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TECHNICAL PEER REVIEW REPORT

REPORT OF THE REVIEW PANEL

REQUIREMENTS FOR DISPOSAL OF REMOTE-HANDLED TRANSURANIC WASTES AT THE WASTE ISOLATION PILOT PLANT

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PEER REVIEW CRITERIA AND FINDINGS OF THE RP

The findings of the RP with respect to the review criteria are as follows:

Criterion 1

Is the draft *RCRA Class 3 Permit Modification* optimized in format and content to facilitate the regulatory review and approval process?

Finding of the RP

The draft *RCRA Class 3 Permit Modification* is optimized in a format to facilitate the regulatory review and approval process. Throughout the document the text has been modified to show the new information added, and there are strike-outs to show the information deleted. The Overview section includes tables showing the regulatory references and their corresponding location in the document. In addition, Table 2 lists all of the sections of the document that have been modified. However, the draft *RCRA Class 3 Permit Modification* is lacking some information that would facilitate the regulatory review and approval process as described in the Findings to several of the Criteria.

Criterion 2

Are the parameters—for which RH-TRU waste will be analyzed—appropriate, and the rationale for the selection of these parameters adequately justified in the draft*Request for RCRA Class 3 Permit Modification*?

Finding of the RP

The draft *Request for RCRA Class 3 Permit Modification* lists the appropriate parameters and attempts to justify the selection of these parameters in the "ITEM 2" section of the document. This section includes the characterization approach, characterization methods, and data reporting and validation requirements. Table 2-1 attempts to justify all of the modifications of CH-TRU parameters to account for RH-TRU. Table 2-2 addresses the differences for Data Quality Objectives (DQOs). Table 2-3 addresses the differences for the Acceptable Knowledge (AK) criteria. Table 2-4 addresses the differences for Radiography, and Table 2-5 addresses the differences for Visual Examination. However, some of the information is presented only as background information and is not referenced in the permit.

Criterion 3

Is the acceptability of relying on AK as the sole analysis tool to meet characterization requirements chosen in the draft *Request for RCRA Class 3 Permit Modification* consistent with relevant regulations as interpreted jointly by the U.S. Environmental Protection Agency (EPA) and the U.S. Nuclear Regulatory Commission (USNRC)

Finding of the RP

In many cases, reliance on AK as the analysis tool to meet the waste characterization requirements listed in the draft *Request for RCRA Class 3 Permit Modification* as the sole analysis tool can be consistent with the relevant regulations as interpreted by the EPA and the USNRC. There may be cases where AK is not sufficient to meet the regulatory requirements. The WIPP has proposed additional characterization methodologies in a hierarchy of methods to allow for the characterization of all wastes accepted at the WIPP that will meet the DQOs. There will be cases where AK alone is sufficient, but this will be determined on a case-by-case basis depending on the nature of the AK available.

Criterion 4

Is AK alone sufficient to meet the DQOs?

Finding of the RP

In many cases, AK alone will be sufficient to meet the DQOs. Whether or not it is sufficient will be dependent on the nature of the waste and the source and completeness of the data that constitute the AK. For example, AK for waste generated from a chemical conversion process may consist of: 1) material balance and operating data; 2) historical records of the analyses of samples of the waste; and 3) inventory and custody records. Such AK should be sufficient to meet the DQOs. The AK for a drum of scrapped equipment and other waste (not specified) from a decommissioning activity may not provide sufficient information to meet the DQOs.

Criterion 5

Does the draft *Request for RCRA Class 3 Permit Modification* make a clear distinction between characterization activities using AK versus supplementary; confirmatory; or verification activities involving physical and other measurements?

Finding of the RP

The draft *Request for RCRA Class 3 Permit Modification* makes a distinction between characterization activities using AK versus supplementary, confirmatory, or verification activities involving physical and other measurements. Detailed records exists at the generating sites on many waste forms that will require disposal. Depending on process knowledge and other information sources, AK can be used successfully to fully characterize wastes to meet WIPP acceptance criteria. In some cases the existing information may be insufficient to meet the characterization requirements. When this occurs, supplementary information must be developed by other means. In the draft *Request for RCRA Class 3 Permit Modification*, several characterization methods—including AK, Radiography, and Visual Examination—are described, as well as their intended use in characterization activities. However, in the draft*Request for RCRA Class 3 Permit Modification,* figures such as R-2 do not provide for the use of other characterization methods should AK be

insufficient.

Criterion 6

Is the application of the Performance-Based Measurement System approach consistent with the relevant EPA's guidance on performance-based measurement systems?

Finding of the RP

The application of the Performance-Based Measurement System approach meets the EPA's guidance on performance-based measurement systems. The performance-based approach is designed to produce the desired results which eliminates characterization processes that do not produce information used to meet performance requirements. The DOE chose a performance-based approach to meet EPA's guidelines for RH-TRU waste. The characterization objectives for EPA requirements cover metals; residual liquids; cellulosic; plastics and rubber; total radioactivity; and surface dose rate. Baseline calculations for CH-TRU were used for comparisons to determine the relative effects of bounding assumptions regarding characterization data. The performance factors are specified in 40 CFR 191 and 40 CFR 194. Section 40 CFR 194.24 (c)(3) of EPA regulations allows AK and requires the QA standards—as specified in 40 CFR 194.22—to be applied to the process. Furthermore, 40 CFR 194.24 (c)(4) requires a system of controls and packaging of waste components to confirm that the total amount of each waste component falls within the performance limits. It appears that the EPA expects the performance assessment of an RH-TRU package to include uncertainty estimates, and that the actual diverse RH waste streams radionuclide contents be below the estimates.

Criterion 7

Does the draft *Request for RCRA Class 3 Permit Modification* present an RH-TRU waste characterization program that is consistent with the recommendations of the National Research Council?

Finding of the RP

The draft *Request for RCRA Class 3 Permit Modification* presents an RH-TRU waste characterization program that is not consistent in all cases with the recommendations of the National Research Council. The draft *Request for RCRA Class 3 Permit Modification* still includes characterization requirements which the National Research Council criticized as being self-imposed and overly conservative. The draft request presents evolutionary steps regarding characterization as site programs evolve.

Criterion 8

Does the *Waste Analysis Plan* (WAP) included in the draft *Request for RCRA Class 3 Permit Modification* meet the requirements for characterizing hazardous waste?

Finding of the RP

The WAP included in the draft *Request for RCRA Class 3 Permit Modification* broadly meets the requirements for characterizing hazardous waste. The RH-TRU waste analysis plan has been prepared for the management, storage, and disposal activities at the WIPP facility, to meet the requirements of the New Mexico Administrative Code (NMAC) that incorporates the EPA's 40 CFR 264.13 regulations. However, the WAP as presented is not sufficiently detailed and clear on the information that each waste-generating site must supply to the WIPP—particularly with respect to AK (see also Findings 1 and 2). Guidance concerning the characterization of mixed, hazardous, and radioactive waste has been incorporated into the preparation of the RH WAP. This RH WAP addresses waste stream identification requirements; waste stream parameters; waste characterization and confirmatory methods; data validation; and reporting. Characterization requirements for RH-TRU mixed waste are the same regardless of waste stream designation (i.e., debris, homogeneous solids, soil/gravel) or when the waste was generated (i.e., newly generated versus retrievably stored).

Criterion 9

Does the WAP included in the draft *Request for RCRA Class 3 Permit Modification* contain excessive requirements for characterizing hazardous waste?

Finding of the RP

Although the WAP follows guidance documents for characterizing hazardous waste, DOE has interpreted the requirements—quite conservatively—such that various proposed characterization methods have no legal or safety basis.

Criterion 10

Is the *Notification of Proposed Change to the EPA 40 CFR Part 194 Certification of the Waste Isolation Pilot Plant (Notification of Proposed Change)* clear and descriptive of the nature and scope of the proposed RH-TRU waste Characterization Program?

Finding of the RP

Section 2.0 "Nature and Scope" of the *Notification of Proposed Change to the EPA 40 CFR Part 194 Certification of the Waste Isolation Pilot Plant* describes the nature and scope of the proposed RH-TRU Waste Characterization Program. Attachment C is a matrix that lists 40 CFR Part 194 requirements and the manner that the RH-TRU program complies with the requirements. Attachment D is a checklist that demonstrates how the RH-TRU program—as compared to the CH-TRU program—complies with the EPA's Compliance Application Guidelines (CAG). All items are completed as suggested by the EPA's CAG. There are no items completed differently than suggested by the CAG, and there are no open items.

Criterion 11

Is the DOE's assessment of the consequences for compliance with EPA disposal regulations clearly and

adequately presented in the *Notification of Proposed Change* document?

Finding of the RP

Consistency with EPA disposal regulations is fully demonstrated and documented in resource documents. The performance assessment conducted by Sandia National Laboratory is complete and consistent with EPA regulations in 40 CFR 191 and 40 CFR 194. Also, this conclusion is validated by the recent National Research Council's analysis of disposing RH-TRU at WIPP. The RP fully concurs with the analysis as presented.

Criterion 12

Is the significance of the change in the *Notification of Proposed Change* clearly and adequately addressed?

Finding of the RP

The significance of the change in the *Notification of Proposed Change* is clearly and adequately addressed in section 2.0 "Nature and Scope" and section 3.0 "New Information." Section 2.0 reviews the historical record leading to the need to submit a change to the EPA's WIPP 40 CFR 194 certification to permit the disposal of RH-TRU in the WIPP. It also summarizes the RH-TRU Waste Characterization Program that is discussed in detail in Appendix A "RH-TRU Waste Characterization Implementation Plan." Section 3.0 explains the changes in the DOE's TRU waste characterization program to accommodate RH-TRU.

Criterion 13

Are the consequences for compliance determinations clearly stated in the *Notification of Proposed Change* document and technically justified in the *RH TRU Inventory Impact Assessment Report*?

Finding of the RP

The consequences for compliance determinations are clearly-stated in the*Notification of Proposed Change* document and are technically justified in the *RH TRU Inventory Impact Assessment Report* which is Attachment B of the *Notification of Proposed Change* document. Attachment B demonstrates by analysis that the repository performance of the WIPP would not be compromised even for large deviations from the planned inventories of both radioactive and non-radioactive waste placed in the repository.

Criterion 14

Does the *RH TRU Waste Characterization Program Implementation Plan* present a viable, effective, and efficient performance-based waste characterization program?

Finding of the RP

The *RH TRU Waste Characterization Program Implementation Plan* presented meets the performance factors of the waste characterization program. Applying knowledge of the characteristics of the waste using available information minimizes additional risk and exposure due to RH TRU. There is an overall balance in the program activities to characterize RH TRU waste to the extent possible. The efficiencies are gained by balancing the requirements for providing definitive characterizations data of the waste streams with those circumstances where sampling and analysis are neither feasible nor necessary, given the need for the data. The AK—when used appropriately in combination with NDA/NDE—yields a viable, effective, and efficient performance-based waste characterization program. The *RH TRU Waste Characterization Program Implementation Plan* provides the sites with considerable latitude in meeting the WIPP-Waste Acceptance Criteria (WAC) requirements; it would be better if WIPP provided definitive requirements for the different sites.

Criterion 15

Does the *RH TRU Waste Characterization Program Implementation Plan* clearly identify and justify the waste components to be characterized?

Finding of the RP

Comprehensive RH-TRU inventory and waste streams were identified, along with a comparison between CH and RH-TRU disposal volume projections. The waste components have been identified and justified in a general sense, but a detailed description of waste streams from the waste-generating sites is lacking. The documents fail to adequately describe the contact and communication among WIPP and the RH-TRU generators.

Criterion 16

Is the associated DQO appropriate for each waste component and consistent with the relevant guidance of the EPA?

Findings of the RP

The documents and the Project Team presentation indicate that the DOE-Carlsbad Field Office has adopted DQOs for metals; liquids; and cellulosic, plastics, and rubber (CPR) materials. The programmatic AK steps outlined in the *RH TRU Waste Characterization Program Implementation Plan* are sufficient to accomplish the DQOs adopted by the DOE-Carlsbad Field Office and can be reasonably relied upon to meet the DQOs for materials received at WIPP. The DQOs are somewhat conservative but they are consistent with the NMED and EPA requirements.

The WIPP-limiting values for radiological components in RH-TRU waste are based on surface-level exposure rates. The methodologies for determining exposure levels are well established, and these levels will be measured and documented for all shipments and disposal containers. These measured values constitute one

of the criteria for meeting the DQOs for RH-TRU exposure levels, and therefore, supplement AK.

Criterion 17

Is the reliance on AK as the primary method to meet DQOs and satisfy characterization objectives fully-justified?

Finding of the RP

The acceptability of relying on AK as the primary method in order to: 1) meet the DQOs; and 2) satisfy the characterization objectives, is fully justified for those RH-TRU wastes that have well-documented information regarding their generation and control. The DQOs for the WIPP facility were established using the EPA's Guidance for the DQO's Process (EPA, 2000). Furthermore, the DQOs are identified in the proposed WAP, and they reflect parameters that must be known in order to dispose of waste at the WIPP facility. The DQOs are derived from making a determination of the following waste characteristics: physical form of the waste; absence of prohibited items; and hazardous constituents in the waste. In many cases, the existing documentation would allow these DQOs to be verified with no further characterization efforts required on the part of the waste generator. If the physical form or the absence of prohibited items can not be determined from AK, then other methods (such as radiography) can be used to supplement AK in making a determination that satisfies both the DQOs and the characterization objectives.

Criterion 18

Is the acceptability of relying on AK as the sole method to meet characterization requirements and any DQOs sufficiently explained in relation to the relevant regulations—as interpreted jointly by the EPA and USNRC?

Finding of the RP

The use of AK as a sole method is not sufficiently explained or justified. The AK can be the dominant measure for determining DQOs for RCRA regulated materials and even for meeting the DQO for radionuclide concentration limits for RH-TRU materials. The explanation of the acceptability of sole reliance on AK represents an apparent inconsistency because as explained in Finding 16 of the RP, meeting the DQOs for RH components at WIPP relies on measured radiation levels for all containers which supplants AK. Therefore, although AK can be a dominant method and sometimes a completely adequate method, it is unlikely to be the sole method.

Criterion 19

Does the *RH TRU Waste Characterization Program Implementation Plan* draw a clear distinction between characterization activities using AK versus supplementary; confirmatory; or verification activities involving

physical measurement?

Finding of the RP

The distinction among the characterization activities, AK, supplementary, confirmatory, or verification is inadequate in the *RH TRU Waste Characterization Program Implementation Plan,* and is made particularly confusing by the definitions. All available information about the state of the waste should be used in deciding whether or not the characterization is adequate. It is inefficient to perform additional measurements unnecessarily. The AK is information that has already been obtained (such as process knowledge) before any specific WIPP RH-TRU requirements have been established and sometimes when the waste is already in a container. Supplementary information is used to fill in gaps in the required knowledge. Confirmatory and verification data determine whether the AK is reliable, but the distinction between confirmatory and verification is less clear. There are insufficient examples showing how the required information will be obtained using each of the various methods for each of the major types of waste.

Criterion 20

Does the *Notification of Proposed Change* adequately explain and justify how AK and the WIPP Waste Information System are used to satisfy quantification and control requirements?

Finding of the RP

The *Notification of Proposed Change* adequately explains and justifies how AK and the WIPP Waste Information System (WWIS) are used to satisfy the quantification and control requirements. The WWIS tracking and control system is currently in use in the CH-TRU waste program, and it is operating satisfactorily. To meet additional tracking and control requirements imposed on RH-TRU waste by the Land Withdrawal Act, WWIS will be modified by the addition of data fields. Each waste cannister will be assigned an identification number that will be entered into the WWIS. Characteristics such as curie content and surface dose rates (when the dose equivalent rate exceeds 100 rem/h) will be entered into WWIS to enable tracking and control for that particular container.

Criterion 21

Does the *RH TRU Waste Characterization Program Implementation Plan* adequately describe a Quality Assurance program that meets or exceeds appropriate requirements?

Finding of the RP

In general, the *RH TRU Waste Characterization Program Implementation Plan* describes a Quality Assurance

program that addresses the appropriate requirements but lacks sufficient detail. However, to meet the WIPP WAC, the site must develop and implement a quality assurance program that addresses all the applicable requirements specified in the waste analysis plan. Sites may use AK, Radiography, and/or Visual Examination (VE) to assist in the characterization of the waste streams. Qualitative data generated by AK, Radiography, and VE are not amenable to statistical data quality analysis. Rather, these methods provide qualitative data useful for determining the Summary Category Group, EPA Hazardous Waste numbers, and the absence of prohibited items in a waste container. Quality Assurance Objectives (QAOs) complement the DQOs by defining the precision, accuracy, completeness, comparability, and representativeness for each of the characterization methods (AK, Radiography, VE) that may be used. The validation methods are appropriately described and evaluated in Attachment R3 of the *RH TRU Waste Characterization Program Implementation Plan.*

Criterion 22

Does the Plan clearly and adequately explain how the provisions of 40 CFR 194.22 (b) will be utilized in the RH-TRU waste characterization program?

Finding of the RP

Use of the provisions of 40 CFR 194.22 in waste characterization is sufficiently-explained; however, it is important for DOE-CBFO to recognize that additional amplification (similar to that provided to the RP during the peer-review meeting) may be needed. The NMED's earlier limitation of its certification to CH-TRU was clearly based on the information provided which was deemed insufficient for inclusion of RH-TRU in the permit.

Criterion 23

Does the Plan present an RH-TRU waste characterization program that is consistent with recommendations from the National Research Council's Report, *Improving Operations and Long-Term Safety of the Waste Isolation Pilot Plant*?

Finding of the RP

The RH-TRU waste characterization program is reasonably consistent with theNational Research Council's Report, *Improving Operations and Long-Term Safety of the Waste Isolation Pilot Plant,*including its finding of self-imposed requirements that have no legal or safety basis.

Criterion 24

Are the *Request for RCRA Class 3 Permit Modification* and *RH TRU Waste Characterization Program Implementation Plan* consistent with the ALARA concept?

Finding of the RP

The *Request for RCRA Class 3 Permit Modification* and *RH TRU Waste Characterization Program Implementation Plan* are consistent with the ALARA concept. However, the reduction of worker exposure—as interpreted by the USNRC Guidance RM-30-2—is by itself not an argument for a modification, nor is it possible to use ALARA to justify repackaging in the interest of repository performance. In the proposed modification, there is no explicit explanation of why the AK-based waste characterization approach is needed to maintain repository integrity and avoid exposures. Reference is made to 40 CFR 194 and a presumption is made that if the requirements of 40 CFR 194 are met, the integrity of the repository will be maintained and such exposures will be ALARA.

Additional Findings of the RP

Finding 25

The AK is the key methodology proposed by the WIPP for characterization of RH-TRU waste. The AK can be most useful. However, its usefulness can be improved by ensuring that the stakeholders achieve a clear understanding of the basis for, and use of AK in a suite of analytical characterization tools.

Finding 26

The communication between the regulated and regulatory communities does not appear to be optimal for the efficient processing of permit modifications. It appears that there are not sufficient free and full exchanges to keep all parties fully informed of each other's needs and accomplishments. An example of this is the apparent lack of communication regarding the advances in nondestructive testing using radiography to identify the absence of prohibited items.

Finding 27

Although there is a clear statement of the regulatory requirements for the characterization of the waste, there is no statement of the scientific requirements for such characterization upon which the regulatory requirements are based. It would, for example, be useful to know that many safety factors are already included in these requirements before discussing whether or not the requirements can be met. A failure to discuss such matters inevitably results in requirements not justified by safety as decried by the National Research Council's review panel.

Finding 28

Communication between WIPP and the waste generating sites is not at a level to foster efficient planning and implementation of WIPP WAC.

Finding 29

The draft *Request for RCRA Class 3 Permit Modification* has a good basic structure but lacks—in many cases—sufficient details and specificity to facilitate regulatory review.

Finding 30

Audit plans were not provided to the RP.

Finding 31

It is unclear what fraction of the RH-TRU waste has already been containerized or packaged as compared to that which is still to be generated or is stored in bulk.

Finding 32

Significant emphasis is placed on determining EPA's Hazardous Waste Numbers for either listed or characteristic wastes, which in some cases may include organic compounds. Based on the impact study (Appendix B of the *Notification of Proposed Change*), there appears to be no impact on repository performance that depends on this identification.

Finding 33

In keeping with the National Research Council's recommendation to "think smart" good health physics practice and the ALARA philosophy, the efforts to swipe all RH-TRU waste containers is questionable. The containers hold sealed units that have been determined by waste generators and shippers to be "free" of contamination. The commitment to take and analyze six smears—because of the difficulty and complexity of the remote swiping operation—can be a single-point failure in an otherwise straightforward system of waste receipt and emplacement. This approach appears to have evolved from conservative health physics practices used in laboratories and facilities that are relatively clean and quite variable. Records of contamination detected on CH-TRU packages already received could provide a useful baseline of the effectiveness of the waste system in controlling contamination and the degree to which such information has affected WIPP operations. For example, is minimal contamination on one smear (or the absence of a smear result) a basis for not placing an RH-TRU container in the WIPP?

RECOMMENDATIONS

Based on a careful assessment of the information presented to the RP and the findings developed in response to the review criteria, the RP provides the following recommendations:

1. A detailed procedure for determining whether there is sufficient AK available on a waste, should be developed as part of the permit application. This procedure should be consistent across all waste

generating sites.

2. In the final *Request for RCRA Class 3 Permit Modification* a detailed procedure should be provided to go to other characterization methods if AK is found to be insufficient. For example, figures such as Figure R-2 of the draft *Request for RCRA Class 3 Permit Modification* and the accompanying text, should be reviewed.
3. The DOE should implement the National Research Council's recommendation that review of characterization and packaging requirements continue, especially implementation "... over the entire National TRU Program."

4. The DOE should provide to the EPA a complete inventory of radionuclides and waste forms so that the EPA may verify the repository performance (that WIPP complies with 40 CFR 191 and 40 CFR 194) using its own methods for certification.
5. The DOE should initiate a more appropriate interaction with the EPA and the NMED, not only to determine and meet their respective requirements but also to ensure that the relevant recommendations—such as those by the National Research Council—are evaluated and implemented.
6. Prior to submission, all permit-related documents—in addition to currently planned reviews—should be reviewed in detail for completeness, specificity, and clarity by a team experienced in the permitting process.
7. The *Request for RCRA Class 3 Permit Modification* must be expanded to include more specifics and examples for clarity and completeness.
8. The discussion for Table 1 of the draft *Request for RCRA Class 3 Permit Modification* should be expanded to justify why sections of the documents require "no action" or "no changes".
9. As part of the permit application, supplemental information should be supplied detailing the waste characterization plans for each waste generating site and DOE's procedures for determining that these plans meet the WIPP WAC.
10. Detailed audit procedures for WIPP and the waste generating sites should be provided as part of the permit application.
11. More detail and specificity on WAC using AK, VE, and Radiography (including types of instrumentation to be used) should be provided in the permit application.
12. The DOE should evaluate the necessity of identifying waste streams by the EPA's Hazardous Waste Numbers or Characteristics. If there is no impact on WIPP performance and integrity, the DOE should work with the regulatory agencies to remove this requirement.
13. Whereas it is desirable to preclude contamination and its potential spread, a complete review should be made of what is gained from the remote swiping procedure for "clean" RH-TRU containers and how the information will be used.

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BIOGRAPHICAL SUMMARIES OF THE MEMBERS OF THE RP

Alan S. Corson is a consultant in hazardous waste issues. He has over 25 years of experience in a number of environmental issues, notably those related to the regulations and management of hazardous waste. Subsequent to his retirement from the U.S. Environmental Protection Agency (EPA), he served in an advisory role to Jacobs Engineering Group and to the Versar Corporation for both government and private sector clients regarding hazardous waste management programs. During his employment at the EPA, he worked at the Office of Solid Waste where he was responsible for regulatory programs and establishing national standards for generators and transporters of hazardous waste; development of sampling and analytic methods for evaluating solid/hazardous waste including the quality assurance/quality control program; and development and management of programs to establish risk assessment of hazardous waste management practices. Alan Corson was instrumental in the development of the original regulatory program defining standards for solid waste and hazardous waste, and setting national standards for recycling hazardous waste. He also initiated, developed, and managed the original program for restricting hazardous wastes from land disposal management options. The framework developed under this program is currently in-place and used for all evaluations in the land-ban program. Alan Corson served as the EPA Office of Solid Waste representative on many intra- and inter-agency workgroups including PCBs, Reportable Quantities, chlorinated solvents, and transportation of hazardous materials. He developed a guide for effective management of infectious wastes—a predecessor to the current regulatory program for medical wastes; characteristics and listings of hazardous waste; and many regulatory options papers for presentation. Alan Corson managed the preparation of numerous regulatory packages for all aspects of the program implementing the Resource Conservation and Recovery Act (RCRA). He has spoken widely and has taught numerous courses on RCRA and its various regulations. He served on numerous national and international panels including review panels of the American Society of Mechanical Engineers. He received a B.S. in Electrical Engineering and an M.S. in Engineering Management from the Drexel Institute of Technology in Philadelphia, PA.

Tom A. Hendrickson is currently an Independent Consultant in the fields of energy, engineering, and technology. His career encompasses service to both government and industry. He was Senior Executive of Raytheon Federal Engineers & Constructors Company, developing high technology projects which included a privately-financed New Production Reactor; the Accelerator Production of Tritium; and the North Korean nuclear energy program. While working at DOE during the Bush Administration, he was Principal Deputy Assistant Secretary of the Office of Nuclear Energy, including: Civilian Reactor Development; the Naval Nuclear Propulsion Program; Uranium Enrichment; Space and Defense Power Systems; Isotope Production; and Nuclear Safety Policy. He later became the Director of the New Production Reactors for the DOE, responsible for designing and building new trituim production capacity for nuclear weapons; research and development; safety and environmental compliance; and construction. Concurrently, he served as acting Under Secretary of Energy responsible for all defense and nuclear weapons activities of the Department. Early in his career, he served on Admiral H. G. Rickover's staff at the Atomic Energy Commission in Washington, DC. He directed the headquarters staff and contractors involved in submarine nuclear propulsion engineering, including: research, development, design, and construction. During this period, he also served as Project Officer for all new submarine developments including the NR-1; the USS Los Angeles SSN-688 class of over 60 attack submarines, and the electric drive submarine. He helped with the development of port-entry safety

procedures and sea trials of the United States' first nuclear powered surface ships, the USS Long Beach and the USS Enterprise, as well as the first refueling of the Shippingport Atomic Power Station. He is a member of the following professional organizations: The American Nuclear Society, The American Society of Mechanical Engineers, and The American Physical Society. Tom Hendrickson received a B.A. degree in Physics from Harvard College and a M.S. degree in Physics from Georgetown University. He is a Licensed Professional Engineer.

Michael C. Kirkland is an independent consultant in radioactive nuclear waste, nuclear technology, and environmental management. He led a team that performed a Congressionally-mandated External Independent Review of the Spallation Neutron Source Project at Oak Ridge. He assisted in the planning and review of a management assessment at a U.S. Department of Energy (DOE) Site that involved the restart of a plutonium facility. He participated in planning, procurement, and review activities in the environmental remediation area that included decommissioning activities at a shut down nuclear test reactor; and designed and installed a ground water cleanup technology. He also provided design oversight for a new facility related to the DOE weapons complex. During his tenure at Savannah River Site (SRS), Michael Kirkland was a Technical Advisor, Project Manager, and Director of the Project Engineering Division. He evaluated nuclear and mixed waste conditions and aspects of high-level wastes and spent nuclear fuel; determined material inventories; performed pollution prevention; environmental health and safety evaluations for a proposed waste treatment facility; served as technical advisor to a study administered by the Savannah River Operations Office; and developed integrated schedules defined for this project. Michael Kirkland was director of the Project Engineering Division and managed the SRS design and construction program. He has been involved with waste management and environmental projects; cutting edge technology programs; and worked with lasers and magnetic containment. He served as Director of the Waste and Fuel Cycle Technology Office and planned and coordinated the programs of the DOE National High Level Waste Technology Office; the SR Fuel Cycle Technology Program; and the Commercial Interim Spent Fuel Management Program. He planned the initial construction of the Consolidated Incinerator Facility which thermally destroys excess benzene created by the In-Tank Precipitation process that was to prepare feed material for the Defense Waste Processing Facility. Michael Kirkland was Director of the Commercial Nuclear Spent Fuel Storage Project Office and managed a contract between DOE and the Barnwell Commercial Nuclear Fuel Reprocessing Facility constructed by Allied General Nuclear Services. Michael Kirkland holds a B.S. in Mechanical Engineering from the University of South Carolina in Columbia, SC. He is registered as a Professional Engineer in South Carolina.

Peter B. Lederman is a consultant with over 48 years of experience in all facets of process engineering, environmental management, control, and policy development. This includes hazardous substance management; environmental remediation; environmental audit; pollution prevention; development of air pollution control devices; and reuse of waste products. He recently retired as Executive Director of the Center for Environmental Engineering & Science, Executive Director for Patents and Licensing, and Research Professor of Chemical Engineering and Environmental Policy at the New Jersey Institute of Technology. Peter Lederman managed major programs in industrial waste treatment research and development,and in oil and hazardous material spill control and remediation. Most recently, he was responsible for a study of the Economic Impact of Environmental Regulations. He has been responsible for technology transfer efforts

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James E. Martin is currently Associate Professor of Radiological Health at the University of Michigan's Department of Environmental and Industrial Health where he is involved in research and teaching related to radiation protection. His interests include: radiation physics; radiological assessment; radio-analytical measurements; internal radiation dosimetry; radioactive waste management; and radiation protection standards and their regulatory aspects. After a 25-year career with the US Public Health Service and the Environmental Protection Agency, he served as Chief of the Hazardous and Solid Waste Program at the Colorado State Health Department which included consultations with the legislature and EPA. James Martin is Certified in Health Physics by the American Board of Health Physics. He has been involved in numerous scholarly and policy activities including: chair of the Michigan Toxic Substance Control Commission; committee member of the National Research Council on CDC Radiation Studies; member of the EPA's National Advisory Committee on Environmental Protection for Radwaste; member of the Environmental Management Board of the U.S. Department of Energy; Chair of the Committee on Formerly Utilized Sites Remedial Action Program (FUSRAP); member of the Advisory Committee on Nuclear Facility Safety to the Secretary of Energy; and a member of EPA's Science Advisory Board-Radiation Advisory Committee. Professor Martin received the Meritorious Service Award from the U.S. Public Health Service, and has published numerous papers in peer-reviewed journals on radiation measurements, radioactive waste, and radiation protection. He received a B.A. degree in physics from Vanderbilt University in Nashville, TN; an MPH degree in radiological health; and a Ph.D. degree in radiological health from the University of Michigan in Ann Arbor, MI.

Wade O. Troxell is President and Founder of Sixth Dimension, Inc., a development stage company offering Internet-based products and services to the electric power industry. He has been on leave-of-absence as an Associate Professor of Mechanical Engineering, Colorado State University (CSU) in Fort Collins, CO; and Director, Robotics and Autonomous Machines Laboratory at CSU. His research interests include: product realization process; design support systems; behavior-based robots; and robot programming and control. He was Executive Director, U.S. National Institute of Standards and Technology (NIST)/Mid-America Manufacturing Technology Center, Colorado Regional Office; Director, Manufacturing Excellence Center, CSU; Robotic Consultant to the Public Service Company of Colorado, Nuclear Engineering Division (Fort St. Vrain Station on the controller retrofit of the fuel handling robot);and NATO Postdoctoral Fellow. He was also a Consultant specializing in product design and process automation. Wade Troxell is currently Advisor to the Senior Vice President of the American Society of Mechanical Engineers'(ASME) Council of Member Affairs. He serves on the ASME Inter-Council Committee for Federal R & D, ASME/NIST Interaction Committee, and is ASME Chair of the Distinguished Lecturers Program. He is an ASME Past Vice President for Region XII (Rocky Mountains). Wade Troxell serves as Chair of the Mechanical Engineering Program for the National Technological University. He is author or coauthor of over 50 refereed

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Richard Wilson is currently Mallinckrodt Research Professor of Physics at Harvard University in Cambridge, MA. He is also an affiliate of the Center for Middle Eastern Studies; the Harvard Center for Risk Analysis; and of the Program on Science and International affairs at the Kennedy School of Government. He used the principle of detailed balance to measure the spin of the pi-zero meson and studied nucleon-nucleon scattering at the Harvard Cyclotron Laboratory. He was involved in converting the Harvard University Cyclotron from nuclear physics use to medical treatment. He was the first to analyze elastic scattering data in terms of the electric and magnetic form factors. He studied nucleon structure by electron-proton scattering and muon proton scattering. He was a participant in the Cambridge Electron Accelerator "by-pass" program, which demonstrated an unusually large cross-section for producing hadrons. Richard Wilson closely followed the Russian and Ukrainian radiation accidents at Chernobyl in the Ukraine, and the accidents at the Techa River and the Mayak production complex in the Ural Mountains. He performed research on the risk assessment of chemical carcinogens. Richard Wilson is Chairman of the visiting committee of the radiation medicine department at Massachusetts General Hospital. He is Chairman of an International Advisory Committee to the newly formed Sakharov College of Radioecology in Minsk, Belarus, and serves as a member of the Board of Directors of the Andrey Sakhorov Foundation of New York and Moscow. He was the first Chairman of the Harvard Cyclotron Operating Committee and is still a member. He is a Fellow of the American Physical Society, Chaired its committee to study the radiological consequences of severe nuclear power accidents, and received its "Forum Award". Richard Wilson chaired an advisory committee for the Minister of Economic Affairs of the Republic of China. He is a founder/member of the Society of Risk Analysis, as well as the recipient of its Distinguished Service Award. He is a member of the American Nuclear Society and the Society of Toxicology. He served as the Director of the NE Regional Center of the National Institute of Global Environmental Change. He has held various positions as a Visiting Professor, Scholar, and Scientist and served on numerous government advisory committees in many different agencies and countries. Richard Wilson is the author or coauthor of more than 800 published papers. He is the editor of the English translation of the Russian Journal, *Radiation and Risk,* which is published by the Russian Medical Research Laboratory in Obninsk and is mainly about the effects of Chernobyl. Richard Wilson holds a B.A. degree; an M.A. degree and a Ph.D. degree; all in Physics and all from Christ Church, Oxford University, Oxford, England.