Independent Technical Review Report

Summary and Recommendations: EM Landfill Workshop

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Sponsored by:

The Office of Engineering and Technology (EM-20)

21 November 2008

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EXECUTIVE SUMMARY

On 7-8 October 2008, a workshop was conducted by the US Department of Energy (DOE) to discuss four technological issues relevant to nearly all sites in the DOE complex:

- Waste subsidence and its impact on the long-term effectiveness of final covers over low-level radioactive waste (LLRW) disposal sites.
- The impact of waste forecasting and characterization on the required size and operation of LLRW disposal facilities.
- Long-term performance of final covers on LLRW disposal sites, given the 1000-yr life expectancy period.
- The role of liners in CERCLA/RCRA and DOE-regulated disposal sites.

Personnel from DOE (headquarters and sites), academicians, and industry representatives attended the workshop. The participants concluded that quick wins could be achieved by conducting and publishing state-of-the-art reviews on the following topics:

- Transport properties of radionuclides in barrier materials.
- Hydrologic and transport performance of liners, including barrier and drainage materials
- Hydrologic performance of final covers.
- Life expectancy of liner and cover component materials (natural and geosynthetic) in LLRW environments.
- Criteria for acceptable differential settlement in covers and cover materials.

The following longer-term research and development topics and strategies were identified to fill knowledge gaps:

- Establish a program to collect, compile, analyze, interpret, and publish settlement data from DOE sites.
- Identify liner and cover systems in the DOE complex that be used as benchmarks to quantify long-term performance. Monitor these systems and document the performance data in a forum open to the public.
- Develop techniques for reliably predicting settlement of soil-like and containerized waste forms, including parameters for design and performance prediction.
- Conduct studies to define the transport properties and life expectancy of barrier and drainage materials in LLRW environments.
- Develop probabilistic methods to address uncertainty in effectiveness of barrier and drainage materials that could be used in performance assessments.
- Conduct field studies to support site-specific and/or complex-wide characterization and field screening methods for forecasting waste streams.
- Characterize the time-dependence of engineering properties of cover system components, develop in situ methods to detect such changes, and develop and

validate predictive methods for performance assessments that account for time-dependent engineering properties.

- Evaluate the reliability and utility of point-based and remote-monitoring methods for covers, and develop best practices regarding monitoring cover performance.
- Develop strategies to design covers that are resistant to damage by differential settlement.
- Develop and/or refine models and modeling strategies for final covers using high-quality field data for validation.
- Develop ecological engineering strategies to design covers that mimic sustainable natural systems.
- Establish site-specific programs to develop improved methods for design of final covers.

The following topics were recommended for development of guidance documents and white papers.

- Develop a decision-making framework for settlement assessment and abatement that is tied to performance assessments.
- Develop guidance on implementing settlement analysis in design, operations, and performance assessments.
- Develop consistent methods that can be applied complex wide for field screening of D&D materials, estimating waste types and volumes, and sequencing of waste streams.
- Develop a decision-making framework that can be used on a site-specific basis to evaluate the efficacy of employing liners at DOE waste disposal facilities. Ensure that framework can be incorporated into the performance assessment methodology.
- Evaluate the paradigm of permanent cover systems and the possibility of implementing evolutionary cover designs that include periodic upgrading or replacement.
- Evaluate the paradigm of permanent cover systems and the possibility of implementing evolutionary cover designs that include periodic upgrading or replacement.
- Develop guidance on incorporating the contributions of liner systems, leachate collection systems, and final cover systems in performance assessments.
- Develop guidance on how to address the impact of extreme events on the performance of DOE's waste containment facilities.
- Compile a summary of waste types and level of contamination, soil-to-debris ratios, placement practices, and lessons learned from disposal operations in the DOE complex. Compare actual waste volumes and contamination levels to values anticipated during site characterization.

The workshop participants indicated that these issues should be addressed with the best available science, and that the scientific findings should be published in the archival, peer-reviewed literature to ensure widespread distribution and complete transparency.

INTRODUCTION

Between March 2007 and October 2008, the US Department of Energy (DOE) reviewed low-level radioactive waste (LLRW) disposal operations conducted at Hanford, Idaho, Oak Ridge, Portsmouth, Paducah, the Nevada Test Site, and the Savannah River Site. The review was conducted by an independent technical review (ITR) team, which also authored this report (Craig H. Benson – University of Washington, William H. Albright – Desert Research Institute, David P. Ray – US Army Corps of Engineers, and John Smegal – Legin Group). The review was conducted to provide an independent perspective that could identify factors in existing disposal operations that might hinder meeting long-term performance goals or could improve the effectiveness of the operation.

Four technological issues were indentified from these reviews that applied to nearly all sites in the complex:

- Waste subsidence and its impact on the long-term effectiveness of final covers over LLRW disposal sites.

- The impact of waste forecasting and characterization on the required size and operation of LLRW disposal facilities.

- Long-term performance of final covers on LLRW disposal sites, given the 1000-yr life expectancy period.

- The role of liners in CERCLA/RCRA and DOE-regulated disposal sites.

On 7-8 October 2008, a workshop was conducted to discuss these issues and to make recommendations for technological investments. The workshop consisted of a plenary session that provided an overview of primary technological issues, followed by discussion sessions covering each of the four issues listed above. The discussion sessions consisted of brief presentations by 4-6 expert panelists followed by a facilitated discussion that included all workshop participants. The panelist presentations addressed a series of questions posed by the ITR team beforehand.

This report describes the findings of this workshop and provides recommendations for technological investment by DOE. A list of the panelists is included in the workshop agenda in Appendix A. Panelists for each session included academicians and practitioners having experience within and outside the DOE complex. Questions posed to the panelists are in Appendix B and the list of participants is in Appendix C. Presentations made by the panelists are available at:

https://mywebspace.wisc.edu/chbenson/EM_Landfill_Workshop/

SESSION A: SETTLEMENT

The panel for the session on settlement included Patrick Fox (Ohio State University), William Albright (Desert Research Institute), Michael Reimbold (CH2M Hill), Richard Finno (Northwestern University), and David Ray (US Army Corps of Engineers). Tuncer Edil of the University of Wisconsin led the discussion.

The panel presentations indicated that differential settlement is an important factor affecting the long-term performance of final covers. Presentations by the panelists indicated that most of the methods used to predict settlement are empirically based, although more sophisticated analyses using numerical models are conducted in some cases. In nearly all cases, input to empirical or numerical models used for prediction includes parameters estimated from information in the literature pertaining to other waste forms or materials because data describing the compressibility of DOE-type wastes is scant. The panel presentations also indicated that there was a need to determine the amount of differential settlement that covers can tolerate and to quantify settlement behavior of DOE wastes using large-scale laboratory testing, field observations, and inverse analysis. The panel concluded that settlements induced by collapse of voids (e.g., containers or vessels) are the most problematic and difficult to predict, and require the greatest amount of attention.

Key points raised during the panel presentations and the follow-on discussion included:

- Systematic settlement monitoring data for DOE wastes is scant, but can be obtained by installing instruments at DOE waste disposal sites.

- Subsidence features are corrected when observed during operations and institutional control, but may become more problematic when lesser controls are in place farther in the future.

- Operations and cover construction should be conducted in such a way that most settlement issues are addressed prior to installation of the final cover.

- The amount of differential settlement that covers can withstand is unknown and needs to be determined.

- The impact of local cover failures on performance objectives is not well understood and needs to be explored.

- Settlement of waste masses comprised primarily of soil is expected to be more predictable than settlement of waste masses comprised of soil and other objects that can collapse features (e.g., containers and vessels).

SESSION B: LINERS

The panel for the session on liners included Rudolph Bonaparte (Geosyntec), Charles Shackelford (Colorado State University), Tuncer Edil (University of Wisconsin), John Daniels (National Science Foundation), and Kevin Pavlik (US Army Corps of Engineers). Craig Benson of the University of Washington led the discussion.

The panel presentations indicated that liners are effective in reducing uncertainty in the spatial and temporal distribution of contaminant release from waste disposal facilities. A long track record of liner performance now exists, and shows that modern liners are very effective in controlling the discharge of liquids and the migration of contaminants. However, most of the information on transport of contaminants through liners pertains to constituents (organic and inorganic) derived from municipal and hazardous waste landfills. Little information on transport of radionuclides through liners exists, and the information that is available has not been compiled in an archival scientific publication. The panel also acknowledged that liners are not needed in all applications, and that a framework is needed to rigorously assess how and when liners should be employed.

Key points raised during the panel presentations and the follow-on discussion included:

- CERCLA/RCRA and IAEA/NRC/DOE employ fundamentally different philosophies towards design and performance assessment of waste disposal facilities and evaluate disposal facilities over very different time scales (decades vs. millennia).

- A consistent set of scientific principles that transcend existing regulatory paradigms can be applied to evaluate the need and utility of a liner.

- Liners can reduce uncertainty and have been shown to function very well over the existing performance record (≈ 30 yr).

- Liners may or may not be necessary depending on the type of waste and the constituents released by the waste. Any assessment of need is complicated by the challenges associated with accurately characterizing the contaminant source term within the disposal facility.

- Liners may be more important for containment during operations and shortly after closure, and covers more important for long-term containment.

- Barriers used in liners work in concert with drainage layers, and both need to function for a barrier layer to achieve optimal functionality.

- More scientific information regarding the life expectancy and functionality of liners in the environments characteristic of DOE disposal facilities is needed for liners to receive credit in performance assessments

- Liners may be more useful for radionuclides with shorter half-lives.

- Archival scientific publications that review and document the transport characteristics of radionuclides in barrier materials are needed to provide the scientific underpinning required for performance assessments.

SESSION C: FORECASTING

The panel on forecasting included Martin Letourneau (US DOE LFRG), Gary Snow (Washington Closure Hanford), Jay Beech (Geosyntec), Ken Redus (Redus and Associates), David Maloney (CH2MHill), and John Hampshire (Bechtel-Jacobs Company). John Smegal of the Legin Group led the discussion.

The panelists indicated that accurate waste forecasting of waste volumes and dosages is one of the most critical aspects of cost-effective disposal operations. Site managers that generate waste should use forecasting tools to optimize their waste stream to the fullest extent possible. Various site-specific waste forecasting models exist within the complex that are used when making short-term and long-term decisions on budgets, volume requirements, contamination levels, waste staging, handling, and scheduling. Short-term waste forecasting has been found to be more accurate than long-term forecasting, but forecasting at both time scales is important for planning and upward reporting. Forecasting models need to be simple, but flexible enough to easily incorporate changing conditions.

Discussion that followed the forecasting panel emphasized the following points:

- Factors that impact waste forecasting include funding, accuracy of site remediation characterization, waste acceptance restrictions, and placement criteria. Uncertainties in these factors can be quantified using Monte Carlo simulation.

- Pretreatment requirements in a waste stream as well as demolition and removal methods can impact total projected volumes and schedules.

- Waste sequencing is a critical factor, and ideally waste generation rates should match placement rates in the waste cell. Waste generation and disposal rates are impacted by weather, personnel and equipment limitations, crew experience, and remedial site unknowns.

- Complete remedial site characterization and rapid field screening techniques are vital to reduce down time. The site manager should have options for alternative waste streams in the event the primary remediation site waste stream is shut down for some reason.

- Regulator understanding and acceptance of site issues is a key to fast decision making on waste disposition.

- Long-term forecasting is vital to planning; design and construction of landfill expansions can require as long as three years.

- Probabilistic forecasting techniques developed for Oak Ridge should be considered for use at Portsmouth and Paducah, where volumes and dose levels may be uncertain.

SESSION D: COVERS

The panel for the session on covers included William Albright (Desert Research Institute), Jody Waugh (Stoller Corporation), Craig Benson (University of Washington), Michael Fayer (Pacific Northwest National Laboratory), and David Ray (US Army Corps of Engineers). Patrick Fox of Ohio State University led the discussion.

The panelists indicated that covers were the most important factor affecting the long-term performance of a waste disposal facility. The presentations showed that the performance of covers varies over time, that changes in performance are related to the type of materials used to construct the cover, and that these changes are difficult to predict with models a priori. For example, compacted clay barriers have been shown to become very permeable over short periods of time (0.5-4 yr) periods, whereas composite covers (geomembrane over a clay barrier) are very effective over longer periods of time under typical conditions. The effectiveness of all covers is influenced by presence and effectiveness of drainage layers above the barrier layer as well as biotic and abiotic interactions with the surrounding environment. A holistic ecological engineering approach to covers was recommended by the panel that included traditional civil and geotechnical design along with the interaction of the cover with its surrounding environment. The panel also emphasized the need to couple predictive modeling with monitoring programs that can be used to validate assumptions made in performance assessments and the need to develop a process that ensures stewardship of covers that transcend generations and societal change. Remote-sensing technologies are likely to be used as part of stewardship activities; however, periodic human inspection of sites probably will be needed for the foreseeable future.

The following points were raised in the follow-on discussion:

- The final cover is the most important element of a LLRW containment system after operations cease.

- Barrier-based covers that employ geosynthetic barriers are needed in humid climates when a performance assessment requires that percolation into the waste be limited to small amounts.

- Evapotranspiration covers can be viable in drier climates, but require a more intensive, site-specific design and more monitoring.

- Simple designs are preferred to complex designs over the long term, provided simple designs will meet performance objectives.

- At some sites, the long-term performance of the cover may be compromised by subsidence or degradation of cover materials. For sites with such concerns, occasional replacement of the cover system may be considered or an interim cover might be deployed until subsidence has ceased. This would represent a significant paradigm shift from the current view of final covers as permanent.

- Remote sensing technologies are attractive but do not replace in-situ sensors and physical site inspections. Point-based sensors may not be suitable for long-term monitoring.

- Time-dependent material properties are a key consideration for long-term performance. Uncertainty/sensitivity analyses needed to identify key parameters.

- Differential settlement, earthquakes, and other processes that induce ground motion pose substantial threats to the functioning of cover systems.

RECOMMENDATIONS

The following recommendations for technological investments were developed by the workshop participants. These recommendations are listed by issue and are not arranged in order of priority. A follow-on survey of the workshop participants will be conducted to identify recommendations regarding priority.

Waste Settlement

1. Establish criteria to define when settlement is an important issue and how much settlement is acceptable for maintaining an intact barrier.

2. Establish a program of settlement data collection, compilation, analysis, and interpretation at DOE sites.

3. Develop a decision-making framework for settlement assessment and abatement that is tied to performance assessments.

4. Develop verified techniques for settlement prediction of both soil-like and more importantly containerized waste including parameterization for design.

5. Develop guidance on implementing settlement analysis in design, operations, and performance assessment.

Liners

1. Compile and publish existing information regarding transport properties of radionuclides in barrier materials.

2. Compile and publish existing information regarding life expectancy of barrier and drainage materials in LLRW environments.

3. Conduct follow-on studies to fill gaps identified in information regarding transport properties and life expectancy of barrier materials.

4. Develop probabilistic methods to address uncertainty in effectiveness of barrier and drainage materials that could be used in performance assessments.

5. Develop framework that can be applied on a site-specific basis to evaluate the efficacy of deploying liners at DOE waste disposal facilities. Ensure that the framework can be incorporated into the performance assessment methodology.

6. Develop guidance on incorporating the contributions of liner systems, leachate collection systems, and final cover systems in performance assessments.

7. Identify liner systems in the DOE complex that be used as benchmarks to quantify long-term performance. Monitor these systems and document the performance data in a forum open to the public.

Forecasting

1. Develop consistent and universal methods for estimating waste resulting from D&D projects that can be applied complex wide.

2. Develop field-screening methods for waste subject to land disposal restrictions.

3. Conduct field studies to support site-specific and/or complex-wide characterization methods.

4. Compile a summary of waste types and level of contamination, soil-to-debris ratios, placement practices, and lessons learned from disposal operations in the DOE complex. Compare actual waste volumes and contamination levels to values anticipated during site characterization.

Covers

1. Evaluate the paradigm of permanence for cover system design. Can an interim cover be employed while subsidence is occurring, with eventual replacement by a permanent final cover? Is perpetual replacement a more practical and realistic

option than a permanent cover? Can evolutionary cover designs replace a single permanent final cover design? If an evolutionary cover can be employed, can the design be less stringent?

2. Evaluate the time-dependence of engineering properties of cover system components, including in situ detection of such changes, and develop predictive methods that can be used in performance assessments.

3. Evaluate the reliability and utility of point-based and remote monitoring methods for covers, and develop best practices regarding monitoring cover performance.

4. Develop strategies to design covers that are resistant to damage by differential settlement.

5. Compile and analyze data regarding the performance of covers and liners and publish it in the archival scientific literature.

6. Continue to develop and refine models and modeling strategies using high-quality field data for validation.

7. Develop ecological engineering strategies to design covers that mimic sustainable natural systems.

8. Identify cover systems in the DOE complex that be used as benchmarks to quantify long-term performance. Monitor these systems and document the performance data in a forum open to the public.

9. Develop guidance on how to address the impact of extreme events on the performance of DOE's waste containment facilities.

ACKNOWLEDGEMENT

Mark Gilbertson (DOE-HQ) provided funding for the workshop. Dinesh Gupta (DOE-HQ) and Vincent Adams (DOE-HQ) were instrumental in defining the scope and content of the workshop. Rosalind Blocker of Savannah River National Laboratory provided webcasting services for the workshop. Christine Goddard of MSE Technologies arranged for the workshop facility and provided logistical support. The assistance provided by each of these individuals is gratefully acknowledged.

APPENDIX A – WORKSHOP AGENDA AND PANELIST BIOGRAPHICAL SKETCHES

Workshop Agenda

The purpose of this workshop is to discuss technological issues affecting on-site disposal facilities in the DOE complex and to define a roadmap for DOE landfill technology advancement.

Day 1 – 7 October 2008	
7:30 — 8:30 am	**Registration**
8:30 — 8:45 am	**Welcome and Introduction** Welcome and Introduction, Goals, and Questions to be Answered – *Vincent Adams, EM-22.*
8:45 — 9:15 am	**DOE EM Landfill Assessment Project Findings and Lessons Learned –** *Craig H. Benson, Department of Civil and Environmental Engineering, University of Washington* **Approach for the Workshop –** *Craig H. Benson, Univ. of Washington*
9:15 — 9:30 am	**Break**
9:30 — 12:30 pm	**Discussion Topic A – Predicting and Controlling Waste Subsidence** *This session will begin with five 8-minute presentations intended to address a set of questions relating to waste subsidence, followed by a facilitated discussion. The panelists include:* - *Michael Reimbold - CH2M Hill* - *William Albright - DRI* - *Richard Finno - Northwestern University* - *Patrick Fox - Ohio State University* - *David Ray - USACoE* *Discussion Leader: Tuncer B. Edil, University of Wisconsin* *Scribe: John Smegal, Legin Group*
12:30 — 1:30 pm	**Lunch**
1:30 — 2:00 pm	**Summary of Predicting and Controlling Waste Subsidence Discussion –** *Tuncer B. Edil, Department of Civil and Environmental Engineering, University of Wisconsin-Madison*
2:00 — 5:00 pm	**Discussion Topic B – Liner Requirements and Performance Prediction** *This session will begin with five 8-minute presentations intended to address a set of questions relating to liner requirements and performance, followed by a facilitated discussion. The panelists include:*

	- *Rudolph Bonaparte - Geosyntec* - *Charles Shackelford - Colorado State University* - *Kevin Pavlik - USACoE* - *John Daniels - NSF* - *Tuncer Edil - U. of Wisconsin – Madison* *Discussion Leader: Craig H. Benson, University of Washington* *Scribe: Bill Albright, DRI*
5:00 — 5:30 pm	**Summary of Liner Requirements and Performance Prediction –** *Craig H. Benson, Department of Civil and Environmental Engineering, University of Washington*

Day 2 – 8 October 2008	
7:30 — 8:00 am	**Coffee and Discussion**
8:00 — 9:00 am	**Waste Acceptance Criteria Forecasting and Analysis Capability System (WACFACS) –** *TJ Abraham, MSE and Ken Redus, Redus and Associates LLC*
9:00 — 12:00 am	**Discussion Topic C – Waste Forecasting** *This session will begin with six 8-minute presentations intended to address a set of questions relating to waste forecasting, followed by a facilitated discussion. The panelists include:* - *Martin Letourneau - LFRG* - *Gary Snow - Hanford* - *Jay Beech - Geosyntec* - *Ken Redus, Redus and Associates* - *David Maloney, CH2M Hill* - *John Hampshire – OR-Bechtel Jacobs Company* *Discussion Leader: John Smegal, Legin Group* *Scribe: David Ray, USACoE*
12:00 — 1:00 pm	**Lunch**
1:00 — 1:30 pm	**Summary of Waste Forecasting –** *John Smegal, Legin Group*

1:30 — 4:30 pm	**Discussion Topic D – Final Cover Design and Long-Term Performance** *This session will begin with five 8-minute presentations intended to address a set of questions relating to final cover design and long-term performance, followed by a facilitated discussion. The panelists include:* - *Michael Fayer - PNNL* - *Jody Waugh - Stoller* - *William Albright - DRI* - *David Ray - USACE* - *Craig Benson - U. of Washington* *Discussion Leader: Patrick Fox, Ohio State University* *Scribe: John Smegal, Legin Group*
4:30 — 5:00 pm	**Summary of Final Cover Design and Long-Term Performance –** *Patrick Fox, Ohio State University*
5:00 — 5:30 pm	**Technology Prioritization and Concluding Remarks***: Craig H. Benson, University of Washington and Bill Albright, DRI*

Discussion Topic A Panelists – Predicting and Controlling Waste Subsidence

Michael Reimbold is a senior project manager and geotechnical engineer for CH2M HILL specializing in the geotechnical aspects of solid and hazardous waste disposal and management. He served as the design manager and lead geotechnical engineer for two DOE low-level and mixed low-level radioactive waste disposal facilities -- the ICDF at INEL and the IDF at Hanford. Mr. Reimbold is currently the operations manager for CH2M HILL's engineering design group in the Northwest region. He is responsible for design operations for a wide-variety of design projects in the water and environmental market segments.

Bill Albright is an Associate Research Hydrogeologist with the Desert Research Institute within the Division of Hydrologic Sciences, Nevada System of Higher Education. He served as a member of the EM Landfill Independent Technical Review team, and is an expert in waste containment systems, particularly landfill cover design and performance. Dr Albright helped develop the concept of alternative cover design assessment for an EPA-funded program to provide field-scale data for the development of design guidance, improved numerical modeling, and regulatory revision for the design and evaluation of solid waste landfill covers.

David Ray serves as Chief of the Geotechnical Engineering and Sciences Branch, Omaha District, US Army Corps of Engineers. He also served as a member of the EM Landfill Independent Technical Review team. He currently leads a team of 83 engineers, geologists, and scientists that provides geotechnical data and design for military and civil works customers, and provides support to military and EPA customers on hazardous, toxic, and radioactive waste (HTRW) remediation.

Rich Finno is a Professor of Civil Engineering at Northwestern University. Dr. Finno has long been involved in combining theory and practice to reconcile full-scale field performance with analytical and numerical predictions. As a consequence, he has conducted research in the areas of full-scale performance of deep excavations and tunnels, numerical analysis, landfill liners, inverse analysis techniques and constitutive responses of soft clays. He is the author or co-author of 121 reviewed technical papers and 20 technical reports.

Patrick Fox is a professor in the Department of Civil & Environmental Engineering & Geodetic Science at the Ohio State University. His area of specialization is geotechnical and geoenvironmental engineering, with emphasis in landfills, landslides, groundwater, geosynthetics, retaining structures, consolidation, settlement, underground mines, and soil dynamics. Dr. Fox has published over 120 technical papers on his research. He is currently Editor of the ASCE *Journal of Geotechnical and Geoenvironmental Engineering*, Editorial Board Member for *Geosynthetics International* and the ASCE *International Journal of Geomechanics*.

Discussion Topic B Panelists – Liner Requirements and Performance Prediction

Rudolph Bonaparte is the President and CEO of Geosyntec Consultants, Inc. Dr. Bonaparte has focused his professional engineering practice in the areas of solid, hazardous, and low-level radioactive waste disposal facility design and permitting; and geoenvironmental and geotechnical engineering. He was the design engineer of record for the initial phases of the DOE Fernald on-site disposal facility. He is the author or co-author of more than 50 technical papers, several book chapters, and several reports published by the U.S. Environmental Protection Agency.

Charles Shackelford is a Professor in the Department of Civil and Environmental Engineering, Colorado State University. He has 21 years of experience pertaining to the geoenvironmental aspects of waste management and environmental remediation. Dr. Shackelford's research is focused on evaluating flow and transport of hazardous liquids and contaminants through soil and geosynthetic containment barriers, such as compacted clay liners and geosynthetic clay liners, commonly used in waste disposal (landfills) applications, as well as through vertical (soil) cutoff walls used for *in situ* containment and remediation of polluted sites. His most significant contributions have related to characterizing diffusion of potential contaminants through these barrier materials.

Kevin Pavlik is a Civil Engineer with the US Army Corps of Engineers, Omaha District. Mr. Pavlik has served for 20 years as a geotechnical design engineer in support of the Military Construction, Civil Works, and Hazardous, Toxic, and Radioactive Waste (HTRW) programs. HTRW project experience is primarily with containment projects such as landfill covers and liners for military sites. As part of this effort, he coordinates plans, specifications, and keeps lines of communication open. He also performed technical reviews for the Environmental Protection Agency and Navy landfill projects.

John Daniels is currently a Program Director in the Directorate for Engineering at the National Science Foundation. He is on sabbatical from the University of North Carolina at Charlotte where he is an Associate Professor in the Department of Civil and Environmental Engineering. Much of this work has focused on physical and chemical controls on soils and industrial byproducts. His recent textbook, co-authored with H-Y. Fang, is entitled "Introductory Geotechnical Engineering: An Environmental Perspective." His teaching interests include waste containment, groundwater, chemical fate and transport, ground improvement, and soil mechanics.

Tuncer Edil is a professor of Civil and Environmental Engineering and Geological Engineering at the University of Wisconsin. His current research interests are in the areas of use of recycled industrial byproducts, environmental geotechnics, soft ground engineering, geosynthetics, coastal erosion and landslides, ground improvement. His present consulting activities include shoreline erosion and landslide control, landfill and dam slope stability, construction over peat and soft clay deposits and foundation settlements, and industrial byproducts recycling. He has published over 300 papers in the field of geotechnical and geoenvironmental engineering.

Discussion Topic C Panelists – Waste Forecasting

Martin Letourneau has 22 years experience in both public and private environmental management and has been with the Department of Energy's Environmental Management program since 1991. Mr. Letourneau currently works in the Environmental Management Office of Compliance. He is the Chair of the LFRG and is the Headquarters Program Manager for high-level waste tank closure waste determinations. Mr. Letourneau also was the project manager for the development of DOE Order 435.1.

Gary Snow is the Deputy Director on the River Corridor Contract (RCC) for Washington Closure Hanford (WCH). The RCC Project is responsible for cleaning up about 218 square miles of Columbia River corridor. Prior to his current assignment Gary was the technical authority for WCH Waste Operations. The Waste Operations organization is responsible for managing ERDF, designating, transporting, treating and disposing of contaminated material generated by facility demolition and waste site and burial ground clean up across the Hanford site.

Jay Beech is a Principal and Vice President at Geosyntec Consultants. He has nearly 30 years of experience on waste containment and subsurface barrier systems, demolition and remediation of former industrial sites, and geotechnical and civil engineering. Dr. Beech served as the Principal-in-Charge for resident engineering and CQA activities associated with the construction and operation of the DOE Fernald on-site disposal facility. He has authored or co-authored over 30 technical papers, many related to design procedures of waste containment systems.

Ken Redus is a Principal with Redus and Associates LLC in Oak Ridge. He has over 35 years of experience applying operations research, systems engineering, and statistical analyses to DOE and DOD programs and commercial clients. Mr. Redus is member of the EMWMF WAC Attainment Team. He developed WACFACS – the Waste Acceptance Criteria Forecasting and Analysis Capability System in 2002 to support Oak Ridge CERCLA waste disposition at the EMWMF. His primary development interests deal with probabilistic modeling, simulation, and optimization.

David Maloney is Technology Director for the Nuclear Business Group of CH2MHill, responsible improving operational safety, costs, and schedule for decommissioning, remediation, and waste management work at DOE. From 1997-2003 he managed the technology component of closure strategy, project planning, and programmatic risk assessments at Rocky Flats. From 2003-2008, he has been supporting the Hanford tank waste and River Corridor waste excavation and disposal projects.

John Hampshire is the Waste Acceptance Criteria (WAC) Attainment Team Manager for the EMWMF. He assisted in the development and implementation a one-of-a-kind methodology for probabilistic, risk-based WAC for the mixed waste CERCLA cell. He also negotiated all WAC requirements for the EMWMF. Mr. Hampshire devised a methodology to accurately track disposed and predicted volumes of waste, and wrote the resultant annual Capacity Assurance Remedial Action Reports (CARAR).

Discussion Topic D Panelists – Final Cover Design and Long-Term Performance

Bill Albright is an Associate Research Hydrogeologist with the Desert Research Institute within the Division of Hydrologic Sciences, Nevada System of Higher Education. He served as a member of the EM Landfill Independent Technical Review team, and is an expert in waste containment systems, particularly landfill cover design and performance. Dr Albright helped develop the concept of alternative cover design assessment for an EPA-funded program to provide field-scale data for the development of design guidance, improved numerical modeling, and regulatory revision for the design and evaluation of solid waste landfill covers.

David Ray serves as Chief of the Geotechnical Engineering and Sciences Branch, Omaha District, US Army Corps of Engineers. He also served as a member of the EM Landfill Independent Technical Review team. He currently leads a team of 83 engineers, geologists, and scientists that provides geotechnical data and design for military and civil works customers, and provides support to military and EPA customers on hazardous, toxic, and radioactive waste (HTRW) remediation.

Michael Fayer has 24 years of experience at Hanford investigating the movement of water and contaminants in arid and semiarid environments. Dr. Fayer's work encompasses field, laboratory, and numerical studies related to performance assessment of waste disposal activities, surface cover evaluation, and recharge estimation. His activities also include laboratory and field measurements of the physical and hydraulic properties of soils and sediments of the vadose zone. Dr. Fayer is the primary developer of the UNSAT-H model that is used to predict recharge rates and to evaluate surface covers for waste disposal sites.

Jody Waugh has more than 25 years of research and operations experience designing and monitoring landfill covers for hazardous and radioactive wastes for DOE. His work has focused on the design, ecology, soil hydrology, and long-term performance of conventional and alternative covers for uranium mill tailings. He has served on national technical working groups for DOE, EPA, the Advisory Council on Nuclear Waste, the Interstate Technology and Regulatory Council, and the National Academy of Sciences. He is currently Lead Ecologist with S.M. Stoller Corporation working on long-term stewardship issues for the DOE Office of Legacy Management.

Craig Benson is the Chairman of the Department of Civil and Environmental Engineering at the University of Washington. For more than 20 years, Dr. Benson has been conducting experimental and analytical research on barriers to flow and contaminant transport, and is regarded as one of the leading international experts on the performance of barrier systems. Dr. Benson has been conducting research on the effectiveness of waste containment since 1992. This research has included laboratory studies, large-scale field experiments, and modeling. Currently, Dr. Benson is one of the principal investigators for USEPA's Alternative Cover Assessment Project (ACAP). He also served as the lead for the EM Landfill ITR Team.

APPENDIX B – PANELIST QUESTIONS

Questions for Waste Subsidence Panel

1. Describe the methods used to predict total settlement of waste masses associated with DOE D&D wastes placed in on-site disposal facilities.

2. Describe the methods used to predict differential settlement of waste masses associated with DOE D&D wastes placed in on-site disposal facilities.

3. Describe how parameters used to predict settlement of DOE D&D waste masses are measured, and how these measured properties reflect field conditions.

4. Describe the uncertainty anticipated for settlement predictions of DOE D&D waste masses at 10, 50, 100, and 1000 yr after closure, and the methods used to determine that uncertainty.

5. What are the most important topics for technology development in predicting waste settlement?

Questions for Liner Panel

1. Describe the merits of lined and unlined disposal facilities in the context of short-term and long-term protection of ground water quality.

2. Describe the uncertainty associated with predictions of leakage and contaminant flux from lined and unlined disposal facilities in the near term and the long term. Describe best methods to monitor leakage and contaminant flux from liners.

3. What knowledge exists regarding adsorption and transport of radionuclides for materials commonly used as liners for waste containment?

4. What are the most important topics for technology development regarding appropriate selection and design of liners for DOE waste containment facilities?

Questions for Waste Forecasting Panel

1. What are the most important factors affecting the accuracy of waste forecasts? Explain.

2. What waste characterization issues differ between sites, and what issues are universal in the DOE complex?

3. Describe your most important experiences and lessons learned regarding waste forecasting for DOE D&D projects. If possible, comment on how lessons learned have been incorporated into future DOE D&D projects.

4. What are the most important characteristics of tools (e.g., computer models) used for waste forecasting in DOE D&D projects? Why? If available, provide examples of tools with these characteristics.

5. What are the most important topics for technology development in waste forecasting (site specific and complex wide topics are relevant)

Questions for Cover Panel

1. Describe existing knowledge regarding the hydrologic performance of final covers for waste containment, and indicate the best methods to monitor field performance of final covers.

2. Describe factors affecting longevity of barrier materials, and what is known about the resilience of barrier materials in use today.

3. Describe key factors that may affect the long-term performance of final covers, and field data demonstrating the significance of these factors.

4. Describe the uncertainty in final cover performance associated with DOE disposal facilities at 10, 50, 100, and 1000 yr after closure.

5. What are the most important topics for technology development in design and prediction of final cover performance?

APPENDIX C – ON-SITE WORKSHOP PARTICIPANTS

Workshop Participants

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