CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

CORRECTIVE ACTION REQUEST

CAR No: 2002-03

Associated AR, SR, NCR No: CNWRA 2002-1

PART A: DESCRIPTION OF CONDITION ADVERSE TO QUALITY

The CQAM, section 3.3.10 requires that data interpretation and analysis be documented in sufficient detail as to purpose, method, assumptions, input, references, and units such that a technically qualified person may review, understand, and verify the analysis without recourse to the originator.

- The RSSA scoping analysis report did not justify some assumptions, particularly those based on NRC direction.
- The TSPA issue resolution blueprint report was inconsistently referenced.

A possible contributing factor to this condition is that QAP-002 (the review process) instructions to technical reviewers does not convey the full scope of the requirements of CQAM 3.3.10.

Initiated by: R. Brient

Date July 30, 2002

PART B: PROPOSED ACTION

Responsible EM: B. Sagar

Response Due: 8/27/2002 BS

1) Extent of Condition:

SEE ATTACHED TEXT

2) Root Cause:

SEE ATTACHED TEXT

3) Remedial Action:

SEE ATTACHED TEXT

Proposed Completion Date: 12/31/2002

4) Corrective Action to Preclude Recurrence:

SEE ATTACHED TEXT

Proposed Completion Date: 12/31/2002

Element Manager: Budhi Sagar

Date: 10/17/2002

PART C: APPROVAL KBS, ATL 10/18/02

Comments/Instructions

Director of QA: [signature]

Date: 10/18/2002

PART D: VERIFICATION OF CORRECTIVE ACTION IMPLEMENTATION

See attached page describing corrective action implementation.

Verified by: Mark R. Ehnstrom **Date:** 3/19/03

Distribution:

CNWRA FORM QAP 14-2

CAR 2002-03: Part B: Proposed Action

Extent of Condition: Review packages for three CNWRA deliverables from the TSPAI key technical issue project and three CNWRA deliverables from the decommissioning project were examined to determine the extent of the condition. Deliverables from these projects were selected for review to determine if the condition identified in the audit of the Total System Performance and Integration Issue Resolution Blueprint report (quality assurance file tracking number Q200110010005) from the TSPAI key technical issue project and the Scoping Analysis of Exposure Scenarios Associated with Reused Soil report (quality assurance tracking number Q20020419004) from the decommissioning project could be the result of systematic, incorrect implementation of CNWRA quality assurance procedures by the managers of these projects. The cognizant project managers responsible for each report directed the technical reviewer(s) to check if the assumptions are reasonable and clearly stated. Each of the six review packages was evaluated with respect to the six criteria listed below to determine the extent of the condition.

- **Statement of Assumptions Required.** Do the nature and content of the CNWRA deliverable and the intended audience for the CNWRA deliverable require that the author(s) include a description of all assumptions underlying data interpretation and analysis of sufficient detail that a technically qualified person may review, understand, and verify the analysis without recourse to the originator? (See Section 3.3.10 of the CQAM) Some CNWRA deliverables, such as requests for additional information (RAI) submitted to license applicants, reports that record the results of discussions held with an applicant or potential applicant, or reports that do not include discussion of data interpretation and analysis, may not need to include statements of assumptions. In such cases, the project manager should not check the box on the QAP-12 form that instructs the technical reviewer to check that the "assumptions are reasonable and clearly stated." CNWRA deliverables that describe the results of data interpretation and analyses conducted by the authors are required to state all relevant assumptions made.

- **Assumptions Stated in Report.** If the CNWRA deliverable describes the results of data interpretation and analyses, have the authors clearly stated the assumptions upon which the data interpretation and analyses are based? For complex mathematical derivations the authors should explain the assumptions made in key steps of the derivation. For calculations, the authors should state the assumptions that support the use of numerical values that are not accepted physical constants, such as the speed of light in a vacuum. For complex equations or multi-step calculations, the authors should list the assumed values for constants, parameters, and coefficients in a table.

- **Assumptions Justified in Report.** If the CNWRA deliverable describes the key assumptions made to support data interpretation and analyses, have the authors justified the assumptions? In instances where the authors of a technical report have been directed by the client to make specific assumptions in their analyses, the authors should clearly state so. For cases where the authors have listed the assumed values for constants, parameters, and coefficients in a table, one column should identify the source of the assumed value.

- **Review of Assumptions Requested on QAP-12.** If the CNWRA deliverable meets the

2

first criterion, has the project manager directed the technical reviewer(s) to check if the assumptions are reasonable and clearly stated by marking the box on the QAP-12 form?

- **Review of Assumptions Recorded on TOP-3**. If the project manager directs the technical reviewer to check if the assumptions are reasonable and clearly stated, has the technical reviewer documented the results of this check on the TOP-3 forms? Meeting this criterion is not a requirement of section 5.1 of QAP-002—the technical reviewer indicates completion of checking the assumptions by initialing the box on the lefthand side. Although not explicitly required, technical reviewers in many instances record comments on the TOP-3 form that directly question the validity of assumptions made by the authors in conducting data interpretation and analysis, thereby providing written documentation that corroborates their checking the box.

- **Review of Assumptions Effective**. Was the technical review effective in assessing the extent to which assumptions that support data interpretation and analysis are reasonable and clearly stated? Did the technical reviewer fail to identify key assumptions made but not stated in support of data interpretation and analysis?

The following section provides a series of brief synopses of the extent to which the six deliverables reviewed satisfied the six criteria. These criteria, which were developed solely to measure the extent of the condition, may or may not reflect the general investigative approach adopted by the auditors whose findings led to the corrective action request.

TSPAI Key Technical Issue Project, Deliverable 1, a journal paper entitled "Importance of Transparency and Traceability in Building a Safety Case for a High-Level Waste Repository." by S. Mohanty and B. Sagar. (Quality Assurance file tracking number Q200109100001)

1. **Statement of Assumptions Required**. No. This is a conceptual paper that describes the need for transparency in performance assessments supporting safety cases for HLW repositories and traceability of the data and models used in the performance assessment. No data interpretation or analysis is described.
2. **Assumptions Stated in Report**. NA.
3. **Assumptions Justified in Report**. NA.
4. **Review of Assumptions Requested on QAP-12.** Yes, but based on the content of the deliverable, the project manager should not have requested this review.
5. **Review of Assumptions Recorded on TOP-3**. NA.
6. **Review of Assumptions Effective.** NA. See 1 and 4 above.

TSPAI Key Technical Issue Project, Deliverable 2, a conference paper entitled "Mean-based Sensitivity or Uncertainty Importance Measures for Identifying Influential Parameters." By S. Mohanty and Y.-T. Wu. (Quality Assurance file tracking number Q200203010004)

1. **Statement of Assumptions Required**. Yes. This is a highly technical paper that requires the reader to possess a sophisticated understanding of probability and statistics. Data interpretation and analysis are described. Complete understanding of the mathematical derivations may require the reader to perform intermediate steps in the derivations.
2. **Assumptions Stated in Report**. Yes, but limited. Some mathematical or statistical

assumptions are described in the paper, such as use of a normal distribution for a test statistic on the basis of the Central Limit Theorem. Page limits imposed by conference organizers preclude full development of equations with attendant descriptions of all key assumptions.

3. **Assumptions Justified in Report.** Yes, but very limited. See 2 above.
4. **Review of Assumptions Requested on QAP-12.** Yes.
5. **Review of Assumptions Recorded on TOP-3.** Yes. Reviewer questioned simplifying assumptions made by authors in deriving one equation.
6. **Review of Assumptions Effective.** Yes. The technical reviewer, who was both qualified to conduct the review and representative of the intended audience, appeared to understand the implicit assumptions made in many of the mathematical derivations, but also made comments about simplifying assumptions that were less apparent.

TSPAI Key Technical Issue Project, Deliverable 3, a conference paper entitled "Sensitivity Analysis Methods for Identifying Influential Parameters in a Problem with a Large number of Random Variables." By S. Mohanty and R. Codell (Quality Assurance file tracking number Q200203010002)

1. **Statement of Assumptions Required**. Yes. This is a fairly technical paper that assumes the reader understands standard statistical methods such as regression analysis, tests of hypothesis, and the design and analysis of experiments. Data interpretation and analysis are described. Complete understanding of the results would require the reader to read the referenced documents.
2. **Assumptions Stated in Report**. Yes, but limited. Explicit identification of assumptions supporting the application of various sensitivity methods is provided in a few cases, for all other applications references are made to other reports. For several methods, such as the application of linear regression, the implicit assumptions should be familiar to those in the intended audience. The conference likely imposes page limits on papers, hence attempting to state more than a few of the assumptions underlying each method reduces the page space needed by the authors to present their key ideas.
3. **Assumptions Justified in Report**. No.
4. **Review of Assumptions Requested on QAP-12.** Yes.
5. **Review of Assumptions Recorded on TOP-3**. No.
6. **Review of Assumptions Effective.** Yes. The technical reviewer, who was familiar with the assumptions that support the application of the various sensitivity analysis methods presented in the document, did not identify any major concerns. There did not appear to be any instances where the technical reviewer failed to identify key missing assumptions or inadequate references.

Decommissioning Project, Deliverable 1, a report entitled "Review of the Draft NUREG Entitled 'Reevaluating of the Indoor Resuspension Factor for the Screening Analysis of the Building Occupancy Scenario for Nuclear Regulatory Commission License termination Rule.'" By J.R. Weldy, R.R. Benke, R.L. Mason, and B. Sagar. (Quality Assurance file tracking number Q200004200002)

1. **Statement of Assumptions Required**. Yes. This report describes an independent evaluation of a draft NUREG conducted by CNWRA staff in response to concerns about

the technical content of the draft NUREG that were raised by member of the NRC staff. Data interpretation and analysis is described. Much of the content of the report is a critique of the assumptions made by the authors of the draft NUREG. The CNWRA authors of the report conducted very limited data interpretation and analysis (one analysis identified) to support their review comments.

2. **Assumptions Stated in Report**. Yes.
3. **Assumptions Justified in Report**. Yes. Assumed room size values used only to illustrate the potential mitigating effects of volumetric dilution.
4. **Review of Assumptions Requested on QAP-12.** Yes.
5. **Review of Assumptions Recorded on TOP-3**. Yes. Comment by reviewer resulted in authors including a calculation to demonstrate the effects of dilution.
6. **Review of Assumptions Effective.** Yes. See 5 above. Assumptions made about volumetric dilution effects were expanded in a calculation in response to a comment by the technical reviewer.

Decommissioning Project, Deliverable 2, a report entitled "Review of Draft NUREG-1640, Radiological Assessments for Clearance of Equipment and Materials from Nuclear Facilities.'" by J. Weldy, R. Benke, R. Brient, R. Pabalan, and L. Yang. (Quality Assurance file tracking number Q200011160006)

1. **Statement of Assumptions Required**. Yes. This report describes an independent "vertical slice" review and re-evaluation of the technical correctness of a draft NUREG. Data interpretation and analysis is described. The CNWRA authors identified several new scenarios and conducted the corresponding pathway-dose calculations.
2. **Assumptions Stated in Report**. Yes. The assumptions made by the CNWRA authors for the pathway-dose calculations supporting the additional scenarios are described in the deliverable.
3. **Assumptions Justified in Report**. Yes, but not completely. References were provided for the metal weights and dimensions; however, some assumptions, such as exposure durations, are not supported by reference.
4. **Review of Assumptions Requested on QAP-12.** Yes.
5. **Review of Assumptions Recorded on TOP-3**. No.
6. **Review of Assumptions Effective.** Yes. Assumptions made in support of data interpretation and analyses conducted during the review of NUREG-1640 and reported in the body of the report are clearly stated. Most of the calculations performed by CNWRA staff during their review are contained in Appendix A and Appendix B and the assumptions made to support these, are also clearly stated in general. Two technical reviewers made comments on the equation presented in Appendix A. Although these comments did not directly question an assumption, they were indicative of the reviewers' attempt to identify implicit assumptions that may have required more explicit treatment.

Decommissioning Project, Deliverable 3, a report entitled "Input for an Environmental Assessment of the Proposed Decommissioning Plan for the Molycorp, Inc. Facility in Washington, Pennsylvania" by P. LaPlante. (Quality Assurance file tracking number Q200006190001)

1. **Statement of Assumptions Required**. No. This deliverable consists of written input to

an environmental assessment, in which the CNWRA author provides an overview of the complex quantitative analysis and detailed site description contained in the applicant's site decommissioning plan. No original data interpretation or analysis is contained in the deliverable. The input appears to based solely on the data interpretation and analysis conducted by the applicant as part of their decommissioning plan.

2. **Assumptions Stated in Report.** No. Assumptions made by the applicant in their decommissioning plan are repeated as necessary to support the environmental assessment.
3. **Assumptions Justified in Report.** No. See 2 above.
4. **Review of Assumptions Requested on QAP-12.** Yes. Based on the content of the deliverable, the project manager should not have requested this review.
5. **Review of Assumptions Recorded on TOP-3.** No.
6. **Review of Assumptions Effective.** NA.

Based on examination of the six review packages using the six criteria, it does not appear that there is any systematic defect in the application of the existing technical review procedure that would result in an unacceptable number of failures to identify key assumptions supporting data interpretation and analysis contained in CNWRA reports. Nonetheless, this examination does indicate that the technical review method described in section 5.1 of QAP-002 and in the QAP-012 form does not fully and accurately implement section 3.3.10 of the CQAM and should be revised. In particular, the project or element manager responsible for assigning the technical review checks listed on the QAP-012 form, should not assign the "assumptions are reasonable and accurately stated" check for those documents that do not contain data interpretation and analysis. Although the condition identified in the corrective action request does not extend to the six review packages examined here, it would be prudent nonetheless to add language to the QAP-012 form directing the reviewer to check that the "assumptions are reasonable and documented in sufficient detail that a technically qualified person may review, understand, and verify the analysis without recourse to the originator."

Root Cause: The portion of the QAP-12 form that directs the technical reviewer(s) to verify that the assumptions are reasonable and clearly stated does fully or accurately convey the data interpretation and analysis requirements defined in section 3.3.10 of the CQAM.

Remedial Action: The final RSSA report will be revised to include a list of all technical assumptions that the NRC directed the CNWRA to use in performing the dose-pathway calculations. New footnotes will be added to the TSPAI KTI Issue Resolution Blueprint report to make clear at which subissue resolution technical exchange specific TSPAI agreement items were discussed.

Corrective Action to Preclude Recurrence: Revise the QAP-12 form so that the technical reviewer is reminded that section 3.3.10 of the CQAM requires that the assumptions be documented in sufficient detail that a "technically qualified person may review, understand, and verify the analysis without recourse to the originator." The technical reviewer should be required to check a box affirming that the preceding quoted statement is true. In addition, indicate that an "assumptions check" is not to be assigned if the report does not contain data interpretation and analysis. See attached proposed revisions to QAP-012 form.

Corrective Action 2002-03

Verification of Corrective Action Implementation

With the March 2003 submission of the report titled, "Analysis Of Exposure Scenarios Associated With Reused Soil", this Corrective Action Request (CAR) 2002-03 can be closed. New footnotes were added to the TSPAI KTI Issue Resolution Blueprint report as described in the remedial action of the CAR. Form QAP-012 was revised in October 2002 and now includes more definition and instruction for the individual performing the assumptions review for technical correctness. The three requirements described in the remedial action of the CAR are now complete and this CAR had been satisfactory closed.

Mark R. Ehnstrom
Mark R. Ehnstrom 3/19/03

Reviewed By: Bruce Mabrito / Approved 3/19/2003

Bruce Mabrito

CENTER F... R NUCLEAR WASTE REGUL... ORY ANALYSES
INSTRUCTIONS TO TECHNICAL REVIEWERS
Technical Review Items to Verify

TO: ______________________________

SUBJECT: Review of ______________________________

Please perform a Technical Review of the subject document in accordance with CNWRA QAP-002, verifying the specific items identified below. Technical comments shall be documented on the attached Comment Resolution Record and presented to the author for resolution. Initial blanks on right side of page to show completion of assigned review.

Required review completion date: ______________________________

ASSIGNED **ACCOMPLISHED**

TECHNICAL CORRECTNESS

- [ ] Assumptions are reasonable and clearly stated. [ ]
- [ ] Appropriate techniques are used.* [ ]
- [ ] Existing data are qualified (or exempted) in accordance with QAP-015. [ ]
- [ ] Conclusions are properly supported by correctly interpreted data.* [ ]

* *Novel or beyond state-of-the-art techniques or significant uncertainties in data and interpretations warrant application of the Peer Review.*

Are there calculations? YES [ ] NO [ ] If yes, are "over checks" required? YES [ ] NO [ ]

If no "over checks" are required, explain why: ______________________________

- [ ] Calculations are correct, documented and verified in accordance with QAP-014 (**document** this review by a statement on the TOP-3 form). [ ]

READABILITY

- [ ] Document is written for the intended audience, with correct grammar and syntax. [ ]
- [ ] Illustrations and tables clearly present basic information and emphasize relationships. [ ]

CONTENT AND FORMAT

- [ ] Title reflects the objectives of the document. [ ]
- [ ] Abstract states purpose, describes study, and summarizes the pertinent results and conclusions. [ ]
- [ ] Introduction states the objectives and scope of the work and presents background information. [ ]
- [ ] Body of the manuscript is logically organized and presents the basic information. [ ]
- [ ] Conclusions and results summarize the principal findings and answer each of the objectives of the work. [ ]
- [ ] References are cited in the text and in the references section. [ ]
- [ ] Costs and financial tables are included and agree with text. [ ]

ELEMENT MANAGER	DATE	COGNIZANT DIRECTOR	DATE

OLD Form

CNWRA FORM QAP-12 (Rev.2/2001)

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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
INSTRUCTIONS TO TECHNICAL REVIEWERS
Technical Review Items to Verify

REVIEWER: ______________________

TITLE: ______________________

Please perform a Technical Review of the subject document in accordance with CNWRA QAP–002, verifying the specific items identified below. Technical comments shall be documented on the attached Comment Resolution Record and presented to the author for resolution. Initial blanks on right side of page to show completion of assigned review.

Required review completion date: ______________________

TECHNICAL CORRECTNESS **ACCOMPLISHED**

☐	Assumptions are reasonable and documented in sufficient detail that a technically qualified person may review, understand, and verify the analysis without recourse to the originator. (Do not assign if report does not contain data interpretation and analysis.)	☐
☐	Appropriate techniques are used.	☐
☐	Existing data are qualified (or exempted) in accordance with QAP–015.	☐
☐	Conclusions are properly supported by correctly interpreted data. *(Novel or beyond state-of-the-art techniques or significant uncertainties in data and interpretations warrant application of a Peer Review.)*	☐

Are there calculations? YES ☐ NO ☐ If yes, are "over checks" required? YES ☐ NO ☐

If no "over checks" are required, explain why: ______________________

If "over checks" are required, specify type(s) of calculation (per Section 3.2 and 3.2.3 of QAP–014) and describe extent of verification.

- ☐ Controlled Software ______________________
- ☐ Uncontrolled Software ______________________
- ☐ Commercial Off-the-Shelf Software ______________________
- ☐ Other Calculation(s) ______________________

☐	Calculations are correct, documented and verified in accordance with QAP–014, Section 3.2.3. Document this review by a statement on TOP–3 form explaining which calculations were checked, and how they were checked. Attach verification calculation, in accordance with Section 3.2.4 of QAP–014.	☐

CNWRA FORM QAP–12 (Rev. 10/2002)

NEW FORM

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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
INSTRUCTIONS TO TECHNICAL REVIEWERS
Technical Review Items to Verify

READABILITY		ACCOMPLISHED
☐	Document is written for the intended audience, with correct grammar and syntax.	☐
☐	Illustrations and tables clearly present basic information and emphasize relationships.	☐

CONTENT AND FORMAT		ACCOMPLISHED
☐	Title reflects the objectives of the document.	☐
☐	Abstract states purpose, describes study, and summarizes the pertinent results and conclusions.	☐
☐	Introduction states the objectives and scope of the work and presents background information.	☐
☐	Body of the manuscript is logically organized and presents the basic information.	☐
☐	Conclusions and results summarize the principal findings and address each of the objectives of the work.	☐
☐	References are cited in the text and in the references section.	☐
☐	Costs and financial tables are included and agree with text.	☐

ELEMENT MANAGER	DATE	COGNIZANT DIRECTOR	DATE

CNWRA REPORT REVIEW / COMMENT RESOLUTION RECORD		PAGE OF PAGES
PROJECT NUMBER	DOCUMENT DATE	DOCUMENT NUMBER
TITLE:		

The comments shown below address questions and concerns of a technical and/or programmatic nature which arose in this review. Because of possible implications, they require action and response.	RESPONSE: (Write "accept" and note briefly how comment was incorporated, or give justification if rejected.)
REVIEWER SIGNATURE: DATE:	RESPONDER SIGNATURE: DATE:
Response accepted by: Signature Date	If resolution cannot be achieved, the matter shall be elevated to the next level of authority. Distribution: This completed form shall be maintained in a record file.

CNWRA Form TOP-3 (Rev. 6/90)

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

MEMORANDUM

August 27, 2002

TO: QA Records Corrective Action Requests 2002-03 and 2002-04 Folder

FROM: Bruce Mabrito, Director of Quality Assurance

SUBJECT: Extension of Time on CARs 2002-03 and 2002-04

REFERENCE: CAR 2002-03 and 2002-04, Annual 2002 CNWRA QA Audit

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This memorandum to the Corrective Action Requests (CARs) 2002-03 and 2002-04 folder is to document progress and extend a time extension for the responses.

CARs 2002-03 and 2002-04 were originated July 30, 2002, following the conclusion of the 2002 annual CNWRA QA Audit. They were responded to by B. Sagar and G. Wittmeyer on August 26, 2002, but I reviewed their responses and rejected their responses.

The original responses lacked sufficient information from a QA perspective and they were returned to B. Sagar with a request to resubmit them with changes. There have been several discussions between B. Mabrito, B. Sagar and G. Wittmeyer regarding these two CARs and it is expected that several more iterations of CAR proposed actions will be submitted before CNWRA QA accepts the input.

For the purpose of this memorandum to the file, it should be noted that the initial response to the CARs were prior to response due date of 8/27/2002.

An extension of the two CAR response due dates is acceptable considering the on-going discussions and circumstances. An extension to September 26, 2002 is hereby granted.

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

MEMORANDUM

September 26, 2002

TO: QA Records Corrective Action Requests 2002-03 and 2002-04 Folder

FROM: Bruce Mabrito, Director of Quality Assurance

SUBJECT: Second Extension of Time on CARs 2002-03 and 2002-04

REFERENCE: CAR 2002-03 and 2002-04, Annual 2002 CNWRA QA Audit

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This memorandum to the Corrective Action Requests (CARs) 2002-03 and 2002-04 folder is to document progress and extend a time extension for the responses.

CARs 2002-03 and 2002-04 were originated July 30, 2002, following the conclusion of the 2002 annual CNWRA QA Audit. They were responded to by B. Sagar and G. Wittmeyer on August 26, 2002, but I reviewed their responses and rejected their responses. This is the second time extension on this set of CARs.

The original responses lacked sufficient information from a QA perspective and they were returned to B. Sagar with a request to resubmit them with changes. There have been several discussions between B. Mabrito, B. Sagar and G. Wittmeyer regarding these two CARs and it is expected that several more iterations of CAR proposed actions will be submitted before CNWRA QA accepts the input. Due to travel situations and preparation of Operations Plans, B. Sagar has not presented CNWRA QA with the new responses to CARs 2002-03 and 2002-04.

For the purpose of this memorandum to the file, it should be noted that the initial response to the CARs were prior to response due date of 8/27/2002. The first extension was to September 26, 2002.

I am reluctantly documenting a second extension for these two CAR responses. The new due date for both the CARs is October 11, 2002. It is expected that B. Sagar and G. Wittmeyer will have their responses to CNWRA QA by this second extension date.

cc: B. Sagar
G. Wittmeyer
M. Padilla
M. Ehnstrom
B. Mabrito

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

MEMORANDUM

October 11, 2002

TO: QA Records Corrective Action Requests 2002-03 and 2002-04 Folder

FROM: Bruce Mabrito, Director of Quality Assurance

SUBJECT: Third Extension of Time on CARs 2002-03 and 2002-04

REFERENCE: CAR 2002-03 and 2002-04, Annual 2002 CNWRA QA Audit

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This memorandum to the Corrective Action Requests (CARs) 2002-03 and 2002-04 folder is to document progress and extend a time extension for the responses.

CARs 2002-03 and 2002-04 were originated July 30, 2002, following the conclusion of the 2002 annual CNWRA QA Audit. They were responded to by B. Sagar and G. Wittmeyer on August 26, 2002, but I reviewed their responses and rejected their responses. This is the third time extension on this set of CARs.

The original responses lacked sufficient information from a QA perspective and they were returned to B. Sagar with a request to resubmit them with changes. There have been several discussions between B. Mabrito, B. Sagar and G. Wittmeyer regarding these two CARs and it is expected that several more iterations of CAR proposed actions will be submitted before CNWRA QA accepts the input. Due to travel situations and preparation of Operations Plans, B. Sagar has not yet presented CNWRA QA with the new responses to CARs 2002-03 and 2002-04.

For the purpose of this memorandum to the file, it should be noted that the initial response to the CARs were prior to response due date of 8/27/2002. The first extension was to September 26, 2002. The second extension was to October 11, 2002. More discussions have taken place to resolve differences in approach to resolving these two CARs.

Based on the recent discussions between B. Sagar and myself, it has been agreed that the deadline for completing all action on these two CARs is December 31, 2002. This date will allow certain remedial actions to take place according to the Element Managers affected.

cc: B. Sagar
M. Padilla
M. Ehnstrom
B. Mabrito

T is The objective evidence for Corrective Action Request 2002-03 [signature] 1/03/2003

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January 3, 2003
Contract No. NRC–02–02–002
Account No. 20.06002.01.111

U.S. Nuclear Regulatory Commission
ATTN: Mr. James Firth
Office of Nuclear Material Safety and Safeguards
Division of Waste Management
Performance Assessment and High-Level Waste Integration Branch
Mail Stop 7C–18
Washington, DC 20555

Subject: TRANSMITTAL OF REVISED VERSION OF DESCRIPTION OF THE TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION ISSUE RESOLUTION BLUEPRINT—IM 20.01402.761.140

Dear Mr. Firth:

The purpose of this letter is to transmit the revised version of the Description of The Total System Performance Assessment And Integration Issue Resolution Blueprint, which was previously submitted to fulfill IM 20.01402.761.140. The original objective of the report was to document comments on Total System Performance Assessment and Integration Key Technical Issue arising from staff review of the Total System Performance Assessment–Site Recommendation, analysis and model reports, and process model reports. In addition, the report documents the prelicensing interaction process culminating in the development of DOE and NRC agreements on TSPAI. The following changes were incorporated into the report

- Comment OI 0.3.1 was renumbered to OI 0.3.15 and the DOE response and Agreement were revised to more accurately convey prelicensing interaction information.

- Presentations on the Overview of Total System Performance Assessment and Integration Meeting and Verification and Validation were added to Appendix B.

- Clarifications were added for those comments under the scenario analysis subissue lacking a DOE response. The DOE responses included in the report are reproductions of written responses provided in a table (referred to by the DOE as the delta table) and distributed during the May and August 2001 technical exchanges. In general, a DOE response in the delta table is not available because the comment was discussed at a previous technical exchange or the comment was more pertinent of the model abstraction subissue.

- It is stated that comments pertaining to Demonstration of Compliance with the Postclosure Public Health and Environmental Standards Subissue were mainly aimed at the Demonstration of Compliance with the Postclosure Individual Protection Standard. A limited number of comments were aimed at Demonstration of Compliance with the Human Intrusion Standard and

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no comments were aimed at Analysis of Repository Performance that Demonstrates Compliance with Separate Ground-Water Protection Standards, because 10 CFR Part 63 was not in final form during the August 2001 technical exchange.

- It is mentioned that the Yucca Mountain Review Plan was released after the publication of 10 CFR Part 63 and after the completion of the TSPAI technical exchanges.

- Minor editorial and typographical errors were corrected.

If you have any technical or programmatic questions about the content of the review report, please contact Osvaldo Pensado at (210) 522-6084 or me at (210) 522-5082.

Sincerely yours,

Sitakanta Mohanty for

Gordon W. Wittmeyer, Ph.D.
Manager, Performance Assessment

GW/cw

cc:
J. Linehan
B. Meehan
D. DeMarco
E. Whitt
J. Greeves
W. Reamer
L. Kokajko
A. Campbell
J. Peckenpaugh
C. McKenney
T. McCartin
R. Johnson
D. Esh
R. Codell
C. Grossman
J. Danna
M. Thaggard
W. Patrick
CNWRA Directors
CNWRA Element Managers
T. Nagy (SwRI Contracts)
P. Maldonaldo
O. Pensado
S. Mohanty

DESCRIPTION OF THE TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION ISSUE RESOLUTION BLUEPRINT

Prepared for

U.S. Nuclear Regulatory Commission
Contract NRC–02–97–009

Prepared by

S. Mayer
S. Mohanty
O. Pensado

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

January 2003

1 INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) and its contractor, the Center for Nuclear Waste Regulatory Analyses (CNWRA), are involved in prelicensing consultations with the U.S. Department of Energy (DOE). Such consultations are called for in the Nuclear Waste Policy Act of 1982 and have the objective that any license application prepared by DOE will be of high quality and complete. An agreement was also reached in 1992 between the DOE and the NRC that staff-level resolution can be achieved on any potential issue during prelicensing consultation. Staff-level issue resolution is intended to assure that sufficient information is available to enable the NRC to docket a license application.[1] During prelicensing, issue resolution at the staff level is achieved when the staff have no further questions or comments regarding how the DOE is addressing an issue.

For issue resolution, the NRC and CNWRA staffs review the DOE documents, perform independent experiments and confirmatory calculations, and document issues based on the current understanding of the site characteristics, waste form characteristics, design data, and modeling and analysis approaches. The results of the review efforts are then provided to the DOE periodically during technical exchanges.

The DOE and NRC have engaged in several rounds of prelicensing interactions on the total system performance assessment process, including interactions associated with the 1995 DOE Total System Performance Assessment (CRWMS M&O, 1995) and Total System Performance Assessment–Viability Assessment (DOE, 1998). The NRC and the CNWRA prepared numerous written comments on these two total system performance assessment processes, and presented the findings to the DOE. The Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a,b), which is the latest total system performance assessment conducted by the DOE in support of a site suitability decision, provides the NRC and CNWRA staffs with a rich resource of new information to be used in the prelicensing interactions.

Appendix A, documents all Total System Performance Assessment and Integration Key Technical Issue comments generated by the NRC and CNWRA staffs from the review of Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a) and its supporting documents. To facilitate prelicensing interactions, comments generated during the review were first compiled in the form of WordPerfect® tables. This compilation of comments is referred to as the blueprint; Appendix A is an organized version of the original blueprint.

The comments presented in this document were discussed with the DOE during a series of technical exchanges. The first technical exchange, held May 15–17, 2001,[2] focused on the Scenario Analysis Subissue and, in particular, on the screening of features, events, and processes for total system performance assessment. The second technical exchange, held August 6–10,

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[1]Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review.

[2]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration-Features, Events, and Processes (May 15–17, 2001)." Letter (May 30) to S.J. Brocoum, DOE. Washington, DC: NRC. 2001

2001,[3] focused on the remaining portions of the Scenario Analysis Subissue and the remaining subissues within the Total System Performance Assessment and Integration Key Technical Issue. Additional comments were also discussed at the Igneous Activity Technical Exchange on September 5, 2001.[4]

In the following sections, the review approach and the documentation of the review findings are described. Section 2 describes the scope of the review. Section 3 describes how the review was conducted in a risk-informed manner. Section 4 describes and documents review findings. Conclusions and the path forward are presented in Section 5. Appendix A contains the comments discussed during the various technical exchanges. Appendix B includes the summary highlights of the Total System Performance Assessment and Integration Technical Exchange[5] and NRC presentations delivered at this technical exchange intended to clarify technical aspects of specific NRC comments.

2 SCOPE OF REVIEW

The scope of the review is limited to the information available prior to the release of the Science and Engineering Report (DOE, 2001). The review is not based on a complete and thorough reading of all available documents, but rather a limited, focused, risk-informed review of selected portions of DOE documents that support the Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a). These documents include analysis and model reports, process model reports, the Repository Safety Strategy (CRWMS M&O, 2000c), the Total System Performance Assessment–Site Recommendation Technical Document (CRWMS M&O, 2000a), and the Total System Performance Assessment–Site Recommendation Model Report (CRWMS M&O, 2000b).

The focus of the review is specifically guided by the objective of resolving subissues. The NRC developed three categories to present the status of resolution. Subissues are closed if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decisionmaking at the time of any initial license application. Subissues are closed-pending if the NRC staff have confidence that the DOE proposed approach and agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably address the NRC questions such that no information beyond that provided or agreed to will likely be required at the time of the initial license application. Subissues are open if the NRC has identified questions regarding the DOE approach or information and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application. For transparency and to

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[3]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S.J. Brocoum, DOE. Washington, DC: NRC. 2001.

[4]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (September 5, 2001)." Letter (September 12) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

[5]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S.J. Brocoum, DOE. Washington, DC: NRC. 2001.

facilitate prelicensing interactions the NRC and CNWRA staffs prepared specific comments (i.e., questions or concerns) under each subissue and presented them to the DOE. Staff questions range from transparency and traceability (i.e., gaining clarification) to questions addressing technical aspects of models and supporting data.

The review findings were classified in the four Total System Performance Assessment and Integration Key Technical Issue Subissues: (i) System Description and Demonstration of Multiple Barriers, (ii) Scenario Analysis, (iii) Model Abstraction, and (iv) Demonstration of Compliance with the Postclosure Public Health and Environmental Standards. The review findings in each subissue were also mapped to the Yucca Mountain Review Plan—Draft Report for Comment (NRC, 2002) individual acceptance criteria that provide a transparent and consistent measure for the review of data, design detail, and analyses in DOE documents. Note that the Yucca Mountain Review Plan was updated after the publication of final regulations in 10 CFR Part 63 (NRC, 2001), and consequently, subsequent to comments and responses documented in this report. The following is a summary of the review areas.

Comments on multiple barriers addressed the system of natural and engineered barriers that would provide isolation of waste. Comments were written for three major aspects of multiple barriers: (i) identification of barriers, (ii) description of barrier capabilities to isolate waste, and (iii) the technical basis for barrier capabilities. The comments do not include the evaluation of the demonstration of multiple barriers by the DOE because final regulations in 10 CFR Part 63 (NRC, 2001) were released after the completion of the Total System Performance Assessment and Integration Technical Exchange.[6]

Comments generated from the review-of-scenario analysis included the DOE identification, screening, and construction of scenarios from features, events, and processes relevant to the Yucca Mountain site. The review addressed the manner in which the DOE addressed the full range of features, events, and processes and if additional data or analyses are needed to support screening arguments.

Comments on model abstraction addressed the 14 integrated subissues and relate to those aspects of the engineered, geosphere, and biosphere subsystems shown to be most important to performance. The 14 integrated subissues (and a symbol to refer to the subissue) are

- Degradation of Engineered Barriers, ENG 1
- Mechanical Disruption of Engineered Barriers, ENG 2
- Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms, ENG 3
- Radionuclide Release Rates and Solubility Limits, ENG 4
- Climate and Infiltration, UZ 1
- Flow Paths in the Unsaturated Zone, UZ 2
- Radionuclide Transport in the Unsaturated Zone, UZ 3
- Flow Paths in the Saturated Zone, UZ 4
- Radionuclide Transport in the Saturated Zone, SZ 1
- Volcanic Disruption of Waste Packages, SZ 2

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[6]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S.J. Brocoum, DOE. Washington, DC: NRC. 2001.

- Airborne Transport of Radionuclides, SZ 3
- Dilution of Radionuclides in Groundwater Due to Well Pumping, DOSE 1
- Redistribution of Radionuclides in Soil, DOSE 2
- Reasonably Maximally Exposed Individual Lifestyle and Reference Biosphere, DOSE 3

The review concentrated on if the DOE has adequately addressed all five of the generic acceptance criteria specified in the Yucca Mountain Review Plan—Draft Report for Comment (NRC, 2002). The five generic acceptance criteria include (i) data and model justification, (ii) data uncertainties, (iii) model uncertainties, (iv) model support, and (v) integration.

Comments on the Demonstration of Compliance with the Postclosure Public Health and Environmental Standards Subissue were mainly aimed at the evaluation of Demonstration of Compliance with the Postclosure Individual Protection Standard. Comments involved evaluating the adequacy, appropriateness, and acceptability of the (i) scenarios considered in the calculation of the expected annual dose, (ii) methods the DOE will use to demonstrate that the annual dose to the reasonably maximally exposed individual in any year during the compliance period will not exceed the exposure standard, and (iii) the DOE total system performance assessment is providing a credible representation of repository performance. Demonstration of Compliance with the Human Intrusion Standard received limited discussion during prelicensing issue resolution. On the other hand, Analysis of Repository Performance that Demonstrates Compliance with Separate Ground-Water Protection Standards received no discussion. The reason is that regulations pertaining to these two areas were in the process to be finalized in 10 CFR Part 63 (NRC, 2001), to comply with anticipated requirements in 40 CFR Part 197 (Environmental Protection Agency, 2001). In general, compliance with the proposed standards in 10 CFR Part 63 was not considered during prelicensing issue resolution, but only the methodology for evaluating the Demonstration of Compliance with the Postclosure Public Health and Environmental Standards.

Consideration of the DOE quality assurance procedure was not part of the DOE total system performance assessment process review. Comments were prepared, however, on model validation, software verification, and technical errors or inconsistencies. References were also made to the DOE Corrective Action Reports, which had already identified deficiencies in the implementation of quality assurance procedures for validation and verification. The NRC and CNWRA staffs found technical errors and inconsistencies between the Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a) reports and the analysis and model reports, computer codes, and hand calculations. Although these findings are documented in this report in a generic sense, a letter from the NRC to the DOE[7] covers the full scope of the findings.

3 RISK-INFORMED REVIEW

Consistent with the risk-informed approach employed in 10 CFR Part 63 (NRC, 2001), the review focused on those aspects of the repository system and the DOE analyses that are most important to safety. To risk inform their reviews, NRC and CNWRA staff

- Identified the major components of the DOE safety case

[7] Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Conference Call Regarding Quality Assurance and Performance Assessment Issues." Letter (May 17) to S.J. Brocoum, DOE. Washington, DC: NRC. 2001.

- Identified important scenarios
- Determined the principal barriers considered for demonstrating multiple barriers
- Considered the importance of conceptual model uncertainty within the abstraction
- Identified and evaluated the importance of major assumptions
- Identified the importance of conceptual model uncertainty
- Evaluated the importance of coupled processes
- Identified the important parameters and models controlling system behavior
- Evaluated the importance of correlations between parameters.

Staff efforts to risk inform the review also recognized the timing of available information. Technical information on specific components of the DOE analyses was available in the form of analysis and model reports before the DOE completed its total system performance assessment for the current repository design and before the DOE completed the Repository Safety Strategy (CRWMS M&O, 2000c). Information was also available to the staff at the Appendix 7 meetings; DOE and NRC technical exchanges, including the January 2001 Technical Exchange on the Total System Performance Assessment–Site Recommendation;[8] and audit observation of the DOE audit of technical activities. The staff reviewed the available technical information that addressed previous staff concerns and new risk-significant information. The staff refined their review comments when the Total System Performance Assessment–Site Recommendation [i.e., technical document (CRWMS M&O, 2000a) and model report (CRWMS M&O, 2000b)] and the DOE Repository Safety Strategy (CRWMS M&O, 2000c) became available.

The staff conducted a few bounding calculations and total system performance assessments using the NRC Total-system Performance Assessment (TPA) code and confirmatory analyses using process-level models; however, in-depth, detailed analyses were limited. The NRC TPA code was used to risk inform the review. In the review, the emphasis was on the DOE total system performance assessment process. Therefore, the staff reviewed the information provided by the DOE that led to risk insights. Independent NRC calculations using the NRC TPA code (Mohanty and McCartin, 1998) were used to complement the risk insights gained by reviewing the DOE analyses. The staff also used the risk insights already gained from the NRC and CNWRA sensitivity and uncertainty analyses (Mohanty, et al., 1999) to risk inform the review on the relative importance of model abstractions, conceptual model uncertainty, major assumptions, coupled processes, parameters (e.g., data range and distribution type), and parameter correlations. In addition, the NRC TPA code results were used to help understand the results of the DOE Total System Performance Assessment–Site Recommendation (CRWMS M&O, 2000a,b). The staff also used other codes, such as MULTIFLO (Lichtner, et al., 2000), to conduct analyses to verify questions raised on the DOE total system performance assessment process. In-depth, detailed calculations, however, were limited to only a few applications.

4 DOCUMENTATION OF REVIEW FINDINGS

Appendix A contains all staff comments presented at the previously mentioned Subissue Resolution Technical Exchanges. The principal outcome of these technical exchanges was the

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[8]Chan, K. "Forthcoming U.S. Nuclear Regulatory Commission and U.S. Department of Energy Technical Exchange on Total System Performance Assessment - Site Recommendation." Memorandum (January 10, 2001) to C.W. Reamer, NRC, transmitting agenda of subject technical exchange on January 23, 2001. Washington, DC: NRC. 2001.

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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

MEMORANDUM

December 31, 2002

TO: QA Records Corrective Action Requests (CARs) 2002-03 and 2002-04 Folder

FROM: Bruce Mabrito, Director of Quality Assurance

SUBJECT: Extension of Time for Closure on CARs 2002-03 and 2002-04

REFERENCE: CARs 2002-03 and 2002-04

This memorandum to the CAR 2002-03 and CAR 2002-04 folders is to document progress to date on these Corrective Action Requests.

CAR 2002-03 and CAR 2002-04 were originated July 30, 2002 at the conclusion of the 2002 annual CNWRA QA Audit. Remedial actions and corrective actions to preclude recurrence have taken place since that time.

Pertaining to CAR 2002-03, a revised version of the description of The Total System Performance Assessment and Integration Issue Resolution Blueprint (IM 20.01402.761.140) will be submitted to the NRC in early calendar year 2003.

Work continues on the closure of CAR 2002-04. Reports containing calculations submitted in FY2002 were identified in the QA Records Room and returned to the cognizant Element Managers for additional review. The reviews on these reports are approximately 90-percent complete and the entire effort to support closure of the CAR should be finished by the end of February 2003.

The cognizant Element Managers have asked for additional time to complete their deliverables to the NRC in order to fulfill all the corrective actions to close these CARs.

Based on discussions I have held with the Element Managers and the Technical Director, I am extending the time to complete the corrective actions to February 28, 2003.

cc: M. Ehnstrom
T. Mayces
R. Folck
G. Wittmeyer
J. Russell

CNWRA ***A center of excellence in earth sciences and engineering***

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February 21, 2003
Contract No. NRC–02–02–002
Account No. 20.06002.01.111

U.S. Nuclear Regulatory Commission
ATTN: Mr. James Firth
Office of Nuclear Material Safety and Safeguards
Division of Waste Management
Performance Assessment and High-Level Waste Integration Branch
Mail Stop 7C–18
Washington, DC 20555

Subject: TRANSMITTAL OF CORRECTION TO THE REVISED VERSION OF DESCRIPTION OF THE TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION ISSUE RESOLUTION BLUEPRINT — IM 20.01402.761.140

Dear Mr. Firth:

The purpose of this letter is to transmit the corrected revised version of the "Description of The Total System Performance Assessment And Integration Issue Resolution Blueprint," which was previously submitted to fulfill IM 20.01402.761.140, and then re-submitted as a revised version on December 31, 2002. As was noted in your letter of January 24, 2003, one change that you had requested in your April 22, 2002 letter was not correctly made. In response to your request, three specific corrections were made to Technical Exchange Tracking Number: J-O4.1 in the blueprint database to provide a more accurate portrayal of the NRC's original comment.

If you have any technical or programmatic questions about the content of the review report, please contact Osvaldo Pensado at (210) 522-6084 or me at (210) 522-5082.

Sincerely yours,

Gordon W. Wittmeyer, Ph.D.
Manager, Performance Assessment

GW/rm

cc: J. Linehan, W. Reamer, B. Meehan, L. Kokajko, D. DeMarco, A. Campbell, E. Whitt, J. Peckenpaugh, J. Greeves, C. McKenney, T. McCartin, R. Johnson, D. Esh, R. Codell, C. Grossman, J. Danna, M. Thaggard, W. Patrick, CNWRA Directors, CNWRA Element Managers, T. Nagy (SwRI Contracts), P. Maldonaldo, O. Pensado, S. Mohanty

Washington Office • Twinbrook Metro Plaza #210
12300 Twinbrook Parkway • Rockville, Maryland 20852-1606

3/13/03

Bruce,

The attached pages are highlighted to indicate changes in response to RSSR CAR from FY2002.

Main changes

— added references to NRC communications/direction throughout

— added more detailed explanations in Appendix A, with many new references and changed heading in Appendix A tables to read "Assumptions" rather than "Rationale." Use of the word rationale was overstating what was provided in the tables (i.e. level of detail and support).

ANALYSIS OF EXPOSURE SCENARIOS ASSOCIATED WITH REUSED SOIL

— Tables 3-2, 3-3, 3-5, 3-6 added to report to specify additional assumptions and direction provided by NRC.

Prepared for

U.S. Nuclear Regulatory Commission
Contract NRC–02–97–001

Let me know if you need additional documentation.

Thanks,
–Mike

Prepared by

M. Smith
I. Chichkov
L. Howard
O. Povetko
J. Weldy

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

March 2003

ABSTRACT

This report documents analyses performed to determine the potential dose for a limited number of exposure scenarios from reused soil using a unit concentration of radionuclides. The scenarios include an agricultural worker, a truck operator, a landscaper, a child in a playground, and a rural resident. Other exposure scenarios are possible, but these scenarios were selected to assist the U.S. Nuclear Regulatory Commission (NRC) staff in assessing the impacts from soils originating from NRC- or NRC Agreement State-licensed facilities. Moreover, the NRC staff want this study to be comparable to other NRC studies about the potential impacts from materials that may be reintroduced into commerce or disposed of in alternative fashions (e.g., landfills). These studies include research performed by the Interagency Steering Committee on Radiation Standards Sewage Sludge and Ash Modeling Group. The study documented in this letter report has been coordinated with the Interagency Steering Committee on Radiation Standards.

Probabilistic calculations were performed using the RESRAD Version 6.1 code (Yu, et al., 2001), and deterministic calculations were performed using spreadsheets and the MCNP Version 4A code (Los Alamos National Laboratory, 1995). Probabilistic analyses of the exposure scenarios allow uncertainty to be considered in the calculations by specifying distributions for uncertain input. The mean results of these analyses were compared to determine the most limiting scenario for each of the 20 radionuclides considered.[1] These analyses did not identify any single exposure scenario that was bounding for all radionuclides considered. In these analyses, the landscaper exposure resulted in the limiting dose for 22 radionuclides, the rural resident exposure for 14 radionuclides, and the playground exposure for 3 radionuclides. The agricultural worker and truck operator exposures were not limiting for any radionuclides.

The results of these analyses may be used to direct more detailed dose assessments related to soils containing residual radioactivity originating from NRC- or NRC Agreement State-licensed facilities. These analyses identify specific pathways and parameters that may contribute significantly to dose. Additional work can be focused on those significant pathways and parameter distributions.

REFERENCES

Los Alamos National Laboratory. "MCNP 4A, Monte Carlo N-Particle Transport System. RSIC Computer Code Collection." CCC–200. Los Alamos, New Mexico: Los Alamos National Laboratory. 1995.

Yu, C., A.J. Zielen, J.-J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W.A. Williams, and H. Peterson. "User's Manual for RESRAD Version 6." ANL/EAD–4. Argonne, Illinois: Argonne National Laboratory. 2001.

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[1]Multiple isotopic mixtures of certain radionuclides were included and resulted in the analyses considering a total of 39 radionuclides and mixtures.

ACKNOWLEDGMENTS

This report was prepared to document work performed by the Center for Nuclear Waste Regulatory Analyses (CNWRA) for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. NRC–02–97–001. The activities reported here were performed on behalf of the NRC Office of Nuclear Material Safety and Safeguards, Division of Waste Management. The report is an independent product of the CNWRA and does not necessarily reflect the views or regulatory position of the NRC.

The authors acknowledge invaluable support received from E. Brummett, F. Cardile, G. Gnugnoli, R. Hogan, A. Huffert, C. McKenney, R. Meck, T. Nicholson, and other NRC staff who helped formulate scenarios, identify references, and review precursors of this report.

The authors wish to thank R. Benke for his technical review and B. Sagar for his programmatic review of this report; their contributions led to improvements in the quality and readability of this report. Secretarial support provided by A. Ramos is appreciated as are the editorial reviews by C. Cudd, B. Long, and A. Woods.

QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

DATA: No CNWRA-generated original data were used in this report. Sources for the cited data should be consulted for determining the level of quality for those data. These data sources included the Interagency Steering Committee on Radiation Standards Sewage Sludge and Ash Modeling Group, RESRAD manuals, and NRC staff.

ANALYSES AND CODES: The computer codes RESRAD Version 6.1 (Yu, et al., 2001) and MCNP Version 4A (Los Alamos National Laboratory, 1995) were used to perform the analyses described in this report. These codes are controlled under the CNWRA quality assurance program. Microsoft® Excel was used to perform some calculations. All computer files are included in the quality assurance files associated with this report. Scientific Notebook Nos. 462E and 467 contain material relevant to this report.

REFERENCES

Los Alamos National Laboratory. "MCNP 4A, Monte Carlo N-Particle Transport System. RSIC Computer Code Collection." CCC–200. Los Alamos, New Mexico: Los Alamos National Laboratory. 1995.

Yu, C., A.J. Zielen, J.-J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W.A. Williams, and H. Peterson. "User's Manual for RESRAD Version 6." ANL/EAD–4. Argonne, Illinois: Argonne National Laboratory. 2001.

1 INTRODUCTION

1.1 Background

The U.S. Nuclear Regulatory Commission (NRC) has received requests from its licensees regarding the disposition of soils and other types of bulk materials (i.e., concrete, metal, and wood), which could be slightly contaminated by radionuclides handled by the licensee. Some of these materials may not be contaminated from activities related to the nuclear facility operations; however, they are still within the controlled area established by the license. Soil is the focus of this report. There are no generally applicable, national standards for the routine removal of soils and other materials from the controlled areas of nuclear facilities, irrespective of size or complexity.

Other radioactively contaminated materials resulting from activities associated with facilities using radioactive materials are already addressed by existing federal and state regulations and are not within the scope in this report.

Although no generally applicable standards exist currently in this area, licensee requests for such removals, either as a provision of their existing licenses or as case-specific proposals, are based on evaluations of the materials' characteristics, expected use, and ultimate disposition. In many cases, the materials in question have no intrinsic value and would normally be disposed of as trash in a solid waste landfill. If the source is a licensed nuclear facility; however, issues are raised that would otherwise not be germane. Some of these requests address materials that had no exposure to the nuclear facility operations and have no radioactive content beyond what would normally be expected in such materials in noncontrolled areas.

This report provides the computational approach used in calculating the doses resulting from a selected number of exposure scenarios in which members of the public could come into contact with soils removed from licensed nuclear facilities.

The soil material proposed for release generally has little or no additional radioactivity beyond natural background levels. Furthermore, this material would be surveyed, prior to its removal from the NRC-licensed[1] site, to assure regulated materials are not improperly removed from the facility.

1.2 Purpose of the Current Scenario Assessment

As input to NRC decisionmaking, it is useful to have estimates for potential doses if licensees seek to remove solid materials from NRC-licensed facilities. This report focuses on soil. For example, licensees may seek to have excess soil removed from their facilities because of construction or regrading. This report evaluates the potential doses to members of the public from soils that originate from the controlled areas of NRC-licensed facilities.

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[1]In this document, "NRC-licensed" includes those sites or facilities that may be regulated by NRC Agreement States, which have authority relinquished by the NRC according to provisions of the Atomic Energy Act (Section 274, as amended in 1959).

As a first step in this effort, the U.S. Department of Agriculture National Agricultural Library examined potential soil reuse scenarios and issued a draft report for public comment on July 19, 2000. The final report was recently published as "NUREG–1725 Human Interaction with Reused Soil: A Literature Search" (NRC, 2002). Building on information developed in NUREG–1725, the Center for Nuclear Waste Regulatory Analyses was tasked to perform calculations for several scenarios to assess exposures that could result if soil were removed from NRC-licensed facilities and reused. The report also incorporates scenario developmental work performed by the Interagency Steering Committee on Radiation Standards Sewage, Sludge, and Ash Modeling Group.[2]

The results of this report may be used to prioritize work to refine calculations and parameter values for the most significant scenarios. These analyses have not considered all potential exposure scenarios. For scenarios having multiple and complex pathways (e.g., involving groundwater transport), more powerful, computer-based tools may be needed to establish an adequate technical basis for decisionmaking.

These techniques can be applied in the NRC staff review of licensee requests for disposal of radioactively contaminated soils in compliance with 10 CFR 20.2002.

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[2]See www.iscors.org/Dose-Modeling-Report-Draft-2001-web.pdf.

2 GENERAL APPROACH TO ASSESSMENT

2.1 Isotopes of Interest

For these dose-to-source ratio calculations, a limited set of radionuclides, considered common at U.S. Nuclear Regulatory Commission-licensed facilities, has been selected. For example, Co-60, Cs-137, and Sr-90 were chosen because they may be found at nuclear power plants, and C-14 and I-125 were chosen because they may be associated with medical facilities. This limited set includes radionuclides with a wide variety of decay and transport characteristics:

- Radionuclides that are alpha-, beta-, and gamma-emitters
- Radionuclides that are relatively mobile in the environment
- Radionuclides that sorb strongly to soil
- Radionuclides with short and long half-lives

The set of radionuclides used in the calculations is representative of radionuclides that may be associated with licensed nuclear facilities, and the conclusions about the more important scenarios should not change significantly by the consideration of other radionuclides. The radionuclides for which dose-to-source ratios (discussed further in Section 2.2) were calculated are listed in Table 2-1.

For these calculations, it is not possible to define a time period for the decay progeny to build up to an equilibrium concentration. The soil may have been contaminated many years before removal from the site, allowing the radionuclides in a decay series to reach equilibrium, or the soil may have been contaminated shortly before leaving the site. Additionally, some radionuclides may or may not be separated from their progeny. To attempt to account for this uncertainty for radionuclides that have radioactive decay progeny, which through time will build up to an equilibrium concentration with the parent radionuclide, two dose calculations were performed.

The first calculation assumed that the radionuclide is initially pure when the soil is reused (i.e., no progeny are present at the beginning of the dose assessment). Calculations performed in the dose assessment account for build up of progeny in the soil through time, but depending on the half-lives of the progeny, the progeny may not provide a significant contribution to dose during the 1,000 years for which the dose calculations were performed. The second calculation assumes all members of a radionuclide's decay chain are in secular equilibrium with the parent radionuclide.

The second calculation is performed only if the half-life of the progeny radionuclides is shorter than the parent radionuclide (a criterion for secular equilibrium) but greater than 30 days (making the time to reach equilibrium significant). Otherwise, the progeny are taken into account by using inhalation, ingestion, and direct exposure dose conversion factors that include these short-lived progeny.

These two analyses bound the two characteristic nodes for dose factors possible for radionuclides with radioactive progeny. Actual radionuclides in the released soil will have progeny present at a concentration between zero and equilibrium concentration, depending on if

sufficient time has passed to approach equilibrium conditions and on the half-lives of the progeny.

Table 2-1. Radionuclides Used for Reused Soil Scenario Analyses				
H-3	Ni-63	Cs-134	Th-232*	Enriched Uranium (3% U-235)
C-14	Sr-90	Cs-137	U-233*	Depleted Uranium (0.25% U-235)
S-35	Zr-95*	Eu-154	U-234*	Pu-238
Mn-54	Tc-99	Po-210	U-235*	Pu-239
Fe-55	I-125	Ra-226*	U-238*	Pu-241
Co-60	Sb-125*	Th-228	Natural Uranium*	Am-241
*Radionuclide includes separate calculation with decay chain in equilibrium with the parent.				

2.2 Unit Concentration Analysis

The results of these analyses are expressed as radionuclide-specific normalized dose conversion factors[1] that relate specific radionuclide concentrations to the dose to the average member of the critical group for the selected scenario. Hereafter, these normalized dose conversion factors are referred to as dose-to-source ratios. The dose-to-source ratios provide estimates of the radiation dose received by a member of the public during 1 year for a unit initial concentration of radioactivity measured in Bq/g [pCi/g] for the specified set of exposure parameters that make up the scenario. Because the dose-to-source ratios developed for the different scenarios are based on the same initial concentration of radionuclides, a comparison of the dose calculated for the different scenarios will identify the more significant scenarios that may need a detailed analysis. Doses to the receptor group exposed to the soil can be estimated by multiplying the concentration of a radionuclide in the soil by the derived dose-to-source-ratio. If multiple radionuclides are present in the released soil, dose contributions from the radionuclides present would have to be summed to compare the predicted dose from the soil to any applicable dose constraint.

[1]A normalized or unit dose conversion factor is the ratio of the dose to the soil concentration of the radionuclide generating it. This ratio has the effect of providing a factor by which any concentration in the soil can be evaluated by multiplying that concentration with the appropriate conversion factor to result in the equivalent dose from such an exposure to that radionuclide in the soil. This normalized dose is frequently referred to as a dose-to-source ratio.

3 DESCRIPTION OF SCENARIOS AND KEY INPUT PARAMETERS

Scenarios by which soil could be reused must be developed to estimate exposures if soil is removed from U.S. Nuclear Regulatory Commission (NRC)-licensed facilities. A subset of the potential exposure scenarios was selected for analysis in this report. The focus was to identify and analyze scenarios that were different from those analyzed in parallel work performed by other groups, including the NRC, the interagency group analyzing the release of sewage sludge, and the group analyzing the release of metals and concrete (NRC, 1999).

The scenarios identified for these analyses were associated with the reuse of soil that may be removed from NRC-licensed facilities. The first scenario calculates the dose to agricultural workers who work on land where reused soil has been applied. The second scenario determines the dose to a truck operator who transports the reusable soil between the source and the application locations and helps to load and unload the soil. The third scenario determines the dose to a landscaper who works closely with the soil for extended periods. The fourth scenario is a child who plays in a playground that has a top layer of soil composed of reused soil. The final scenario is a rural resident with a home built on reused soil. The doses from the various scenarios were calculated based on unit concentrations of radionuclides in dry soil measured in Bq/g [pCi/g].[1]

Radionuclides with radioactive decay progeny were modeled in two calculations, one assuming the radionuclide of interest in the soil has undergone no radioactive progeny ingrowth at the time of release and the other assuming radioactive decay products were in secular equilibrium with the parent radionuclide. These two calculations show how important the buildup of decay products is to the results of the analysis. Tabular results presented in Chapter 5 use a "D" notation following radionuclide names to indicate when calculations start with decay progeny in secular equilibrium. The magnitude of the increase in the dose-to-source ratio by including decay progeny at secular equilibrium varies by radionuclide and scenario, ranging from no change for Sb-125 in the truck operator scenario to greater than three orders of magnitude for U-234 in the rural resident scenario.

3.1 Agricultural Worker

This section describes initial efforts to determine the potential impact to agricultural workers from a field with a surface layer of soil originating from an NRC-licensed facility. The analyses were performed using RESRAD Version 6.1 code (Yu, et al., 2001) with input parameter values provided by the NRC staff and other sources, as cited in this report.

3.1.1 Description of Scenario

Agricultural workers were identified as a group that could receive a dose from reused soil originating from an NRC-licensed facility. Because these individuals spend their working hours in a field that could contain soil removed from an NRC-licensed facility, these individuals would spend a significant amount of time potentially exposed to such soils. In this scenario, it is

[1]Dry soil is used as the basis to avoid any possible confusion about the water content of the soil.

assumed that the farm received several truckloads of soil from an NRC-licensed facility and applied the released soil to fields in the initial year of the dose assessment. It is assumed that the workers spend all their working hours in the affected fields and leave the site during nonworking hours. Workers are exposed directly to external radiation emitted from radionuclides in the released soil, as well as internally from the inhalation and inadvertent ingestion of associated dust. Additionally, workers are assumed to obtain a fraction of their drinking water, plants, meat, and milk from local sources impacted by the reused soil. Separate calculations were performed, one assuming the worker drinks water from a groundwater source and another assuming the worker drinks water from a surface water source. A summary of the exposure pathways is contained in Table 3-1. It should be noted that the contribution from the groundwater pathway to the dose-to-source ratio may be delayed, while the contribution from other pathways is more immediate. For these analyses, soil application is assumed to occur only during the first year. The peak dose-to-source ratio for all radionuclides in this scenario occurs during the first year, so little contribution is noted from the groundwater pathway. For cases with ongoing soil application (several years), higher dose-to-source ratios might be expected with the contribution of the groundwater pathway resulting from previous soil applications being added to the more immediate contribution by the other pathways resulting from the most recent soil application.

3.1.2 Key Input Parameters

In this scenario, the source field was covered with released soil during the initial year of the assessment. For this analysis, it is assumed that five truckloads of material were deposited to a thickness of 15 cm [5.9 in] on the field. The five truckloads vary in size from 5 m^3 [177 ft^3] to 400 m^3 [14,000 ft^3], with a discrete probability distribution function defined as being equally probable that the volume is 5 m^3 [180 ft^3], 10 m^3 [350 ft^3], 100 m^3 [3,500 ft^3], 200 m^3 [7,100 ft^3] , 300 m^3 [11,000 ft^3], or 400 m^3 [14,000 ft^3]. The larger volumes were included to ensure that larger areas would be analyzed. This deposit is assumed to be spread uniformly across an area, calculated from the volume of soil and depth of application, between 167 m^2 [1,800 ft^2] and 13,333 m^2 [140,000 ft^2].[2] As indicated previously, the analysis was based on a unit concentration for each radionuclide measured in Bq/g [pCi/g] of dry soil. Other parameters derived from the application area size, such as the length of the affected area parallel to groundwater flow and the dimensions of the affected zone, assumed a circular area of application.

The workers are assumed to work a regular schedule at the same farm location throughout the year, for a total of 2,000 hours/year. It is assumed their entire work schedule is spent on the area of affected soil and that they obtain some food and water from local sources. Specifically, workers are assumed to get 50-percent water intake from a well that pumps water from groundwater that can receive leachate from the applied soil, and the 25-percent food intake, including plants, milk, and animals, comes from locally raised, similarly affected sources. It is assumed all plants grown onsite are raised in the affected soil and irrigated with groundwater that may contain radionuclides leached from that soil. This groundwater is also assumed to be used for consumption by any farm livestock. The workers are assumed to inadvertently ingest 100 mg [2.2×10^{-4} lb] of the subject soil during each 8-hour working day.

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[2]The range corresponds to the range of truck haulage capacities.

<table>
<tr><th colspan="5">Table 3-1. Environmental and Exposure Pathways for the Agricultural Worker Scenario</th></tr>
<tr><th colspan="5">Agricultural Worker (e.g., Field Laborers Using Hand Implements) Pathway</th></tr>
<tr><th>Exposure Pathway</th><th colspan="2">Environmental Pathway/Subpathway</th><th>Pathway Included?</th><th>Description</th></tr>
<tr><td>External Radiation</td><td colspan="2">Direct exposure from ground</td><td>Yes</td><td>Agricultural field, 15-cm [5.9-in] depth of distribution</td></tr>
<tr><td rowspan="3">Inhalation</td><td colspan="2">Resuspended dust</td><td>Yes</td><td>Resuspended dust in air</td></tr>
<tr><td colspan="2">Indoor radon</td><td>No</td><td>—</td></tr>
<tr><td colspan="2">Outdoor radon</td><td>Yes</td><td>Radon emanates from reused soil and water</td></tr>
<tr><td rowspan="2">Ingestion—Water</td><td colspan="2">Groundwater</td><td>Yes</td><td>50% ingested water from well; dilution of well water by unaffected aquifer</td></tr>
<tr><td colspan="2">Surface water (runoff)</td><td>Yes</td><td>Surface water runoff from affected field areas</td></tr>
<tr><td rowspan="2">Ingestion—Plants</td><td colspan="2">Irrigation water</td><td>Yes</td><td>100% irrigation water from well</td></tr>
<tr><td colspan="2">Soil</td><td>Yes</td><td>Includes foliar and root uptake</td></tr>
<tr><td rowspan="4">Ingestion—Meat/Milk</td><td colspan="2">Livestock water</td><td>Yes</td><td>100% water from well</td></tr>
<tr><td rowspan="2">Fodder</td><td>Irrigation water</td><td>Yes</td><td>100% water from well</td></tr>
<tr><td>Soil</td><td>Yes</td><td>Animal products from livestock eating fodder having foliar and root uptake</td></tr>
<tr><td colspan="2">Soil</td><td>Yes</td><td>Animal products from livestock eating reused soil on fodder and in water</td></tr>
<tr><td>Ingestion—Fish</td><td colspan="2">Surface water (through runoff, groundwater, or both)</td><td>Yes</td><td>Affected by surface water runoff</td></tr>
<tr><td>Ingestion—Soil</td><td colspan="2">Inadvertent ingestion of soil</td><td>Yes</td><td>Inadvertent ingestion of soil particles resuspended in air</td></tr>
</table>

Most default parameter values in the RESRAD Version 6.1 code were used because the analysis is generic for soil reuse throughout the United States. A list of the parameter values that were changed from their default values is provided in Appendix A. For example, it was determined that the default distribution assigned for the mass loading of soil in the air was not appropriate for modeling this scenario. Because the inhalation pathway contributes a relatively small fraction (<8 percent) of the total dose for any particular radionuclide in this scenario, these minor differences in the mass loading value will not have a significant effect on the total dose. Further discussion of this modification is provided in Appendix B.

3.2 Truck Operator

This section describes initial efforts to determine the potential impact to truck operators when loading, unloading, and transporting soil removed from NRC-licensed facilities. The analyses were performed using the MCNP Version 4A code (Los Alamos National Laboratory, 1995) and calculations in a Microsoft® Excel spreadsheet with appropriate exposure parameter values, as cited in this report.

3.2.1 Description of Scenario

The receptor group for this scenario is defined as a group of truck operators that transport soil removed from NRC-licensed facilities throughout the year. The basic assumptions of the truck operator scenario are that the same truck is used to haul soil, and it is operated by the same driver on a full-time basis during an entire year (2,000 hours/year). Four different truck types were considered in the analyses: pickup truck, light/medium truck, standard dump truck, and heavy dump truck. Basic truck and operator occupational parameters are presented in Tables 3-2 and 3-3. Exposure pathways for an operator are direct exposure (from soil in the truck bed) while inside the cab and direct exposure, inhalation, and ingestion (i.e., inadvertent ingestion of the transported soil) while outside the truck. Although the driver could also be exposed through the inhalation of radon while outdoors, this (not while driving) pathway was not included in this exposure scenario because the results of the agricultural worker scenario show that the radon pathway contributed a negligible amount to the total dose for outdoor exposure. A summary of the exposure pathways for the truck operator scenario is listed in Table 3-4. The source term for the truck operator is defined as a volume source (soil in the truck) while the operator is inside the cab, and, while outside the truck, it is defined as contaminated soil resuspended in the air in addition to the volume source and reused soil layer spread on the ground. Dose analyses were performed using the MCNP Version 4A code to estimate the external deep dose equivalent caused by exposure to the volume source during the first year of work with the released soil {having unit initial specific activity measured in Bq/g [pCi/g] for parent radionuclides and for each component in mixtures of parent and decay progeny}. Spreadsheet calculations were used to estimate committed effective dose equivalents resulting from the intake of radionuclides through inhalation and ingestion and from direct exposure to the soil spread on the ground with 15-cm [5.9-in] thickness. Dose conversion factors from Oak Ridge National Laboratory (1988) were used in spreadsheet calculations. Reduction of the initial activity caused by radioactive decay was taken into account (decay was averaged for the first year of work).

Table 3-2. Truck Parameters for the Truck Operator Scenario*†				
	Truck Operator Scenario Truck Types			
Parameter	**Type 1 (Pickup Truck)**	**Type 2 (Light/Medium Truck)**	**Type 3 (Standard Dump Truck)**	**Type 4 (Heavy Dump Truck)**
Cargo box length	2.0 m [6.5 ft]	2.4 m [8.0 ft]	3.0 m [10.0 ft]	5.2 m [17.0 ft]
Cargo box width	1.532 m [5.025 ft]	1.8 m [6.0 ft]	2.1 m [7.0 ft]	2.1 m [7.0 ft]
Height of soil in cargo box front "shining plane"‡	0.37 m [1.2 ft]	0.76 m [2.5 ft]	0.91 m [3.0 ft]	1.2 m [4.0 ft]
Cargo box wall thickness	0.089 mm [0.0035 in]	0.476 mm [0.0187 in]	0.476 mm [0.0187 in]	0.476 mm [0.0187 in]
Volume of soil in cargo box	1.3070 m^3 [46.157 ft^3]	3.7546 m^3 [132.59 ft^3]	6.2251 m^3 [219.84 ft^3]	15.357 m^3 [542.34 ft^3]
Mass of soil in cargo box	2,091 kg [4,610 lb]	6,007 kg [13,243 lb]	9,960 kg [21,958 lb]	24,571 kg [54,169 lb]
Sphere cab diameter	80.0 cm [31.5 in]	80.0 cm [31.5 in]	100.0 cm [39.4 in]	100.0 cm [39.4 in]
Sphere cab wall thickness	0.089 mm [0.0035 in]	0.089 mm [0.0035 in]	0.089 mm [0.0035 in]	0.089 mm [0.0035 in]
Position of operator in cab	Shifted 30 cm [11.8 in] down and 5.02 cm [1.98 in] back from cab center toward cargo box	Center of cab	Center of cab	Center of cab
Distance from center of modeled operator to "shining plane"‡	30.4 cm [12.0 in]	81.476 cm [32.077 in]	101.476 cm [39.951 in]	101.484 cm [39.95 in]

*Philip, J. and T. Nicholson. Geometry parameters for different truck types are based on personal communications (May) to G. Gnugnoli (NRC). Washington, DC: NRC. 2001.
†Philip, J. and T. Nicholson. Soil density and geometry are based on personal communications (May) to G. Gnugnoli (NRC). Washington, DC: NRC. 2001.
‡Front plane surface of the hauled soil closest to the receptor.

Table 3-3. Occupational Parameters for the Truck Operator Scenario*†				
	Truck Operator Scenario Truck Types			
Parameter	**Type 1 (Pickup Truck)**	**Type 2 (Light/Medium Truck)**	**Type 3 (Standard Dump Truck)**	**Type 4 (Heavy Dump Truck)**
Fraction of work time truck operator is driving and externally irradiated	0.25	0.25	0.25	0.45
Fraction of work time truck operator is externally irradiated and inhaling/ingesting soil dust while standing on reused soil and loading/unloading	0.5	0.25	0.25	0
Fraction of work time not exposed to reused soil	0.25	0.5	0.5	0.55

*Philip, J. and T. Nicholson. Geometry parameters for different truck types are based on personal communications (May) to G. Gnugnoli (NRC). Washington, DC: NRC. 2001.
†Philip, J. and T. Nicholson. Soil density and geometry are based on personal communications (May) to G. Gnugnoli (NRC). Washington, DC: NRC. 2001.

Table 3-4. Environmental and Exposure Pathways for the Truck Operator Scenario			
Truck Operator Pathway			
Exposure Pathway	**Environmental Pathway/Subpathway**	**Pathway Included?**	**Description**
External Radiation	Direct exposure from soil	Yes	Volume of soil in truck and soil spread on ground
Inhalation	Resuspended dust	Yes	Resuspended dust in air
	Indoor radon	No	—
	Outdoor radon	No	—
Ingestion—Water	Groundwater	No	—
	Surface water (runoff)	No	—
Ingestion—Plants	Irrigation water	No	—
	Soil	No	—
Ingestion—Meat/Milk	Livestock water	No	—
	Fodder — Irrigation water	No	—

		Soil	No	—
	Soil		No	—

Table 3-4. Environmental and Exposure Pathways for the Truck Operator Scenario (continued)			
Truck Operator Pathway			
Exposure Pathway	**Environmental Pathway/Subpathway**	**Pathway Included?**	**Description**
Ingestion—Fish	Surface water (through runoff, groundwater, or both)	No	—
Ingestion—Soil	Inadvertent ingestion of soil	Yes	Inadvertent ingestion of soil particles resuspended in air while outside of truck

3.2.2 Key Input Parameters

Various key input parameters were used to define the truck operator exposure scenario and are listed in Appendix A. The dry soil loaded into the truck is compacted to a 1,600-kg/m^3 [100-lb/ft^3] density and is loaded so the surface of the soil in the truck slopes up 3.75 degrees to the rear of the truck.[3] While the truck is loaded, the radionuclides in the soil are assumed to be uniformly mixed throughout the truck load. During loading and unloading operations, soil particles are assumed to be resuspended in the air, and the operator breathes these particulates while outside the truck. The mass loading of soil particulates in the air was assumed to be 240 μg/m^3 [1.5×10^{-8} lb/ft^3], as described in Appendix B. The operator is assumed to ingest 100 mg [2.2×10^{-4} lb] of soil per working day, and this ingestion occurs during working hours (EPA, 1997).

Additionally, it is assumed the truck operator stands on the ground covered with reused soil while loading and unloading. The exposure geometry, while loading and unloading the soil, is expected to be similar enough to the geometry in the cab of the truck, hence, separate geometry factors were not calculated for the soil loading operations. In addition, the contribution to external exposure from reused soil on the ground was added to that from soil in the truck for the time spent on loading operations.

The truck cargo box is modeled as a stainless steel box, and the truck cab is modeled as a stainless steel sphere. The truck operator is modeled as a 70-kg [154-lb] sphere positioned in the center of the cab for truck Types 2 and 3. For truck Type 1 (pickup truck), the position of the modeled operator was shifted down and toward the cargo box so the distance between the shining plane of the soil in the cargo box and the modeled operator sphere surface is 0.3 m [1 ft] (approximating relative positioning of the truck operator and the soil cargo).

3.3 Landscaper

This section describes initial efforts to determine the potential impact to landscapers when loading, unloading, transporting, and working closely with soil removed from NRC-licensed

[3]Philip, J. and T. Nicholson. Soil density and geometry are based on personal communications of May 2001 to G. Gnugnoli (NRC). Washington, DC: NRC. 2002.

facilities. The analyses were performed using the MCNP Version 4A code (Los Alamos National Laboratory, 1995) and Microsoft® Excel spreadsheet with appropriate exposure parameter values, as cited in this report.

3.3.1 Description of Scenario

The receptor group for this scenario is defined as a group of landscapers who use soil removed from NRC-licensed facilities throughout the year. The basic assumptions of the landscaper scenario are that the pickup truck is used to haul soil (2,000 hour/year). Basic truck parameters are presented in Table 3-5 that are the same as used for truck Type 1 in the truck operator scenario. Basic landscaper occupational parameters are presented in Table 3-6. Exposure pathways for a landscaper are direct exposure, inhalation, and inadvertent ingestion of the transported soil while outside the truck. Although the landscaper could also be exposed to radon through inhalation while outdoors, the radon pathway was not included in this exposure scenario because the results of the agricultural worker scenario show that the radon pathway contributed a negligible amount to the total dose for outdoor exposure. A summary of the exposure pathways for the landscaper scenario is listed in Table 3-7. The source term for the landscaper is defined as contaminated soil resuspended in the air in addition to the volume source in the truck cargo box and reused soil layer spread on the ground. The MCNP Version 4A code was used to estimate the recipient external deep dose equivalent caused by the exposure to the volume source during the first year of work with the released soil {having initial specific unit activities measured in Bq/g [pCi/g] for parent radionuclides and for each component in mixtures of parent and decay progeny}. Spreadsheet calculations were used to estimate committed effective dose equivalents resulting from the intake of radionuclides through inhalation and ingestion and from direct exposure to the soil spread on the ground with 15-cm [5.9-in] thickness. Dose conversion factors from Oak Ridge National Laboratory (1988) were used in spreadsheet calculations. Reduction of the initial activity caused by radioactive decay was taken into account (decay was averaged for the first year of work).

3.3.2 Key Input Parameters

Appendix A contains a list of key input parameter values for the landscaper scenario. The dry soil loaded into the truck is compacted to a 1,600-kg/m^3 [100-lb/ft^3] density and is loaded so the surface of the soil in the truck slopes up 3.75 degrees to the rear of the truck.[4,5] While the truck is loaded, the radionuclides in the soil are assumed to be uniformly mixed throughout the truck load. During loading and unloading operations, soil particles are assumed to be resuspended in the air, and the landscaper breathes these particulates while outside the truck. The mass loading of soil particulates in the air was assumed to be 240 μg/m^3 [1.5×10^{-8} lb/ft^3], as described in Appendix B. The worker is assumed to ingest 100 mg [2.2×10^{-4} lb] of soil per working day, a value recommended for residential and agricultural scenarios (EPA, 1997). These recommended soil ingestion rates are characterized by U.S. Environmental Protection Agency (EPA) as being reasonable, but uncertain (EPA, 1997). To compensate for this

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[4]Philip, J. and T. Nicholson. Soil density and geometry are based on personal communications (May) to G. Gnugnoli (NRC). Washington, DC: NRC 2001.

[5]Philip, J. and T. Nicholson. Soil density and geometry are based on personal communications (April) to G. Gnugnoli (NRC). Washington, DC: NRC 2002.

uncertainty, the scenario assumes all the worker's daily soil ingestion occurs during working hours and is composed of soil removed from NRC-licensed facilities.

Table 3-5. Truck Parameters for the Landscaper Scenario*†	
Cargo box length	2.0 m [6.5 ft]
Cargo box width	1.532 m [5.025 ft]
Height of soil in cargo box front "shining plane"‡	0.37 m [1.2 ft]
Cargo box wall thickness	0.089 mm [0.0035 in]
Volume of soil in cargo box	1.3070 m^3 [46.157 ft^3]
Mass of soil in cargo box	2,091 kg [4,610 lb]
Sphere cab diameter	80.0 cm [31.5 in]
Sphere cab wall thickness	0.089 mm [0.0035 in]
Position of operator in cab	Shifted 30 cm [11.8 in] down and 5.02 cm [1.98 in] back from cab center toward cargo box
Distance from center of modeled operator to "shining plane"‡	30.4 cm [12.0 in]

*Philip, J. and T. Nicholson. Geometry parameters for different truck types are based on personal communications of May 2001 to G. Gnugnoli (NRC). Washington, DC: NRC. 2002.
†Philip, J. and T. Nicholson. Soil density and geometry are based on personal communications of May 2001 to G. Gnugnoli (NRC). Washington, DC: NRC. 2002.
‡Front plane surface of the hauled soil closest to the receptor.

Table 3-6. Occupational Parameters for the Landscaper Scenario*	
Fraction of work time landscaper is driving and externally irradiated	0
Fraction of work time landscaper is externally irradiated and inhaling/ingesting soil dust while standing on reused soil and loading/unloading	1
Fraction of work time landscaper is not exposed to reused soil	0

*Gnugnoli, G. Occupational parameters are based on personal communications of May 2002 to M. Smith (CNWRA). Washington, DC: NRC. 2002.

Table 3-7. Environmental and Exposure Pathways for the Landscaper Scenario				
Landscaper Pathway				
Exposure Pathway	**Environmental Pathway/Subpathway**		**Pathway Included?**	**Description**
External Radiation	Direct exposure from soil		Yes	Volume of soil in truck and soil spread on ground
Inhalation	Resuspended dust		Yes	Resuspended dust in air
	Indoor radon		No	—
	Outdoor radon		No	—
Ingestion—Water	Groundwater		No	—
	Surface water (runoff)		No	—
Ingestion—Plants	Irrigation water		No	—
	Soil		No	—
Ingestion—Meat/Milk	Livestock water		No	—
	Fodder	Irrigation water	No	—
		Soil	No	—
	Soil		No	—
Ingestion—Fish	Surface water (through runoff, groundwater, or both)		No	—
Ingestion—Soil	Inadvertent ingestion of soil		Yes	Inadvertent ingestion of soil particles resuspended in air while outside of truck

Additionally, it is assumed the landscaper stands on the ground covered with reused soil while handling the soil. The exposure geometry, while handling the soil, is similar enough to the geometry in the cab of the truck that separate geometry factors were not calculated for the soil handling operations.

Radionuclides with radioactive decay progeny were modeled in two calculations, one assuming the radionuclides of interest in the soil have not undergone any radioactive decay with ingrowth of progeny and the other assuming radioactive decay progeny were in equilibrium with the parent radionuclide. These two calculations show how important the buildup of decay products is to the results of the analyses. Tabular results presented in Chapter 5 use a "+ D" notation following

radionuclide names to indicate when calculations start with decay progeny in secular equilibrium.

3.4 Child in Playground

This section describes initial efforts to determine the potential impact to a child from soils removed from an NRC-licensed facility and reused in a playground setting. The analyses were performed using the RESRAD Version 6.1 code (Yu, et al., 2001) with appropriate input parameter values, as cited in this report. In general, parameter values were selected assuming a child of approximately 3–11 years of age.

3.4.1 Description of Scenario

The playground scenario was used to determine the potential impact to a child who may spend time on a playground constructed with reused soil. The scenario playground is modeled as a 625 to 10,000-m^2 [6.73×10^3 to 1.08×10^5-ft^2] square-shaped area with a 15-cm [5.9-in] cover of reused soil. To investigate the potential contribution of the indoor radon pathway, the playground is assumed to contain a small playhouse structure with a dirt floor. Of the time spent at the playground, the child is assumed to spend 25 percent inside the playground structure with a dirt floor. Because this is not a resident scenario, only the following pathways for spending limited time at the playground were considered: external gamma, inhalation, inadvertent soil ingestion, and radon. A summary of exposure pathways for the playground scenario is included in Table 3-8.

3.4.2 Key Input Parameters

The probabilistic default values for the RESRAD Version 6.1 code were used for most parameters in the calculations. Appendix A contains a list of RESRAD Version 6.1 code parameter values that were changed from the default values and the reason for selecting those values. The RESRAD Version 6.1 code calculations were made with unit concentrations measured in Bq/g [pCi/g] of the radionuclides of interest, including separate calculations for some radionuclides with radioactive decay progeny in secular equilibrium. Tabular results presented in Chapter 5 use a "+D" notation following radionuclide names to indicate when calculations start with decay progeny in secular equilibrium. Additionally, calculations were made for natural uranium, depleted uranium (0.25 percent), and enriched uranium (3 percent) with unit concentrations of activity. Two calculations were made for natural uranium, one with only uranium initially present (subsequently tracking the buildup of decay progeny) and one with all decay progeny initially in secular equilibrium. The child is assumed to spend 220 minutes/day playing on the playground (EPA, 1997), with 25 percent of the time assumed spent inside an enclosed playground structure with a dirt floor and the remaining time spent playing outdoors. The child's soil ingestion is assumed to range between 100–400 mg [$2.2–8.8 \times 10^{-4}$ lb] of soil per day (EPA, 1997), which is assumed to occur while playing on the affected soil areas at the playground. The breathing rate of the receptor ranged from 9,204 ± 4,558 m^3/yr [$3.250 \times 10^5 \pm 1.610 \times 10^5$ ft^3/yr], to represent the outdoor breathing rate of a 10–12-year-old child (EPA, 1997). Additionally, the default parameters describing the building were modified in the RESRAD Version 6.1 code to represent a playground structure with a dirt floor instead of a house.

<table>
<tr><th colspan="5">Table 3-8. Environmental and Exposure Pathways for the Playground Scenario</th></tr>
<tr><th colspan="5">Playground Use (e.g., Playground Dirt and Sand Boxes) Pathway</th></tr>
<tr><th>Exposure Pathway</th><th colspan="2">Environmental Pathway/Subpathway</th><th>Pathway Included?</th><th>Description</th></tr>
<tr><td>External Radiation</td><td colspan="2">Direct exposure from ground</td><td>Yes</td><td>15-cm [5.9-in] depth</td></tr>
<tr><td rowspan="3">Inhalation</td><td colspan="2">Resuspended dust</td><td>Yes</td><td>Resuspended dust in air</td></tr>
<tr><td colspan="2">Indoor radon</td><td>Yes</td><td>Radon diffuses into playground structure from reused soil and water</td></tr>
<tr><td colspan="2">Outdoor radon</td><td>Yes</td><td>Radon emanates from reused soil and water</td></tr>
<tr><td rowspan="2">Ingestion—Water</td><td colspan="2">Groundwater</td><td>No</td><td>—</td></tr>
<tr><td colspan="2">Surface water (runoff)</td><td>No</td><td>—</td></tr>
<tr><td rowspan="2">Ingestion—Plants</td><td colspan="2">Irrigation water</td><td>No</td><td>—</td></tr>
<tr><td colspan="2">Soil</td><td>No</td><td>—</td></tr>
<tr><td rowspan="4">Ingestion—Meat/Milk</td><td colspan="2">Livestock water</td><td>No</td><td>—</td></tr>
<tr><td rowspan="2">Fodder</td><td>Irrigation water</td><td>No</td><td>—</td></tr>
<tr><td>Soil</td><td>No</td><td>—</td></tr>
<tr><td colspan="2">Soil</td><td>No</td><td>—</td></tr>
<tr><td>Ingestion—Fish</td><td colspan="2">Surface water (through runoff, groundwater, or both)</td><td>No</td><td>—</td></tr>
<tr><td>Ingestion—Soil</td><td colspan="2">Inadvertent ingestion of soil</td><td>Yes</td><td>Inadvertent ingestion of soil particles resuspended in air</td></tr>
</table>

3.5 Rural Resident

This section describes initial efforts to determine the potential impact to a rural resident from reused soil. The analyses were performed using the RESRAD Version 6.1 code (Yu, et al., 2001) with input parameter values provided by NRC and other sources, as cited in this report.

3.5.1 Description of Scenario

The rural resident scenario takes place in a home built on a large lot of several hectares. The critical group for this scenario is a rural resident family occupying a single-family house, using only well water for all their needs (well water is sufficient for human and livestock consumption, irrigation, and other activities). The family conducts limited gardening and raises a few livestock for family consumption. Additional analyses were performed to calculate the dose to a resident who drinks water and eats fish from a pond that receives reused soil washed in from surface water runoff. The reused soil was applied only once on a 1,000-m^2 [1.10 × 10^4-ft^2] area, including that portion of the residential lot under the house. The contribution from the groundwater pathway for these analyses is delayed and provides little contribution to the peak dose-to-source ratio that occurs during the first year. As discussed in Section 3.1.1, the groundwater pathway might contribute to the peak dose-to-source ratio for cases with multiyear soil applications. A summary of the exposure pathways for the rural resident scenario is included in Table 3-9. Members of the family incur a radiation dose by

- Direct radiation from radionuclides in the reused soil
- Inhalation of resuspended dust (while outdoors and indoors)
- Inhalation of radon and its decay products (if radon parent nuclides are present in the soil above natural background levels)
- Ingestion of food from crops grown in the reused soil
- Ingestion of meat and milk from livestock whose feed was grown in the affected area
- Ingestion of water from a well affected by radionuclides leached from the reused soil into the water table aquifer
- Inadvertent ingestion of reused soil tracked indoors

3.5.2 Key Input Parameters

For this scenario, a probabilistic calculation used the RESRAD Version 6.1 code with default value input parameters. RESRAD Version 6.1 code default values were used for a majority of parameters, except as specified in Appendix A. It was assumed that the radionuclides were uniformly mixed within the top 15 cm [5.9 in] of soil. Soil density was assumed to be 1,500 kg/m^3 [95 lb/ft^3]. Specific unit radionuclide activities were measured in Bq/g [pCi/g] of dry soil. Residents spend 65.7 percent of the time indoors, 11.8 percent of the time outdoors, and the remaining time offsite. Mass loading for inhalation was assumed to be 4.5×10^{-5} g/m^3 [2.81×10^{-9} lb/ft^3] of air. Inadvertent ingestion of soil was assumed to be 18.5 g/yr [0.04 lb/yr], which is only 50 percent of the RESRAD Version 6.1 code default value, and the drinking water intake was assumed to be 460 L/yr [120 gal/yr], approximately 10 percent lower than the RESRAD Version 6.1 code default value. Only family members and livestock use water from an onsite well for drinking, irrigation, and other needs.

Table 3-9. Environmental and Exposure Pathways for the Rural Resident Scenario				
Rural Resident Pathway				
Exposure Pathway	**Environmental Pathway/Subpathway**		**Pathway Included?**	**Description**
External Radiation	Direct exposure from ground		Yes	15-cm [5.9-in] depth
Inhalation	Resuspended dust		Yes	Resuspended dust in air
	Indoor radon		Yes	Radon diffuses into house from reused soil and water
	Outdoor radon		Yes	Radon emanates from reused soil and water
Ingestion—Water	Groundwater		Yes	Radionuclides leach into groundwater from applied soil
	Surface water (runoff)		Yes	Impacted by local surface water runoff
Ingestion—Plants	Irrigation water		Yes	Plants uptake irrigation water
	Soil		Yes	Includes foliar and root uptake
Ingestion—Meat/Milk	Livestock water		Yes	Animal products from livestock drinking affected well water
	Fodder	Irrigation water	Yes	Animal products from livestock eating fodder irrigated with affected well water
		Soil	Yes	Animal products from livestock eating fodder having foliar and root uptake
	Soil		Yes	Animal products from livestock eating reused soil contained on fodder and in water
Ingestion—Fish	Surface water (through runoff, groundwater, or both)		Yes	Affected by surface water runoff
Ingestion—Soil	Inadvertent ingestion of soil		Yes	Inadvertent ingestion of soil particles tracked indoors and ingestion with plants and vegetables

7 SUMMARY AND CONCLUSIONS

A series of analyses was conducted to examine the potential dose for selected scenarios involving the reuse of soil that may be removed from U.S. Nuclear Regulatory Commission (NRC)-licensed facilities. The scenarios evaluated in these analyses chosen by NRC staff in consultation with Center for Nuclear Waste Regulatory Analyses investigators included an agricultural worker working in a field covered with reused soil; a truck operator who transports, loads, and unloads reused soil; a landscaper who works closely with reused soil; a child who plays on a playground covered with reused soil; and a rural resident who lives and raises food on land covered with reused soil. These potential receptor groups are expected to be among the most representative for the potential doses resulting from reused soil removed from NRC-licensed facilities.

The landscaper and rural resident scenarios generally are limiting (i.e., produce the greatest dose-to-source ratio) with regard to radioactivity in reused soils. The child in a playground scenario is the only other scenario that may lead to higher dose-to-source ratios for some radionuclides. A comparison of the results for the different scenarios analyzed with the RESRAD Version 6.1 (Yu, et al., 2001) and MCNP Version 4A (Los Alamos National Laboratory, 1995) codes is shown in Table 7-1. The results presented in Table 7-1 include only the results for the agricultural worker and rural resident scenarios using groundwater as the source of drinking water, because groundwater is viewed as the more likely source of drinking water. These results show that the child in a playground scenario is limiting for some radionuclides because of the large amount of soil ingestion assumed for this scenario and the exposure to radon during the fraction of time spent inside an enclosed playground structure. The landscaper scenario is limiting for many fission products because they account for most of the direct exposure pathway, which dominates the total dose for this scenario. The rural resident scenario tended to be limiting for other fission product radionuclides and nonactinides.

The truck operator and agricultural worker scenarios do not result in the greatest dose-to-source ratio for any radionuclide and result in the second highest dose-to-source ratio for only a few radionuclides. These scenarios include several relatively conservative assumptions, such as all working hours are spent in close proximity to the reused soil and all soil ingested by workers is assumed to occur during working hours.

To obtain insights from the reported results, regression analyses were performed for the agricultural worker, child in playground, and rural resident scenarios to identify the sampled parameters that have the most significant effect on the variability of the results. The regression analyses were performed using built-in capabilities of the RESRAD Version 6.1 code, which is based on the methodology of Iman, et al. (1985). No regression analyses are reported for the truck operator and landscaper scenarios that were analyzed using the MCNP Version 4A code. Table 7-2 presents the frequency of occurrence of the most sensitive parameters associated with the agricultural worker, child in playground, and rural resident scenarios for all radionuclides considered. There are a few examples where a parameter is important for each of the scenarios (i.e., density of contaminated zone), but for most cases, a parameter has either a low frequency of occurrence for each scenario (i.e., inhalation rate) or a high frequency of occurrence for just one or two scenarios (i.e., density of unsaturated zone). The results indicate that the importance of a particular parameter to the results is dependent on both the scenario and the radionuclide. Identification of sensitive parameters should be based on the results of

several methods rather than any single method (LePoire, et al., 2000). Therefore, these results provide some useful guidance, but further analysis is recommended.

The analyses for the child in playground scenario utilized adult-dose conversion factors while employing age-dependent parameter values. To determine if adult-dose conversion factors are sufficient for the child in playground analyses, they were compared to guidance provided by the International Commission on Radiological Protection (1996) and the National Council on Radiation Protection and Measurements (1999) for external, inhalation, and ingestion exposures using a range of species selected to represent volatile and nonvolatile alpha-, beta-, and gamma-emitting radionuclides. For external exposure, a scaling factor of 1.3 ± 0.1 is recommended by the National Council on Radiation Protection and Measurements (1999) for converting adult-dose conversion factors to child-dose conversion factors. Using age-dependent inhalation dose conversion factors from International Commission on Radiological Protection (1996) results in approximately a one-order-of-magnitude increase of the inhalation dose conversion factors for the selected radionuclides. For radionuclides with a large contribution to the dose-to-source ratio from the inhalation pathway, with or without radon, the one-order-of-magnitude increase in the inhalation dose conversion factor, by using an age-dependent inhalation dose conversion factor over the adult value, appears relatively significant. Using age-dependent ingestion dose conversion factors from International Commission on Radiological Protection (1996) results in approximately doubling the ingestion dose conversion factors for the selected radionuclides. For radionuclides with a significant contribution to the dose-to-source ratio from the ingestion pathway, the doubling of the ingestion dose conversion factor by using an age-dependent ingestion dose conversion factor appears to be nearly equivalent to the magnitude of change incurred by varying individual parameter values.

Because the landscaper and rural resident scenarios resulted in the limiting dose-to-source ratios for many of the radionuclides, it is recommended that the input parameters for these scenarios be analyzed further to ascertain if the values used are realistic. For example, it may not be reasonable to assume all fruits and vegetables the rural residents ingest are produced on their farm because few families in the United States actually produce all the fruits and vegetables they consume. Reducing the fraction of ingested food locally produced to more realistic values could have a significant effect on the results of the analysis. A more detailed analysis may provide better estimates of the dose-to-source ratio for any scenario involving reused soil. Additional analyses may further clarify the scenarios likely to be the most limiting and provide an additional technical basis for calculating dose-to-source ratios for soil that contains a low concentration of radionuclides.

SUMMARY OF KEY INPUT DATA

Except for the truck operator and landscaper scenarios, analyses in this report primarily used the default probabilistic input data set provided with the RESRAD Version 6.1 code (Yu, et al., 2001) with selected parameter values modified to represent the scenario being modeled. The truck operator and landscaper scenarios were modeled using a simple Microsoft® Excel spreadsheet because the exposure pathways were straightforward to calculate. This appendix lists the key input data modified from the default values provided with the dose modeling codes and the basis for these modified parameter values. Table A–1 lists the key input data for the agricultural worker scenario as modified from the default values in the RESRAD Version 6.1 code. Tables A–2 and A–3 list the key input data for the truck operator and landscaper scenarios. Table A–3 lists the key input data for the child in the playground scenario as modified from the default values in the RESRAD Version 6.1 code. Table A–4 lists the key input data for the rural resident scenario as modified from the default values in the RESRAD Version 6.1 code. Finally, Table A–5 lists the activity fractions of the isotopes of uranium used to determine the doses from natural uranium, depleted uranium, and enriched uranium.

Table A–1. RESRAD Version 6.1 Code* Parameter Values that Have Been Changed from the Default Values for the Agricultural Worker Scenario

Parameter	Default Value	Scenario Value	Assumptions
Area of contamination	10,000 m^2 [1.1×10^5 ft^2]	Range between 167 m^2 and 13,333 m^2 [1,800 ft^2 and 1.4×10^5 ft^2]	Five deliveries per year with thickness 15 cm [5.9 in] for these six truck volumes: 5 m^3 [1.8×10^2 ft^3], 10 m^3 [3.5×10^2 ft^3], 100 m^3 [3.5×10^3 ft^3], 200 m^3 [7.1×10^3 ft^3], 300 m^3 [1.1×10^4 ft^3], and 400 m^3 [1.4×10^4 ft^3].
Length of contamination parallel to aquifer flow	100 m^2 [328 ft^2]	Range between 14.6 and 130.3 m [48 and 427 ft]	Contaminated area is circular; value is correlated with $r^2 = 0.999$.
Thickness of contaminated zone	2 m [6.6 ft]	0.15 m [0.5 ft]	Thickness at which soil is applied.
Fraction of time spent indoors	0.5	0	Scenario consists only of outdoor exposure.
Fraction of time spent outdoors	0.25	0.228	2,000 working hours in a year divided by 8,766 hours in a year.

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Table A–1. RESRAD Version 6.1 Code* Parameter Values that Have Been Changed from the Default Values for the Agricultural Worker Scenario (continued)			
Parameter	**Default Value**	**Scenario Value**	**Assumptions**
Milk consumption	Triangular: min = 60 L/yr [15.9 gal/yr], mode = 102 L/yr [26.9 gal/yr], max = 200L/yr [52.8 gal/yr]	Triangular: min = 15 L/yr [4.0 gal/yr], mode = 25.5 L/yr [6.7 gal/yr], max = 50 L/yr [13.2 gal/yr]	25% milk originates locally.
Mass loading for inhalation	Deterministic input: 1×10^{-4} g/m^3 [6.2×10^{-9} lb/ft^3]	Deterministic input: 4.5×10^{-5} g/m^3 [2.8×10^{-9} lb/ft^3]	See Appendix B.
	Probabilistic input: Continuous linear, range from 0 to 1×10^{-4} g/m^3 [0 to 6.2×10^{-9} lb/ft^3]	Probabilistic input: Continuous frequency with 8 value/cdf pairs in g/m^3: 15, 0.00425; 30, 0.1105; 45, 0.2521; 60, 0.4958; 75, 0.7663; 105, 0.932; 150, 0.9901; 240, 1.000 [in lb/ft^3: 9.4×10^{-10}, 0.00425; 1.9×10^{-9}, 0.1105; 2.8×10^{-9}, 0.2521; 3.7×10^{-9}, 0.4958; 4.7×10^{-9}, 0.7663; 6.6×10^{-9}, 0.932; 9.4×10^{-9}, 0.9901; 1.5×10^{-8}, 1.000]	

*Yu, C., A.J. Zielen, J.-J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo, III, W.A. Williams, and H. Peterson. "User's Manual for RESRAD Version 6.1." ANL/EAD–4. Argonne, Illinois: Argonne National Laboratory. 2001.

Table A–2. Key Input Parameters for the Truck Operator and Landscaper Scenarios		
Parameter	**Scenario Value**	**Assumptions**
Mass loading for inhalation while outside truck	2.4×10^{-4} g/m^3 [1.5×10^{-8} lb/ft^3]	See Appendix B
Soil ingestion rate	100 mg/d [2.2×10^{-4} lb/yr]	Consistent with agricultural worker scenario

Table A–3. RESRAD Version 6.1 Code* Parameter Values that Have Been Changed from the Default Values for the Child in Playground Scenario			
Parameter	**Default Value**	**Scenario Value**	**Assumptions**
Erosion rate	Continuous logarithm with 4 value/cdf pairs in m/yr: 5×10^{-8}, 0; 0.0007, 0.22; 0.005, 0.95; and 0.2, 1 [in ft/yr: 1.6×10^{-8}, 0; 0.0023, 0.22; 0.16, 0.95; and 0.66, 1]	0	No erosion
Inhalation rate	Triangular: min = 4,380 m^3/yr [1.5×10^5 ft^3/yr], mode = 8,400 m^3/yr [3.0×10^5 ft^3/yr], max = 13,100 m^3/yr [4.6×10^5 ft^3/yr]	Triangular: min = 4,646 m^3/yr [1.6×10^5 ft^3/yr], mode = 9,204 m^3/yr [3.3×10^5 ft^3/yr], max = 13,763 m^3/yr [4.7×10^5 ft^3/yr]	Average outdoor inhalation rate for elementary school students (10–12 years) using weighted recommended fractions of slow, medium, and fast levels of activity (0.365, 0.459, 0.176)†
Exposure duration	30 yr	1 yr	Intent is to determine exposure from being onsite for 1 year
Indoor time fraction	Continuous linear: 0, 0; 0.05, 0.375; 0.25, 0.521; 0.5, 0.625; 0.75, 0.809; 0.9, 0.938; 095, 0.992; 1, 1	0.0382	25% time on playground spent in indoor playground structure based on 220 min/d (95th percentile value for children 5–11 yr for time spent outdoors on school grounds/playground†)
Outdoor time fraction	0.25	0.1146	75% time on playground spent outdoors based on 220 min/d (95th-percentile value for children 5–11 yr for time spent outdoors on school grounds/playground†)
Indoor dust filtration factor	0.4	1	All dust found indoors is reused soil
Shape of contaminated zone	circular	square	Typical playground is square
Area of contaminated zone	10,000 m^2 [1.1×10^5 ft^2]	Triangular: min = 625 m^2 [6.7×10^3 ft^2], mode = 2,400 m^2 [2.6×10^4 ft^2], max = 10,000 m^2 [1.1×10^5 ft^2]	Range of reasonable playground sizes so parameter can be tested during regression analysis; mode set to 2,400 m^2 to match DandD Version 2.1 code‡ default value

Table A–3. RESRAD Version 6.1 Code* Parameter Values that Have Been Changed from the Default Values for the Child in Playground Scenario (continued)			
Parameter	**Default Value**	**Scenario Value**	**Assumptions**
Soil ingestion	Triangular: min = 0 mode = 18.3 g/yr [0.04 lb/yr], max = 36.5 g/yr [0.08 lb/yr]	Triangular: min = 239.0 g/yr [0.5 lb/yr], mode = 478.1 g/yr [1.1 lb/yr], max = 956.2 g/yr [2.1 lb/yr]	Range of recommended values so parameter can be tested during regression analysis; EPA recommended mean 100 mg/d [0.22 lb/d], conservative mean 200 mg/d [0.44 lb/d], and upper percentile of 400 mg/d†; These input values correspond to recommended values after accounting for occupancy factor (0.1528)
Building foundation density	2.4 g/cm^3 [150 lb/ft^3]	Truncated normal: mean = 1.52 g/cm^3 [94 lb/ft^3], SD = 0.23 g/cm^3 [14 lb/ft^3], lower quantile = 0.001, upper quantile = 0.999	Density equivalent to default soil cover values; playground structure with dirt floor instead of constructed floor
Building room height	2.5 m [8.2 ft]	Uniform: min = 1.5 m [4.9 ft], max = 2.5 m [8.2 ft]	Range of reasonable values so parameter can be tested during regression analysis; smaller possible playground structure height compared to standard housing structure
Foundation depth below ground	-1 m [-3.3 ft]	0	Playground structure built directly on top of affected soil layer
Building foundation thickness	0.15 m [0.5 ft]	0	Playground structure with no foundation (has dirt floor)
Thickness of contaminated zone	2 m [6.6 ft]	0.15 m [0.5 ft]	Depth of application of affected soil
Depth of soil mixing layer	Triangular: min = 0 mode = 0.15 m [0.5 ft], max = 0.6 m [2 ft]	Triangular: min = 0, mode = 0.15 [0.5 ft], max = 0.3 m [1 ft]	Unlikely mixing layer down to 1 m [3.3 ft] on playground, but desired to test this parameter during regression analysis; upper value reduced to 0.3 m [1 ft], but left slightly greater than thickness of applied soil

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Table A–3. RESRAD Version 6.1 Code* Parameter Values that Have Been Changed from the Default Values for the Child in Playground Scenario (continued)			
Parameter	**Default Value**	**Scenario Value**	**Assumptions**
Building air exchange rate	0.5 hr^{-1}	Uniform: min = 0.5 hr^{-1}, max = 5 hr^{-1}	Range of reasonable values so parameter can be tested during regression analysis; typical air exchange rate for closed buildings 0.45 hr^{-1}†; typical air exchange rates for closed buildings range 0.1–1.0 hr^{-1}§; typical playground structure may have open windows and greater air exchange rate; air exchange rates measured in Southern California during summer, when windows likely open, had 50th percentile, 90th percentile, and max values near 2.3 hr^{-1}, 5.9 hr^{-1}, and 23 hr^{-1}†; air exchange rates for tents reported 1–3.5 hr^{-1}‖

*Yu, C., A.J. Zielen, J.-J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo, III, W.A. Williams, and H. Peterson. "User's Manual for RESRAD Version 6." ANL/EAD–4. Argonne, Illinois: Argonne National Laboratory. 2001.
†EPA. *Exposure Factors Handbook*. EPA/600P–95/002Fa. Washington, DC: EPA. 1997.
‡McFadden, K., D.A. Brosseau, W.E. Beyeler, and C.D. Updergraff. NUREG/CR–5512, "Residual Radioactive Contamination from Decommissioning: User's Manual DandD Version 2.1." Vol. 2. Washington, DC: NRC. April 2001.
§Yu, C., A.J. Zielen, J.-J. Cheng, Y.C. Yuan, L.G. Jones, D.J. LePoire, Y.Y. Wang, C.O. Loureiro, E. Gnanapragasam, E. Faillace, A. Wallo III, W.A. Williams, and H. Peterson. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0." Working Draft for Comment. Argonne, Illinois: Argonne National Laboratory. 1993.
‖Zhou, C. and Y.-S. Cheng. "Characterization of Emissions from Kerosene Heaters in an Unvented Trent." *Aerosol Science and Technology*. Vol. 33, No. 6. pp. 510–524. 2000.

Table A–4. RESRAD Version 6.1 Code* Parameter Values that Have Been Changed from the Default Values for the Rural Resident Scenario			
Parameter	**Default Value**	**Scenario Value**	**Assumptions**
Thickness of contaminated zone	2 m [6.6 ft]	0.15 m [0.5 ft]	Thickness at which soil is applied
Fraction of time spent indoors	0.5	0.657	Consistent with DandD Version 2.1 code† default value‡
Fraction of time spent outdoors	0.25	0.118	Consistent with DandD Version 2.1 code† default value‡
Soil ingestion rate	36.5 g/yr [0.08 lb/yr]	18.5 g/yr [0.04 lb/yr]	Consistent with DandD Version 2.1 code† default value‡

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Table A–4. RESRAD Version 6.1 Code* Parameter Values that Have Been Changed from the Default Values for the Rural Resident Scenario (continued)			
Parameter	**Default Value**	**Scenario Value**	**Assumptions**
Milk consumption	92 L/yr [24.3 gal/yr]	Triangular: min = 30 L/yr [7.9 gal/yr], mode = 51 L/yr, [13.5 gal/yr] max = 100 L/yr [26.4 gal/yr]	50% milk intake grown locally
Meat consumption	63 kg/yr [139 lb/yr]	31.5 kg/yr [69.5 lb/yr]	50% meat intake grown locally
Mass loading for inhalation	Deterministic input: 1×10^{-4} g/m^3 [6.2×10^{-9} lb/ft^3]	Deterministic input: 4.5×10^{-5} g/m^3 [2.8×10^{-9} lb/ft^3]	See Appendix B
	Probabilistic input: Continuous linear, range from 0 to 1×10^{-4} g/m^3 [0 to 6.2×10^{-9} lb/ft^3]	Probabilistic input: Loguniform: min = 1×10^{-7} g/m^3 [6.2×10^{-12} lb/ft^3] max =1×10^{-4} g/m^3 [6.2×10^{-9} lb/ft^3]	

*Yu, C., A.J. Zielen, J.-J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W.A. Williams, and H. Peterson. "User's Manual for RESRAD Version 6." ANL/EAD–4. Argonne, Illinois: Argonne National Laboratory. 2001.
†McFadden, K., D.A. Brosseau, W.E. Beyeler, and C.D. Updergraff. NUREG/CR–5512, "Residual Radioactive Contamination from Decommissioning: User's Manual DandD Version 2.1." Vol. 2. Washington, DC: NRC. April 2001.
‡Input parameter was modified according to input parameters in DandD Version 2.1 files provided by NRC in 2001 for suburban and rural gardener (modeling U-238 and Co-60).

Table A–5. Activity Fractions* Used for Natural Uranium, Depleted Uranium (0.25 Percent), and Enriched Uranium (3 Percent) Calculations			
Uranium Type	**U-234**	**U-235**	**U-238**
Natural Uranium	0.491	0.0224	0.487
Depleted Uranium (0.25 percent by weight)	0.0824	0.0144	0.903
Enriched Uranium (3 percent by weight)	0.825	0.0288	0.147

*Los Alamos National Laboratory. *Los Alamos Radiation Monitoring Handbook.* LA–YR–00–2589. Los Alamos, New Mexico: Los Alamos National Laboratory. 2001.

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Yu, C., A.J. Zielen, J.-J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W.A. Williams, and H. Peterson. "User's Manual for RESRAD Version 6." ANL/EAD–4. Argonne, Illinois: Argonne National Laboratory. 2001.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

To: CAR Folder

CAR 2002-03

February 27, 2003

NOTE: Based This correspondence and direction from Dr. J. Russell, The closure of CAR 2002-03 will be delayed until March 14, 2003. [signature] 2/27/2003

Wesley C. Patrick, President
Center for Nuclear Waste
Regulatory Analyses
6220 Culebra Road
PO Drawer 28510
San Antonio, TX 78228-0510

Subject: Modification No. 12 to Task Order No. 10 Under Contract NRC-02-97-001

Dear Dr. Patrick:

The purpose of this modification is to extend the expiration date of the period of performance of the subject task order from February 28, 2003, to March 14, 2003, at no additional cost or obligation to the Government.

A summary of obligations for this task order from award date through the date of this action is given below:

FY01 Obligation Amount:	$ 94,038
FY01 Deobligation Amount:	20,000
FY02 Obligation Amount:	189,311
FY03 Obligation Amount:	9,841
Cumulative Total: $273,190	

This modification does not obligate funds.

The issuance of this task order modification does not change any terms or conditions of the contract.

Please indicate your acceptance of this modification by having an official authorized to bind your organization execute three (3) copies of this document in the space provided and return two (2) copies to the U.S. Nuclear Regulatory Commission, Attn: Barbara Meehan, ADM/DC/CMC1, Mail Stop T7I2, Washington, DC 20555. You should retain the third copy for your records.

If you have any questions regarding this modification, please contact the undersigned on 301-415-6730.

Sincerely,

Barbara Meehan

Barbara Meehan, Contracting Officer
Contract Management Center No. 1
Division of Contracts
Office of Administration

Accepted:

____
Name

____
Title

____
Date

TELECOPY TRANSMITTAL

DATE 2/27/03

TO: W. Patrick, P. Maldonado, H. Garcia

COMPANY: Southwest Research Institute, Center for Nuclear Waste Regulatory Analyses

Phone: 210-522-5158

U.S. NUCLEAR REGULATORY COMMISSION, CONTRACT MANAGEMENT BRANCH NO. 2, DIVISION OF CONTRACTS AND PROPERTY MANAGEMENT, M/S T712, WASHINGTON, DC 20555

FROM: Barbara D. Meehan, NRC

PHONE: 301-415-6730

FAX NO.: 301-415-5396

THIS MESSAGE CONSISTS OF THIS COVER PAGE PLUS 2 PAGE(S)

FEB 2 7 2003

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March 12, 2003
Contract No. NRC–02–97–001
Task Order 10
Account No. 20.08801.101

U.S. Nuclear Regulatory Commission
ATTN: Edna Knox-Davin
Program Management, Policy Development and Analysis Staff
Office of Nuclear Material Safety and Safeguards
Mail Stop T–8 A23
Washington, DC 20555

Subject: Transmittal of Revised Report Entitled, Scoping Analysis of Exposure Scenarios Associated With Reused Soil, Contract Number NRC–02–97–001 Deliverable Intermediate Milestone 08801.120.005

Dear Ms. Knox-Davin:

The subject report is a revision of the Scoping Analysis of Exposure Scenarios Associated with Reused Soil report submitted by the Center for Nuclear Waste Regulatory Analyses (CNWRA) on April 17, 2002. This revision incorporates changes in response to requests in the April 25, 2002, letter to me from Giorgio Gnugnoli. It is a product of Task Order 10 of the CNWRA Technical Assistance for Reviewing Licensee Submittals Concerning Decommissioning, Contract Number NRC–02–97–001, for the U.S. Nuclear Regulatory Commission.

Additional sensitivity analyses were performed on the radon diffusion coefficient for the playground scenario. The original report considered only the cover radon diffusion coefficient and it showed that dose was not sensitive to it in the playground scenario. The new analyses considered two additional parameters, the building foundation and contaminated zone radon diffusion coefficients. The dose was found to be sensitive to the contaminated zone radon diffusion coefficient in the playground scenario. Description of these analyses is provided in Section 5.3.2.4. Revisions include

- Reported values in Table 5-2 were corrected. Many of the values included incorrect exponential notation.
- In Table A–4, information on the indoor dust filtration factor was added and information on soil ingestion was updated to accurately reflect the analyses conducted.
- As requested, numerous editorial- and typographic-type changes were made to the report. Where appropriate, the word "contaminated" was changed to "affected." However, use of the word "contaminated" was retained when referring to assigned RESRAD code parameter names (i.e., area of contaminated zone, density of contaminated zone, contaminated zone total porosity).

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Edna Knox-Davin
March 12, 2003

The attached report Scoping Analysis of Exposure Scenarios Associated With Reused Soil provides results of scoping analyses conducted for various soil reuse scenarios that can be used as a basis for future detailed analyses. The deliverable report is provided in electronic format on a CD-ROM and hardcopy format.

Please contact Mr. Michael Smith at 210.522.6828 or me at 301.881.0289 if there are questions concerning this report.

Sincerely yours,

for John L. Russell
Project Manager

JLR: ar
Enclosures

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