above). Descriptions of the data forms in Table 5-10 are included to demonstrate Weldon Spring's management of and response to high bioassay results.</p> <p>And on page 66 of the ER, NIOSH states that it has conducted a thorough investigation into documentation that gives no indication of significant accidents or incidents at the facility. While several events were identified through document searches and interviews with former workers, there were no indications of events that could have resulted in exceptionally high personnel exposures or exposures that are not already accounted for within the data in the available records.</p>			

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SC&A Initial Review

The issue to be addressed is not if **identified** high levels of exposures were investigated—naturally these would have been under the direction of the AEC. Instead, it is the off-normal situations and accidents/incidents that were not sufficiently identified at the time as radiological events.

Off-normal Situations – An area not addressed by either the ER or the TBDs are exposure potentials not normally encountered in routine operations at the plant. For example, WSS workers transported material and spent some time at the MCW St. Louis site, the quarry where Destrehan Street material was dumped, and the airport site; were these workers appropriately monitored? Another example is the workers that transported and handled the material sent to the Bevatron; were they appropriately monitored? How were exposures from episodic plant releases accounted for?

Accidents/Incidents – During onsite interviews with former WSS workers, the subject of accidents/incidents was often brought up with the concern that MCW did not identify and document radiological events sufficiently, either through lack of knowledge of the radiological hazards, or as a manner of policy at that time. SC&A’s preliminary investigation of several cases indicates that the accidents described by former workers were not evident or were not recorded sufficiently in the workers’ DOE files. For example, a serious furnace accident occurred in 1960; however, the only mention of it in the worker’s DOE records was a couple of brief sentences describing the *medical* aspect of the worker’s complaints; no investigation into the radiological aspect of the accident was evident. There was no other documentation of the accident in the worker’s files that SC&A could locate. Another serious accident apparently occurred in 1961; the only reference in the worker’s DOE file was an entry in the “PERSONAL MONITORING SUMMARY RECORD,” which stated “Data included in Feb. Accident File.” There was no other record of it in the worker’s DOE records. Fortunately, this accident was written up in an MCW report and the dose reconstructor evaluated the dose received from the accident during the dose reconstruction process. However, this may not always be the case.

NIOSH Reply to SC&A Finding

NIOSH provided indications that, although not necessarily documented as radiological accidents/incidents, such situations where workers were potentially exposed resulted in monitoring data being available. Most situations where a worker may have been involved in an accident/incident can be evaluated by searching the SRDB by worker name, keywords, etc.

SC&A Response

SC&A did have a question concerning the last statement on page 4 of NIOSH’s response, where it is stated “In fact, the use of workgroup monitoring data is likely to result in a more favorable dose estimate.” NIOSH is to provide clarification/basis of this statement.

NIOSH Reply

At the September 13, 2011, WSS WG meeting, NIOSH provided clarification that this statement applies to unmonitored workers. SC&A agrees with this statement and recommends that the WG consider this issue for closure.

Weldon Spring SEC & Site Profile Issues Matrix

SC&A SEC Issue No. 9	SCA TBD Finding No. Primary Finding 25	NIOSH TBD Reply No. 8	Issue ORAUT-TKBS-0028-6: Geometry and Extremity Issues not Addressed
<p>NIOSH ER Position (SC&A reading)</p> <p>NIOSH states in the ER, on page 67, that the petitioner’s concerns of a lack of a documented badging policy with geometry correction factors was one among several broad statements that were the basis for qualifying the petition. These concerns resulted in the evaluation of the petition for the Weldon Spring Plant and the responses to these concerns are encompassed in the ER.</p>			
<p>SC&A Initial Review</p> <p>The problems associated with handling uranium material [contact work as stated on page 20 of ORAUT-TKBS-0028-6] close to the body/hands and having the dosimeter badge located on the chest area were not addressed in the ER or ORAUT-TKBS-0028-6 or other WSS documents. A film badge does not register the same dose as the worker’s tissue/organs are receiving from the beta and low-energy photons when handling, machining, scooping, etc., uranium-containing materials. For example, a 1958 office memo illustrates the fact that the shielding on a lathe greatly affects the beta dose measured (i.e., decreases it from an average of 122 mrep/hr to 0), and Table I of that document lists non-trivial beta doses as high as 10,000 to 35,000 mrep/hr (mrep ~ mrem). Therefore, any material/distance between the beta source and the badge on the worker’s chest that is not between the beta source and the worker’s trunk area will cause an under-response in the recorded dose.</p> <p>Compounding the geometry issue is the fact that there does not appear to have been any extremity monitoring at the WSS; which, as indicated above, was needed. Contrary to the ER statement, neither the ER nor ORAUT-TKBS-0028-6 addressed the geometry or extremity issues. This area needs to be addressed.</p>			
<p>NIOSH Reply to SC&A Finding</p> <p>No extremity monitoring is known to have been done, nor is it necessary to establish a probability of causation for the current population of Weldon Spring Plant claims requiring a dose reconstruction. NIOSH does not concur that a geometry correction factor is necessary for adequate dose reconstruction at this time.</p>			
<p>SC&A Response</p> <p>SC&A questions the assumption that a geometry factor is not necessary for DR for WSS workers. From the May 9, 2011, WG meeting discussion, NIOSH is to show how geometry correction factors and extremity monitoring from other DOE sites and OCAS-TIB-0013 can be applied to Weldon Spring recorded dose data to correct for lack of geometry and extremity monitoring at Weldon Spring.</p>			
<p>NIOSH Reply</p> <p>As per the September 13, 2011, WSS WG meeting, NIOSH will provide geometry correction factors in a revised TBD from established technical documents, and implement a PER for consistent assignment of geometry factors in WSS DR cases.</p>			

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SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Primary Finding 10	NIOSH TBD Reply No. 1	Issue ORAUT-TKBS-0028-4: Lack of Atmospheric Monitoring Data for Operational Period
NIOSH ER Position (SC&A reading) Not applicable			
SC&A Initial Review There is no substantial site-wide atmospheric monitoring data available for the operational period to assure an accurate and integrated onsite environmental dose assessment. The TBD recognizes this lack and relied upon the use of dose estimates for the public, derived from its reviews of the Fernald plant data, to estimate the onsite environmental dose for the WSCP workers. This is problematic, in that raw emissions data from Fernald are not easily converted to environmental dose for the WSS workers when several emission points of varying geographic locations have to be considered, as well as the lack of knowledge that could place workers at specific locations during exposure events. SC&A believes that the limited environmental data presented in the TBD and the lack of environmental surveys of onsite locations over time does not support the supposition and/or conclusion of negligible dose to onsite personnel.			
NIOSH Reply to SC&A TBD Finding Measured perimeter air concentration data for the WSCP and WSQ can be found in quarterly and semi-annual environmental monitoring reports (Mallinckrodt Chemical Works, MCW 1961a, p. 36 and pp. 53–54; 1961b, p. 6; 1962, p. 14, p. 44, p. 65, and pp. 85–86; 1964a, p. 9 and p. 12; 1964b, pp. 10–11; 1965, pp. 13–14; 1966a, pp. 10–11; 1966b, p. 9 and p. 11), and in the summary report by Meshkov et al. (1986, p. 101 and pp. 103–104). Full references are at the end of this table. An atmospheric dispersion model can be used to extrapolate the activity concentrations at the fence-line to a location near the operating center of the facility. The resulting uranium air concentration data can be used to determine environmental intake rates. A scaling factor based on the mass of other isotopes that were processed can be applied to obtain intake rates for other particulate isotopes. Based on uranium mass throughput and other factors, Meshkov et al. (1986) estimated an annual release rate of Rn-222 during the operating period in the range of 12 to 34 Ci. This radon was released from the acid recovery building stack. Atmospheric dispersion calculations can be used to estimate the annualized concentration of radon in the operating area.			
SC&A Response See SEC Issue #4			

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SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Primary Finding 11	NIOSH TBD Reply No. 2	Issue ORAUT-TKBS-0028-4: Insufficient Data for Unmonitored Workers' Internal Environmental Dose
NIOSH ER Position (SC&A reading) Not applicable			
SC&A Initial Review The TBD used one series of measurements (decontaminating 5-ton hoppers) and site parameter measurements to determine contributing intakes to non-bioassayed workers during 1957–1967. The hopper dust monitoring experiment consisted of measurements performed on one day under one particular condition, and the parameter measurements contributed very little (<1%) to the final results. These limited (in space, operations, and time) airborne/intake data are not sufficient to construct an adequate intake dose database for unmonitored workers at the WS complex, especially considering that a sizable fraction of the work force was not bioassayed on a routine basis during this period.			
NIOSH Reply to SC&A TBD Finding See SEC Issue #4.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Primary Finding 12	NIOSH TBD Reply No. 3	Issue ORAUT-TKBS-0028-4: Lack of Validation for Maximum Environmental Dose
NIOSH ER Position (SC&A reading) Not applicable			
SC&A Initial Review The TBD fails to validate the adequacy of estimating the maximum environmental dose due to source terms at differing locations at the Weldon Spring Plant. In the current TBD, NIOSH has offered that existing air monitoring data do not distinguish the source of emissions; therefore, to some measure, it only allows evaluation of cumulative emissions and dose. The estimation of dose methodology currently being applied by NIOSH does not reasonably address maximum dose to workers who are not routinely monitored across the site, which could have been 50% of the site workers. SC&A believes that the lack of air monitoring stations in general and the overall lack of stations within a particular geographic location at the WSCP (of known higher releases of uranium and thorium) do not readily enable one to accurately estimate environmental dose using only the very limited existing air monitoring data.			
NIOSH Reply to SC&A TBD Finding See SEC Issue #4.			

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SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Primary Finding 18	NIOSH TBD Reply No. 4	Issue ORAUT-TKBS-0028-5: Incomplete Assessment of Uranium Decay Products
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
<p>The TBD recommendations for dose estimates from decay products of U-238 are incomplete, and not always claimant favorable. The dose from inhaled Th-234 is not included along with the dose from inhaled U-238 in the dose calculations. What is included is the dose from Th-234 that builds up inside the body after an intake of U-238 takes place. Additionally, the dose contribution due to Pa-234m from the decay of Th-234 in the body also needs to be included in the internal dose calculations. While it is true that the Pa-234m outside the body only contributes to the external dose, the Pa-234m originating inside the body from Th-234 decay must be included in the internal dose calculations.</p>			
NIOSH Reply to SC&A TBD Finding			
<p>This comment refers to Section 5.2.2. Th-234 was present in equilibrium concentrations during the initial processing in Bldg. 101, but it contributes only slightly to internal dose. For all but a few organs the Th-234 dose, which includes all of the progeny that decay in the body, is <1% of the U-238 dose for an equal activity.</p> <p>NIOSH dose reconstruction methodologies account for dose from progeny by crediting all uranium internal exposures to U-234, since this provides for the highest internal dose for the isotopes most likely to be encountered.</p> <p>NIOSH intends to revise the TBD to include the contributions of Th-230 and Th-232 and their decay products, which are much more important for internal dose. MK-Ferguson 1989, pp. 72–75, will be used to determine the ratios to Th-230, with the conservative assumption that Th-230 will be in equilibrium with U-234. These changes will only be applicable to intakes before initial processing.</p>			
SC&A Response			
SC&A concurs with this solution.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Primary Finding 20	NIOSH TBD Reply No. 6	Issue ORAUT-TKBS-0028-5: Different Solubility Classes Listed for the Same Element
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
<p>The TBD provides a list of solubility classes for uranium and thorium compounds in some of the buildings at the WSCP; however, the TBD lists different solubility classes for the same element. Because there were no means of separating isotopes of a given element at the WSCP, the chemical properties were the same for all uranium isotopes, as well as for all thorium isotopes. According to ICRP Publication 78 (ICRP 1997), the biokinetic behavior is the same for U-234, U-235, and U-238. The same applies for Th-232 and Th-228.</p>			

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<p>In view of the operations that took place at the WSCP, the TBD should provide justification/clarification concerning the use of different classes of solubility for the same element at the WS site.</p>			
<p>NIOSH Reply to SC&A TBD Finding</p> <p>This comment refers to Section 5.2.5. This section provides all of the available data to dose reconstructors in case it would be of value in a specific case. However, the general approach is to use the most favorable solubility class for the cancer site. Nothing in this section was intended to require the use of a given solubility class.</p>			
<p>SC&A Response</p> <p>NIOSH's explanation is acceptable, and NIOSH will provide clarification in the revised TBD.</p>			
<p>SC&A SEC Issue No. Not applicable</p>	<p>SCA TBD Finding No. Primary Finding 21</p>	<p>NIOSH TBD Reply No. 7</p>	<p>Issue ORAUT-TKBS-0028-5: Missed Dose and Coworker Data Not Adequately Addressed</p>
<p>NIOSH ER Position (SC&A reading)</p> <p>Not applicable</p>			
<p>SC&A Initial Review</p> <p>The TBD does not address potentially missed internal doses, which should be part of a TBD for internal dose. The limits of detection (LODs) were generally high in the earlier years, which could result in significant missed doses. For the dose reconstructor to assign missed dose, the TBD needs to provide some information concerning the minimum detectable activity (MDA) for given bioassay techniques for the important radionuclides of concern at the WSS as a function of time. Additionally, the TBD provides some coworker internal dose information, but does not provide sufficient instructions for its use or the details of the data, such as the percent of workers bioassayed or the representativeness of the data (especially important at the WSS, because not all workers were bioassayed and none continuously). Also, most internal dose TBDs provide a summary section in the main text or as an appendix with recommendations and procedural steps for using coworker data.</p>			
<p>NIOSH Reply to SC&A TBD Finding</p> <p>This comment refers to Section 5.3.1.1 (and subsequent sections). A discussion of the MDA which may be used is included in Section 5.3.1.1.3. The TBD does not contain a formal coworker study. The urine data summarized in Tables 5-8 to 5-17 may be used by dose reconstructors to estimate doses if the employee's records do not contain data for a given period. Since the median, 95th percentile, and maximum concentrations are given, it will always be possible to calculate a best estimate or maximum dose.</p>			
<p>NIOSH Additional Response</p> <p>NIOSH provide additional response to the MDA issue in an attachment to the April 21, 2011, e-mail.</p>			
<p>SC&A Response</p> <p>Discussion of this issue took place at the WSS WG meeting of May 9, 2011. SC&A asked for clarification of the last sentence on page 3 of this response; NIOSH indicated that the statement should be removed, as it was not relevant to this issue. Considering the results of this discuss, the WSS WG recommended that this issue be closed as of May 9, 2011.</p> <p>The coworker issue is addressed in SEC Issue #1d.</p>			

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SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Primary Finding 26	NIOSH TBD Reply No. 9	Issue ORAUT-TKBS-0028-6: Badging Policy Not Consistent
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
<p>The TBD does not provide sufficient and/or consistent information concerning the badging policies at the WSS. This raises the question of what badging criteria were actually used in practice, and if workers not considered at the time to be exposed to radiation were potentially exposed but not monitored because of being in a pre-defined category. The lack of a consistent and documented badging policy may negatively impact dose reconstruction, because the dose reconstructor could assign an unbadged worker only external environmental dose, when the worker should have been assigned coworker external dose. Additionally, badging policies could impact the validity of the coworker dose database.</p>			
NIOSH Reply to SC&A TBD Finding			
<p>A film badge notification memorandum by the Health and Safety Department (MCWa 1958, pg. 27-32/71) indicates that the WSP film badge program began on March 1, 1958. Before that time, dosimetry performed at WSP was more than likely provided by the MCW St. Louis plant. A memo from Brandner to Mason (Brandner 1956a, pg. 3-4/101) states that some St. Louis employees transferred to the Weldon Spring plant “where they are no longer being monitored for radiation exposure with film badges.” This agrees with a footnote from individual film badge data summary sheets in 1966 that states “during start-up at Weldon Spring in 1958 and later, some persons were not badged because [they were] not involved in radiation work” (an example is shown in fig. 6A-7).</p> <p>Each employee, with the exception of “office females” (Brandner 1956a, pg. 5-16/101), wore a combination film badge and security badge. The film monitors were changed biweekly or more often as necessary. Burr (1959a, pg. 41/71) indicates that for turret lathe operators, film badges were exchanged weekly on Monday night. An undated report entitled “Film Badge Report 1958” (WSP pg. 19-32/86) indicates a bi-weekly exchange for dingot forge and chem. Operators, but later states they were changed to monthly. Burr (1959b, pg. 42/71) also states that “monthly exchange of film badges for all plant personnel is scheduled for January 30, 1959.” Another undated report entitled “Personnel External Radiation Monitoring Program” (MCWb undated, pg. 61-64/71) describes the MCW program. It states that “wage personnel film badges are exchanged monthly and salaried personnel film badges quarterly.” A 1965 Summary of Health Protection Practices states that “operations badges are exchanged and processed on a calendar month schedule, all others on a three-month schedule.” If the exchange frequency cannot be explicitly identified, the dose reconstructor should make the claimant-favorable assumption to use the most frequent exchange frequency for the period.</p> <p>Personnel in operating areas of the plant and in some laboratories were required to wear badges continuously at work. Permanent badges were also assigned to those workers who frequently entered what were called “badged” areas. Spare badges were provided in available racks for those personnel who had a casual need to enter a badged area. Badges (dosimeters) were located in various process/work areas to provide reference data about changes in average radiation levels. Use of film badges by visitors or subcontract personnel was predetermined by the person who authorized entry and was on a self prescribed basis (MCW 1965).</p> <p>MCW (1965) also stated that “operations badges are exchanged and processed on a calendar [sic] month schedule, all others on a three-month schedule.” The term “operations badges” is assumed to refer to badges worn by personnel working in the operational, as opposed to administrative, sections of the plant. Ingle (1998) states that “film badge results were collected and read on a weekly basis until 1959 when the external program adopted a quarterly reading.” Dupree et al. (1999) stated that film badges were read weekly from 1945 to 1954 (which would be pre-Weldon Spring), biweekly from 1955 to 1958 (which includes the initial startup of Weldon Spring), and monthly for production workers and quarterly for all other workers from 1959 to 1966. The exception to this is the weekly exchange period for the turret lathe and dingot operators in</p>			

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<p>the early period of operation (MCW 1956c). Because of this confusion, it is suggested that if the exchange frequency cannot be determined from the claimant file, a claimant-favorable exchange frequency of bi-weekly be assumed for all operations workers, except for the turret lathe and dingot operators, which would be weekly through 1958, and that an exchange frequency of monthly for production workers and quarterly for all other workers be assumed from 1959 to 1966.</p>			
<p>SC&A Response See SEC Issue #1.</p>			
<p>SC&A SEC Issue No. Not applicable</p>	<p>SCA TBD Finding No. Primary Finding 27</p>	<p>NIOSH TBD Reply No. 10</p>	<p>Issue ORAUT-TKBS-0028-6: Lack of Sufficient Coworker Data Development for External Dose</p>
<p>NIOSH ER Position (SC&A reading) Not applicable</p>			
<p>SC&A Initial Review The TBD provides annual average gamma and beta exposures. However, the TBD does not provide any information concerning the details of this information, such as the number of data points for each entry, the percent of workers badged, the range of readings, if background was subtracted, if zeroes or outliers were included, if a threshold dose was used, etc. The data presented are a good start in creating a coworker database; however, in order to determine their validity and representativeness, there needs to be additional work performed on the data, as mentioned above. Plus, for internal coworker data, some guidance for use of the data in a summary form would be appropriate.</p>			
<p>NIOSH Reply to SC&A TBD Finding The SEC Evaluation Report for Petition SEC-00143 identified approximately 8,000 external monitoring records in the ORAU CER database representing approximately 1,850 employees during the period 1957 through 1967. A coworker model for external dose at the Weldon Spring Plant is not deemed to be necessary.</p>			
<p>SC&A Response See SEC Issue #1d.</p>			
<p>SC&A SEC Issue No. Not applicable</p>	<p>SCA TBD Finding No. Primary Finding 3</p>	<p>NIOSH TBD Reply No. Yet to be determined</p>	<p>Issue ORAUT-TKBS-0028-5 and ORAUT-TKBS-0028-6: Individual Exposures versus Average Exposures</p>
<p>NIOSH ER Position (SC&A reading) Not applicable</p>			
<p>SC&A Initial Review The TBDs rely heavily on the fact that mostly natural uranium (>97%) was processed at the WSCP; therefore, the contributions from other forms of uranium (DU, EU, or RU) and other radionuclides (thorium, radium, etc.) are small, compared to natural uranium. Whereas the most likely exposures (internal and external) may have been from natural uranium, this does not negate the fact that individuals or certain groups of workers may have been exposed to materials that contained greater concentrations of other forms of uranium and radionuclides, especially in or near plant locations dedicated to the other forms of radioactive material processing and in areas around discharge streams, waste, and raffinate pits.</p>			

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<p>Assuming that natural uranium predominates as the source of a worker's dose could lead to an underestimate of the worker's correct dose, if the worker was exposed to radioactive materials other than natural uranium.</p>			
<p>NIOSH Reply to SC&A TBD Finding</p> <p>See Sec Issue #1.</p>			
<p>SC&A SEC Issue No. Not applicable</p>	<p>SCA TBD Finding No. Secondary Finding 6</p>	<p>NIOSH TBD Reply No. Not applicable</p>	<p>Issue ORAUT-TKBS-0028-3: Inconsistency in Frequency of X-ray Exams</p>
<p>NIOSH ER Position (SC&A reading)</p> <p>Not applicable</p>			
<p>SC&A Initial Review</p> <p>TBD-3 (ORAUT 2005c, page 8) assumes annual x-rays for all periods, and in Section 3.1.2 (page 7), it recommends annually from 1955 through 1966. However, in the same paragraph it states, "A review of pre-1970 files indicates that, approximately 30% of the time, workers received two sets of chest x-rays in a period of 9 months or less (excluding x-rays for termination of employment); the files do not provide reasons for this."</p> <p>TBD-3 (ORAUT 2005c) should recommend a defined set of claimant-favorable x-ray exam schedules, so that dose reconstructions can be performed in a consistent manner. It should also be determined if some workers or groups of workers [such as those that wore respirators, were food handlers (tested for tuberculosis), etc.] may have had more frequent x-ray exams; perhaps this was the reason for the increase in frequency noted in Section 3.1.2 of the TBD.</p>			
<p>NIOSH Reply to SC&A TBD Finding</p> <p>All x-ray exams conducted off site; therefore, not a WSS dose. Issue closed.</p>			
<p>SC&A SEC Issue No. Not applicable</p>	<p>SCA TBD Finding No. Secondary Finding 7</p>	<p>NIOSH TBD Reply No. Not applicable</p>	<p>Issue ORAUT-TKBS-0028-3: PFG Exams Not Adequately Addressed</p>
<p>NIOSH ER Position (SC&A reading)</p> <p>Not applicable</p>			
<p>SC&A Initial Review</p> <p>TBD-3 (ORAUT 2005c) mentions photofluorography (PFG) exams on page 7. However, no recommendations to the dose reconstructor are made concerning this type of exam, other than that there had not been any indications that PFG exams were conducted at the WSCP. ORAUT-OTIB-0006 (ORAUT 2005g, page 21) states, "It is reasonable to presume that at least some of the occupational medical diagnostic chest x-rays with the DOE and its predecessor organizations were accomplished by PFG and, in the absence of data to the contrary, the use of PFG should be assumed to ensure claimant-favorable dose reconstructions." Table 7-6 of ORAUT-OTIB-0006 (page 24) also indicates that DOE/AEC facilities used PFG equipment from 1953–1968, which would encompass the 1957–1966 operating period at WSCP. If PFG equipment was not located at the WSCP site, workers may have had occupational PFG exams performed at offsite locations, such as Barnes Hospital Labs, which serviced MCW workers in the earlier years. TBD-3 (ORAUT 2005c) does not show evidence of investigating this subject sufficiently (such as checking Missouri state records, etc.) to justify discounting</p>			

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the possibility that some WSS workers received PGF exams.			
NIOSH Reply to SC&A TBD Finding			
All x-ray exams conducted off site; therefore, not a WSS dose. Issue closed.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 8	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-3: Lumbar Spine Exams Not Addressed
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
TBD-3 (ORAUT 2005c) makes no mention of lumbar spine x-rays and states on page 7 that, “Therefore, the analysis for this TBD assumed annual PA and LAT chest x-ray examinations for all employees, and considered no other view.” This excludes both PFG and lumbar spine exams. Lumbar spine exams were sometimes performed for workers that performed heavy and strenuous work, such as laborers and construction workers, or those with back problems. ORAUT-OTIB-0006 (ORAUT 2005g, page 21) states, “However, the possibility of periodic lumbar spine examinations, including an exit employment physical examination should not be precluded.” Therefore, TBD-3 should address the issue of lumbar spine exams for WSS workers.			
NIOSH Reply to SC&A TBD Finding			
All x-ray exams conducted off site; therefore, not a WSS dose. Issue closed.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 9	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-3: Use of ICRP-34 Instead of ICRP-74
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
TBD-3 (ORAUT 2005c) utilizes ICRP 34 (ICRP 1982) instead of ICRP 74 (ICRP 1996), which was used in NIOSH’s OCAS-IG-001 (NIOSH 2002) to determine absorbed dose from kerma values. Preliminary studies by SC&A indicate that the use of ICRP 34 may tend to underestimate the absorbed dose. ICRP 34 does not have 10 organs that are now in ICRP 74. The use of ICRP 74 is particularly important when the medical examinations included PFG chest x-ray exams, where doses can double or triple based on the differences between ICRP 34 and ICRP 74; for PA and lateral x-rays, the underestimations are not as significant. This issue amplifies the need to ascertain whether WSS workers received PFG exams, as outlined in the previous finding.			
NIOSH Reply to SC&A TBD Finding			
All x-ray exams conducted off site; therefore, not a WSS dose. Issue closed.			

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SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 14	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-4: Stated Uranium/Thorium/Radium/Lead Ratios should be used with Caution
NIOSH ER Position (SC&A reading) Not applicable			
SC&A Initial Review TBD-4 assumes that during the operations period, Th-230 was 5% of the U-238 activity, Ra-226 was 1% of the U-238 activity, and Pb-210 was 1% of the U-238 activity (ORAUT 2005d, page 9). These values may have been applicable for some locations and time periods at the WSS; however, this may not have been true for certain locations, as acknowledged in TBD-5 (ORAUT 2005e, page 14).			
NIOSH Reply to SC&A TBD Finding As of January 25, 2011, NIOSH to issue white paper & TBD revision.			
SC&A Response This issue has been addressed and may be closed.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 15	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-4: Natural Thorium-232 Not Always Negligible
NIOSH ER Position (SC&A reading) Not applicable			
SC&A Initial Review TBD-4 (ORAUT 2005d, page 9) assumes that because the amounts of natural thorium handled/processed at the WSS were a small fraction of the total uranium materials handled and processed, natural thorium is probably not a significant contributor to environmental inhalation doses during the operational period. This may be true on average, but this assumption does not consider the fact that some workers or certain groups of workers may have received a substantial portion of their inhalation dose from thorium and its decay products for a significant amount of time near a thorium-handling process, or from operations that concentrated thorium, such as the raffinate pits. A 1983 WSS document (Eberline 1983, page 10) shows that the raffinate pits contained significant concentrations of Th-232 as compared to U-238; approximately 20% on average. Therefore, assuming that Th-232 was insignificant compared to uranium should be used with caution, as it may not apply to all situations of potential exposure at the WSS during the operational period.			
NIOSH Reply to SC&A TBD Finding As of January 25, 2011, NIOSH to issue white paper & TBD revision.			

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SC&A Response			
This issue has been addressed and may be closed.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 16	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-4: Use of External Environmental Dose from Protracted Fernald Estimated Data
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
<p>TBD-4 (ORAUT 2005d, page 25) outlines the method used to determine the environmental external dose values at the WSS for the time period of 1957–1967. The external dose of 383 mrem per 2,000 hours (1 work-year) was derived from using the dose information from the Fernald site TBD-4 (ORAUT 2004a) and is listed in Table 4-11 of TBD-4 (ORAUT 2005d, page 27) for the WSS. The data from the Fernald site were not measured directly, but were derived from measurements post-1976 and then projected back to the pre-1976 period by scaling of production levels. This methodology is unreliable and may not result in appropriate external environment dose assignments to WSS workers.</p> <p>It is concluded that TBD-4 does not provide sufficient data to allow the construction of an adequate database for assigning external environmental doses to unmonitored workers at the WS complex with reasonable confidence. Additionally, because a considerable fraction of the workers at the WSS were not monitored, this could potentially impact a significant number of workers.</p>			
NIOSH Reply to SC&A TBD Finding			
See SEC Issue #4.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 22	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-5: Cost-Center Codes may not be Reliable for Dose Reconstruction
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
<p>The use of the cost-center codes listed on pages 19 and 22–27 of TBD-5 (ORAUT 2005e) are not practical, because workers' DOE files generally do not contain cost-center information; some may contain job titles, or work locations.</p> <p>The internal dose assessment for WSCP is very complex, because the workers were exposed to different uranium compounds (or different classes of solubility), as well as natural, recycled, depleted, and enriched uranium and thorium. Additionally, the measurement technique for urinalysis used at the WSCP was mainly photofluorimetric, which did not provide sufficient information to have a reliable dose assessment when there was a mixture of uranium compounds and uranium isotopes. Based on these facts, it would be more appropriate to have the data grouped according to work location or job title, such as in TBD-6 (ORAUT 2005f, pages 17–18), to avoid confusion and possible incorrect assignment of dose.</p>			

Weldon Spring SEC & Site Profile Issues Matrix

NIOSH Reply to SC&A TBD Finding			
NIOSH stated that these will not be used for WSS data – Closed.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 23	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-5: Negative In-vivo Results Do Not Necessarily Indicate Lack of Thorium Uptake
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
TBD-5 (ORAUT 2005e, page 28) indicates that a portable whole-body counter was set up for in-vivo thorium measurements in 1966. On page 29, it states the following: <i>The overall results showed workers involved in areas 101, 103, 301, 403, Maintenance, and Health and Safety, which were principal exposure positions, had a more frequent occurrence of ‘trace’ detections. No workers monitored showed a ‘positive’ designation. (Ingle 1991)</i>			
Because the limits of detection for this bioassay technique were generally very high during that period, the results of these measurements should not be considered as indicative of a lack of internal exposure. Hence, measurements recorded as “negative result” should not be interpreted as the workers not being exposed to thorium. These in-vivo measurements were only performed once in July 1966; the TBD does not address the issue of workers potentially exposed to thorium in early periods and if the thorium and/or decay products would be sufficiently present in the workers’ lungs to be detected by this method.			
NIOSH Reply to SC&A TBD Finding			
NIOSH stated that these will not be used for WSS data – Closed.			
SC&A SEC Issue No. Not applicable	SCA TBD Finding No. Secondary Finding 24	NIOSH TBD Reply No. Not applicable	Issue ORAUT-TKBS-0028-5: Enriched Uranium Not Sufficiently Addressed
NIOSH ER Position (SC&A reading)			
Not applicable			
SC&A Initial Review			
TBD-5 (ORAUT 2005e) discusses EU on page 12, where it is stated, “WSCP also processed depleted uranium and slightly enriched (up to 1%) uranium as well as natural thorium.” And on page 13, where it states, “For slightly enriched uranium, it is reasonable to assume that the composition of 1% enriched uranium in the Technical Basis Document for the Fernald Environment Management Project – Occupational Internal Dosimetry (ORAUT 2004b, Table 5-3) is applicable to slightly enriched uranium at WSCP.” In addition, it states, “Although uranium with enrichments of less than 1% might have been processed at WSCP, it is claimant-favorable to assume 1% enrichment for all slightly enriched uranium at WSCP.” These statements imply that if the dose reconstructor uses 1% EU with the composition as listed in the Fernald TBD [and reproduced in Table 5-5 of WS site TBD-5 (ORAUT 2005e)], then this is likely an overestimate and, therefore, claimant favorable. TBD-5 (ORAUT 2005e, page 35) recommends that the dose constructor use 1% EU for the period 1963–1967. However, a maximum enrichment of 1% is not supported by the documentation presented.			

Weldon Spring SEC & Site Profile Issues Matrix

NIOSH Reply to SC&A TBD Finding

NIOSH provided reference to document that WSS only received $\leq 1\%$ EU.

SC&A Response

SC&A reviewed SRDB Ref. #3644, page 15 (as provided at May 9, 2011, meeting), to determine if Weldon Spring only received EU of $\leq 1\%$. SC&A determined that this issue was satisfactorily addressed and as of June 2011 and recommends that this issue be closed.

Weldon Spring SEC & Site Profile Issues Matrix

SC&A References:

Battelle-TBD-6001, *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium*, Rev. FO; Battelle Team Dose Reconstruction Project for NIOSH; December 13, 2006; SRDB Ref ID: 30673

Battelle-TIB-5000, *Default Assumptions and Methods for Atomic Weapons Employer Dose Reconstruction*, Rev. 00; Battelle Team Dose Reconstruction Project for NIOSH; April 2, 2007; SRDB Ref ID: 32016

DOE 2000. *DOE Ohio Field Office Recycled Uranium Project Report*, Final; Department of Energy (DOE); May 15, 2000; SRDB Ref ID: 3644.

DOE 2003. *Recycled Uranium: United States Production Enrichment and Utilization*, Department of Energy (DOE); DOE/SO-0003, May 2003.

Eberline (Eberline, Inc.) 1983. *Weldon Spring, E2457, Sludge Analysis*, 18 August 1983. SRDB Ref ID: 14778.

ICRP 1982. *Protection of the Patient in Diagnostic Radiology*, Annals of the International Commission on Radiological Protection, Publication 34, Vol. 9/2, Pergamon Press, Oxford, England. SRDB Ref ID: 32466.

ICRP 1996. *Conversion Coefficients for Use in Radiological Protection Against External Radiation*, International Commission on Radiological Protection Publication 74, Pergamon Press, Oxford, England. SRDB Ref ID: 7979.

ICRP 1997. *Individual Monitoring for Internal Exposure of Workers* – International Commission on Radiological Protection Publication 78. Pergamon Press, Oxford. SRDB Ref ID: 36902.

NIOSH. 2002. *External Dose Reconstruction Implementation Guideline*, Rev. 1, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. August 2002.

NIOSH. 2009. *SEC-00143 – Petition for All employees who worked in any area at the Weldon Spring Plant from January 1, 1957 through December 31, 1966*. National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. September 11, 2009.

NIOSH 2010a. *SEC Petition Evaluation Report, Petition SEC-00143*, Rev. 0. National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. April 16, 2010.

Weldon Spring SEC & Site Profile Issues Matrix

NIOSH 2010b. *NIOSH Responses to SC&A Comments on the Weldon Spring Site Profile*. National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. October 12, 2010.

NIOSH 2011a. *NIOSH Responses to Weldon Spring Plant Review – may contain Privacy Act information*, April 21, 2011, e-mail from Mark Rolfes, with six attachments. National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio.

NIOSH 2011b. *NIOSH Responses to Weldon Spring Plant Review – may contain Privacy Act information*, July 1, 2011, e-mail from Mark Rolfes, with one attachment, titled *Weldon Spring Recycled Uranium Dose Response to ABRWH WG*, Rev 00, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio.

NIOSH 2011c. *NIOSH Responses to Weldon Spring Plant Review – may contain Privacy Act information*, September 7, 2011, e-mail from Mark Rolfes, with one attachment, titled *Evaluation of Blunders Associated With Daily Weighted Average (DWE) Reports at the Weldon Spring Plant*, Rev 00, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio.

OCAS-IG-001. 2006. *External Dose Reconstruction Implementation Guideline*, Rev. 2, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. August 25, 2006.

ORAUT 2004a. *Technical Basis Document for the Fernald Environmental Management Project – Occupational Environmental Dose*, ORAUT-TKBS-0017-4, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. April 2004.

ORAUT 2004b. *Technical Basis Document for the Fernald Environmental Management Project – Occupational Internal Dose*, ORAUT-TKBS-0017-5, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. May 2004.

ORAUT 2005a. *Weldon Spring Plant – Introduction*, ORAUT-TKBS-0028-1, C. Little and R. Meyer, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. June 28, 2005.

ORAUT 2005b. *Weldon Spring Plant – Site Description*, ORAUT-TKBS-0028-2, C. Little and L. McDowell-Boyer, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. June 24, 2005.

ORAUT 2005c. *Weldon Spring Plant – Occupational Medical Dose*, ORAUT-TKBS-0028-3, T. Lopez and J. Furman, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. June 24, 2005.

ORAUT 2005d. *Weldon Spring Plant – Occupational Environmental Dose*, ORAUT-TKBS-0028-4, L. McDowell-Boyer and C. Little, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. June 28, 2005.

Weldon Spring SEC & Site Profile Issues Matrix

ORAUT 2005e. *Weldon Spring Plant – Occupational Internal Dose*, ORAUT-TKBS-0028-5, Janet A. Johnson and Roger B. Falk, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. June 28, 2005.

ORAUT 2005f. *Weldon Spring Plant – Occupational External Dosimetry*, ORAUT-TKBS-0028-6, J. Langsted and C. Little, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. June 24, 2005.

ORAUT 2005g. *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, ORAUT-OTIB-0006, Rev. 03, Oak Ridge Associated Universities Team, Cincinnati, Ohio. April 19, 2005.

SC&A 2007. *Review of the Feed Materials Production Center (FMPC) Special Exposure Cohort (SEC) Petition-00046 and the NIOSH SEC Petition Evaluation Report*, Rev. 0. SCA-TR-TASK5-0056. SC&A, Inc., Vienna, Virginia, and Saliant, Inc., Jefferson, Maryland. May 31, 2007.

SC&A 2009. *Review of the NIOSH Site Profile for the Weldon Spring Site in Weldon Spring, Missouri*, Revision 0. SCA-TR-TASK1-0028, February 10, 2009.

SC&A 2010. *Matrix Issues for the Weldon Spring Site Special Exposure Cohort Petition and NIOSH Evaluation Report Review*. SCA-TR-TASK5-0015, October 18, 2010.

SC&A 2011a. *Issues Matrix for the Weldon Spring Site Special Exposure Cohort Petition and NIOSH Evaluation Report, and SC&A's Review of the Weldon Spring Site Profile*. White paper provided to the Weldon Spring Work Group. SC&A, Inc., Vienna, Virginia. August 3, 2011.

SC&A 2011b. *SC&A'S Evaluation of NIOSH'S July 1, 2011, Response Concerning Recycled Uranium (SEC Issue #5) at Weldon Spring*. White paper provided to the Weldon Spring Work Group. SC&A, Inc., Vienna, Virginia. August 3, 2011.

SC&A 2011c. *SC&A's Evaluation of NIOSH's Weldon Spring Response of April 21, 2011, and the Work Group Meeting of May 9, 2011*. White paper provided to the Weldon Spring Work Group. SC&A, Inc., Vienna, Virginia. August 3, 2011.

SC&A 2011d. *SC&A's Initial Test of External and Bioassay Data Completeness for the Weldon Spring Site*. White paper provided to the Weldon Spring Work Group. SC&A, Inc., Vienna, Virginia. August 15, 2011.

SC&A 2011e. E-mail from Ron Buchanan (SC&A) to the WSS Work Group, Subject: *Weldon Spring SEC Issue #6-neutron n/p value*. September 20, 2011.

SC&A 2011f. *SC&A's Evaluation of NIOSH's Response of September 7, 2011, to Daily Weighted Exposure Blunders in Weldon Spring Data*. White paper provided to the Weldon Spring Work Group. SC&A, Inc., Vienna, Virginia. September 27, 2011.

Weldon Spring SEC & Site Profile Issues Matrix

NIOSH's References:

References for Item 1

MCW (Mallinckrodt Chemical Works), 1961a, Annual Off-Site Environmental Monitoring Report 1960, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 13762]

MCW (Mallinckrodt Chemical Works), 1961b, Section 2 Environmental Monitoring Report Part 1, 4th Quarter 1960, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 13782]

MCW (Mallinckrodt Chemical Works), 1962, Personnel and Environmental Monitoring Report First, Second & Third Quarter 1962, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 13732]

MCW (Mallinckrodt Chemical Works), 1964a, 2nd Semi Annual and Annual Summary Off-Site Environmental Monitoring Report - 1963, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 11803]

MCW (Mallinckrodt Chemical Works), 1964b, 1st Semi Annual Off-Site Environmental Monitoring Report - 1964, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 11802]

MCW (Mallinckrodt Chemical Works), 1965, 2nd Semi Annual and Annual Summary Off-Site Environmental Monitoring Report - 1964, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 11816]

MCW (Mallinckrodt Chemical Works), 1966a, Environmental Monitoring Report - 1965 (Semiannual and Annual Summary Off-Site), Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 14750]

MCW (Mallinckrodt Chemical Works), 1966b, Environmental Monitoring Report Third Quarter 1961, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 15287]

Meshkov, N., P. Benioff, J. Wang, and Y. Yuan, 1986, *Weldon Spring Historical Dose Estimate*. ANL/EES-TM-308, Argonne National Laboratory, Argonne, Illinois, July. [SRDB Ref ID: 13117]

References for Item 4

MK-Ferguson, 1989, Waste Assessment Radiological Characterization of the Weldon Spring Site Raffinate Pits, Rev. 0, DOE/OR/21548-062; MK-Ferguson Company and Jacobs Engineering Group; August. [SRDB Ref ID: 12541]

References for Item 9

Brandner, K. E., 1956a, "Film Badge Procedures for Transfers to Weldon Spring and New Hires for Weldon Spring," memorandum to M. G. Mason, October 26, 1956, Mallinckrodt Chemical Works, Uranium Division, St. Louis, Missouri. [SRDB Ref ID: 15578]

Weldon Spring SEC & Site Profile Issues Matrix

Burr, R. H, 1959a, "Exchange of Turret Lathe Operators Film Badges," memorandum to W. L. Utnage, January 26, 1959, Mallinckrodt Chemical Works, Uranium Division, St. Louis, Missouri. SRDB Ref ID: 15864.

Burr, R. H, 1959b, "Exchange of Film Badge Boards on January 30, 1959," memorandum to W. L. Utnage, January 29, 1959, Mallinckrodt Chemical Works, Uranium Division, St. Louis, Missouri. SRDB Ref ID: 15864.

Dupree, E. E., Watkins, J. P., Ingle, J. N., and Phillips, J. A., "External Radiation Exposure and Mortality Among a Cohort of Uranium Processing Workers," American Journal of Epidemiology, Vol. 152, No 1, 2000. SRDB 9486.

Ingle, J. N., 1991. "Mallinckrodt Chemical Works: Four Plant Study Classifications," ORAU Memorandum NIPF AU 005101, September 16, Oak Ridge Associated Universities, Oak Ridge, Tennessee. (See pg. 22; found full citation in ORAUT 2005e.)

Ingle, J. N., and Phillips, J. A., Oak Ridge Associated Universities, Oak Ridge, Tennessee, undated. SRDB Ref ID: 9486.

Ingle, N., 1998, "Mallinckrodt Chemical Works Dose Estimate Methodology," memorandum to Dr. Betsy (E.E.) Dupree, Oak Ridge Associated Universities, from N. Ingle, February 4, Delta-21 Resources, Inc., location unknown. SRDB Ref ID: 13176.

MCWa (Mallinckrodt Chemical Works), 1958, "Weldon Spring Plant Film Badge Program," memorandum to W. L. Utnage, no date, Uranium Division, Health and Safety Department, Weldon Spring, Missouri. SRDB Ref ID: 15864.

MCWc (Mallinckrodt Chemical Works), 1956, Film Badge, Technique and Calibration, November 1, Uranium Division, St. Louis, Missouri. SRDB Ref ID: 15864.

MCW (Mallinckrodt Chemical Works), 1965, Summary of Health Protection Practices (Revised 1965), Uranium Division, St. Louis, Missouri. SRDB Ref ID: 14998.

MCWb (Mallinckrodt Chemical Works), undated, Personnel External Radiation Monitoring Program Uranium Division, St. Louis, Missouri. SRDB Ref ID: 15864.

WSP, Film Badge Report 1958, no author, no date. SRDB Ref ID: 15871.