ATTACHMENTS TO COMMENTS FROM OREPA, NUCLEAR WATCH, AND NRDC

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Attachment D: DNFSB, *Confinement of Radioactive Materials at Defense Nuclear Facilities*, October 2004

Attachment E: Recommendations for the Supplement Analysis Process, U.S. Department of Energy, Environment, Safety and Health Office of NEPA Policy and Compliance, July 2005

Attachment F: Dep't of Energy, Office of NEPA Policy and Compliance, *Lessons Learned Quarterly Reports: December 1994 to September 2005*, October 2005

Attachment A: Memorandum from Dr. David Jackson

UNIVERSITY OF CALIFORNIA, LOS ANGELES UCLA

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DEPARTMENT OF EARTH, PLANETARY, AND SPACE SCIENCES
595 CHARLES E. YOUNG DRIVE, EAST
3806 GEOLOGY BUILDING
LOS ANGELES, CALIFORNIA 90095-1567
PHONE: (310) 825-3880
FAX: (310) 825-2779

To: Ralph Hutchison, Oak Ridge Environmental Peace Alliance, and Jay Coghlan, Nuclear Watch New Mexico
From: Dr. David Jackson, Distinguished Professor Emeritus, University of California Los Angeles
Date: June 28, 2018
Re: Analysis of Seismic Risks Pertaining to the Y-12 National Security Complex

Introduction

You have asked me to review the National Nuclear Security Administration's ("NNSA") discussion of seismic risks at the Y-12 National Security Complex, particularly in association with NNSA's May 2018 issuance of a Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex (DOE/EIS-0387-SA-02) ("2018 SA"). I have reviewed the 2018 SA, as well as related documents including NNSA's prior Supplement Analysis from 2016, NNSA's 2011 Site-Wide Environmental Impact Statement, the data and models represented in the 2008 and 2014 United States Geological Survey's ("USGS") seismic hazard maps, as well as more recent seismic hazard maps and underlying data from the USGS. In my professional opinion, NNSA has conducted no rigorous seismic hazard evaluation associated with its activities at the Y-12 National Security Complex. A more thorough consideration of seismic risks is essential in light of the hazardous and nationally important work done at this Complex.

I am a geophysicist with a great deal of experience considering seismic issues, in particular with regard to probabilistic seismic hazard analysis, statistical data analysis, earthquake forecasting and prediction, and the consideration of likely damage from earthquakes. I earned my Bachelors of Science degree in Physics from the California Institute of Technology in 1965 and my Ph.D. in Geophysics from the Massachusetts Institute of Technology in 1969. I served as a professor of geophysics at the University of California Los Angeles from 1969 until 2011, when I became a Distinguished Professor Emeritus and a consultant in seismology, statistics, and natural hazards. In my decades of experience I have authored or co-authored hundreds of articles in peer-reviewed scientific publications covering probabilistic forecasting of earthquakes, simulation and modeling of earthquakes, the testing of earthquake likelihood models, and seismic hazards. I led numerous professional organizations, serving as President of the Seismology Section of the American Geophysical Union and Science Director of the Southern California Earthquake Center. I served on the California Earthquake Prediction Evaluation Council, which advised the Governor thru the Department of Emergency Services; on a research panel for the National Academy of Sciences; and on the National Earthquake Prediction Evaluation Council, an advisory committee to the USGS created by Congress in 1980 to provide expert input and recommendations regarding the best means to issue timely warnings of potential geological disasters. A copy of my CV and a partial list of my publications are attached.

I have reviewed the relevant documents associated with NNSA's analysis of seismic risks at the Y-12 National Security Complex, and I find the agency's analysis to be badly lacking. In my expert opinion, NNSA's review is not a scientifically based review of seismic risks. The agency's review is defective in numerous regards. It falls far short of relevant professional and scientific standards, offers a simplistic analysis of risks that fails to disclose or properly analyze critical underlying data, entirely fails to consider highly relevant new data from the USGS, fails to employ a modern set of tools for analyzing seismic risks, chooses an arbitrary measurement of hazard, and fails to respond in any coherent manner to new information furnished by the USGS and the Defense Nuclear Facilities Safety Board ("DNFSB").

A rigorous scientific evaluation of seismic risks considers numerous features of earthquakes, including: peak ground acceleration at different probabilities; shaking at various wave frequencies that can affect different structures in different ways; secondary risks such as fire, soil liquefaction, landslides, ground settling, and permanent ground displacement; and the very real possibility that earthquakes—even large earthquakes—can and do occur where there have not been previously observed "capable faults." Each of these issues is important and merits thorough analysis. NNSA's review fails to consider most of these issues, and for those it does consider, only touches on them superficially.

NNSA's Deficient Consideration of Data from the USGS

To begin with, NNSA's treatment of the difference between the 2008 and 2014 USGS seismic hazard maps is superficial at best. NNSA only considers that the difference between these two reports is that in 2008, the USGS found a 2 percent probability over 50 years of exceeding peak ground acceleration of 0.2g, while in 2014 the USGS found a 2 percent probability over 50 years of exceeding peak ground acceleration of 0.3g. Here "g" is a unit of ground acceleration equal to the acceleration of gravity at the earth's surface. NNSA's narrow focus on a single aspect of the difference between the USGS reports is inappropriate for several reasons. First, the "2 percent over 50 years" standard is an arbitrary one that seismologists have in the past used to communicate with engineers, because engineers often assume that a 2 percent risk is acceptable for most buildings and that most buildings have a 50-year lifespan. These assumptions are not appropriate for the buildings at Y-12 because these buildings are already more than 50 years old and house extremely hazardous processes and materials that are critical to the NNSA's Enriched Uranium Program. Under these circumstances, a more conservative standard than the "2 percent over 50 year standard" would be more appropriate. In my professional opinion, the hazardous and important nature of the activities at Y-12, and the fact that these buildings are old, decaying, and not constructed according to modern standards (an issue described in greater detail below), warrant consideration of hazards that are less likely but far more disastrous.

Furthermore, NNSA's treatment of the USGS hazard maps is defective because NNSA considered them only in the most simplistic manner. USGS uses color coded maps to represent results of detailed seismic hazard calculations at closely spaced grid points on maps covering the entire country and makes the precise results publicly available in digital form.[1] NNSA apparently relied only on the color maps, ignoring the precise underlying data. NNSA's analysis of the USGS's input lacks rigor because the map color is only an approximation of the full results, rounded off to units of 0.1 g. The detailed results show that at the 2% in 50-year rate, the expected peak ground acceleration was estimated at 0.16 g in 2008, and 0.34 in 2016, more than double the earlier estimate. The underlying USGS data show risks of significantly larger earthquake shaking than that which NNSA has superficially considered. Indeed, the underlying data shows that, while much larger earthquakes are less likely, very strong shaking at Y-12 is a real possibility and merits much more rigorous consideration. Again, the hazardous nature of the work done at Y-12, the importance of this work, and the vulnerability of the aging buildings warrant more careful analysis and consideration of less frequent but much larger shaking than that reported for 2% in 50 years.

Following recent dramatic increases in earthquake occurrence in the Central and Eastern Unites States, USGS has since issued three updated sets of seismic hazard estimates in 2016, 2017, and 2018 that in my opinion are relevant to the risks at Y-12 and should be considered by NNSA. However, NNSA appears unaware of these publically available estimates and maps.[2] Of particular significance, the 2018 seismic hazard calculations indicate even greater hazard than that represented in the 2014 map. In particular, my review of the data indicates that, even within the "2 percent in 50 years" probability standard (which, again, is not the only standard NNSA should consider), the expected peak ground acceleration in the area of Y-12 is about 0.56g. This is far greater than the levels that the aging buildings at Y-12 could likely withstand.

The updated USGS seismic hazard estimates are important and constitute new information that NNSA should carefully consider. In my professional opinion NNSA has fallen far short of a professional, scientific consideration of the issues by neglecting the recent USGS studies.

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[1] The USGS makes the underlying map data available at https://earthquake.usgs.gov/hazards/hazmaps/conterminous/index.php#2014

[2] See https://earthquake.usgs.gov/hazards/induced/index.php#2018

NNSA's Inappropriate Focus on "Capable Faults"

Neither the 2018 SA nor the NNSA's earlier 2016 SA acknowledge important new seismological observations showing that earthquakes— even very large ones—can and do occur in areas where no prior large earthquakes have been known to occur. Instead, the 2016 and 2018 SAs appear to carry over the analysis in NNSA's 2011 Environmental Impact Statement, which focused principally on "capable faults," which are those faults where earthquakes have been known to occur. However, it is increasingly evident that large earthquakes can occur even in the absence of a known "capable fault". For example, in 2010 a large earthquake (magnitude 7) occurred near Christchurch, New Zealand 20 kilometers from the nearest "capable fault". That earthquake caused serious damage to the city and indeed the entire country of New Zealand. Similarly, in 2012 a record-breaking magnitude 8.6 earthquake in the Pacific Ocean west of Sumatra struck where there was no capable fault, in spite of extensive sub-sea geological studies there. Accordingly, seismologists realize that large earthquakes can occur in areas where no capable fault is known. In my opinion, NNSA should give greater consideration to the possibility of a large earthquake in the vicinity of Y-12, because a focus on "capable faults" is inappropriate in light of the new seismological information.

Scientists at the University of Tennessee[3] and their colleagues at other institutions have recently studied geological evidence for faulting and magnitude 6 or larger earthquakes in the Eastern Tennessee Seismic Zone (ETSZ). Their techniques allowed them to detect deep faulting that is not evident in surface studies. At just one site near Dandridge TN they found seismically generated features indicating subsurface faulting and several earthquakes, at least one exceeding magnitude 6, during the last 13,000 years. The seismological networks do not extend far enough back in time to record these earthquakes but the geological evidence clearly indicates that the ETSZ, including the neighborhood of Y-12, is capable of magnitude 6 and larger earthquakes.

Although NNSA states that it is currently preparing additional seismic studies, including updating earthquake sources, maximum earthquake magnitudes, frequency of earthquake occurrences, historical earthquake databases, and related uncertainties, the fact that NNSA has chosen not to disclose any material information about these new studies is extremely troubling. Independent experts like myself cannot evaluate the seriousness of the risk and NNSA's decision to proceed with construction before these studies are completed. In my expert opinion, NNSA must disclose the methods, scope, research plans, and results of these studies *before the agency decides to continue to use aging, vulnerable buildings.* Committing to the use of these vulnerable facilities before obtaining any real understanding of the risk associated with their ongoing use is illogical, scientifically flawed, and deeply imprudent.

NNSA's Inadequate Consideration of Secondary Hazards

The risks associated with an earthquake are not limited to the immediate shaking of the ground. Secondary hazards from earthquakes include liquefaction, in which seismic shaking causes soil to lose cohesion, which can undermine building foundations or roads; landslides; fires caused by damage to electrical components and containers of flammable fluids; access and safety constraints on emergency response; and the risk that effects on one building could carry over to nearby buildings. Fires cause by the great San Francisco Earthquake of 1906 killed far more people than the earthquake shaking itself. The fires were especially serious because the earthquake disrupted water supply needed for fire suppression. The Fukushima Daiichi Nuclear Power Plant suffered fires and meltdown of three nuclear reactors largely because of secondary failures from the massive Tohoku, Japan earthquake and tsunami of 2011. There is of course no tsunami threat at Oak Ridge, but the lesson of cascading failures still applies.

NNSA has given scant consideration to secondary hazards associated with earthquakes. These risks are especially important where, as in the Y-12 Complex, existing buildings are located very near to one another and are already in advanced states of disrepair. Buildings that are deteriorating that badly during normal operations would likely present additional risks during even a very small earthquake, making emergency operations more difficult or even preventing emergency workers from performing necessary duties altogether.

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[3] K.F. Warrell, R.T. Cox, and R.D. Hatcher, Paleoseismic Evidence for Multiple Mw> 6 Earthquakes in the Eastern Tennessee Seismic Zone during the Late Quaternary, Bull. Seis. Soc. Amer., 107 (4), 1610 – 1624, 2017. Doi: 10.1785/0120160161.

The risk of fires associated with an earthquake at Y-12 is also difficult to overstate. Because the aging buildings at Y-12 contain numerous hazardous, flammable chemicals and equipment in varying states of disrepair, the possibility that an earthquake could cause a fire is quite real. In fact, NNSA does not intend to complete the replacement of the existing buildings' sprinkler systems until 2020, and does not plan to complete the replacement of high fire risk electrical equipment until 2021. Accordingly, even in a small earthquake, the possibility that the existing buildings at Y-12 could experience a fire is significant. Moreover, a fire could cause a criticality event; NNSA has not been able to show that its nuclear processes would remain sub-critical in the event of an earthquake or a resulting fire. The close proximity of existing buildings at Y-12 could cause fires to spread easily. Collapse of one building could initiate a domino effect and compromise the integrity of buildings nearby.

In my professional opinion, NNSA's failure to adequately consider secondary effects from an earthquake is a glaring defect.

NNSA's Failure to Conduct a Modern Analysis of The Risk Associated with Using Existing Buildings

Since the construction of the existing buildings at Y-12 during the Manhattan Project and the Cold War, building standards and the techniques used to evaluate risks have changed very significantly. As a result of more sophisticated abilities to model and evaluate risks, building standards have become far more rigorous and now require certain structural elements that allow buildings to better withstand the forces associated with an earthquake. Building codes require that structures be built to withstand prescribed shaking levels, depending on the size and intended use of the structures. The actual implementation depends in part on engineering calculations for how each structure would respond to that shaking. Recent experience and more sophisticated calculations show that many of the old designs would not in fact meet the standards for which they were designed. However, although NNSA acknowledges that the existing buildings at Y-12 are not built according to modern building standards and do not meet modern safety codes, including seismic safety codes, NNSA has obfuscated the importance of this issue.

For example, NNSA's reliance solely on probabilistic hazard analysis (e.g. the "2 percent in 50 years" standard) is far too simple, neglecting the many ways the buildings and contents could fail. Modern analysis of seismic risk entails the use of sophisticated computer models that simulate many hundreds of potential earthquakes and their likely effects on a structure. Designers then use the output from these models to amend the design of a building to ensure that it is best capable of withstanding the forces associated with an earthquake. These analysis methods would be far more effective at modeling the likely impacts on these buildings from earthquakes of various sizes. I have seen no evidence that NNSA applied any such analysis to the existing buildings at Y-12. In my opinion, the failure to use these modern tools is a significant deficiency in NNSA's analysis.

Similarly, NNSA's failure to implement any non-linear modeling of seismic hazard risks—even after the DNFSB expressly recommended this analysis—is a glaring deficiency. Linear analysis is an overly simplified method wrongfully assuming that the deformation that a building undergoes during an earthquake scales in a linear fashion with the force of that earthquake. This assumption fails badly even for moderate shaking, because of "progressive degradation": each shaking cycle weakens the structure. In reality, building components have varying levels of ability to resist the forces associated with an earthquake. For example, different types of welds or rivets are more or less capable of withstanding different types of forces; a structural component that may be very capable of resisting compression may be very weak under tension. As a result, the various components of a building may experience failure when faced with different levels of force; even a weak earthquake may be sufficient to damage or destroy weaker building components. Once certain portions of a building's structure fail, the other components likely face greater stress potentially leading to collapse of the entire building. Modern, non-linear analysis can take this type of progressive degradation into account, no doubt one important reason why the DNFSB stressed that NNSA should undertake non-linear analysis if it intends to continue using existing aging buildings. NNSA's failure to follow DNFSB's recommendation to use modern analytical techniques is another egregious defect in its consideration of seismic risk.

Indeed, the critical difference between NNSA's assumptions about linear risks and modern non-linear analysis illustrates the importance of the fact that the existing buildings at Y-12 do not meet modern seismic standards. These seismic standards are updated precisely because non-linear analysis and other modern modeling techniques can identify structural upgrades that allow buildings to better withstand earthquake forces. The fact that the buildings at Y-12 have not been updated to meet modern standards—and in all likelihood *cannot be upgraded to*

meet these standards—is not merely a failure on paper to meet a building code. The structures themselves lack the features that modern engineering analysis shows to be necessary to withstand earthquake shaking.

Conclusion

NNSA's analysis of seismic risks is not well founded scientifically. It suffers from numerous analytical defects, ignores or downplays important data, obfuscates the importance of the fact that existing buildings do not meet modern standards, and fails to employ modern tools for seismic risk analysis. NNSA has given only very cursory attention to important new information the agency obtained since 2011, including the USGS seismic hazard maps and input from the DNFSB. Moreover, NNSA has ignored altogether the most critical underlying data from the USGS's updated seismic hazard reports and has failed to even consider the USGS's 2016, 2017, and 2018 updated seismic hazard reports. As a result, in my professional opinion, NNSA's analysis is patently deficient, and a more thorough consideration of the seismic risks associated with the ongoing use of aging, vulnerable buildings at the Y-12 Complex is necessary, particularly in light of the hazardous and important work done at these facilities.

Yours truly,

David D. Jackson, Professor

DAVID D. JACKSON

Department of Earth, Planetary, and Space Sciences, UCLA
Los Angeles, CA 90095-1567

June 18, 2018

Professional Preparation:

- B.S., Department of Physics, California Institute of Technology,1965
- Ph.D, Department of Earth and Planetary Science, MIT, 1969

Appointments:

- Professor of Geophysics, UCLA 1969 – 2011
- Distinguished Professor of Geophysics, Emeritus, UCLA 2011 - present

Awards and Honors:

- National Science Foundation Graduate Fellowship, 1966-1968
- Fannie and John Hertz Foundation Fellowship, 1967-1969
- National Academy of Sciences/Natural Research Council, Senior Resident Research Associateship, 1981-1982
- Elected to Steering Committee, University NAVSTAR Consortium (UNAVCO) 1987, 1988, 1989, 1990, 1991, 1992.
- Elected Secretary, Seismology Section, American Geophysical Union, 1989.
- Elected President, Seismology Section, American Geophysical Union 1991.
- Fellow, American Geophysical Union 1993.
- Elected Chair, US National Committee for the International Union of Geodesy and Geophysics (IUGG). 1999-2003.
- Elected Secretary, USNC/IUGG 2003-2007.
- Elected to Finance Committee, IUGG 2003-2007.
- Appointed Chair, Dept. Earth and Space Sciences, UCLA 2004-2007.
- Elected to Bureau of IUGG, 2007 – 2011.

Service:

- California Earthquake Prediction Evaluation Council, Office of Emergency Services, State of California 1984-2002.
- Committee on Seismology, National Academy of Sciences, National Research Council.
- Panel on Crustal Movement Measurements, Committee on Geology, National Academy of Sciences/National Research Council (NAS/NRC).
- Panel on Science of Earthquakes, NAS/NRC 1996-2003,
- Chair, Committee on Public Affairs, American Geophysical Union 1996-1998,
- Science Director, Southern California Earthquake Center 1996-1999.
- U. S. National Committee for IUGG 1995-2007.
- National Earthquake Prediction Evaluation Council, 2007 – 2014.
- Appointed International Association for Seismology and Physics of the Earth's Interior (IAPEI) Liaison to Georisk Commission, 2007-2015

David D. Jackson
Distinguished Emeritus Professor of Geophysics
Department of Earth, Planetary, and Space Sciences
University of California at Los Angeles
2018 July 1

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Attachment B: Memorandum from Robert Alvarez

To: Ralph Hutchison, Oak Ridge Environmental Peace Alliance, and Jay Coghlan, Nuclear Watch New Mexico
From: Robert Alvarez
Date: June 27, 2018
Re: Comments on the Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex (DOE/EIS-0387-SA-02), May 2018

You have asked me to review the National Nuclear Security Administration's (NNSA) Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex (DOE/EIS-0387-SA-02), May 2018, and related documents. I am familiar with the Y-12 National Security Complex and have written about it in detail in several prior articles, which are attached to this letter. Having familiarized myself with the current developments at Y-12, I remain convinced that the statements I made in my earlier detailed articles about this Complex remain valid. Those articles contain a detailed description of the Y-12 Complex and the NNSA's Enriched Uranium Program; for the sake of brevity, I do not repeat those descriptions here.

I have extensive experience with the Y-12 National Security Complex and with the workings of the NNSA and the Department of Energy more generally. While serving in the U.S. Department of Energy I visited the Y-12 site and was involved in environmental, safety and health nuclear material storage vulnerability assessments, including highly enriched uranium at the Y-12 Plant. I currently serve as an Associate Fellow at the Institute for Policy Studies, and Adjunct Professor at Johns Hopkins University, where I teach a graduate course about nuclear non-proliferation. I previously served as senior policy adviser to the Secretary of Energy and deputy assistant secretary for national security and the environment from 1993 to 1999. During this tenure, I led teams in North Korea to establish control of nuclear weapons materials. I also coordinated the Energy Department's nuclear material strategic planning and established the department's first asset management program. Before joining the Energy Department, I served for five years as a senior investigator for the US Senate Committee on Governmental Affairs, chaired by Sen. John Glenn, and as one of the Senate's primary staff experts on the US nuclear weapons program. In 1975, I helped found and direct the Environmental Policy Institute, a respected national public interest organization. I have published articles in *Science*, *Science and Global Security*, the *Bulletin of Atomic Scientists*, *Technology Review*, and *The Washington Post*. I have been featured in the television programs *NOVA* and *60 Minutes*. In 2006, as senior scholar at the Institute for Policy Studies, I authored an extensive and highly relevant report, *Reducing the Risks of Highly Enriched Uranium at the US Department of Energy's Y-12 National Security Complex.*

Because of my tenure with DOE as well as my other I am extremely knowledgeable regarding DOE's obligations under the National Environmental Policy Act (NEPA) as well as the technical aspects of the Y-12 National Security Complex. In my expert opinion, the NNSA's current methodology for reviewing the environmental impacts of its modernization of the Y-12 National Security Complex falls far short of what is logically or legally required, in large part because the NNSA is failing to consider its

actions as a unified whole. Instead, the NNSA has chosen to limit the scope of analysis in several highly problematic ways, including: by (1) wrongfully limiting its analysis in its first Supplement Analysis to the new Uranium Production Facility and ignoring the risks and impacts associated with its ongoing use of aging, dilapidated buildings; (2) wrongfully limiting the scope of its second Supplement Analysis to a scope of five years, when NNSA's actions have a much longer life and when a thorough analysis of environmental impacts requires a broader temporal scope; (3) failing to take into consideration new information about increased seismic risks; and (4) wrongfully invoking a series of categorical exclusions for numerous activities at Y-12 that should be analyzed as part of a unified program with significant environmental impacts. These deficiencies are illustrative of the larger problem with NNSA's analysis, which is that it wrongfully divides the scope of analysis into many piecemeal segments with ostensibly limited impacts, when all these activities are part of the NNSA's ongoing efforts to modernize its Enriched Uranium Program—a program that without question has significant environmental impacts.

The Supplement Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex (DOE/EIS-0387-SA-02; hereinafter SA2) is the second Supplement Analysis prepared by the National Nuclear Security Administration in two years in an ostensible attempt to satisfy NNSA's legal obligations under NEPA to consider the environmental consequences of proposed actions at the Y-12 nuclear weapons facility in Oak Ridge, Tennessee.

The 2011 SWEIS and the two subsequent SAs are not the only NEPA documents prepared by NNSA pertaining to the Enriched Uranium program at Y-12. Instead, NNSA has also assembled a library of Categorical Exclusions (CX), including for technologies in development that will be deployed in the Enriched Uranium operations at Y-12. The CXs are intended to exempt the new technologies from detailed analysis of the environmental consequences that would be required in an Environmental Assessment or an EIS.

Taken together, the SAs and the CXs break the single Enriched Uranium program at Y-12 into separate and distinct pieces. This segmentation is a clear violation of NEPA's requirement—and contravenes logic and common sense—that the full scope of an activity must be considered so that the cumulative impact is considered as well as any discrete impacts of separate parts. The NNSA must treat the Enriched Uranium program at Y-12 in its entirety, as it set out to do when it prepared the Y-12 SWEIS in 2011.

The Enriched Uranium Program

Much of the infrastructure and workforce at the Y-12 National Security Complex is dedicated to the Enriched Uranium mission. Faced with the challenges arising from an aging infrastructure, in 2005 the National Nuclear Security Administration undertook to prepare a Site-Wide Environmental Impact Statement for the Y-12 facility. By the time it was completed six years later, the Y-12 SWEIS proposed to consolidate all enriched uranium operations under one roof in the Uranium Processing Facility and issued a Record of Decision to that effect.

That plan ran into schedule and budget problems so severe that, in late 2013, the NNSA commissioned a "Red Team" to provide recommendations for the future of EU operations at Y-12.

That report, issued in April 2014, said "The US Department of Energy National Nuclear Security Administration must develop an overarching enriched uranium mission strategy...based on people, plant, process, and materials that takes into account both the current and future program demands and the condition and predicted life of current facilities and processes." The report went on to say:

> The Uranium Processing Facility (UPF) must be considered in the context of the broader enriched uranium stewardship mission. A program requirements document (PRD) encompassing this mission must be developed and issued under the ownership of the US Department of Energy National Nuclear Security Administration (DOE/NNSA) Defense Programs Office (NA-10). The PRD could take the form of an update to the UPF PRD; however, it would not be specific to a facility. Rather, it should specify a set of requirements to satisfy mission need across all facilities in the uranium system at Y-12 for it takes the entire system of linked uranium facilities to deliver on uranium missions. The mission-specific PRD would be used to validate the overall facilities strategy, which includes utilization of existing facilities, relocation of current processes that are at risk, and a new build(s) to meet long-term mission readiness requirements with acceptable risk for a subset of critical operations. (p.1)

The recommendations of the Red Team were subsequently adopted by the NNSA and became the template for the latest iteration of the Uranium Processing Facility program. The originally proposed "Big Box" UPF is now divided into five separate new buildings. The EU program will also utilize two aging facilities, the 9215 Complex and Building 9204-2E, for important portions of the EU program. Some activities currently taking place in the badly dilapidated 9212 Complex will be relocated into the new UPF; others will be moved to the 9215 Complex or to 9204-2E.

New technologies, in development at that time, were to be installed in the UPF to increase efficiency and reduce labor and other costs in the EU program. At least one of those new technologies, electro-refining, will now be located in the 9215 Complex. Others will be used in the UPF.

Current Enriched Uranium operations at Y-12 include:

- Receipt, storage, and protection of highly enriched uranium
- Nuclear weapons refurbishment and Life Extension Programs
- Recycle/recovery of strategic materials
- Dismantlement of nuclear weapons components

These operations, according to NNSA, are essential for our nation's security. The capacity to carry them out successfully and in a timely manner is the central mission of Y-12.

The current high-level strategic plan for EU operations at Y-12 is driven largely by the need to vacate the Building 9212 Complex which is in an advanced state of deterioration. After 24 years, since it was shut down for safety reasons, the Y-12 highly enriched uranium foundry in building 9212 has yet to achieve an adequate operational capacity. The plan calls for certain key uranium operations—casting, oxide production, and salvage and accountability of enriched uranium—to be transferred from 9212 to the new UPF nuclear facility.

Other EU operations, including uranium purification and scrap processing, will be moved from 9212 to the 9215 Complex which also performs fabrication and machining operations, and which is itself aging and increasingly vulnerable to an array of risks.

Radiography capabilities have already been moved from the 9212 Complex to Building 9204-2E which is also scheduled to be used for assembly of Enriched Uranium and other components. (GAO-17-577, Modernizing the Nuclear Security Enterprise, p.10, September 2017).

In its 2017 report, the Government Accountability Office is unsparing in its critique of the NNSA's uranium program, noting that the NNSA *"has not developed a complete scope of work, life-cycle cost estimate (i.e., a structured accounting of all cost elements for a program), or integrated master schedule (i.e., encompassing individual project schedules) for the overall uranium program, and it has no time frame for doing so."* The GAO concluded, *" without NNSA setting a time frame for when it will (1) develop a complete scope of work for the overall uranium program, to the extent practicable, and (2) prepare a life-cycle cost estimate and an integrated master schedule for the program, NNSA does not have reasonable assurance that decision makers will have timely access to essential program management information for this costly and important long-term program."*

Seemingly for no other purpose than administrative convenience, the NNSA has made the decision to segment the Enriched Uranium program into several constituent parts and to prepare separate, inadequate NEPA documents for several of the parts. A considerable portion of the EU program, the portion related to the UPF, is covered by the 2011 SWEIS and the subsequent 2016 SA. Other parts, relating to the 9215 Complex and Building 9204-2E are addressed in part in the SAs, but await further analysis; the 2018 SA describes a plan to assemble a team of experts to prepare a new analysis of the structural integrity of the facilities. In the meantime, NNSA pushes ahead with the UPF as though the safety and suitability determinations for 9215 and 9204-2E have already been made—which they have not, and which cannot, according to NNSA, be completed for many years.

There is no legitimate reason for this segmentation; instead, it is an expression of NNSA's haste to begin construction of the UPF, a project on which it has spent more than $3 billion to date. NNSA is operating under significant political pressure to construct the UPF for a maximum of $6.5 billion, and its arbitrary division of the Enriched Uranium Program modernization effort is an attempt to artificially claim that it will be able to stay within this budget cap, when the full costs will be much greater. For example, NNSA will have to expend significant sums renovating and eventually replacing the 9215 Complex and Building 9204-2E, which are integral parts of the activities at the UPF in that the UPF cannot function without the activities housed in these buildings, which will drive the agency's expenses far past the $6.5 billion cap.

The other constituent parts of the artificially and arbitrarily segmented Enriched Uranium program are the technologies being developed for installation in the UPF and the 9215 Complex. Many of these technologies are new and unproven designs, and the NNSA has decided to deal with them separately by granting themselves a Categorical Exclusion, exempting them from thorough study of potential environmental impacts. The use of these categorical exclusions is profoundly inappropriate both because it wrongfully avoids the duty to analyze the activities and environmental impacts at Y-12, and because categorical exclusions are not the appropriate mechanism to analyze many of these activities in any event.

The Problem of Categorical Exclusions

A categorical exclusion is a NEPA document that is appropriate only in the narrow circumstance where an agency has determined in advance that a kind of action will not "individually or cumulatively have a significant effect on the human environment and which have been found to have no such effect in procedures adopted by a Federal agency."[1] Categorical exclusions are never appropriate if there is any "extraordinary circumstance related to the proposal," which NNSA defines as "unique situations presented by specific proposals, including, but not limited to: *scientific controversy about the environmental effects of the proposal; uncertain effects or effects involving unique or unknown risks; and unresolved conflicts concerning alternative uses of available resources.*"[2]

Additionally, a categorical exclusion is never appropriate where an action has been segmented to avoid looking at the overall impact of the action.[3] DOE's own NEPA regulations specify that "[s]egmentation can occur when a proposal is broken down into small parts in order to avoid the appearance of significance of the total action." DOE's NEPA regulations further state that "[t]he scope of a proposal must include the consideration of connected and cumulative actions," which means that a categorical exclusion can only be appropriate if "the proposal is not connected to other actions with

[1] 40 C.F.R. § 1508.4
[2] 10 C.F.R. § 1021.410(b)(2).
[3] *Id.* § 1021.410(b)(3).

potentially significant impacts [and] is not related to other actions with individually insignificant but cumulatively significant impacts."[4]

Here, NNSA has invoked an entire compendium of categorical exclusions for important aspects of its modernization of the Y-12 Complex in total disregard of the critical limitations on the use of this type of document. For example, the 2018 SA notes that in 2016 NNSA invoked no less than ***67*** categorical exclusions for activities that are designed to prolong the lives of the aging, vulnerable buildings on which the agency intends to continue to rely for at least another 25 years. Indeed, the 2018 SA also notes that the environmental evaluation for NNSA's entire Extended Life Program—the program of sustaining these aging, decrepit buildings—has consisted of "***primarily categorical exclusions***").[5] NNSA's refusal to prepare any meaningful NEPA analysis of the Extended Life Program—a program that NNSA created only after the agency concluded in 2014 that housing all EU activities in one "big box" UPF facility would be too expensive—and instead to rely primarily on categorical exclusions is a totally inappropriate segmentation of this project in flagrant violation of NNSA's own regulations. The Extended Life Program is clearly a new federal action, undertaken after 2014, that proposes to prolong the lives of aging, badly deteriorated buildings *in ways that NNSA still has not decided or publicly disclosed*, and merits full environmental analysis that considers the Program as a whole—not unlawful and illogical reliance on categorical exclusions. The need for holistic environmental analysis is even more crucial because the Extended Life Program is also an indispensable part of NNSA's overall Enriched Uranium Program, which also demands a comprehensive environmental analysis rather than artificial and arbitrary division into small components ostensibly subject to categorical exclusions.

Nor are the 67 categorical exclusions for the Extended Life Program the only categorical exclusions on which NNSA is illogically relying. Instead, the NNSA has wrongfully elected to rely on categorical exclusions for a large number of other activities at Y-12—all of which are properly viewed as integral parts of the agency's modernization of this Complex. In addition to the 67 categorical exclusions for the Extended Life Program, these activities that NNSA has wrongfully subjected to categorical exclusions include:

- Calciner Project Categorical Exclusion (2013)
- Building 9204-2E Canning Project Categorical Exclusion (2014):
- Electrorefining Project Categorical Exclusion (2015)
- Y-12 Fire Station Facility Categorical Exclusion (2015)
- Electrical Substation and Transmission Line Feeds for the UPF Categorical Exclusion (2016)

The use of these categorical exclusions is inappropriate, illogical, and unlawful because it arbitrarily segments activities that are, in fact, interrelated and indispensable aspects of NNSA's modernization of the Y-12 Complex.

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[4] *Id.*

[5] 2018 SA, at 9.

NNSA's use of categorical exclusions is also inappropriate because there are clearly "extraordinary circumstances" that apply in this situation. The most egregious example of this logical and legal defect is NNSA's use of a categorical exclusion for electrorefining. NNSA chose in 2015 to rely on a categorical exclusion for the installation of an electrorefining project in the 9215 Complex, which, as described above, is an aging, decaying building that requires substantial upgrades to even continue to use at all—and which NNSA is uncertain can be upgraded to withstand seismic risks.[6] The use of electrorefining to purify uranium, as NNSA intends, is an experimental procedure with *no proven history of operational success*, even on a pilot scale.[7] It is being developed to replace the current technologies at Building 9212 at the Y-12 site to stabilize and recover significant quantities of highly enriched uranium from contaminated scrap and residues from a variety of production operations, as well as uranium oxides from casting operations.

In addition to being wholly unproven, electrorefining is also highly hazardous. Among the potentially significant environmental effects associated with electro-refining of enriched uranium are nuclear criticalities,[8] fires, building collapse due to an earthquake,[9] and escape of hazardous nuclear materials to the environment.[10] In particular, design of the electro-refining project throughput involves exceeding the minimum critical mass of 700 grams set at Y-12 to prevent a nuclear criticality accident.[11], [12] In recognition of the uncertain status of electrorefining, the project's designer calls for additional research before deployment because "the systems of interest will only become more complex as the transformation progresses."[13] Notably, the amounts, hazards and disposition of this project's wastes have not been specifically identified, disclosed to the public, or subjected to any environmental analysis.

The risks associated with the electrorefining project are exacerbated by the context of the installation of this hazardous experimental technology in the aging, deteriorating 9215 Complex. The aging facilities at Y-12, including the 9215 Complex have an extensive history of serious safety problems. Between 1992 and 2006, there were at least 23 fires and explosions at the Y-12 complex involving nuclear and non-nuclear materials, and the site's aged electrical and coolant systems. (22 since 1997 – averaging two per

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[6] 2018 SA at 8; *see also id.* at 18-19 (noting that NNSA must update the safety basis designs of the 9215 Complex based on new seismic risk data, and that NNSA does not yet know what upgrades may be possible for this building or whether the building can even be upgraded to meet appropriate seismic design requirements).

[7] Matthew Thornbury, Modernization at the Y-12 National Security Complex: A Case for Additional Experimental Benchmarks, EUO Criticality Safety Engineer, Consolidated Nuclear Security lLLC, (2017)

[8] Op Cit ref 2

[9] U.S. Department of Energy, Defense Nuclear Safety Board, Letter (with enclosure) to the Honorable Frank Klotz, Administrator, National Nuclear Security Agency, from Joyce L Connery, Chairman, October 29, 2015.

[10] Ibid.

[11] Op Cit Ref 1.

[12] U.S. Department of Energy, Office of Inspector General, Investigation Report, Allegations Regarding Management of Highly Enriched Uranium, INS-L-15-03, September 2015

[13] Op Cit ref 1..

year.) A review of DOE operating experience, accident reports, and other DOE performance indicators suggests that since the end of the Cold War, Y-12 has experienced the largest number of such events in the federal nuclear complex. Several resulted in worker injuries, radiological contamination and significant damage. Others were small but are of concern because of the potential for spreading due to deteriorated electric systems, and the collocation of combustible, pyrophoric and explosive materials.[14]

As a general matter, the hazards at the Y-12 complex stem from nuclear, radiological, and other chemicals present at the site, and include standard industrial hazards associated with chemical and metallurgical operations. At the Y-12 complex the risks of fires, explosions, nuclear criticalities, acute and chronic exposure to ionizing radiations and non-radioactive substances to workers and the public are dominant concerns.

To a large extent, potential hazards are associated with large amounts of highly enriched (20 to>90% uranium-235) and other types of uranium containing stored and handled at the Y-12 Complex. [15] Uranium reacts with nearly all non-metals and is flammable and explosive when in contact with carbon dioxide, carbon tetrachloride, or nitric acid. Potentially flammable and explosive uranium hydride is formed when exposed to water and can spontaneously ignite in open air.[16] Uranium is harmful to humans. Soluble forms of inhaled uranium (and a small fraction of less soluble forms) are absorbed into the blood, and deposit in the kidneys and skeletal bone.[17]

Fires and chemical reactions/explosions involving the release of uranium to the environment are considered dominant risks. The Energy Department has estimated that off-site exposures from a uranium fire releasing approximately 25 kilograms of oxide at Y-12 could result in offsite doses ranging from 30 to 90 rem.[18] These risks have been enhanced by the accumulation of large amounts of unstable, and inadequately stored uranium materials and, as especially relevant here, by vulnerabilities associated with facility deterioration.

Against this factual backdrop, it could not be clearer that the use of a categorical exclusion for the installation of an experimental, hazardous electrorefining project in the aging, vulnerable 9215 Complex is entirely inappropriate. To begin with, it is completely illogical to assert that an experimental technology with no proven track record could possibly be subject to a categorical exclusion—which, as described above, is only applicable for activities that an agency *knows* will have no individually or cumulatively significant impacts.

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[14] Robert Alvarez, Reducing the Risks of Highly Enriched Uranium at the U.S. Department of Energy's Y-12 National Security Complex, October 9, 2006, Institute for Policy Studies, Washington, D.C., Table 3. http://www.lasg.org/UPF/Alvarez_Y-12.pdf

[15] U.S. Department of Energy, Highly Enriched Uranium Working Group Report, on Environmental, Safety and Health Vulnerabilities Associated with the Storage of Highly Enriched Uranium, DOE/EH-0525, December 1996.

[16] Ibid.

[17] Ibid.

[18] Ibid

Moreover, even if this experimental technology could ever be subject to a categorical exclusion (which it cannot), the use of a categorical exclusion would still be inappropriate here due to the presence of "extraordinary circumstances." First, this experimental technology is clearly subject to potential operational safety problems. In particular, design of the electro-refining project throughput involves exceeding the minimum critical mass of 700 grams set at Y-12 to prevent a nuclear criticality accident. [19] [20] The experimental technology's own designer notes that further experimentation is necessary before this technology is ready for deployment.[21] And second, the use of this technology clearly has "uncertain effects or effects involving unique or unknown risks," as is clearly demonstrated by the fact that *electrorefining is an experimental and unproven technology with no history of successful use and no history of the evaluation of its impacts*. Similarly, the placement of this hazardous experimental technology in the aging, vulnerable 9215 Complex clearly poses unknown risks because NNSA acknowledges that it has not evaluated the level of seismic risk to this building and does not know whether the building can be updated to withstand seismic risks. Thus, it is clear that NNSA's use of a categorical exclusion for electrorefining is totally inappropriate.

Nor is electrorefining the only hazardous technology for which NNSA has relied on a categorical exclusion or otherwise arbitrarily avoided meaningful environmental review. Instead, NNSA has also refused to fully analyze the following technologies as well:

- **Direct electrolytic reduction to** convert uranium oxide to uranium metal using an electrochemical process similar and additional to electrorefining. This technology is unproven and is contained in the NNSA FY 2019 Budget at a total estimated cost of $45.25 million. It is under scope refinement.[22]
- **Chip processing** technology converts enriched uranium metal scraps from machining operations into a form that can be re-used. According to the GAO, "This technology is already in use, but NNSA is investigating improved technology to potentially simplify the process and reduce the number of chip processing steps, according to NNSA program officials."[23]
- **Calciner technology** – is a high hazard process using high temperatures to convert uranium-bearing solutions into a solid form to enable additional processing. It was given a Categorial Exclusion status under NEPA by NNSA in 2013.[24]
- **Microwave Casting** – Heats and melts bulk metals using microwaves which rely on: *"a multimode microwave cavity, a microwave-absorbing ceramic crucible and*

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[19] Op Cit Ref 1.

[20] U.S. Department of Energy, Office of Inspector General, Investigation Report, Allegations Regarding Management of Highly Enriched Uranium, INS-L-15-03, September 2015

[21] Op Cit ref 1..

[22] U.S. Department of Energy, FY 2019 Congressional Budget Request, National Nuclear Security Administration, Volume 1, DOE/CF-0138, p. 241

[23] Op Cit. Ref 10.

[24] Op Cit Ref. 13

a thermally insulating casket that is microwave-transparent."[25] Research and development of microwave casting was completed in FY2005 and was deployed.[26] Discussion of this technology by NNSA is absent in the Final Site-Wide EIS and recent Supplement Analysis.

The inappropriate categorical exclusion for electrorefining, and the agency's refusal to fully analyze other hazardous technologies, are illustrative of the agency's entirely inadequate environmental review process. Rather than taking a holistic view of the agency's modernization of the Y-12 Complex, and rather than acknowledging and evaluating the full range of risks associated with its ongoing use of aging, decrepit buildings, NNSA has instead opted to artificially and arbitrarily divide its analysis into small components. The result is a segmented analysis that defies logic and the law.

Conclusion

Based on my many years of experience with the activities of the Department of Energy and NNSA, my extensive familiarity with the Y-12 Complex, my intimate familiarity with NEPA and its requirements, and my review of the 2018 SA and other relevant documents, it is my opinion that NNSA's analysis falls far short of the meaningful consideration of environmental impacts that is required by law and logic. NNSA has artificially constrained its analysis in critical ways, including in temporal scope and by arbitrarily dividing the analysis of the modernization of the Y-12 Complex into small components that should instead be considered together. In my opinion, the changes in the NNSA's plans since the decision in 2011 to build a single "big box" UPF, as well as all the new information that NNSA has obtained since that date, cry out for a more thorough analysis. Under these circumstances, it is imperative that the NNSA prepare a new Environmental Impact Statement that comprehensively analyzes the entire modernization of the Y-12 Complex.

Dated: 6/28/2018

Robert Alvarez

Robert Alvarez

[25] Edward B. Ripley and Jason A. Oberhaus, Melting and Heat-Treating Metals Using Microwave Heating, Industrial
Heating, May 10, 2005,
[26] U.S. Department of Energy, FY 2006 Congressional Budget Request, National Nuclear Security Administration, Volume 1, DOE/ME-0046, p. 183

Attachment C: Warrell et al., Paleoseismic Evidence for Multiple Mw> 6 Earthquakes in the Eastern Tennessee Seismic Zone during the Late Quaternary

Bulletin of the Seismological Society of America, Vol. 107, No. 4, pp. 1610–1624, August 2017, doi: 10.1785/0120160161

Paleoseismic Evidence for Multiple $M_w \geq 6$ Earthquakes in the Eastern Tennessee Seismic Zone during the Late Quaternary

by Kathleen F. Warrell,* Randel T. Cox, Robert D. Hatcher Jr., James D. Vaughn,† and Ronald Counts

Abstract The eastern Tennessee seismic zone (ETSZ) is the second-most active seismic zone in the eastern United States, but it has not generated an earthquake larger than M_w 4.8 in historic time. Earthquakes are sourced deep in autochthonous basement, and there are no known faults originating at this depth that break the surface. As a result, until recently, there has been virtually no fieldwork to identify Quaternary paleoseismic features in the ETSZ. We present new results from paleoseismic investigations of coseismic features that indicate the ETSZ generated $M_w \geq 6$ earthquakes during the late Quaternary. Detailed geologic mapping and trenching near Dandridge, Tennessee, record a northeast-trending zone of seismically generated features. Optically stimulated luminescence ages delimit timing for the formation of paleoseismic features crosscutting Quaternary alluvium and alluvium-filled fissures, including a thrust fault with ~1 m displacement. Collectively, this zone of faults and fissures provides significant evidence that the ETSZ has produced at least three large earthquakes during the late Pleistocene and at least one that exceeded M_w 6.

Introduction

Broadly intact cratonic crust in the eastern United States allows moderate-to-large earthquakes (M_w 4.5–7.5) to affect areas at least five times larger than earthquakes of equal magnitude in the western United States, where the crust is more fragmented (Bollinger *et al.*, 1993; Bockholt *et al.*, 2015). Thus, identifying seismogenic faults in the east is vital for accurate seismic-hazard assessments. The eastern Tennessee seismic zone (ETSZ) is second to the New Madrid seismic zone in the frequency of earthquakes in the eastern United States, yet it has not generated an earthquake larger than M_w 4.8 in historic times (e.g., Powell *et al.*, 1994). As a result, even though the ETSZ has far more earthquakes than the Charleston, South Carolina, seismic zone, seismic-hazard estimates for the ETSZ are lower than those for Charleston (Bollinger *et al.*, 1993; Petersen *et al.*, 2014). Several large population centers (e.g., Knoxville, Tennessee and Chattanooga, Tennessee) and critical infrastructures (e.g., nuclear power plants, dams, and highways) are located in the ETSZ and may not be fully prepared for large earthquakes (Fig. 1). In this article, we build on the fieldwork of Hatcher *et al.* (2012) and describe paleoseismic features that suggest that the ETSZ has produced at least one $M_w \geq 6$ earthquake during the Quaternary.

*Now at Department of Earth and Planetary Sciences, Rutgers, The State University of New Jersey, 610 Taylor Road, Piscataway, New Jersey 08854-8066.

†Now at P.O. Box 1732, Fairfield Glade, Tennessee 38558.

Background

The ETSZ extends from northeastern Alabama and northwestern Georgia into eastern Kentucky (Powell *et al.*, 1994; Hatcher *et al.*, 2012; Carpenter *et al.*, 2014), encompassing an area 50 km wide and > 300 km long (Fig. 1). This area is underlain by the late Paleozoic Appalachian foreland fold-thrust belt (Hardeman *et al.*, 1966), but recent seismicity appears to be unrelated to the Paleozoic faults because the basal décollement of the thin-skinned fold-thrust belt is 3–5 km below the surface (Hatcher *et al.*, 2007), and the hypocenters of ETSZ earthquakes lie at 5–26 km depth in Precambrian basement rocks (Vlahovic *et al.*, 1998). To ensure that the features we investigate are related to ETSZ earthquakes and not Paleozoic earthquakes, this article focuses on features that deform late Quaternary river sediments that rest on shale bedrock.

Except for the geologic work by Whisner *et al.* (2003) and Hatcher *et al.* (2012), previous work in the ETSZ has focused on determining focal mechanism solutions of earthquakes and resolving possible fault planes at depth using small earthquakes (Chapman *et al.*, 1997; Dunn and Chapman, 2006; Cooley, 2014; Cooley *et al.*, 2014). These focal mechanism solutions (mostly strike slip and thrust) are compatible with the N70°E orientation of maximum principal compressive stress (σ_1) in the ETSZ, which is hypothesized to derive from ridge-push forces originating at the Mid-Atlantic Ridge (Zoback and Zoback, 1991; Zoback, 1992;

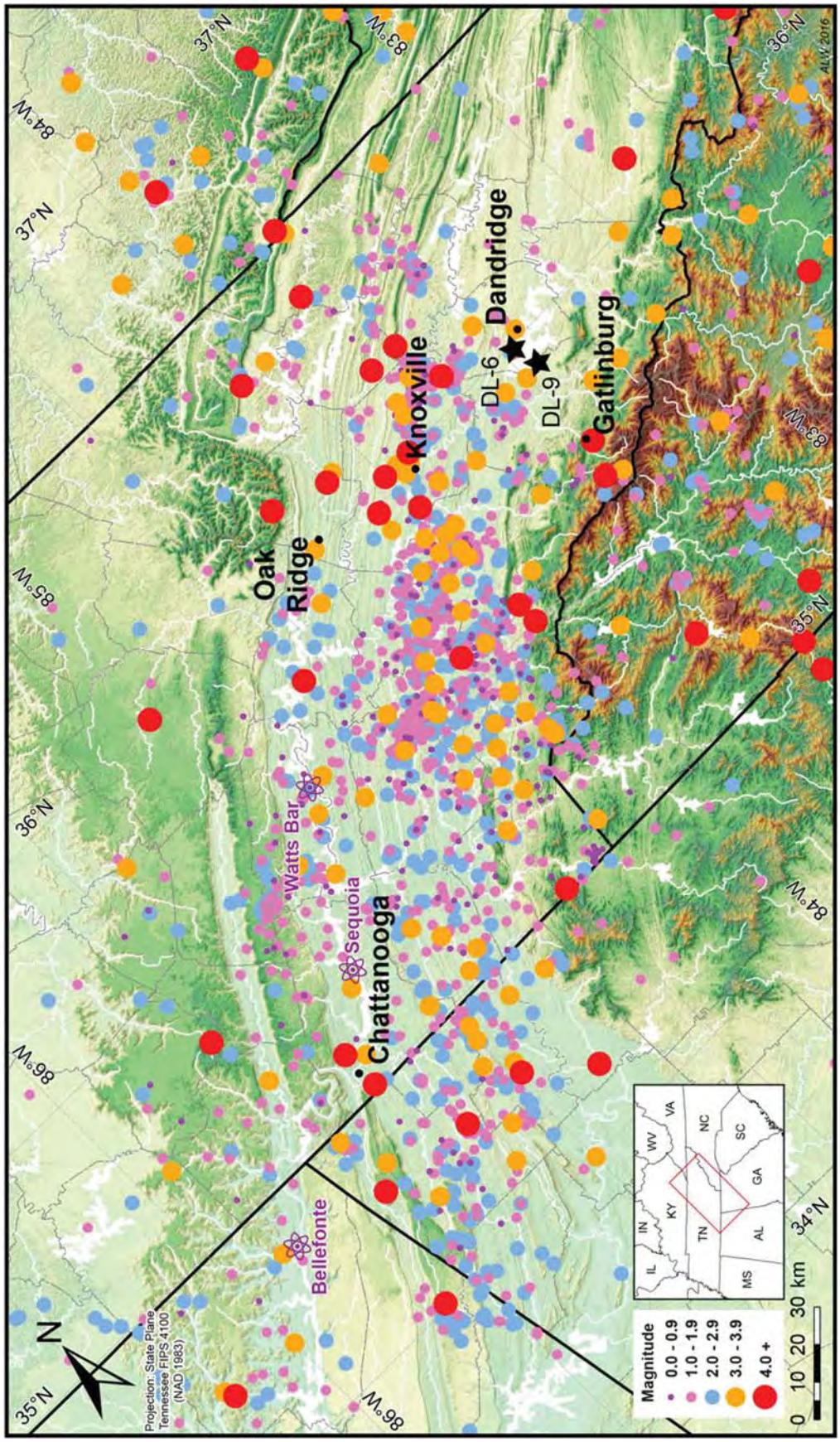

Figure 1. Earthquake epicenters in the eastern Tennessee seismic zone depicted relative to large cities in the region. Dandridge, Tennessee, is the location of the field sites for this article. Earthquake data are from the Advanced National Seismic System Comprehensive Catalog. Regional setting of field sites DL-6 and DL-9. Digital elevation model source = Shuttle Radar Topography Mission 90 m; geographic features from The National Atlas.

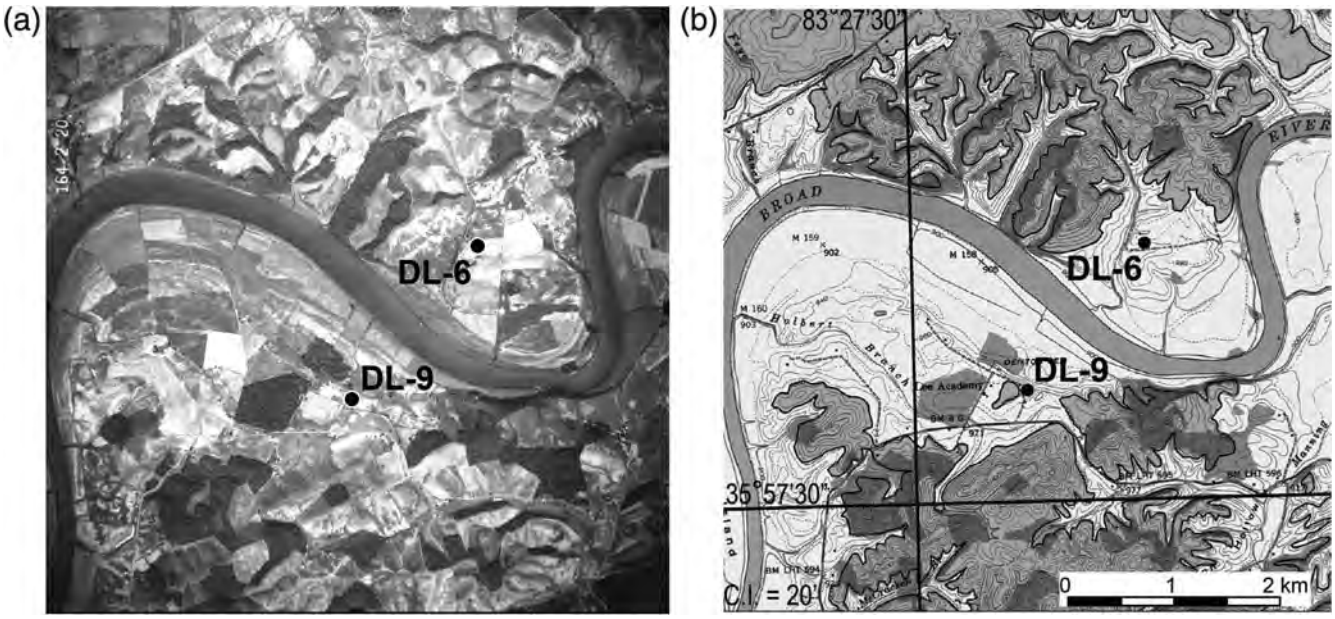

Figure 2. (a) 1938 Tennessee Valley Authority aerial photo of sites DL-6 and DL-9 and the surrounding area. (b) Part of the Shady Grove 7.5 min quadrangle, Tennessee (1939 version), showing the same area in (a) and sites DL-6 and DL-9. (b) Shaded areas indicate land elevations above maximum summer water level (305 m.a.s.l.) in Douglas Reservoir. C.I., contour interval.

Hurd and Zoback, 2012). Additionally, *P*- and *S*-wave arrival times have been used to investigate the relationship of seismic-velocity anomalies in the ETSZ to the New York–Alabama magnetic-gravity lineament (King and Zietz, 1978; Vlahovic *et al.*, 1998; Powell *et al.*, 2014), which probably represents a major crustal boundary in the Grenville orogen (King and Zietz, 1978). Other workers (e.g., Powell *et al.*, 1994, 2014; Steltenpohl *et al.*, 2010; Powell and Chapman, 2012) attempted to correlate the distribution of ETSZ earthquakes with this lineament. Hatcher *et al.* (2012, their fig. 1) stated that this correlation is unlikely because the New York–Alabama lineament has a much larger extent than the ETSZ, and areas of highest earthquake density are not necessarily linear. Recent vertical relocation of ETSZ earthquakes (Powell and Chapman, 2012) indicate that most of the seismicity occurs east of the New York–Alabama lineament, and that the concentration of earthquakes is bounded on the west by the lineament.

The first detailed field-based study of the ETSZ described folded Quaternary sediments in a small part of the ETSZ that could possibly be related to paleoseismic activity (Whisner *et al.*, 2003). More recently, Hatcher *et al.* (2012) made a detailed reconnaissance of French Broad River terraces exposed along Douglas Reservoir near Dandridge, Tennessee, and identified several faults, fractures, and liquefaction features that cut Quaternary sediment at sites along the reservoir.

In this article, we present the results of detailed geologic mapping and optically stimulated luminescence (OSL) ages of sediments at site DL-6 of Hatcher *et al.* (2012) and at site DL-9 (an area of colinear sediment-filled fissures on the opposite shore of the reservoir) west of Dandridge, Tennessee (Figs. 1 and 2b); and use these to develop a chronology of seismic events affecting the sites.

Previous Work

Hatcher *et al.* (2012) identified at least five fluvial strath terraces belonging to the French Broad River along the shores of Douglas Lake. The lowest terrace, the preimpoundment floodplain, is only partly exposed in the upstream limits of Douglas Lake during maximum (winter) drawdown. Winter drawdown increases terrace exposures throughout the reservoir, and these are the focus of Hatcher *et al.* (2012). The ages of French Broad River terraces are not well constrained, but a terrace exposed 200 m south of Dandridge, Tennessee, yielded an OSL age of 203 ± 13 ka (Hatcher *et al.*, 2012). OSL ages of deformed terraces provide only a maximum age for deformation.

Site DL-6 of Hatcher *et al.* (2012) is located on the inside of a meander of the modern French Broad River ~5 km southwest of Dandridge, Tennessee (Fig. 2). This site is a south-facing exposure of a Quaternary terrace (saturated OSL ages > 112 and > 103 ka) and Middle Ordovician Sevier Shale along a small tributary of the French Broad River (Hatcher *et al.*, 2012; Fig. 2). Strong currents in the reservoir at this site have partially eroded the terrace deposits, exposing alluvium above the shale that ranges from 0 to 4.0 m thick. The basal alluvium on the bedrock strath is an ~0.5-m-thick discontinuous layer of pebbles, cobbles, and boulders composed mostly of rounded-vein quartz, some rounded-to-angular chert, minor granitoid and quartzite pebbles, and rare amphibolite and calcsilicate pebbles. The clasts originate from the headwaters of the French Broad River,

possibly as far away as the southeastern flank of the Blue Ridge. This basal cobble layer is overlain by a red clay loam to sandy loam (Hatcher *et al.*, 2012). A dark brown to reddish-yellow BC or BCt soil horizon may be locally developed, and the surface soil is a 3+ m thick, well-developed Ultisol (Hatcher *et al.*, 2012), which suggests the terrace is older than Holocene.

At site DL-6, Hatcher *et al.* (2012) described an ~30 cm wide, N33°E-striking Quaternary fissure in N70°E-striking, 15° SE-dipping Sevier Shale saprolite. The fissure is filled with Quaternary alluvium from the overlying terrace. Because the northeast strike of the fissure is oblique to topographic contours, Hatcher *et al.* (2012) argued that it is unlikely the fissure is related to landsliding, at least on the Holocene landscape. (We present herein new evidence that this fissure is part of a larger zone that crosses the French Broad River valley and thus is not related to landsliding.) Trenching across this fissure revealed an N55°E-striking, southeast-dipping thrust fault with ~1 m displacement of the terrace alluvium/bedrock contact (C–G in Fig. 3a,b and at N7.5 in Fig. 4a; Hatcher *et al.*, 2012). The hanging wall moved uphill, precluding a landslide origin. Fault dip is 30°–40° within terrace alluvium but flattens to 15°, and down-dip becomes listric, parallel to bedding within Sevier Shale saprolite (Figs. 3 and 4e). This thrust cuts the sediment-filled fissure. An N35°W-striking, vertical, sinistral strike-slip fault in the thrust hanging wall offsets the fissure 10 cm (at K14.5 in Fig. 4a). Hatcher *et al.* (2012) also described a liquefaction body in terrace alluvium that predates Ultisol development (blue unit in Fig. 4a; Fig. 5). Bedding has been destroyed by fluidization of the alluvium within the liquefaction body, and it represents a potential source bed for upward clastic intrusions. Rarity of similar features in terrace alluvium around Douglas Lake argues that the destruction of bedding within this body was not caused by a common process like tree throw. It is similar to other liquefaction bodies described previously, such as the bulbous-shaped lens paleoliquefaction feature at site 2 of Bastin *et al.* (2015) in Canterbury, New Zealand. These and other numerous features discovered at site DL-6 by Hatcher *et al.* (2012) suggested at least two $M_w \geq 6$ earthquakes and motivated detailed mapping of a larger area of DL-6, expanded reconnoitering of Douglas Lake winter low-water shore, and additional OSL dating of Quaternary alluvium.

Methods

Our study sites DL-6 and DL-9 (Figs. 1 and 2) are along the winter (low water) shore of Douglas Lake, built by the Tennessee Valley Authority in 1943 by impounding the French Broad River, a principal drainage of the southern Appalachians. This reservoir provides a unique area in which to study paleoseismic features in this region because the Tennessee Valley Authority seasonally lowers the water level of the reservoir some 15 m from late October until mid-April to accommodate winter–spring runoff. As a result, during winter large areas of the unvegetated lakebed expose multiple Quaternary French Broad River terrace deposits. This permits high-quality reconnaissance and detailed geologic mapping of potential paleoseismic features that occur in Quaternary alluvium and underlying bedrock. Alluvial terraces at study sites DL-6 and DL-9 are underlain by Middle Ordovician Sevier Shale, thus avoiding the misinterpretation of sinkhole collapse in carbonate bedrock as deformation related to recent fault movement.

To expand the mapping of Hatcher *et al.* (2012), site DL-6 was bulldozed during winter low water to remove modern lake sediment and topographic irregularities. Using a 2 m grid, we mapped the cleared area in as much detail as possible (Fig. 4a), although terrace alluvium in the mapped area contains few recognizable features because of intense weathering and soil development. We measured strike and dip on fault and fracture surfaces and on bedding in bedrock and measured trend-and-plunge of slickenlines (Fig. 4a–d). Also, at site DL-6, trench 2 of Hatcher *et al.* (2012) was reopened to expose the Quaternary thrust, and the first detailed description of the southwest trench wall is presented here (Fig. 3c,d). A shallow water table prevented excavating the trench deeper than 1.5 m.

Investigation of Quaternary deformation associated with structures observed at site DL-6 was further expanded by reconnoitering the Douglas Lake shoreline at a lower water level than previous attempts. We cleared modern lake sediment at site DL-9 by hand shovel, mapped Quaternary fissures filled with terrace alluvium and joints in Quaternary alluvium using a 1 m grid, and made structural measurements on fissure and joint surfaces (Fig. 6).

OSL samples were collected in opaque tubes to ensure they were not exposed to sunlight, and the OSL samples were sent to the Luminescence Dating Research Laboratory at the University of Illinois-Chicago for analyses. At the University of Illinois-Chicago, OSL ages were calculated using the Galbraith *et al.* (1999) minimum age model which assigns a greater weight to the youngest equivalent dose population. This model was adopted because overdispersion values for these samples are high (> 35%). The coarse-grained (150–250 μm) quartz fraction was analyzed. Equivalent dose values were analyzed under blue-light excitation (470 + 20 nm) following single aliquot protocols of Murray and Wintle (2003). U, Th, and K_2O content were measured by inductively coupled plasma-mass spectrometry at Activation Laboratories Ltd., Ancaster, Ontario, Canada. The cosmic component of the dose rate was estimated from Prescott and Hutton (1994). We collected four new OSL samples from terrace alluvium within fissures in Sevier Shale saprolite: two were collected from the map-view trace of the main fissure at site DL-6 (Fig. 4a) by driving a tube vertically into the alluvium filling the fissure; one was collected from a fissure branch in the west wall of trench 2 at site DL-6 (Fig. 3c,d) by driving a tube horizontally into the alluvium filling the fissure, and one was collected from a fissure exposed in a pit excavated at site DL-9 by driving a tube horizontally into the alluvium filling

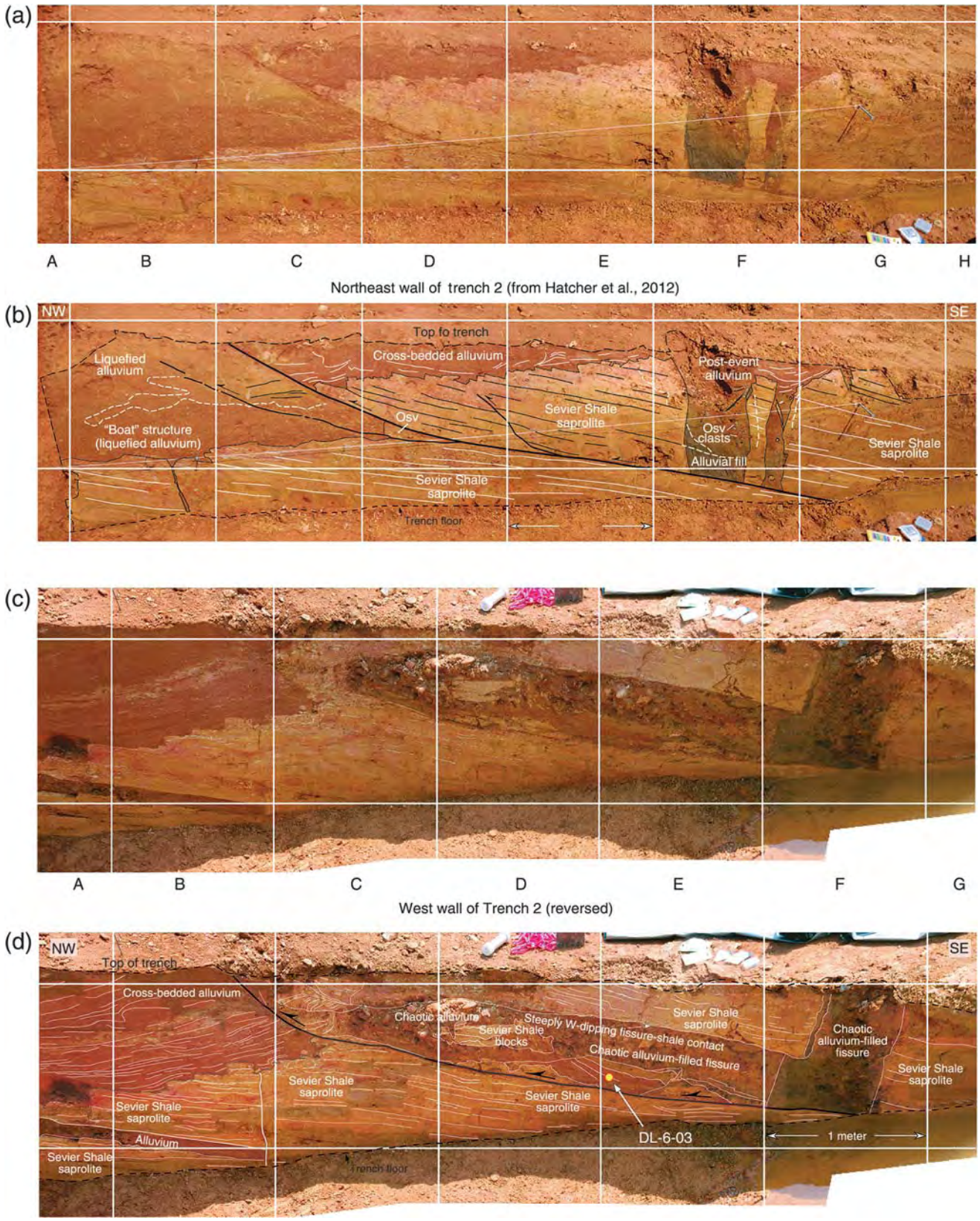

Figure 3. Composite photographs of (a,b) the northeast wall of trench 2 of Hatcher *et al.* (2012) and (c,d) the southwest wall of the same trench (first described herein) at site DL-6 that expose an N55°E-striking thrust fault that truncates an N33°E-striking alluvium-filled fissure, along with sketch overlays of the photographs. Note two small faults splaying from the main thrust on the northeast wall. The main thrust has ~1-m upslope displacement. The location of the southern end of a liquefaction body is also shown on the northeast wall. Half arrowheads denote the dip-slip component of displacement. The trench location is shown in Figure 4a. (Photographs by R. D. H.)

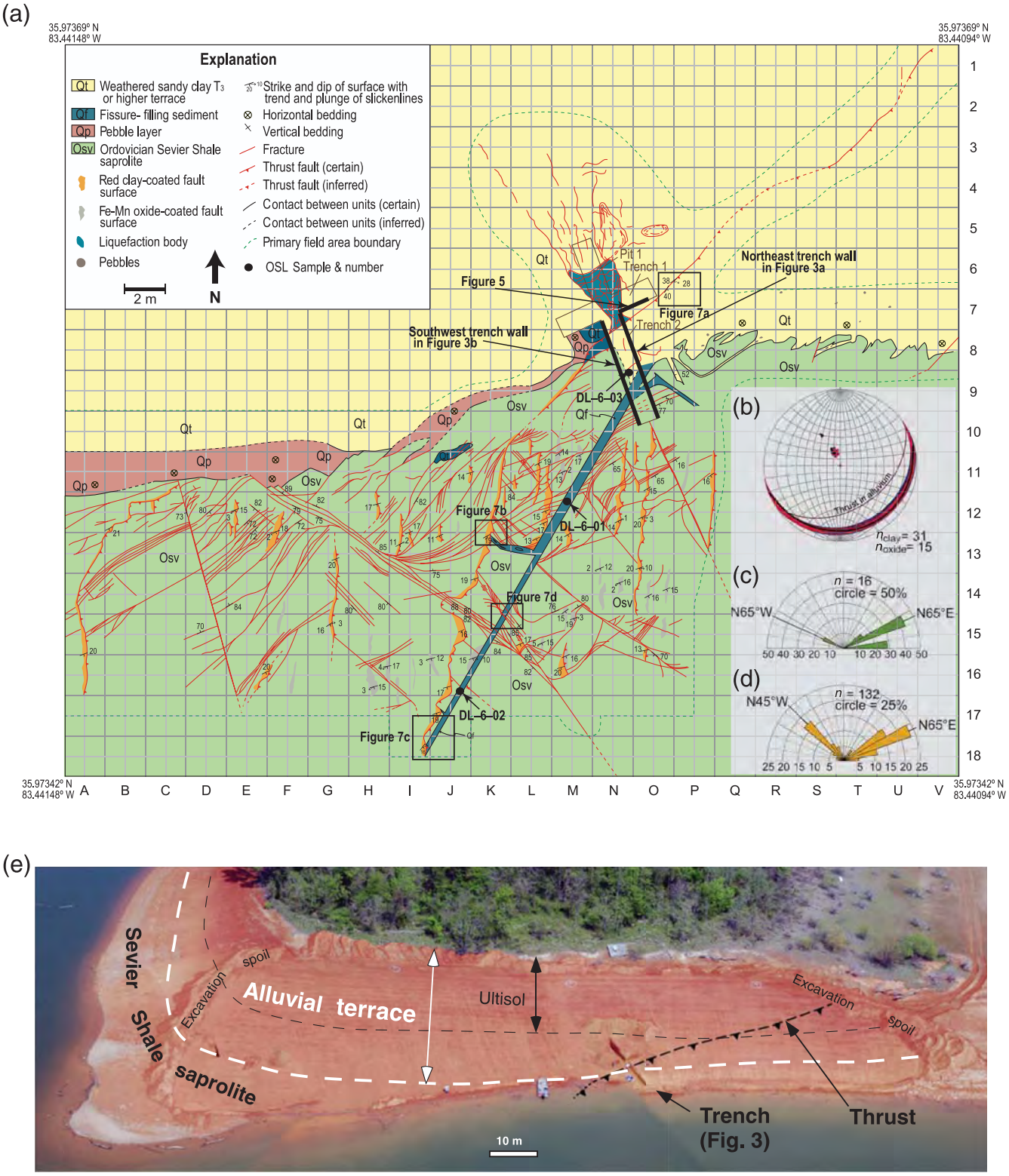

Figure 4. (a) Detailed geologic map of fracture arrays and faults in Sevier Shale saprolite and Quaternary sediments at site DL-6, west of Dandridge, Tennessee. (b) Great circles and poles (points) from fault surfaces and bedrock bedding in the map area. Brown line and pole indicate thrust in alluvium; black line and pole indicate bedding in saprolite; blue lines and poles indicate clay-gouge-coated fault planes; red lines and poles indicate Fe–Mn oxide-coated fault planes. (c) Rose diagram of slickenline azimuths recorded from the map area. Slickenline azimuths on the main thrust are N65°W, and they plunge from 28° to more than 40° SE. The plunges of slickenlines on other bedding plane faults in saprolite are generally less than 5°. (d) Rose diagram of fracture azimuths from the map area. Horizontal axes in (c) and (d) are the percentage of slickenlines or fractures with respective orientations. (Plotted using software by Allmendinger *et al.*, 2012.) (e) Annotated oblique aerial image of site DL-6 looking north.

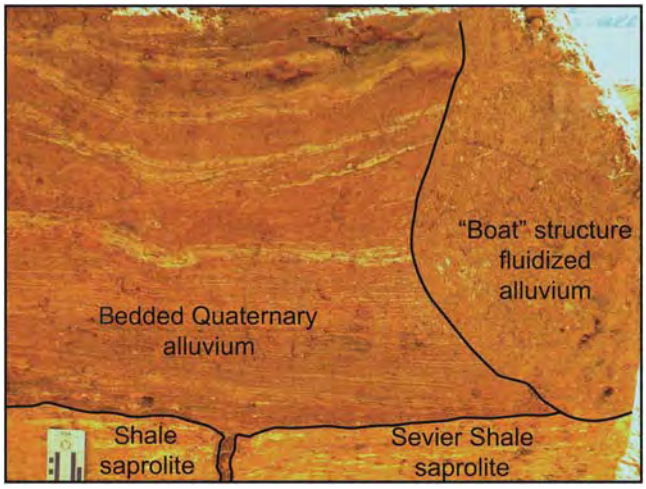

Figure 5. Trench 2 wall exposing a partial cross section through a liquefaction body at site DL-6. The liquefaction body clearly truncates the finely laminated Quaternary alluvium in the left of the photo. (Photograph by K. F. W.) The trench location is shown in Figure 4a.

the fissure (Figs. 6b and 7b). We collected a fifth OSL sample from undisturbed terrace alluvium 1 m topographically above alluvium-filled fissures in bedrock shale saprolite at site DL-9 (Figs. 6b and 7c).

Results

Red Clay-Filled Fractures

We first noted red clay-filled fractures along and adjacent to demonstrable faults in Quaternary alluvium at the DL-6 site and have subsequently found them at numerous other localities in southeastern Tennessee (Hatcher *et al.*, 2012; Glasbrenner *et al.*, 2014; Feng *et al.*, 2015). They are rarely found more than a few tens of meters from localities displaying evidence of Quaternary paleoearthquakes (liquefaction, faults in alluvium, alluvium-filled fissures). Thus, we interpret these red clay-filled fractures to be related to Quaternary earthquakes as possible shear-plane gouge, filled fractures or fissures, and/or enhanced weathering along damage zones. Slickensided, red clay-filled fractures are abundant in Sevier Shale and are intimately related to traceable faults at site DL-6. They appear to locally merge with bedrock joints and alluvium-filled fissures in some places and truncate against these fractures in others (Fig. 4a). Burton *et al.* (2015) documented the presence of similar red clay-filled fractures in trenches in the epicentral area of the 2011 M_w 5.8 Mineral, Virginia, earthquake (Hough, 2012).

Site DL-6

The winter 2012–2013 drawdown of Douglas Reservoir exposed an N55°E-striking, southeast-dipping fault-line scarp in terrace alluvium extending northeast from trench 2 (Figs. 4a and 8a), which is the thrust in trench 2 of Hatcher *et al.* (2012) (Fig. 3). Additional clearing at site DL-6 facilitated detailed geologic mapping of the Quaternary thrust in Sevier Shale saprolite to the south and southwest of trench 2 (Fig. 4a).

The thrust described in DL-6 trench 2 by Hatcher *et al.* (2012) is continuously traceable through the mapped area at site DL-6. Mapping of the Quaternary thrust within Sevier Shale saprolite was aided by a 1-cm-thick red sandy-clay gouge along the fault surface (orange unit in Fig. 4a). Excavation of the site left extensive, continuous exposures of the red clay fault gouge (Fig. 8b,c). The thrust continues at least 15 m to the northeast of trench 2 through Quaternary terrace alluvium (N7 to V1 in Fig. 4a; Fig. 8a) and at least 16 m to the southwest of the trench in shale saprolite (N8 to I18 in Fig. 4a). This thrust fault truncates a west-trending branch of the alluvium-filled fissure (at K13 in Fig. 4a; Fig. 8b), the southern end of the main fissure (at I18 in Fig. 4a; Fig. 8c), and a small N35°W-striking, sinistral strike-slip fault (at K14 in Fig. 4a). Red clay on the thrust displays slickenlines trending S62°E and plunging 28°, with northwest vergence. In the terrace alluvium upslope of the trench, dip on the thrust and plunge of the slickensides steepen to 40° or more. In addition to the thrust, we observed multiple ~N70°E-striking surfaces subparallel to bedding in Sevier Shale saprolite that are also coated with red sandy clay and display horizontal-to-subhorizontal slickenlines (Fig. 4a). These slickensided surfaces strike between N55°E and N70°E, most (57%) slickenlines trend between N50°E and N70°E and verge generally west-southwest (Fig. 4c), but no marker beds are present for measurement of displacement. Slickenlines were also identified on Fe–Mn oxide-coated fault surfaces in bedrock (dark gray screen in Fig. 4a), although these surfaces are not as areally extensive or as traceable through the map area as the red sandy clay gouge fault material. In addition to the set of N70°E-striking, bedding-parallel faults at site DL-6, there are two sets of subvertical fractures in saprolite clustered at N55°E–N75°E (55%) and N40°W–N50°W (45%) (Fig. 4d). We also mapped the sinistral strike-slip fault originally described by Hatcher *et al.* (2012) that offsets the sediment-filled fissure ~10 cm (Fig. 8d); it is absent in the footwall of the Quaternary thrust fault.

Our re-entry of trench 2 revealed the thrust and the alluvium-filled fissure on the northeast trench wall as described by Hatcher *et al.* (2012) and on the southwest trench wall. The shale saprolite-terrace alluvium contact is an irregular scoured, step-like surface that we interpret as the product of hydraulic plucking of the shale beds by the river current (C–E/F in Fig. 3a,b and A–C in Fig. 3c,d).

There are two additional fissures in shale saprolite in the southwest trench wall filled with terrace alluvium (Fig. 3c,d). Both fissures strike northwest and are parallel to the trench wall, thus displaying a subhorizontal apparent dip in Figure 3c,d. One of these fissures extends from B/C to F in the thrust hanging wall, and the other fissure extends from a joint near B/C to the end of the trench past A in the footwall of the thrust (Fig. 3c,d).

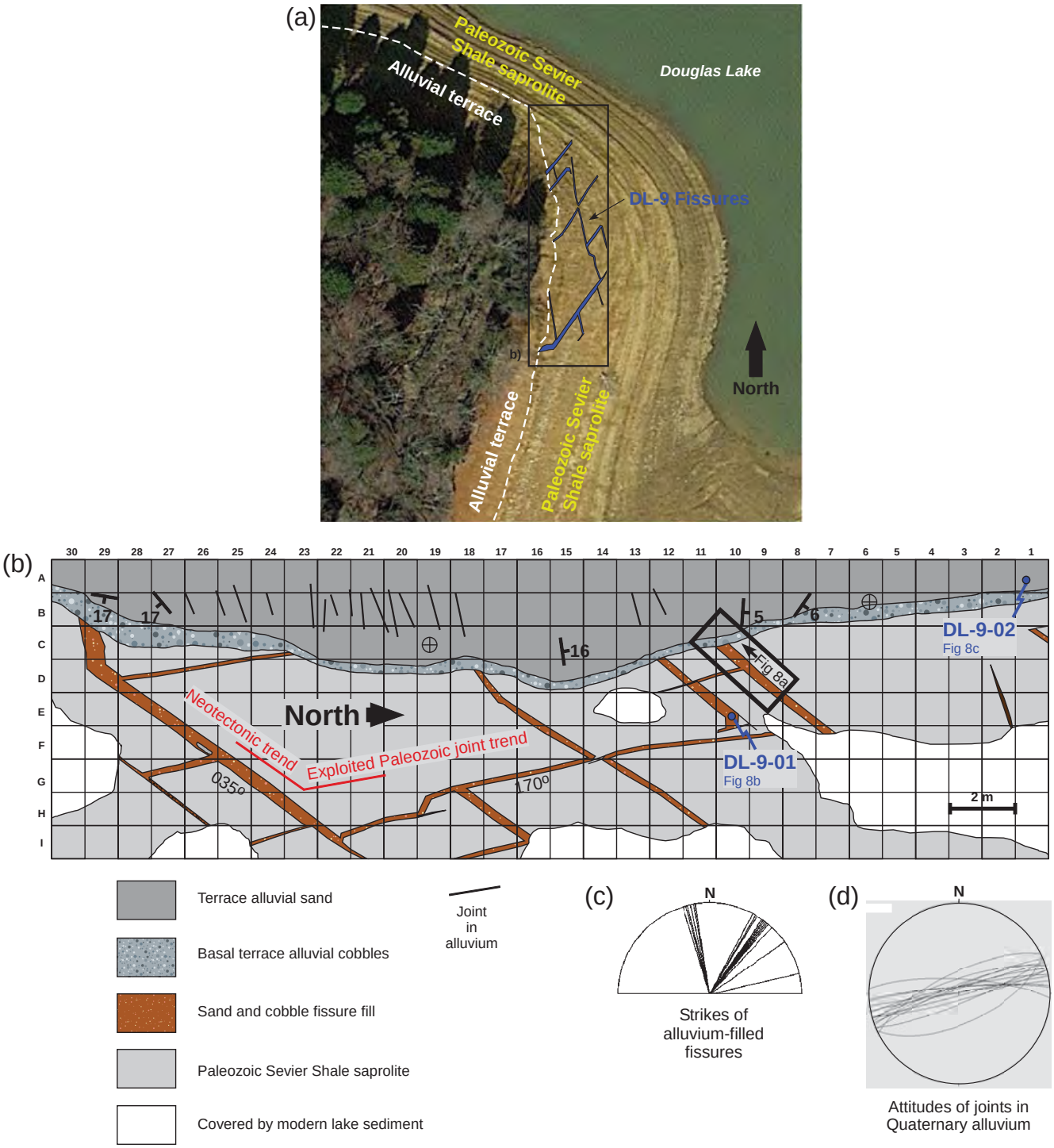

Figure 6. (a) Annotated aerial photo of site DL-9. Shore parallel lines on the photo are Douglas Lake water lines. (b) Geologic map of site DL-9 showing alluvium-filled fissures in Sevier Shale saprolite bedrock and joints in Quaternary terrace alluvium. (c) Strike-azimuths of fissures. (d) Equal-area projection of planes to joints.

Site DL-9

At site DL-9, N35°E-striking fissures up to 60 cm wide in Sevier Shale saprolite were filled from above by Quaternary terrace alluvium (Fig. 6), as previously observed at site DL-6 (with the same strike). A secondary set of alluvium-filled, N10°W-striking fissures ≤20 cm wide exploits a widespread Paleozoic or Mesozoic joint set. Site DL-9 is along strike and southwest of the large fissure and thrust at site DL-6 (Fig. 2b) and contains the only bedrock fissures filled with Quaternary alluvium found during our comprehensive survey of the south shore of Douglas Lake.

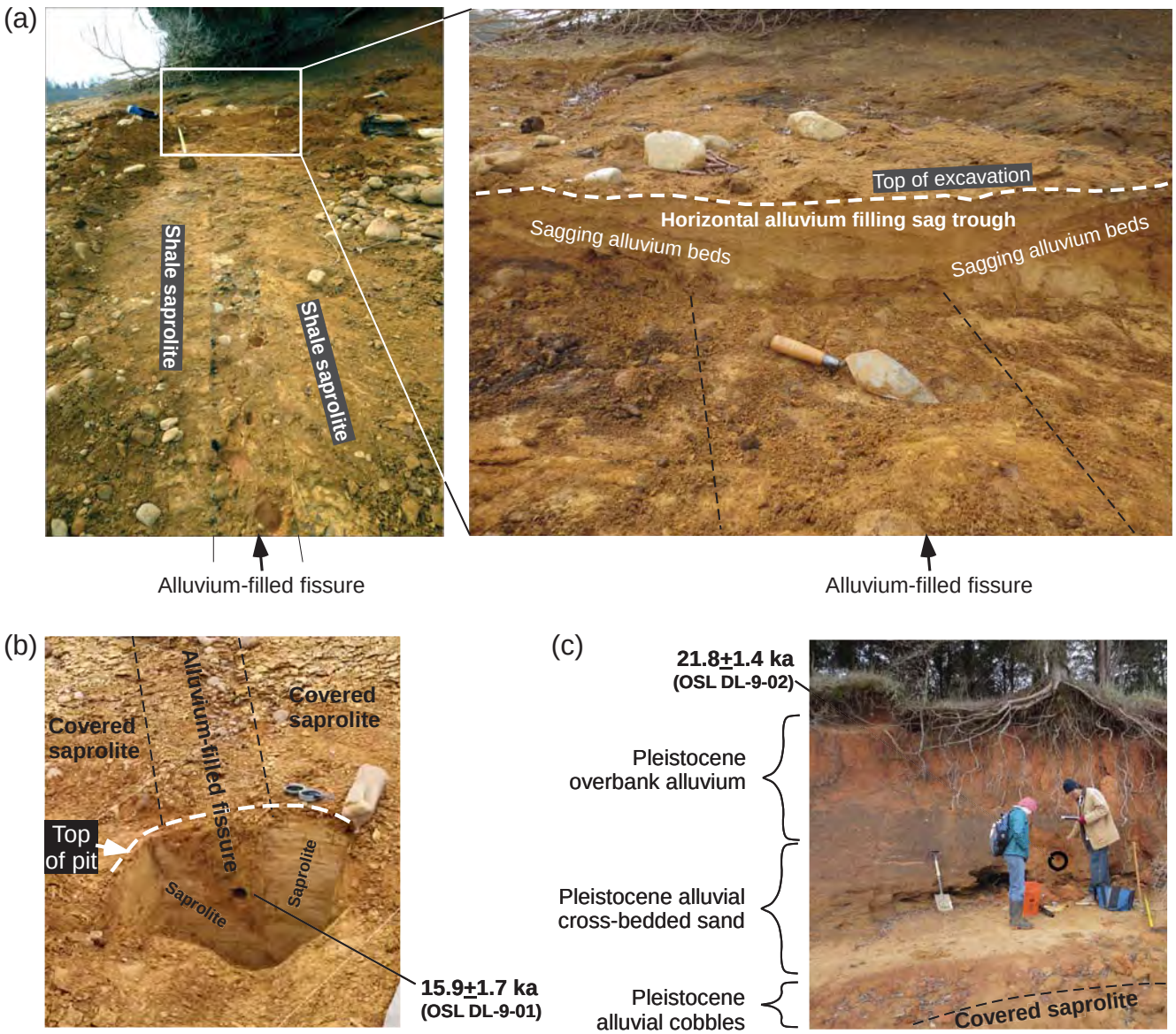

Figure 7. (a) Photographs from DL-9 showing basal alluvium of the Quaternary terrace sagging into an alluvium-filled fissure in Sevier Shale saprolite bedrock and horizontally bedded alluvium filling the sag trough. Trowel is 25 cm long. (b) Optically stimulated luminescence (OSL) sample DL-9-01 collection site within sandy alluvium fissure fill. Brunton compass is 15 cm long. (c) OSL sample DL-9-02 collection site within cross-bedded sands in the overlying alluvial terrace deposit. Locations are shown in Figure 6. (Photography by R. T. C.)

A 4-m-thick Quaternary alluvial terrace overlies Sevier Shale saprolite bedrock at site DL-9. Although also at a similar elevation as the terrace deposit at site DL-6, the soil profile is thinner (1.5 m) and less developed than the 3+ m thick soil at site DL-6. This suggests that, when the fissures in the saprolite opened, the basal 0.5 m of terrace alluvium collapsed and filled the underlying bedrock fissures (Fig. 7). The overlying yellowish-brown, sand to sandy loam alluvium is horizontally bedded and fills the sag troughs in the basal alluvium above the fissures. A systematic set of vertical joints in the Quaternary terrace alluvium at site DL-9 strikes ~N70°W (Fig. 6). These joints are laterally restricted to the terrace alluvium that overlies the alluvium-filled bedrock fissures, and they extend ~2 m vertically above a basal cobble zone until they become obscured by a moderately developed Ultisol.

Geochronology

OSL samples collected from the terrace at site DL-6 by Hatcher *et al.* (2012) were saturated with respect to the OSL dose level and yielded minimum ages of > 112 and > 103 ka for the terrace at site DL-6. Ages of 203 ± 13 ka and 119 ± 8 ka were obtained from terrace deposits at similar elevations above the French Broad River a few kilometers upstream (Hatcher *et al.*, 2012), consistent with the age of the terrace at DL-6 being > 112 ka. Alluvium from the terrace at

Table 1
Optically Stimulated Luminescence (OSL) Ages and Associated Laboratory Data for Alluvium-Filling Fissures at Sites DL-6 and DL-9 and *in situ* Terrace Alluvium at Site DL-9 (DL-9-02)

Field Number*	Laboratory Number*	Depth (m)	Equivalent Dose (Gray)†	Uranium (ppm)‡	Thorium (ppm)‡	K_2O (%)‡	H_2O (%)	Cosmic dose (mGray/yr)§	Total Dose Rate (mGray/yr)	OSL Age (yr)‖
DL-6-01	UIC3217	1	40.08 ± 4.01	3.4 ± 0.1	16.2 ± 0.1	0.61 ± 0.01	5 ± 2	0.12 ± 0.01	2.59 ± 0.13	15,450 ± 1,745
DL-6-02	UIC3215	0.3	17.05 ± 2.25	4.5 ± 0.1	16.2 ± 0.1	0.61 ± 0.01	5 ± 2	0.12 ± 0.01	3.49 ± 0.21	4,890 ± 700
DL-6-03	UIC3222	1	18.14 ± 1.95	1.5 ± 0.1	8.0 ± 0.1	0.56 ± 0.01	5 ± 2	0.12 ± 0.01	1.53 ± 0.08	11,880 ± 1,420
DL-9-01	UIC3221	1	39.60 ± 3.83	2.8 ± 0.1	12.3 ± 0.1	0.97 ± 0.01	5 ± 2	0.12 ± 0.01	2.50 ± 0.13	15,865 ± 1,735
DL-9-02	UIC3323	2.5	38.39 ± 1.36	2.0 ± 0.1	9.1 ± 0.1	0.70 ± 0.01	10 ± 3	0.14 ± 0.01	1.76 ± 0.09	21,765 ± 1,445

*Analyses were performed by Steven L. Forman at Luminescence Dating Research Laboratory, University of Illinois-Chicago.
†Equivalent dose analyzed under blue-light excitation (470 ± 20 nm) by single aliquot regeneration protocols (Murray and Wintle, 2003). The coarse-grained (150–250 μm) quartz fraction was analyzed.
‡U, Th, and K_2O content analyzed by inductively coupled plasma-mass spectrometry by Activation Laboratories Ltd., Ontario, Canada.
§Cosmic dose rate component is from Prescott and Hutton (1994).
‖Ages calculated using the minimum age model of Galbraith *et al.* (1999) because of high overdispersion values (> 35%), which weights for the youngest equivalent dose population.
All errors are 1σ, and ages were calculated from A.D. 2000.

site DL-9 (OSL sample DL-9-02) has an age of 21.8 ± 1.4 ka (Figs. 6b and 7c; Table 1). This age is from undeformed alluvium above alluvium-filled fissures. Two OSL samples collected at the surface 11 m apart along the map-view trace of the alluvium-filled fissure at site DL-6 had OSL ages of 15.5 ± 1.7 ka at DL-6-01 (upslope) and 4.9 ± 0.7 ka at DL-6-02 (downslope) (Fig. 4a; Table 1). Terrace alluvium from a fissure branch in the southwest wall of trench 2 (DL-6-03) has an OSL age of 11.9 ± 1.4 ka (Figs. 3c,d and 4a; Table 1). Terrace alluvium filling a fissure at site DL-9 (Fig. 2) yielded an OSL age of 15.9 ± 1.7 ka (Figs. 6b and 7b; DL-9-01 in Table 1).

Discussion

Quaternary terrace alluvium and Sevier Shale bedrock saprolite are two very different materials with different physical properties. Terrace alluvium is unconsolidated, nearly cohesionless sediment with soil development in the upper portions, whereas Sevier Shale saprolite is cohesive with bedding planes and Paleozoic joints forming weak surfaces. Some younger fractures postdating Quaternary alluvium/colluvium may be shear fractures related to ETSZ faults. In weak, homogenous Quaternary alluvium, deformation is concentrated along discreet faults. In Sevier Shale saprolite, deformation is distributed diffusely on bedding planes and joints that are weak surfaces that commonly require a lower threshold of stress to activate than is required to form new fractures. In some areas of the Sevier Shale outcrop at site DL-6, however, small faults curve away from bedding planes and pre-existing joints, suggesting that orientations of pre-existing surfaces are not fully compatible with Quaternary stresses. Additionally, in Quaternary alluvium, thrust motion is toward the northwest, whereas in Sevier Shale saprolite thrust motion is toward the west-southwest, further indicating that material properties may have had an influence on direction of displacement.

Crosscutting Relationships of Fractures, Faults, and Sediments

Site DL-6. The large (> 20 cm wide) northeast-striking fissure that is cut by the northeast-striking thrust at site DL-6 is similar to complex coseismic damage described at sites of strike-slip fault surface ruptures of recent decades (Fu *et al.*, 2004; Li *et al.*, 2010; Liu-Zeng *et al.*, 2010; Lin *et al.*, 2011; Villamor *et al.*, 2012). However, the fissure is also typical of bending moment extension in the crest of a surficial fold (Yu *et al.*, 2010), and because the thrust at DL-6 merges down-dip with a bedding plane in shale saprolite bedrock, we suspect that this thrust is due to flexural bedding plane slip during fault-propagation folding above the tip of a blind fault at depth.

The maximum principal compressive stress (σ_1) of the regional stress field in the ETSZ is subhorizontal (S_{Hmax}) and oriented N70°E (Zoback and Zoback, 1991; Hurd and Zoback, 2012), which is subparallel to the majority of mea-

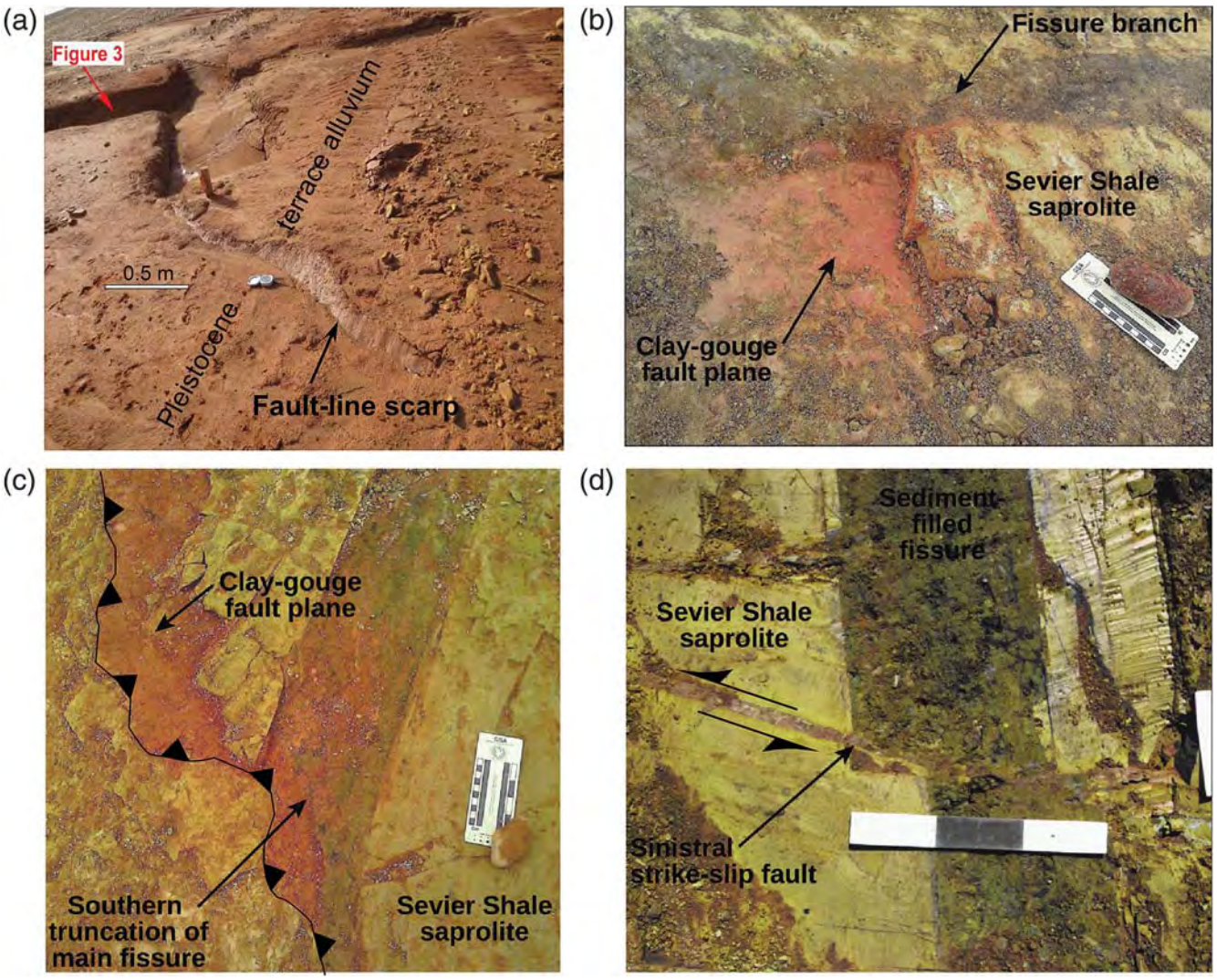

Figure 8. Structures at DL-6 related to earthquake 3 (location shown in Fig. 4). (a) A fault-line scarp produced by erosion during summer 2012 high water along the Quaternary thrust, exposed just east of trench 2 (Fig. 3), view to the southwest. Slickenlines oriented down the dip of the fault are present on the scarp face. (Photograph by R. D. H.) (b) The thrust truncates a west-trending branch of the main alluvium-filled fissure. Scale is 10 cm long. (Photograph by K. F. W.) (c) The thrust also truncates the main fissure at its southern extension. Scale is 10 cm long. (Photograph by K. F. W.) (d) A sinistral strike-slip fault offsets the main fissure ~10 cm. Scale is 30 cm long. (Photograph by J. D. V.)

sured slickenlines in Sevier Shale saprolite at site DL-6 but strongly oblique to the northwest-trending slickenlines on the Quaternary thrust at site DL-6. Azimuths of bedrock fractures measured in shale and siltstone in the Blue Ridge Foothills near Pigeon Forge, Tennessee, and the Valley and Ridge near Oak ridge, Tennessee, contain populations of fractures with azimuths centered at N55°E–N75°E, N80°W, and N45°W (Hatcher *et al.*, 2012, their fig. 12). The near-vertical fracture sets striking N55°E–N75°E and N40°W–N50°W in bedrock at DL-6 are likely pre-existing Paleozoic or Mesozoic fractures based on comparisons with those measured in the Blue Ridge Foothills and western Valley and Ridge, but they are suitably oriented for reactivation as strike-slip faults in the current stress regime. One set of northwest-trending fractures is continuous on both sides of the thrust fault at DL-6 and appears to slightly disturb the bedrock-alluvium contact (at E/F11 in Fig. 4a); several splays off this fracture set curve northeast, and some appear to merge with the fault (at K12.5 in Fig. 4a). This fracture set may be either a reactivated Paleozoic set or a younger set that formed during recent faulting. Farther west (from C11 to E17 in Fig. 4a), a prominent, single northwest-trending fracture truncates many smaller fractures, but no displacement is present, suggesting that it is an old (Paleozoic?) fracture that forms a barrier to later fracture propagation.

Absence of the sinistral strike-slip fault in the footwall of the thrust fault suggests it may be a tear fault in the thrust hanging wall that was coeval with thrusting. The tear fault interpretation is consistent with the near-perpendicular northwest strike of the strike-slip fault to the northeast strike of the thrust fault and with its near-parallel strike to slickenlines plunging S28°E on the thrust near trench 2 (at P6 in

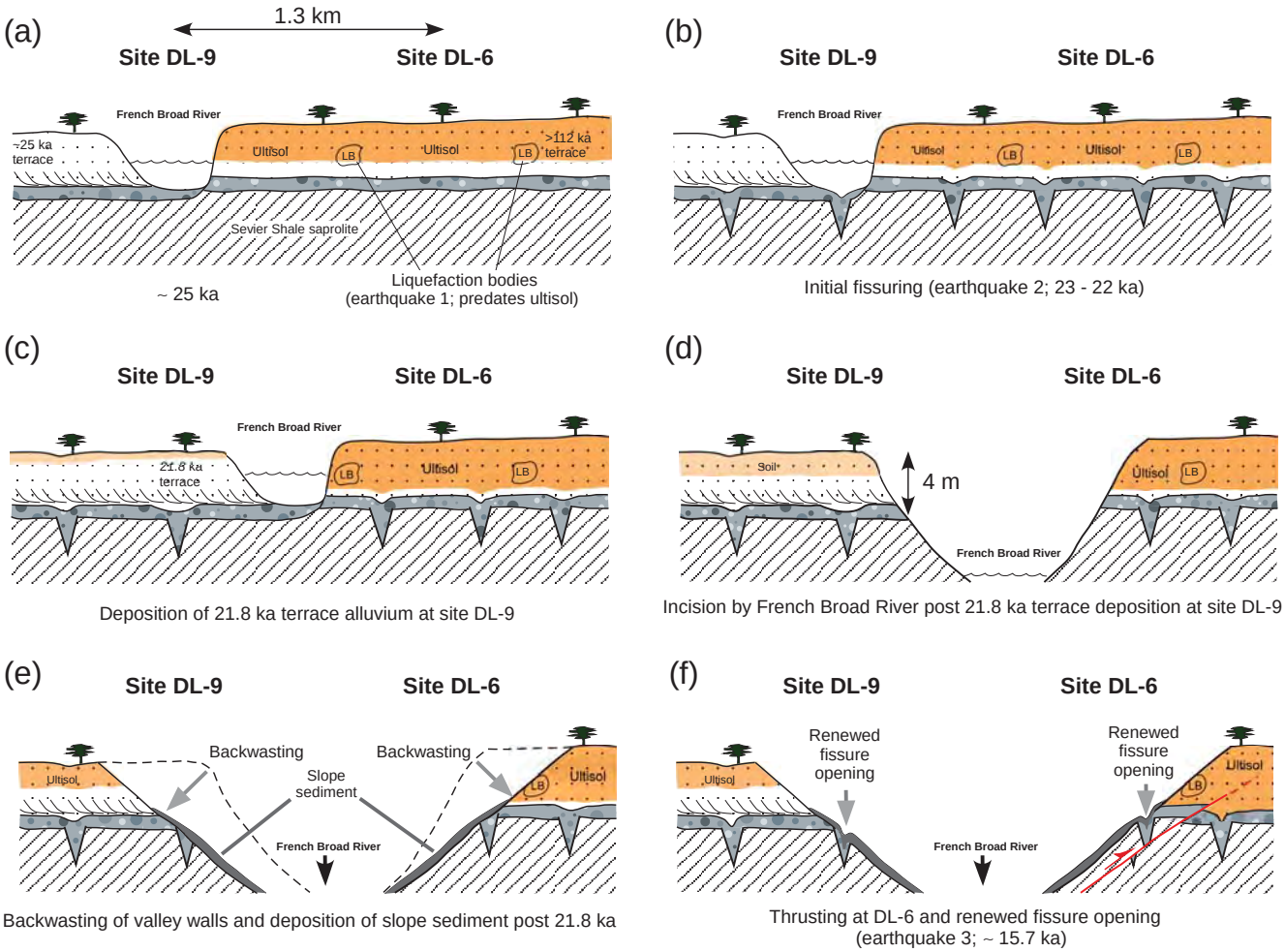

Figure 9. Schematic illustration (not to scale) of the timeline of events at DL-6 and DL-9 near Dandridge, Tennessee. Age constraints were obtained by OSL dating of alluvium (Table 1) and by degree of soil development. Possible paleoearthquakes are numbered. (a) Hypothetical setting of site DL-6 and DL-9 during deposition of basal cobble alluvium at DL-9. The > 112 ka OSL age, Ultisol development, and liquefaction bodies (related to earthquake 1) are adopted from Hatcher *et al.* (2012). (b) Initial development of cobble alluvium-filled fissures during earthquake 2 prior to the deposition of overlying point bar and floodplain alluvium at site DL-9. (c) Lateral migration of the Pleistocene French Broad River, and deposition of upper alluvium at site DL-9 ~21.8 ka (OSL sample DL-9-02; Table 1). (d) Incision by the French Broad River and abandonment of the terrace at site DL-9 post 21.8 ka. (e) Backwasting of the French Broad River valley walls and deposition of slope sediment over exposed cobble alluvium-filled fissures. (f) Thrusting and renewed opening of alluvium-filled fissures at sites DL-6 and DL-9 (earthquake 3) ~15.7 ka (OSL age of fissure fill from samples DL-6-01 and DL-9-01). Additional seismic events may be associated with events on the timeline, but these events lack sufficient evidence to be classified as paleoearthquakes.

Fig. 4a). A slight change of the fissure width across the sinistral fault suggests that it has oblique north-down, left-lateral slip.

Site DL-9. Large (> 20 cm wide) alluvium-filled fissures at site DL-9 are parallel and collinear with the large alluvium-filled fissure at site DL-6 and appear to be a continuous coeval zone of fissures trending northeast, subparallel to ETSZ seismicity. Fissures taper downward at sites DL-6 and DL-9 and terminate at ~4 m depth below the base of the terrace deposit. They taper downslope (Figs. 4 and 6, southward at DL-6 and eastward at DL-9) indicating they formed before the modern topography developed. Fissuring only disturbs the basal cobble terrace alluvium at site DL-9 (Fig. 7c), consistent with initial formation of a zone of fissures before deposition of the overlying cross-bedded sandy terrace alluvium at DL-9 (Fig. 9b).

That the collinear fissures at sites DL-6 and DL-9 seem to comprise a zone that crosses the French Broad River valley argues against landsliding into the valley as the origin of the fissures. Rather, they may have formed in response to near-surface extension in the hinge of a neotectonic fault-propagation fold that is parallel or subparallel to an active fault. No fault cuts the Quaternary alluvium or bedrock at the surface at site DL-9. Thus we interpret that a blind fault underlies the site, consistent with the Quaternary thrust at site DL-6 being a secondary near-surface fault that may have propagated from a bedrock bedding plane during flexural-slip folding above the tip of a propagating blind fault at depth.

N70°E-striking, systematic joints in Quaternary terrace alluvium at DL-9 are parallel to Quaternary σ_1 and to slickenlines on shear planes at site DL-6. These joints postdate OSL sample DL-9-02 (21.8 ka) and are overprinted by moderate Ultisol development near the surface of the terrace.

Relative Timing and Magnitude of Seismic Events

Hatcher *et al.* (2012) reported that deformation at DL-6 provided evidence of at least two strong earthquakes after deposition of the alluvial terrace. The first of these two events liquefied the alluvium. Fractures that cross-cut the liquefaction features and the Ultisol soil profile are evidence of a second earthquake that postdates the Ultisol (several thousands to a few tens of thousands of years ago).

OSL ages suggest that several earthquakes may have initiated and later renewed fissuring at sites DL-6 and DL-9, similar to episodes of fissuring in Canterbury, New Zealand (Quigley *et al.*, 2016). As stated in the Site DL-9 section, we interpret fissures at these two sites to be parts of a formerly continuous zone of fissures that extended across the French Broad Valley and potentially beyond (Fig. 9b). Initial fissuring predates deposition of undeformed terrace alluvium at site DL-9 (OSL sample DL-9-02, 21.8 ka; Table 1). Because the basal conglomerate of the DL-9 terrace is deformed by collapse into fissures, we interpret the timing of initial fissuring to be immediately prior to 21.8 ka. Initial fissuring accompanied fault-propagation folding and the related paleoearthquake. Thrusting at site DL-6 cross-cuts fissures, suggesting a later paleoearthquake.

Stream incision and backwasting of terrace deposits after 21.8 ka exposed downslope fissure segments to sediment younger than the original terrace cover. OSL samples DL-6-01, DL-6-02, DL-6-03, and DL-9-01 (Table 1) yield ages of fissure fill that are younger than the preserved terraces at sites DL-6 and DL-9. Agreement of OSL ages DL-6-01 (15.5 ± 1.7 ka) and DL-9-01 (15.9 ± 1.7 ka) suggests that a paleoearthquake accompanying thrusting at site DL-6 may have renewed opening of fissures at ~15.7 ka. We interpret N70°E-striking systematic joints in late Pleistocene terrace alluvium at site DL-9 as possibly coeval with thrusting and renewed fissure opening ~15.7 ka.

A timeline of events at DL-6 and DL-9 can be formed from the data collected for this study and by Hatcher *et al.* (2012) (Fig. 9). Formation of liquefaction features in terrace alluvium (> 112 ka) at site DL-6 predates strong Ultisol development. We suggest that pedogenic clay enrichment reduced the liquefaction potential and prevented later liquefaction events. This pre-Ultisol event (earthquake 1) predates the opening of bedrock fissures (earthquake 2) that were filled from above by terrace alluvium at site DL-6 and at DL-9 (21–23 ka), which in turn predate the thrust (earthquake 3) at DL-6. We suggest that fissures formed along the hinge of a fault-propagation fold during earthquake 2 as the thrust fault tip propagated nearer to the land surface, later rupturing the surface during earthquake 3. Coeval renewal of fissure opening at both sites DL-6 and DL-9 ~15.7 ka suggests that this is the timing of the significant paleoearthquake that accompanied thrusting at site DL-6 (earthquake 3). N70°E-striking systematic joints that are overprinted by the Ultisol at site DL-9 (Fig. 6) occurred at some time in the late Pleistocene and may have accompanied development of the N65°E-trending slickenlines on red sandy clay-filled shear planes in saprolite at site DL-6 (Fig. 4). The difference between the northwest-trending slickenlines on the thrust and the southwest-trending slickenlines on minor shear planes at DL-6 suggests that these structures may record separate earthquakes. OSL ages from samples DL-6-02 and DL-6-03 may record renewed fissure opening related to earthquakes ~11.9 and ~4.9 ka, but more age data are needed to assess the significance of these dates with respect to paleoearthquakes. It should be noted that crosscutting relationships only provide relative ages for these features, and the time between some events could range from centuries to days or hours, similar to strong aftershocks that followed the 1811–1812 earthquakes in the New Madrid seismic zone and the 2010–2011 Canterbury earthquake sequence in New Zealand (e.g., Guccione, 2005; Quigley *et al.*, 2013).

The estimated magnitude of the earthquake producing the DL-6 thrust fault with 1 m of displacement is $M_w \geq 6.5 \pm 0.2$, using the 95% confidence interval of the empirical relation between maximum displacement and magnitude derived by Wells and Coppersmith (1994). Following Biasi and Weldon (2006), this magnitude value is in agreement with the moment magnitude value (M_0 6.7) for which the probability distribution function for earthquake magnitude is maximized given an observed displacement of 1 m.

Our measured displacement may not be the same as the displacement on the seismogenic fault at depth, but the amount of seismic energy needed to produce secondary faulting with 1 m of displacement likely requires as much or more displacement on the main seismogenic fault. Furthermore, earthquake focal mechanism solutions show that fault movement in the ETSZ is mostly strike-slip (Chapman *et al.*, 1997), and northeast-striking faults are favorably oriented for strike-slip reactivation in the modern stress field (Zoback, 1992). Strike-slip fault systems are characterized by complex branching flower-structure geometries in the near surface (Davison, 1994; Hauksson *et al.*, 2002). If thrusting at DL-6 is related to a strike-slip flower structure, the observed 1 m of slip at DL-6 may be only a component of the total slip during earthquake 3 with additional coeval slip on other splays of the fault system. Thus, M_w 6.5 is a minimum estimate of magnitude for earthquake 3. Overall, the paleoseismic data at DL-6 and DL-9 provide evidence for three large paleoearthquakes (one or more $M_w \geq 6$) during the late Quaternary (Fig. 9).

Conclusions

1. Cross-cutting relationships of faults, fissures, liquefaction bodies, and soil horizons mapped at DL-6 and DL-9

indicate a history of three large earthquakes, at least one of which exceeded M_w 6, on a northeast-trending fault zone within the last 200 ka. All three earthquakes are late Pleistocene events, and OSL dating suggests two occurred within the last 25 ka. However, these ages may be too young because of cryptic pedogenic mixing and bioturbation. Earthquake 1 is recorded by a liquefaction body that predates strong soil development in the terrace alluvium. A thrust fault displacing >112 ka terrace alluvium (earthquake 3) truncates a fissure filled with terrace alluvium, indicating that the fissure formed during a separate, earlier event (earthquake 2). The fissuring event (earthquake 2) postdates late Pleistocene terrace alluvium.

2. A large proportion of slickenline (57% verge N50°E–N70°E) and fracture (55% trend N50°E–N80°E) azimuths measured within Paleozoic shale saprolite at DL-6 are nearly parallel to the current maximum compressive stress (S_{Hmax} = N70°E; Hurd and Zoback, 2012), suggesting they may be Quaternary structures.
3. The data presented here support the occurrence of large ($M_w \geq 6$) prehistoric earthquakes in the ETSZ. These data fortify the need for additional studies to readdress seismic-hazard estimates in the ETSZ.

Data and Resources

Earthquake epicenters used in this study were obtained from the U.S. Geological Survey (USGS) at earthquake.usgs.gov (last accessed October 2014). A negative of the aerial photograph in Figure 2 is available at the National Archives in 8601 Adelphi Road, College Park, Maryland 20740-6001, and a print may be purchased. The archived 1939 topographic map was obtained from the USGS and is freely available at http://landmarkhunter.com/quad/40725 (last accessed May 2017).

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Department of Earth and Planetary Sciences
University of Tennessee
306 Earth and Planetary Sciences Building
Knoxville, Tennessee 37996
(K.F.W., R.D.H.)

Department of Geosciences
University of Memphis
1 Johnson Hall
Memphis, Tennessee 38152
randycox@memphis.edu
(R.T.C.)

Keen Geoserve, LLC, retired
325 East Vine Street
Dexter, Missouri 63841
(J.D.V.)

SubstrataGraphics LLC
7658 Henry Knox Drive
Lorton, Virginia 22079
(R.C.)

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Attachment D: DNFSB, *Confinement of Radioactive Materials at Defense Nuclear Facilities*, October 2004

John T. Conway, Chairman
A.J. Eggenberger, Vice Chairman
Joseph F. Bader
John E. Mansfield
R. Bruce Matthews

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

625 Indiana Avenue, NW, Suite 700, Washington, D.C. 20004-2901
(202) 694-7000

December 7, 2004

The Honorable Spencer Abraham
Secretary of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Abraham:

On December 7, 2004, the Defense Nuclear Facilities Safety Board (Board), in accordance with 42 U.S.C. § 2286a(a)(5), unanimously approved Recommendation 2004-2, *Active Confinement Systems*, which is enclosed for your consideration. This recommendation addresses the confinement of hazardous materials at defense nuclear facilities in the Department of Energy (DOE) complex.

In order to assist you in developing a response to this recommendation, the Board has enclosed a technical report, DNFSB/TECH-34, *Confinement of Radioactive Materials at Defense Nuclear Facilities*. This study compares the benefits of employing a safety-related active confinement ventilation system to a policy of relying only on a passive confinement system.

After your receipt of this recommendation and as required by 42 U.S.C. § 2286d(a), the Board will promptly make it available to the public. The Board believes that the recommendation contains no information that is classified or otherwise restricted. To the extent this recommendation does not include information restricted by DOE under the Atomic Energy Act of 1954, 42 U.S.C. §§ 2161-68, as amended, please arrange to have it promptly placed on file in your regional public reading rooms. The Board will also publish this recommendation in the *Federal Register*. The Board will evaluate the Department of Energy response to this recommendation in accordance with Board Policy Statement 1, *Criteria for Judging the Adequacy of DOE Responses and Implementation Plans for Board Recommendations*.

Sincerely,

John T. Conway
Chairman

c: Mr. Mark B. Whitaker, Jr.

Enclosure

DNFSB/TECH-34

CONFINEMENT OF RADIOACTIVE MATERIALS AT DEFENSE NUCLEAR FACILITIES

Defense Nuclear Facilities Safety Board

Technical Report

October 2004

Confinement of Radioactive Materials at Defense Nuclear Facilities

This report was prepared for the Defense Nuclear Facilities Safety Board by the following staff members:

Farid Bamdad
Roger W. Zavadoski

with assistance from:

Wayne L. Andrews
Timothy J. Dwyer
Matthew B. Moury
Roy E. Kasdorf
David N. Kupferer
Charles M. March

EXECUTIVE SUMMARY

The design of defense nuclear facilities includes systems whose reliable operation is vital to the protection of the public, workers, and the environment. Confinement ventilation systems are among the most important of such systems for protecting the public, and are generally relied upon as the final safety-class barrier to the release of hazardous materials with potentially serious public consequences. The Defense Nuclear Facilities Safety Board (Board) has advised the Department of Energy (DOE) in various ways during the past decade regarding the need to increase attention to the design and operational reliability of these important systems.

The Board, however, has recently observed a fundamental change in the approach to protection of the public at certain defense nuclear facilities. This change has resulted in downgrading of the functional safety classification of confinement ventilation systems. Specifically, DOE contractors operating or designing defense nuclear facilities have, through a strong reliance on analytical estimates of passive leakage, prepared safety bases that have resulted in downgrading and sometimes elimination of the safety-class function of confinement ventilation systems. This approach can potentially result in the unfiltered release of air containing radioactive materials during an accident.

This report describes this misuse of DOE requirements, which provides only minimum levels of required protection to the public. The report also compares this approach with the traditional approach of using a safety-class confinement ventilation system; hence, minimizing more effectively any off-site radiological impact.

In addition, this report demonstrates that analytical tools used to predict passive leakage do not account for many of the uncertainties involved (e.g., the dynamics of the event, diurnal effects, wind, emergency evacuation or egress). Passive leakage analyses often do not consider all of the issues that must be addressed should an accident occur. These include monitoring of releases, limiting contamination, and supporting accident recovery. These uncertainties and additional considerations further justify a preference for a safety-class confinement ventilation system as the primary means of protecting the public against the potential release of radioactive material.

In light of these observations, DOE needs to provide additional guidance and explicitly state its policy regarding adequate protection of the public and workers by mandating a safety-related active confinement ventilation system for those defense nuclear facilities that pose the potential for significant radiological consequences.

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1. INTRODUCTION AND BACKGROUND

A principal risk to the health and safety of the public and workers from defense nuclear facilities is the release and dispersal of radioactive materials. Prevention of such release and dispersal is an important function of confinement systems. This vital function has been the focus of numerous reviews conducted by the Defense Nuclear Facilities Safety Board (Board) during the past decade.

On May 31, 1995, the Board transmitted to the Department of Energy (DOE) the results of a 2-year study on the confinement ventilation systems in the defense nuclear complex in DNFSB/TECH-3, *Overview of Ventilation Systems at Selected DOE Plutonium Processing and Handling Facilities*. In a subsequent letter dated June 15, 1995, the Board requested that DOE provide a "report that evaluates the design, construction, operation, and maintenance of ventilation safety systems at DOE's plutonium processing and handling facilities in terms of applicable DOE and consensus standards . . . ." Although DOE took several actions in response to the issues raised by the Board, the Board believed that the important safety function of confinement required more attention by DOE. Consequently, the Board issued Recommendation 2000-2, *Configuration Management, Vital Safety Systems*, on March 8, 2000.

These efforts by the Board have helped DOE improve the reliability of confinement ventilation systems. In some instances, degraded components have been identified and repaired or upgraded; in other instances, design deficiencies have been discovered and corrected. The Board expects DOE to continue this assessment and improvement process. Such continued vigilance is needed to maintain and improve the reliability of important safety systems.

Despite these efforts by the Board to improve the reliability of confinement ventilation systems at defense nuclear facilities, continued erosion has been observed in recent years in maintaining high expectations for the design and maintenance of such systems. Several DOE contractors have conducted analytical modeling of passive leakage from existing facilities during accident scenarios to demonstrate that off-site doses fall below DOE's evaluation guideline, and subsequently used this approach to downgrade the safety classification of the confinement ventilation systems. Additionally, proposed conceptual or preliminary designs for several new facilities have used passive confinement as the credited safety approach, again relying on calculations of passive leakage to demonstrate that off-site doses remain below DOE's evaluation guideline.

Unfortunately, as demonstrated in this report, the analytical calculation of a value for the unfiltered leakage from a passive structural confinement system is very subjective, dominated by the uncertainties in the computer programs and the analytical tools. Calculations reviewed by the Board have not analyzed all of the important phenomena and evaluated the impact of all of the key assumptions. More importantly, several key assumptions are impossible to maintain during a real accident, due to the unpredictability of the required actions by the emergency crews responding to the event.

As outlined in DOE's requirements, should the unmitigated off-site dose from an accident challenge DOE's evaluation guideline of 25 rem total effective dose equivalent, those systems relied upon to prevent or mitigate the release are to be classified as safety-class. Consistent with good practice, the most effective confinement (especially for nuclear material processing activities) is generally provided by a confinement ventilation system. Rather than a design requirement to confine the radioactive materials, some contractor safety analysts use a design criterion that allows the public dose to be any amount below 25 rem. Using this approach for a new facility and designing controls to a 25 rem design criterion represents a significant change in DOE's approach to protection of the public. For facilities with the potential for significant radiological insult to the public, the confinement ventilation system would need to be classified as safety-class. Similarly, a safety-significant confinement ventilation system should be identified to protect workers from significant consequences.

Section 2 of this report describes the advantages and disadvantages of active and passive confinement systems and demonstrates, through the evaluation of a case study, the uncertainties associated with the lack of active safety-class confinement ventilation systems at defense nuclear materials processing facilities. Section 3 reviews the evolution of confinement requirements in the nuclear industry and the apparent shift in the approach to protecting the public as illustrated by recent proposals to rely on passive instead of active confinement. The final section presents conclusions.

2. ACTIVE VERSUS PASSIVE CONFINEMENT

Confinement of hazardous materials during normal operation and potential accidents should be based on the first principles of systems engineering. That is, the system designed for a certain function should be capable of performing the intended function. Consequently, the decision to use an active or passive confinement feature should be based on the type of activity or event that is being confined by such a system. Using this principle, for example, would lead to the use of passive confinement (or containment) systems for activities (such as storage) with hazardous materials that have no source of energy for releasing the materials. On the other hand, confinement of hazardous materials released by a fire or explosion should use active confinement systems capable of counteracting the energy of the event.

2.1 ACTIVE CONFINEMENT SYSTEMS

These systems are also known as confinement ventilation systems since it is the ventilation system that provides the active function. (Note that the discussion in this report is limited to the purpose and intended function of ventilation systems as they relate to confining hazardous materials.) These systems may consist of air supply, recirculating air, process ventilation, and exhaust air systems, together with associated air filters, fans, dampers, ducts, control instrumentation, and supporting systems (such as power supply and facility structure). DOE Handbook 1169-2003, *Nuclear Air Cleaning Handbook*, is an excellent reference for the parameters that should be considered in the design and operation of such systems.

Active confinement systems are used during normal operations to confine hazardous materials closest to the source and thus protect workers from exposure to such materials. The ventilation flow is, therefore, designed using a cascading system that starts with clean air (e.g., from outside the building or from hallways and office spaces); through the laboratories or rooms where the activities are performed; through the gloveboxes, tanks, or vessels where the highest concentrations of the hazardous materials may exist; and out to the environment through a set of high-efficiency particulate air (HEPA) or sand filters. Such a cascading system can still be as effective during an accident as it is during normal operations if the system remains intact and operating.

Potential operational accidents (e.g., spills, fires, and explosions) may release hazardous radioactive materials outside the intended area (e.g., glovebox) and into a room or laboratory. An active confinement system is usually designed to direct air contaminated by such releases into the ducts and through the HEPA (or sand) filters before it enters the environment, provided the ventilation system remains intact during the event. This function is provided immediately at the release point, thus preventing hazardous materials from flowing upstream and exiting the facility. There is little chance of radioactive materials being spread to the rest of the facility or carried untreated to the outside because of the cascading effect of the active ventilation system. This confinement function of an active ventilation system will:

- Protect those facility workers not in the immediate vicinity of the accident from being exposed to the hazardous material.

- Allow facility workers to exit the facility through the closest emergency egress, consistent with life safety code provisions, while minimizing the release of radioactive materials to the environment.

- Confine the contamination locally and minimize the spread of contamination throughout the facility, easing associated cleanup efforts.

- Protect that portion of the facility not involved in the accident from its consequences, thus protecting the ability of the facility to accomplish its mission and meet its national security commitments.

- Allow the emergency crew more flexibility to access the facility through their preferred access doors and take appropriate action in a timely and effective manner.

- Allow for an assessment of the hazardous environment that the emergency crew would be entering through the sampling of air drawn from the accident area.

- Allow for an assessment of the radioactive material leaving the facility (e.g., through stack monitoring).

- Direct air containing radioactive materials through the HEPA or sand filters before any release to the environment, substantially reducing (e.g., by about four orders of magnitude from HEPA filters) any public exposure to the consequences of the accident.

A safety-related active confinement ventilation system that is identified in a facility's safety basis as mitigating the dose consequences of an event must be effective during certain normal and abnormal conditions and meet a number of functional requirements. These requirements include maintaining a certain negative pressure with respect to the outside atmosphere in a cascading manner to ensure that the flow of air would be directed from cleaner areas to more contaminated ones. Meeting this requirement necessitates limiting the size of facility leakage paths (e.g., cracks around doors and penetrations) to a very small value. Unfiltered leakage of air containing radioactive materials following an accident is not expected if the active confinement system is designed properly (i.e., considers potential leak paths), remains intact, and continues to operate. However, if the active system is not designed to remain operational during accident conditions, these same leak paths could exist during the event and would be combined with those created by emergency access to or egress from the building through temporary opening of the doors.

Other functional requirements may include effective filtration of the materials released during a fire. Active confinement ventilation systems must be capable of operating during a fire and filtering the hazardous materials out through the use of HEPA or sand filters. The fire may release particles and combustion products that could clog the filters and prevent them from performing their intended function, if not designed properly. Detailed guidance regarding the design requirements for protection against such an event is provided in DOE Handbook 1169-2003, *Nuclear Air Cleaning Handbook*, and DOE Standard 1066-99, *Fire Protection Design Criteria*.

To maintain the reliability of an active confinement ventilation system at a level to ensure it performs its safety-related function requires continued vigilance on the part of DOE and its operating contractor. This necessitates routine preventive maintenance and configuration control of the associated system identified in the facility's safety basis.

It should be noted that an active confinement ventilation system would encompass the features that comprise a passive confinement system. That is, should power be lost or unavailable to force the air containing hazardous materials through the filters, the passive confinement boundaries would still be available to confine the hazards to a lesser degree as discussed in the following section.

2.2 PASSIVE CONFINEMENT SYSTEMS

These systems are designed to confine hazards passively. They consist of an identified contiguous boundary between the hazardous material and the environment. Such systems have no active components, and are therefore considered less susceptible to failure when called upon to function. The absence of active components can also lead to reduced installation and maintenance costs, although this is not always the case.

Passive confinement systems are generally used for storage of hazardous materials when sources of energy do not exist within the confinement area and cannot be introduced from the outside to interfere with the system's intended function. For example, containers approved by the Department of Transportation are used for storage or transportation of radioactive materials that are not energetic. These containers are designed to prevent the introduction of external energy sources that could disturb the hazardous materials from their steady-state condition. Less-robust containers, such as storage drums with HEPA filters, may also be used as passive confinement barriers for storage of radioactive materials that lack the potential for energetic events and are not subject to harsh external hazards.

Given the perception of higher reliability and lower installation and maintenance costs, several operating contractors in the defense nuclear complex have recently extended application of the concept of passive confinement to nuclear processing facilities. In applying this concept, the building structure and its connecting ports to the outside (e.g., doors, penetrations, and HEPA filters) are identified as the passive confinement system. The passive confinement system is

credited with confining the hazards generated as a result of operational mishaps or other accidents. The facility ventilation system is not credited in the safety bases as a safety-related component of the confinement boundary, and its active components are not expected to remain operational during an event. Therefore, accidentally released hazardous materials in the facility are captured by HEPA or sand filters only to the extent that air contaminated with the materials may be passively forced to the outside environment through these ports. Ideally, during an accident the confinement boundary remains intact, and there is no unfiltered release of air containing hazardous material to the environment. Should the confinement boundary be breached or have existing leaks, however, hazardous material will escape directly to the environment, carried by air that does not pass through any filtration device.

The concept of passive confinement systems should not be confused with passive safe shutdown. Although the same systems and boundaries may be involved in these two concepts, their intended functions are quite different. The latter systems are designed to temporarily confine the hazardous materials that may exist in a facility (e.g., glovebox contamination or radioactive materials staged in a glovebox or tank) in a nonactive operational mode (shutdown). Under the passive safe shutdown concept, the intent is to provide a confinement system that can be relied upon during a shutdown mode. Operational activities that are capable of disturbing the material are prohibited in this mode. The hazardous material has to be stowed properly before shutdown. In essence, passive safe shutdown systems are similar to storage drums with HEPA filters; that is, the material would remain in its steady-state condition and be confined within the boundaries of the barriers without disturbance. A passive safe shutdown system may consist of the facility boundaries (structure), its HEPA filters, and its penetrations, along with any double doors or airlocks. No active system is needed to meet the intended functional requirements. Strict operational procedures are necessary to enforce the allowed operational mode. Special procedures are also needed to terminate the nonactive operational mode and return to the normal operational mode.

Conceptually, the use of a passive ventilation system is logical and attractive. However, actual implementation and operation of the system is laden with many uncertainties such that, from a safety perspective, its disadvantages outweigh its advantages.

The first difficulty associated with this concept centers on the integrity of the confinement boundary. The system must be capable of performing its confinement function under all plausible upset or design basis accident conditions. The structural features of the boundary must therefore be capable of withstanding these conditions. It is also necessary to consider preexisting exhaust paths, such as door cracks and penetrations, or those paths created as a result of actions taken during an accident, such as emergency crew members entering or facility workers evacuating the building.

The challenge of accurately calculating the passive leakage is the second problem resulting from the use of passive confinement. Predicting the amount of release under passive confinement conditions can be quite complex. Fire or explosions could add energy to the facility's atmosphere and introduce a motive force that could carry hazardous materials through

an exhaust path. In addition, quantifying the leakage area that exists in a facility, which is analogous to the periodic containment leak rate tests required at commercial nuclear reactors, although possible, is not easily and accurately accomplished at nuclear processing facilities. Therefore, determination of the amount of radioactive material that could escape the facility becomes very complex and uncertain. The following list illustrates a number of complications that prevent safety analysts from estimating the consequences of potential events to workers or the public with any degree of accuracy:

- Airborne contaminants would travel throughout the facility following the path of least resistance and under the event's dynamic forces, which generally cannot be analyzed realistically (e.g., smoke and hot gases, pressure waves, or external parameters such as wind).

- Facility workers might use any number of emergency exits to evacuate the facility, thus allowing the radioactive material to be released in an undeterminable fashion.

- The emergency crew and security personnel might access the facility from outside for an indefinite amount of time, allowing air containing the radioactive materials to leave the building unfiltered.

- The uncontrolled spread of radioactive material in the facility could jeopardize the future use of the facility, interfering with its national security mission, as well as resulting in potential worker safety issues during facility recovery and/or decontamination activities.

- Environmental postaccident sampling and monitoring would not be possible because of the unknown location of release, amount of release, and rate of volumetric release.

- Consequences to the public could approach unmitigated values, since this confinement system would allow the unfiltered release of air bearing an undeterminable amount of radioactive material to the outside until the airborne material had settled or been removed by forced interception (e.g., active ventilation or cleanup activities).

Recent attempts by DOE and its operating contractors to quantify accurately the amount of hazardous material released from a passive confinement system after an accident have been unsuccessful. To this end, the contractors have used elaborate computer programs, capable of modeling the facility as dozens of volumes with hundreds of connecting junctions to represent its openings. They have combined several different computer programs to model the phenomena that one program alone could not handle. The uncertainties of these analyses, however, are so high that a conservative estimate of the public dose could become a significant fraction of an unmitigated release.

The attempts to quantify the amount of hazardous material released have also given rise to a further disturbing issue: DOE's 25 rem evaluation guideline has been used as the measure of success in the performance of passive confinement systems. The 25 rem evaluation guideline was not intended to be used as a design criterion for exposure to the public. The 25 rem evaluation guideline was identified as a measure for determining when there is a need for safety-class controls. Several defense nuclear facilities for which passive confinement systems recently have been proposed have unmitigated off-site consequences many times greater than 25 rem.

The following case study illustrates some of these issues and uncertainties.

2.3 CASE STUDY FOR PASSIVE STRUCTURAL CONFINEMENT

The documented safety analysis prepared for a plutonium processing facility used a passive structural confinement system to demonstrate that a safety-class active confinement ventilation system was not needed. The document was submitted to DOE to comply with the requirements of the Nuclear Safety Management Rule (10 CFR 830). For a fire scenario, the unmitigated consequence at the site boundary exceeded the evaluation guideline of 25 rem by more than an order of magnitude. The operating contractor calculated a building leak path factor (LPF)[1] of about 1.6 percent to show that the mitigated consequences of about 3 rem would be acceptable, while crediting the passive confinement features as safety-class. Prior calculations for this facility with no assumed LPF and using an active ventilation system yielded site boundary dose consequences 4 to 8 orders of magnitude smaller (i.e., almost 0 rem) because of the HEPA filtration.

The LPF analysis was based on calculations performed in 1996 and, more recently, an alternative method using the MELCOR computer program to model the facility as 37 volumes or nodes and 122 junctions. The computer analysis resulted in a calculated LPF of 1.6 percent. However, the computer analysis was fraught with a number of uncertainties and nonconservatisms.

MELCOR was originally written for analysis of core melt accidents at commercial nuclear power plants, and is capable of solving mass and energy transfer equations, thereby making it possible to follow the transport of airborne materials through volumetric nodes and junctions. The computer program cannot, however, analyze a fire scenario and must be manipulated externally by providing the temperature rise from a fire as input to the code. Another computer program must be used to model a fire. The contractor used CFAST for this purpose.

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[1] LPF is the percentage of the airborne material that leaves the facility and reaches the environment.

CFAST is a two-zone model used to calculate the evolving distribution of smoke and fire gases and the temperature throughout a building during a fire. Its use involves solving a set of equations that predict state variables (e.g., pressure and temperature) based on the enthalpy and mass flux over small increments of time. CFAST does not include a burning-rate model to predict fire growth, so the user must specify the initial burning-rate, as well as any variations due to changing room conditions. This can have a significant impact on the accuracy of the resulting calculation. Further, burning can take place in several areas of the building, an effect that CFAST does not model. For a fire with sufficient available oxygen, the burning will all take place within the fire plume. For a fire in which oxygen in the fire plume is limited because of ventilation restrictions, burning will take place where there is sufficient oxygen. Under this condition, unburned fuel in the plume will successively move into, and burn in, the upper layer of the fire room, the doorway to the next room, the upper layer of the next room, the doorway to the third room, and so forth, until it is consumed or reaches the outside. This phenomenon can introduce significant uncertainty into the results.

Simply stated, in this case study, CFAST was used to calculate the temperature increase, while MELCOR followed the transfer of airborne contaminants due to the expansion of the air with the rise in temperature. The MELCOR computer program is not capable of calculating increases in the building pressure due to the fire products. Other potential interface issues such as changing fire and ventilation conditions (e.g., fuel burning in adjacent compartments) cannot be addressed in a simple manner. Finally, the combination of the two programs, each designed for a specific, independent purpose, requires a significantly greater number of external analytical manipulations, which can introduce substantial uncertainty into the results. The number of sensitivity analyses required to arrive at a conservative value using such a concatenation quickly becomes prohibitive.

The communication paths between the volumes (e.g., rooms and laboratories), including those connecting the volumes to the outside (such as door gaps) were analyzed using assumed values. Many unconservative values were included in these assumptions—openings to the outside (e.g., penetrations) were not taken into account, and several credited door seals did not exist. The fact is that building leak paths during an accident cannot reliably be predetermined numerically on the basis of facility conditions during normal operations.

The fire scenarios were modeled for an event duration of about 2 hours. However, because of the diurnal effects of the sun and the facility's breathing as the inside and outside temperature varies over time, motive forces capable of driving hazardous materials out of the facility continue to exist well beyond the assumed 2-hour limit. Such phenomena will continue to direct airborne contaminants out to the environment until the contaminants are settled by gravity (i.e., the heavier particles) or removed by other means (e.g., active ventilation or cleanup efforts). Diurnal effects on building leakage cannot realistically be determined using the two computer models discussed above, and their estimation would require the introduction of yet another model or estimation technique. This would further increase the complexity and uncertainty of the results.

The 1.6 percent LPF analysis does not appear to have conservatively modeled the potential impact of the external wind on transporting hazardous material out of the building. In the analysis, the external force of the wind was exerted on the side of the building with the largest openings (e.g., an open emergency exit door) for some scenarios, thus minimizing (or not allowing) the escape of hazardous material from the facility. On the other hand, the effect of external wind on the building was not modeled at all for some more energetic events, such as fire.

Finally, although emergency evacuation of the facility workers was modeled in some analyses (spill events), a sensitivity analysis was not performed on the timing of the evacuation (e.g, opening the room doors at the same time as the building emergency exit doors). On the other hand, the emergency evacuation of the building was not modeled for more energetic events such as fire.

Based on these nonconservative analyses, additional inquiry was made to determine a more conservative value for the building LPF. It was shown that a fire event in one of the rooms would result in an LPF of 25 percent or more. This analysis, however, did not consider the impact of the opening of the emergency doors by facility workers and its effect on the LPF value. It is estimated that such considerations could increase the calculated value of LPF to 40 or 60 percent.

As demonstrated above, the analytical calculation of a value for the unfiltered leakage from a passive structural confinement system can be highly speculative. Such a calculation is likely dominated by the uncertainties and limitations of the computer programs and analytical tools used and is incapable of analyzing all the important phenomena involved and the impact of the controlling parameters. Furthermore, it is generally impossible to model the conditions of a real accident because of the uncertain behavior of the workers and the emergency crew responding to the event. Given these analytical uncertainties, a conservative estimate of the public dose for such a confinement system could be more than 60 percent of the unmitigated event.

3. EVOLUTION OF CONFINEMENT REQUIREMENTS

The U.S. Atomic Energy Commission issued Regulatory Guide 3.12, *General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants*, in August 1973. It sets forth expectations for the design of a ventilation system that, if satisfied, would meet the requirements of 10 CFR 70 that "applicant's proposed equipment and facilities are adequate to protect health and minimize danger to life or property." Regulatory Guide 3.12 considers ventilation systems to be "important to safety because they serve as principal confinement barriers in a multiple confinement barrier system which guards against the release of radioactive or other potentially dangerous materials" and presents the regulatory position that "ventilation systems should assure the confinement of hazardous materials during normal or abnormal conditions including natural phenomena, fire, and explosions." The guide states that "the systems must continue to perform their safety functions effectively under all conditions by confining radioactive or other potentially dangerous materials."

A similar approach was adopted by DOE in its *General Design Criteria Manual*—DOE Order 6430.1 (issued in December 1983) and its revision DOE Order 6430.1A (issued in April 1989). This manual recommends a three-layer approach to achieving confinement objectives:

- Primary confinement—to be provided by piping, tanks, gloveboxes, encapsulating material, and any off-gas system that controls effluent from within the primary confinement.

- Secondary confinement—to be provided by walls, floors, roofs, and associated ventilation exhaust systems of the facility.

- Tertiary confinement—to be provided by walls, floors, roofs, and associated ventilation exhaust systems of the facility.

DOE Order 6430.1A required that the confinement system, defined as a composite of the structure and its associated ventilation systems, remain "fully functional following any credible DBA [design basis accident]," and stated that "unfiltered/unmitigated release of hazardous levels of such materials shall not be allowed following such accidents." It also required that design professionals consider the criteria presented in Regulatory Guide 3.12 for applicability to plutonium processing and handling facilities.

In an effort to overhaul its directives system, in 1995 DOE issued DOE Order 420.1, *Facility Safety*, which superceded DOE Order 6430.1A. The requirements in this new Order, however, were not as prescriptive, and design requirements were left to be determined by safety analysis reports that would establish the identification and functional classification (i.e., safety-class and safety-significant) of the structures, systems, and components (SSCs) for a facility. This Order, as well as its latest revision, DOE Order 420.1A, states that "non-reactor nuclear facilities shall be designed with the objective of providing multiple layers of protection to

prevent or mitigate the unintended release of radioactive materials to the environment." It states further that "defense in depth shall include: siting . . . ; the use of successive physical barriers for protection against the release of radioactivity; . . . and to confine and mitigate radioactivity associated with the potential for accidents with significant public radiological impact." The Order no longer prohibits the unmitigated accidental release of hazardous materials, and relies on the safety analysis process to demonstrate adequate protection of the public and workers. However, the Order does state that "all nuclear facilities with uncontained radioactive materials (as opposed to material contained within drums, grout, and vitrified materials) shall have means to confine them."

In a letter to DOE dated July 8, 1999, the Board expressed its belief that this general approach for identification of safety systems was reasonable "provided that it is made quite clear that the 25 rem evaluation guideline is not to be treated as a design acceptance criterion . . . ." The Board further emphasized that, consistent with the requirements of DOE Order 420.1, the design of Hazard Category 2 and 3 nonreactor nuclear facilities should be based on confining the hazardous radioactive material during normal operation and potential accidents. The Board also noted that confinement systems should be classified as safety-class or safety-significant SSCs.

In January 2001, DOE issued Subpart B of 10 CFR 830. It required contractors to establish a safety basis for Hazard Category 1, 2, and 3 nuclear facilities in accordance with its requirements and to perform work in accordance with the hazard controls identified therein. For new facilities or major modifications, the rule requires contractors to use the safety design criteria identified in DOE Order 420.1 or obtain DOE approval of their proposed criteria. The rule identifies the methodology presented in DOE's *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses* (DOE-STD-3009-94) as a safe harbor for performing safety analyses for new facilities and major modifications, as well as for existing facilities. It should be noted that this methodology was originally developed for preparation of safety bases for existing facilities, and its application to new facilities should be limited to its format and content guidance. In other words, the design requirements identified in DOE Order 420.1 must be met and demonstrated through the safety analyses that are prepared in accordance with DOE-STD-3009-94.

The methodology presented in DOE-STD-3009-94 is hazards-based. That is, based on the significance of unmitigated consequences to the public and workers, safety-class or safety-significant SSCs should be identified to prevent or mitigate events. This approach does not override the requirement of DOE Order 420.1A that "all nuclear facilities . . . shall have means to confine" the hazards. The requirements of the Order must be met, and the methodology from the standard should be used to designate a safety classification for the confinement system.

DOE-STD-3009-94 does not require identification of a safety-related active confinement ventilation system. It only implies that such a system is part of the safety philosophy and defense in depth for a facility, and requires specific discussion of such a system in Chapter 2, "Facility Description," of the documented safety analysis. The standard further states that "the handling of plutonium in a facility with gloveboxes, ventilation zones of confinement, and

HEPA filters . . . would be adequate for closure of environmental contamination concerns." In a discussion aimed at identifying safety-class SSCs, the standard states, "For existing DOE non-reactor nuclear facilities, some safety systems may already be known and designated as such (e.g., fire protection systems and confinement systems, which include HEPA filtration). Some SC [safety-class] designations for such safety system[s] may also be self evident." The standard stops short of explicitly requiring a safety-class active confinement ventilation system.

Although the use of multiple barriers, defense in depth, and confinement of hazards is discussed in the DOE directives, there is sufficient ambiguity in the requirements to allow contractors to deviate from having to identify a safety-related active confinement system. Furthermore, the DOE directives are not integrated. For example:

- The requirements for radiological postaccident monitoring do not appear in the safe harbors of the Nuclear Safety Management Rule.

- The guidance for building reentry after an accident and for postaccident recovery is not related to preparation of the documented safety analyses.

- There are no DOE requirements for protection of a facility's mission, as it relates to national security or nuclear material stabilization, that should be considered in preparation of the safety bases or design of a new facility.

- The emergency response procedures and safeguards and security practices are not clearly linked to the accident analyses.

- Although the documented safety analyses are required to include discussion of the decontamination and decommissioning of the facility, those requirements relate to the final end state of the facility and not to the activities that would be carried out as the result of an accident.

Consequently, due to unclear guidance in the DOE directives, the documented safety analyses and subsequent determinations of adequacy of the confinement systems are mainly focused on the dose at the site boundary should an accident occur and do not reflect consideration of all of the issues discussed above.

4. CONCLUSIONS

DOE's requirements as reflected in its orders and standards for preparation of safety bases appear to be consistent with the principles of Integrated Safety Management advocated by the Board. Those requirements, however, have been implemented using a variety of analytical methods since being issued almost a decade ago. It appears that the 25 rem public dose evaluation guideline is, in some instances, being used as a design criterion. It also appears that some analysts may be underestimating the complexity of problems that are solved analytically, ignoring the uncertainties in the computational results, and underestimating the potential impact on public and worker health and safety. The safety analyses required by DOE are supposed to be an estimate and illustration of how the requirements are met. The analyses should be bounding, the analytical tools must be pertinent and capable of predicting the results, the assumptions ought to be practical, and the uncertainties of the analyses should be accounted for in the design and operational procedures.

Furthermore, DOE's safety requirements for the preparation of safety bases are aimed at the identification of controls for protection of the public and workers during abnormal events. They are not well integrated with other needs, and in some cases may fail to encompass all of the parameters that should be considered in designing and operating a nuclear facility. Postaccident recovery and building reentry, postaccident monitoring and off-site dose measurements for potential worker and public evacuation, and protection of the mission of the facility are just some of the additional parameters that should play an important role in deciding which type of confinement system is best suited for a defense nuclear processing facility.

This report has demonstrated that the application of passive confinement systems for some operational events at defense nuclear processing facilities may be inappropriate. An active confinement system is needed to ensure the safety of the public and workers. Such a system would also provide for some other DOE needs that might not be encompassed by the safety analyses. The boundaries of such systems need to be clearly defined, including their supporting systems, the power supply, and instrumentation and controls. The guidance provided in Regulatory Guide 3.12 and adopted in the cancelled DOE Order 6430.1A appears to set a solid foundation for the design and operational reliability of such systems. DOE needs to provide additional guidance and explicitly state its policy regarding adequate protection of the public and workers by mandating a safety-related active confinement ventilation system for those defense nuclear facilities that pose the potential for significant radiological consequences. New nuclear facilities with offsite consequences that challenge DOE's evaluation guidelines, in particular, should be designed with a safety class active confinement ventilation system backed up by a passive confinement system.

Attachment E: U.S. Department of Energy, Office of NEPA Policy and Compliance, *Recommendations for the Supplement Analysis Process*, July 2005

National
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Recommendations for the Supplement Analysis Process

July 2005

U.S. Department of Energy
Environment, Safety and Health
Office of NEPA Policy and Compliance

Department of Energy
Washington, DC 20585
July 20, 2005

MEMORANDUM TO: Secretarial Officers and Heads of Field Organizations

FROM: John Spitaleri Shaw
Assistant Secretary for
Environment, Safety and Health

SUBJECT: NEPA Guidance for the Supplement Analysis Process

I am pleased to provide the attached guidance, *Recommendations for the Supplement Analysis Process,* for your use in further improving the Department's implementation of the National Environmental Policy Act (NEPA). A Supplement Analysis (SA) is the document DOE prepares when it is unclear whether a supplement to an existing environmental impact statement (also known as a "supplemental EIS") is required in accordance with Council on Environmental Quality (CEQ) implementing regulations.

My staff has prepared this guidance in response to a priority identified by your NEPA Compliance Officers (NCOs), in consultation with the Office of the Assistant General Counsel for the Environment. The guidance maintains the flexibility inherent in the CEQ and DOE regulations, while providing practical advice and direction for completing the SA process. The recommendations are aimed at assisting you in decisions regarding whether to prepare an SA, the substantive content of an SA, procedural aspects of preparing an SA, and outcomes that can result from an SA.

In preparing this guidance, we addressed comments that NCOs provided on a draft discussed at our 2004 annual NEPA Community Meeting and on a revised draft circulated in June 2005. We are distributing the guidance to DOE's NEPA Community and will post it on our DOE NEPA Web site at *www.eh.doe.gov/nepa* under Guidance.

Please refer this guidance to those in your organization who prepare or assist in preparing NEPA documents. Questions regarding *Recommendations for the Supplement Analysis Process* may be directed to Jeanie Loving in the Office of NEPA Policy and Compliance at 202-586-0125 or jeanie.loving@eh.doe.gov.

Attachment

cc: DOE NEPA Community

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Recommendations for the Supplement Analysis Process

July 2005

U.S. Department of Energy
Environment, Safety and Health
Office of NEPA Policy and Compliance

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Recommendations for the Supplement Analysis Process

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1.0 Introduction

When the Department of Energy (DOE) considers a change to a proposed action analyzed in an environmental impact statement (EIS), or new information relevant to the action becomes available, DOE must determine whether a supplement to the EIS (also referred to as a "supplemental EIS") or a new EIS is required. Criteria for determining the need for a supplemental EIS are specified in the Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA) at 40 CFR 1502.9(c) and in the DOE NEPA regulations at 10 CFR 1021.314. (See text box and Attachment 1.)

When the need for a supplemental EIS is unclear, DOE's NEPA regulations require the preparation of a Supplement Analysis (SA). Despite the similarity of their names, a "Supplement Analysis" is not the same as a supplement to an EIS. An SA is the document DOE prepares to provide the information and analysis to determine whether a supplement to an EIS is necessary to meet the requirements of 40 CFR 1502.9(c). In other words, DOE uses an SA to determine whether a change in a proposed action is "substantial" and relevant to environmental concerns or whether new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts are "significant." Throughout this document, the phrase **"a proposed change or new information"** refers to a change in a proposed action or new circumstances or information that may or may not trigger the need for a supplemental EIS pursuant to 40 CFR 1502.9(c).

The DOE regulations at 10 CFR 1021.314(c) provide considerable flexibility in preparing SAs. There is no "one size fits all" template for SAs. A case-by-case review is needed to support sound determinations regarding a proposed change or new information. There are, however, some general elements that should be contained in SAs.

Accordingly, this guidance provides recommendations that are broadly applicable to the SA process, including deciding whether to prepare an SA, the general content of an SA, and outcomes that can result from an SA, with a brief overview of the SA process. (See flow chart, Figure 1, page 12.) These recommendations do not constitute legal requirements, but are intended to enhance compliance with existing NEPA regulations (40 CFR Parts 1500−1508 and 10 CFR Part 1021).

Criteria for Determining the Need for a Supplemental EIS

Excerpt from CEQ NEPA Regulations:

40 CFR Part 1502—ENVIRONMENTAL IMPACT STATEMENT

Section 1502.9 Draft, final, and supplemental statements.

(c) Agencies:

(1) Shall prepare supplements to either draft or final environmental impact statements if:

(i) The agency makes substantial changes in the proposed action that are relevant to environmental concerns; or

(ii) There are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

2.0 Identifying the Need for a Supplement Analysis

The SA process provides a useful method for addressing the CEQ criteria for determining whether a supplemental EIS is required and increases the likelihood that the Department's NEPA reviews will prevail in the event of litigation. (See Attachment 2.)

2.1 When to Prepare an SA

DOE regulations (10 CFR 1021.314(c)) require that an SA be prepared when the need for a supplemental EIS is unclear based on the criteria established in the CEQ regulations. The DOE regulations also provide for the use of an SA to reevaluate the adequacy of a site-wide EIS at least every five years (10 CFR 1021.330(d)). (See text box, below.)

- An SA may be appropriate in reexamining an "old" (existing) EIS if a major Federal action remains to be taken. CEQ recommends that "if the proposal has not yet been implemented, or if the EIS concerns an ongoing program, EISs that are more than 5 years old should be carefully reexamined to determine" if a supplemental EIS is required. (Question 32, "Forty Most Asked Questions Concerning CEQ's NEPA Regulations," as amended, 51 FR 15618, April 25, 1986; hereafter "CEQ's 40 Questions." See text box, page 3.)
- Although the need for an SA typically does not arise until after a final EIS and record of decision (ROD) have been issued, an SA also may be appropriate between issuance of a final EIS and publication of its associated ROD. This would occur,

Requirements for the Preparation of an SA

Excerpts from DOE NEPA Regulations:

10 CFR 1021.314 Supplemental environmental impact statements.

(c) When it is unclear whether or not an EIS supplement is required, DOE shall prepare a Supplement Analysis.

(1) The Supplement Analysis shall discuss the circumstances that are pertinent to deciding whether to prepare a supplemental EIS, pursuant to 40 CFR 1502.9(c).

(2) The Supplement Analysis shall contain sufficient information for DOE to determine whether:

(i) An existing EIS should be supplemented;

(ii) A new EIS should be prepared; or

(iii) No further NEPA documentation is required.

(3) DOE shall make the determination and the related Supplement Analysis available to the public for information. Copies of the determination and Supplement Analysis shall be provided upon written request. DOE shall make copies available for inspection in the appropriate DOE public reading room(s) or other appropriate location(s) for a reasonable time.

10 CFR 1021.330 Programmatic (including Site-wide) NEPA documents.

(d) DOE shall evaluate site-wide NEPA documents prepared under § 1021.330(c) at least every five years. DOE shall evaluate site-wide EISs by means of a Supplement Analysis, as provided in § 1021.314. Based on the Supplement Analysis, DOE shall determine whether the existing EIS remains adequate or whether to prepare a new site-wide EIS or supplement the existing EIS, as appropriate. The determination and supporting analysis shall be made available in the appropriate DOE public reading room(s) or in other appropriate location(s) for a reasonable time.

for example, if DOE receives external comments during the required 30-day waiting period that introduce significant new information relevant to environmental concerns. (Usually, comments received during the waiting period do not trigger the need for an SA and are addressed in the ROD.)

- If, during the preparation of an SA, the need for a supplemental or new EIS appears unlikely, the SA should nevertheless be completed. If, on the other hand, it becomes clear that a supplemental or new EIS is needed or would be beneficial, completion of the SA is not necessary.

2.2 When an SA Is Not Required

An SA may be prepared at any time, as appropriate, to further the purposes of NEPA. However, the following situations illustrate conditions in which an SA is not required.

- DOE is not required to evaluate new information in a supplemental EIS or an SA if there is no major Federal action proposed or that remains to be taken. For example, in a case where an agency had approved an EIS and associated land use plan, the Supreme Court ruled that a supplemental EIS was not required in light of new information because the agency action – issuance of a land use plan – was completed and there was no ongoing major Federal action (*Norton, Secretary of the Interior, et al. v. Southern Utah Wilderness Alliance et al.*, decided June 14, 2004).
- An SA is not required if a proposed change or new information clearly does not have a bearing on environmental concerns. For example, a major cost increase that does not change environmental impacts, or a facility design change that is not relevant to environmental concerns, would not require an SA or a supplemental EIS.
- In other cases, it may be obvious that a change in a proposed action would have negligible effects on environmental impact calculations, and, thus, an SA would not be required. For example, if an EIS analyzed the transportation of 10,000 shipments, a proposal resulting in an additional 10 similar shipments would be unlikely to change the calculation of transportation impacts. If it is obvious that no other resource areas would likely be affected, it may be concluded that a supplemental EIS would not be needed, without the preparation of an SA.
- A supplemental or new EIS without the need for an SA would likely be required if the purpose and need for a new proposed major Federal action differs substantially from that in an existing EIS such that the action alternatives are likely to change. To illustrate, a new proposal to use a former defense materials production facility for waste management purposes may require a new EIS even if the impacts of the

Excerpt from "CEQ's 40 Questions"

32. **Supplements to Old EISs**. Under what circumstances do old EISs have to be supplemented before taking action on a proposal?

A. As a rule of thumb, if the proposal has not yet been implemented, or if the EIS concerns an ongoing program, EISs that are more than 5 years old should be carefully reexamined to determine if the criteria in Section 1502.9 compel preparation of an EIS supplement.

If an agency has made a substantial change in a proposed action that is relevant to environmental concerns, or if there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts, a supplemental EIS must be prepared for an old EIS so that the agency has the best possible information to make any necessary substantive changes in its decisions regarding the proposal. Section 1502.9(c).

proposed waste management operations would be less than in the existing analysis. In this example, a new EIS would be required to analyze the range of reasonable alternatives for accomplishing the new waste management purpose and need, which could differ markedly from the alternatives analyzed in the existing EIS.

- Similarly, a supplemental or new EIS without the need for an SA may be required in some cases if a proposed action differs substantially from all alternatives analyzed in an existing EIS, even if the impacts are likely to be smaller than those estimated in the existing EIS. To illustrate, a proposal to change the location of a major disposal facility analyzed in an EIS from one state to another not analyzed in the EIS would be a substantial change in the proposed action that could warrant a supplemental EIS, even if the impacts were likely to be similar to or less than those in the existing EIS. A key consideration in this instance would be whether there had been adequate NEPA review of the proposed action in the newly proposed host community.
- An SA is not required to determine whether a supplement to a draft EIS is needed. A proposed change or new information can arise between publication of a draft and final EIS, in which case the changes may be addressed in a supplement to the draft EIS,

SAs and Environmental Assessments (EAs)

- DOE NEPA regulations **do not** require preparation of an SA to determine the need for further NEPA review of an action analyzed in an EA.
- When the adequacy of an EA is unclear, a deliberative process similar to that for SAs may help resolve the uncertainty. However, an SA or SA-like process would not be a substitute for any further NEPA review that might be required.
- DOE NEPA regulations (10 CFR 1021.330(d) and (e)) require the evaluation of **site-wide** EAs at least every five years by means of an analysis similar to the SA (unless the need for an EIS is clear). The objective is to determine whether the existing site-wide EA remains adequate, and whether to prepare a new site-wide EA, revise the finding of no significant impact, or prepare a site-wide EIS.
- For site-wide EAs, DOE NEPA regulations (10 CFR 1021.330(e)) also require that the determination and supporting documentation be made available in public reading rooms and other appropriate locations for a reasonable time.

in a revised draft EIS, or in the final EIS. An analytical process similar to that used in preparing an SA will be needed to identify the appropriate course of action. (For additional information about identifying the need to supplement a draft EIS as a result of public comments, see DOE's guidance on *The EIS Comment-Response Process*, available on the DOE NEPA Web site at *www.eh.doe.gov/nepa* under Guidance.)

- The need for extensive data collection and analysis in order to complete an SA may be an indicator that a change in the proposed action is "substantial" or that new circumstances or information requiring additional data for appropriate analysis are "significant." In such cases, early consideration of preparing a supplemental EIS without an SA is warranted.

2.3 Whether to Continue an Action during SA Preparation

When new information comes to light, an agency must consider it, evaluate it, and determine whether it is of such significance as to require a supplemental EIS. The agency is not obligated to suspend the actions it is taking as a result of the existing EIS while it is evaluating the new information.

This principle, however, should be exercised with prudence and common sense. Where it is clear from the nature of the new information that significant adverse impacts could occur (e.g., to a newly designated endangered species) if the ongoing Federal action continues, common sense suggests that the agency should refrain from taking that action until its review of the new information (i.e., an SA) is completed.

3.0 Content of a Supplement Analysis

DOE regulations do not prescribe a specific format or content for an SA. Nevertheless, an SA should address the CEQ criteria for whether to prepare a supplemental EIS and follow basic NEPA principles, e.g., full disclosure, good scientific analysis, clear expression, and use of the sliding scale. (See *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements, Second Edition*, available on the DOE NEPA Web site at *www.eh.doe.gov/nepa* under Guidance.)

3.1 Major Sections of an SA

DOE has prepared adequate SAs that are only a few pages long. Although a number of DOE's complex SAs have been lengthy, a maximum of approximately 20-30 pages is a reasonable goal for most situations. Technical or other supporting documents should be attached or referenced as appropriate and should be available to the public when the SA is issued.

An SA Should Be Brief

- Focus analyses on changes
- Analyze changes commensurate with their contribution to potential impacts
- Evaluate changes absolutely and in comparison to the existing EIS analyses

In general, an SA should include the following elements.

- An introduction, the original statement of purpose and need for action, other relevant background information, and a description of the existing NEPA analyses and decisions.
- A clear statement of the proposed change or new information at issue. This statement should describe, and incorporate by reference as appropriate, any information that raised a question on the need for a supplemental EIS, such as updated environmental monitoring data or research results.
- Identification of those resource areas or aspects of the analysis in the existing EIS that could be affected by the proposed change or new information. An SA need not analyze resource areas that would be unaffected by the changes, but it is necessary to briefly explain why any impact area analyzed in the existing EIS does not warrant further analysis in the SA.
- An analysis – the crux of the SA – of the proposed change or new information in relation to the existing EIS. The analysis should identify the references on which the analysis is based. Section 3.2 discusses the analysis further.
- A findings or conclusions section. This section of the SA should summarize the differences between the impacts of one or more alternatives identified in the existing EIS, as appropriate, and the impacts identified in the SA. This section should allow the reader to readily understand whether the Department considers a change in the proposed action to be substantial

An SA's Findings and Conclusions Should Summarize:

- Changes in the proposed action and/or new circumstances or information
- Comparison of the new proposed action to any pertinent alternative(s) analyzed in the EIS, including a comparison of their potential impacts
- Comparison of new information and circumstances to analyses in the existing EIS

or whether the new circumstances or information are significant, within the meaning of the CEQ regulations. In some cases the question of whether a change in proposed action is "substantial" and "relevant to environmental concerns" will be obvious from the analyses and discussion. In other cases this could be less evident.

In considering the environmental impacts of a proposed change or new information, a finding that the associated environmental impacts would be less than those of any of the analyzed alternatives in the existing EIS would be a strong indicator that a supplemental EIS is not required.

If the potential impacts of the new proposal or those resulting from computations based on new information would exceed the impacts analyzed in the EIS for one or more resource areas, the SA should provide the basis for judging the significance of the increased impacts. An SA might show that the larger impacts are not significant and thus support a determination that a supplemental EIS is not required.

For example, if a change in a proposed action would result in an increase in waste inventories destined for a disposal facility, an SA might show that the increase is too small (i.e., no new disposal facility is needed and transportation impacts would be very small) to trigger a supplemental EIS. In such a case, an incremental increase in risk of 1×10^{-8} above an original EIS risk estimate of 1×10^{-6} would almost certainly be insignificant.

Clearly, "significance" is a key test in developing conclusions based on an SA. This term, as used in a NEPA analysis, requires consideration of both context and intensity, as described in 40 CFR 1508.27. Another key test is whether a change in a proposed action is "substantial," meaning that the difference between the initial and new proposed action is marked or important (e.g., because the change did not receive a hard look in the existing EIS or the change would lead to significant impacts).

An SA for a Site-wide EIS

- DOE NEPA regulations do not contain unique requirements for an SA for a site-wide document, and the recommendations in this guidance regarding process, format, and content apply to site-wide as well as other SAs.
- An SA for a site-wide EIS should focus prospectively on all ongoing and proposed or reasonably foreseeable programs, operations, and activities at a site. A site-wide SA should evaluate new information and changes at a site since issuance of the most recent site-wide EIS and SA, including the cumulative impacts of completed actions. Such impacts could occur, for example, from the operation of a facility whose construction was completed based on an existing EIS.

3.2 Approaches to the Analysis

The analysis should identify the total potential impacts resulting from the proposed change or new information, and compare those potential impacts to the potential impacts of one or more pertinent alternatives identified in the EIS (or more than one EIS or a supplemental EIS, if appropriate).

- The analysis should evaluate the changes from the existing EIS, both in an absolute and comparative sense. In other words, the analysis should identify the total impacts (i.e., the original estimates and any additional impacts) and the differences between the original estimates and the new estimates. For example, a change in the proposed action might result in an increase in the footprint of a facility so that it would require an additional acre of land above the

20 acres required for the design evaluated in the EIS. In absolute terms, the analysis would show a total impact on 21 acres of land. In comparative terms, the analysis would show an increase of five percent in land use requirements attributable to the change.

- The comparison of a proposed change or new information can be to one or more of the alternatives analyzed in detail in the existing EIS. The comparison need not be only to the preferred alternative or alternative selected in a ROD. An SA should always make clear what alternatives are being compared.
- The analysis should identify any differences between the assumptions, including uncertainties, used for the comparative analysis and those used in the existing EIS that are relevant to the interpretation of the results.
- Presentations in the form of tables, bullets, lists, and similar devices can be effective in comparatively presenting proposed changes or new information, discussing associated environmental impacts, and summarizing the key differences. These methods can show at a glance what the existing NEPA document analyzed, the new or different information, and the environmental consequences for each resource area.
- The analysis should be based on the best information available. Typically, this would be the most recent information, such as the latest U.S. Census for population data, which may be different from what was used in the existing EIS.
- Regardless of the approach used (e.g., qualitative, quantitative), the analysis should identify whether and how the resources of interest or regions of influence would change. Accordingly, the analysis should identify whether there would be changes to the impacts for each of the resource areas assessed in the existing EIS and, as appropriate, any new potential impacts that were not associated with alternatives analyzed in the EIS.
- The SA need not analyze a resource area if no change to an impact is expected. As stated in Section 3.1, a brief, substantiated statement indicating that the impacts would be unchanged is sufficient. For example, changes to a facility design that could affect potential air emissions might not change the land use reported in the EIS; thus, in regard to land use impacts, the SA would only need to indicate "no change" and very briefly explain the basis for this conclusion.
- In some cases, a qualitative discussion would be sufficient. For example, a description of changes in potential impacts on bird or small animal nesting areas might be qualitative, explaining, without detailed species counts, whether the impacted areas would be adversely affected by a change in land use.
- In most cases, quantitative estimates are appropriate, especially when quantitative estimates were provided in the existing EIS.

Use comparative presentational tools to highlight key differences in actions and impacts.

Analytical Approaches to Streamline Quantitative Analysis

- Scaling
- Impact indicators
- Numerical sensitivity analysis
- Limited modeling

3.2.1 Streamlining Methodologies

The comparative focus of an SA lends itself to streamlined analytical approaches. Techniques that are sometimes used to streamline quantitative estimates in EAs and

EISs may be very useful in preparing an SA. Several examples follow.

- **"Scaling"** provides an approximation of the relative difference between the original impact estimate and the estimate associated with the proposed change or new information. For example, the scale of change might be identified as a proportional difference between the two estimates, such as a 25 percent increase in waste volume.
- ***Impact indicators*** are the most important parameters used to estimate impacts for an environmental resource. Impact indicators usually are directly proportional to the actual impact, and their determination generally occurs during an intermediate step in an impact calculation. For example, estimating nonradiological air quality impacts often involves estimating pollutant emissions and their rate of release, which are then put in a computer model to determine pollutant concentrations at various locations. The analysis then compares the concentrations to National Ambient Air Quality Standards. Rather than duplicating this analysis, the SA could present an estimate of emissions (the impact indicator) in direct comparison to the emissions estimate used in the original impact analysis. For example, the SA might identify a 10 percent reduction in emissions of a particular pollutant due to a proposed change.
- **Numerical sensitivity analysis** can be used to approximate the impact estimates of more detailed impact models. In general, a sensitivity analysis would not involve the complexity and detail of many quantitative environmental models, yet could provide a reasonable estimate of the extent to which a proposed change or new information could change the analytic results in the EIS. A quantitative sensitivity analysis is well suited to estimating whether a change in a proposed action would affect existing EIS transportation impacts, for example.
- ***Limited modeling*** involves re-running the model used for the EIS analysis, but only for certain scenarios or types of impacts. This might help achieve needed accuracy or a basis for comparison not available with other approaches. For example, a number of DOE EISs involve the transportation of radioactive and/or hazardous materials. If the EIS in this case did not analyze the use of a proposed new container and route(s) between the origin and destination, it might be necessary to compute potential routine and accident impacts to compare the potential risks from the new container traveling over the new route(s).

3.2.2 Strategic Tiering Approach

Attachment 3 contains an approach to project-specific analyses developed by DOE's Bonneville Power Administration (BPA), which addresses a large and diverse number of new projects each year. BPA prepared programmatic EISs to address each of the discrete aspects of its environmental management system and then devised a relatively standardized method for preparing the SAs necessary to evaluate whether the potential impacts of proposed site-specific projects fall within the range of alternatives and impacts the EISs analyzed. Elements of the BPA strategy may be appropriate to a DOE site during review of a site-wide EIS.

4.0 Completing the Supplement Analysis Process

Throughout the SA process, DOE is asking whether to prepare a supplemental or new EIS when the need for an EIS is unclear. If at any point the answer is "yes," the SA may be stopped and the supplemental or new EIS begun. So long as the answer is "no," the SA process continues through completion. (The major elements and decision points in the SA process are summarized in the flow diagram in Figure 1, page 12.)

The SA process ends with approval of the document by an appropriate DOE official and a determination whether or not DOE should prepare a supplemental or new EIS. The determination also may indicate whether an amendment to an existing ROD is needed. After approval, the SA must be filed within DOE and made available to the public.

4.1 Approval Authorities

DOE Order 451.1B, 5(a)(11) assigns responsibility for preparing an SA and the resulting determination to a Secretarial Officer or a Head of a Field Organization. The determination requires the concurrence of DOE counsel. Program and Field Offices are encouraged to consult with the Office of NEPA Policy and Compliance early in the development of their SAs.

Although the Head of a Field Organization is authorized to approve an SA, it can be advantageous to request approval from the cognizant Secretarial Officer. DOE Order 451.1B, 5(b)(3) authorizes Secretarial Officers to issue a ROD for an EIS, after obtaining the concurrence of the Assistant Secretary for Environment, Safety and Health in its environmental content and the concurrence of counsel in its legal adequacy. Thus, if it becomes apparent that a ROD amendment may be needed, it would be prudent to request that the Secretarial Officer also approve the SA.

4.2 Determination

The determination of whether or not DOE should prepare a supplemental or new EIS may be included in the SA or issued as a separate document. (See Attachment 4 for examples of SA determinations.) If the determination is included in the SA itself, the determination language can be a logical extension of the SA conclusions. The following points should be included in the determination.

- A brief description of the proposed change or new information.
- A summary of the results of the analyses DOE performed for the SA in relation to those in the existing EIS.
- A clear statement as to why the preparation of a supplemental or new EIS is or is not necessary based on the CEQ criteria at 40 CFR 1502.9(c).
- A statement that an amendment to an existing ROD is to be issued, if such is the case.
- The signature, date of signature, and title of the approving official.

4.3 Filing an SA within DOE

The DOE NEPA regulations require that a determination and supporting SA be incorporated into any related administrative record on the action that is the subject of the determination (10 CFR 1021.314(e)). In other words, each EIS's administrative record should contain all SAs prepared for that EIS and the associated determinations.

The cognizant NEPA Compliance Officer is to provide three copies and one electronic file of the SA and associated determination to the Office of NEPA Policy and Compliance,

generally within two weeks of the execution of the determination (DOE Order 451.1B, 5(d)(11)). NEPA Compliance Officers are encouraged to report SAs that are in progress to the Office of NEPA Policy and Compliance for inclusion in the DOE-wide NEPA document tracking system.

For filing and identification, assign the same number to an SA as that used for the EIS it addresses. At the end of the character string, append the characters "-SA-…n" in the order of issuance of SAs related to the EIS. For example, the first SA for a given EIS (x) would be DOE/EIS-000x-SA-1, and the tenth SA would be DOE/EIS-000x-SA-10. If an SA addresses multiple EISs, use the document number for the EIS considered to be dominant. Contact the Office of NEPA Policy and Compliance with questions regarding numbering SAs or reporting them to the DOE-wide NEPA document tracking system.

4.4 Making an SA Available to the Public

Each SA and the resulting determination must be made available to the public. DOE must provide copies upon written request, and copies must be available in an appropriate DOE public reading room(s) or other appropriate location(s) for a reasonable time (10 CFR 1021.314(c)(3), 1021.330(d), 1021.330(e)). The Office of NEPA Policy and Compliance also makes SAs and determinations available to the public on the DOE NEPA Web site (*www.eh.doe.gov/nepa/documentspub.html*).

Additional public involvement may further the purposes of NEPA and provide valuable input to DOE. This is optional and at the discretion of the cognizant Program or Field Office.

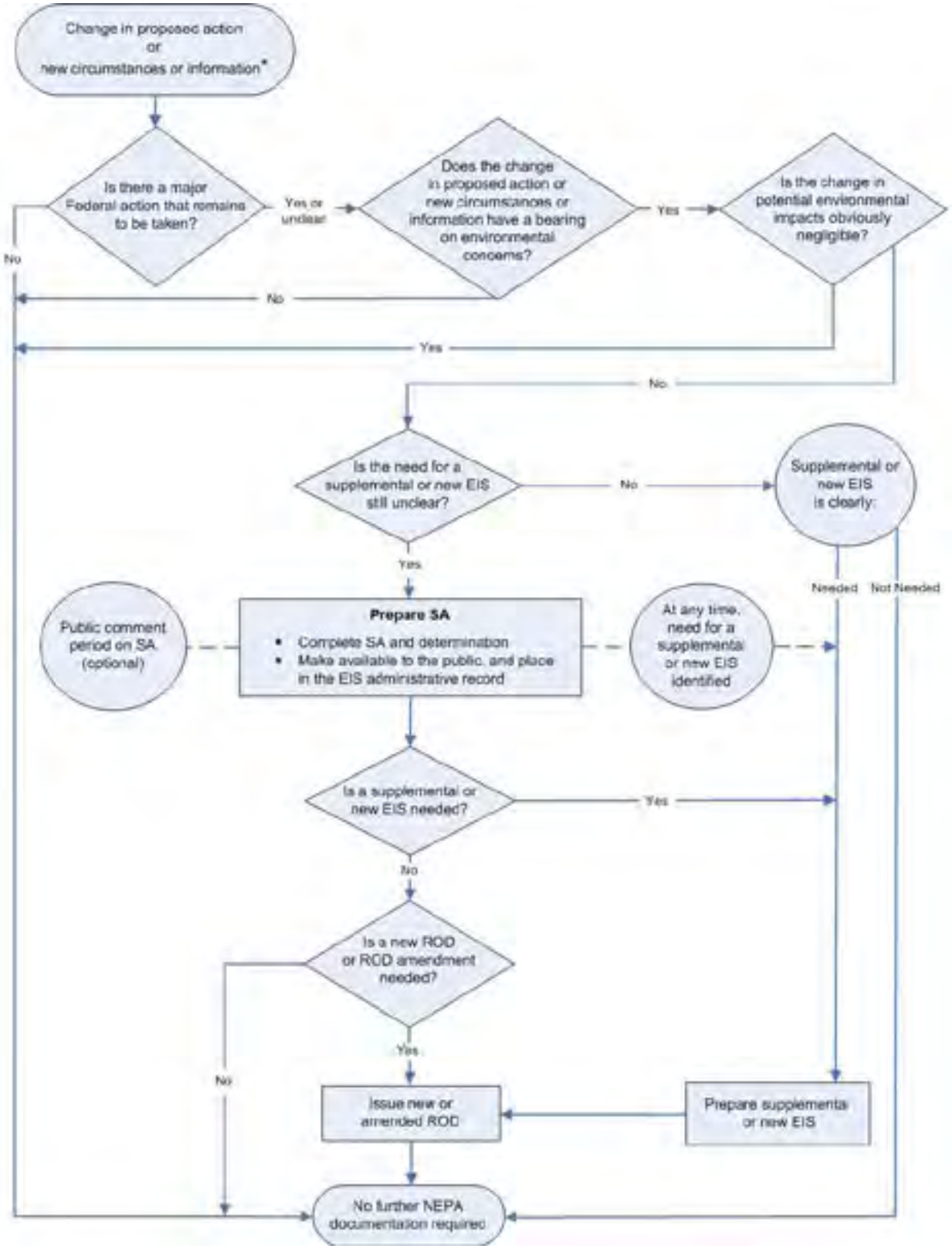
In instances involving heightened public interest or technical controversy, Program or Field Offices may choose to distribute a draft SA for review and comment or distribute a completed SA to the public (e.g., to the persons who received the existing EIS). Mechanisms that can be used to announce or disseminate an SA and determination are the same as for an EIS and include, for example, the *Federal Register*, the U.S. Postal Service, and presentations at site advisory board meetings. If the public is offered an opportunity to comment, DOE should make its responses to the comments available to the public.

Each completed SA and the resulting determination must be publicly available and placed in the Administrative Record.

4.5 SAs and Records of Decision

- When an SA results in a determination that a supplemental or new EIS is needed, DOE would publish an amended or new ROD at the conclusion of the EIS process. (As with any EIS, a 30-day "waiting period" is required before issuance of a ROD.)
- When an SA does not lead DOE to prepare a supplemental or new EIS, the Department may or may not determine that an amendment to an existing ROD is required. An amended ROD would document that DOE has changed some aspect of its decision as published in an earlier ROD and reference the SA. There is no requirement for a waiting period between an SA and an amended ROD.

Figure 1. Summary of the Supplement Analysis Process



* DOE may supplement a draft or final EIS at any time to further the purposes of NEPA (10 CFR 1021.314(b)).

Attachment 1. Regulations and Guidance Relevant to the SA Process

A. Excerpts from CEQ Regulations

40 CFR Part 1502—ENVIRONMENTAL IMPACT STATEMENT

Section 1502.9 Draft, final, and supplemental statements.

(c) Agencies:

(1) Shall prepare supplements to either draft or final environmental impact statements if:

(i) The agency makes substantial changes in the proposed action that are relevant to environmental concerns; or

(ii) There are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

(2) May also prepare supplements when the agency determines that the purposes of the Act will be furthered by doing so.

(3) Shall adopt procedures for introducing a supplement into its formal administrative record, if such a record exists.

(4) Shall prepare, circulate, and file a supplement to a statement in the same fashion (exclusive of scoping) as a draft and final statement unless alternative procedures are approved by the Council.

40 CFR Part 1508—TERMINOLOGY AND INDEX

Section 1508.27 Significantly.

"Significantly" as used in NEPA requires considerations of both context and intensity:

(a) Context. This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant.

(b) Intensity. This refers to the severity of impact. Responsible officials must bear in mind that more than one agency may make decisions about partial aspects of a major action. The following should be considered in evaluating intensity:

1. Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.
2. The degree to which the proposed action affects public health or safety.
3. Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.
4. The degree to which the effects on the quality of the human environment are likely to be highly controversial.
5. The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
6. The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
7. Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.
8. The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historical resources.
9. The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.
10. Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.

B. Excerpt from CEQ's 40 Questions

32. **Supplements to Old EISs**. Under what circumstances do old EISs have to be supplemented before taking action on a proposal?

A. As a rule of thumb, if the proposal has not yet been implemented, or if the EIS concerns an ongoing program, EISs that are more than 5 years old should be carefully reexamined to determine if the criteria in Section 1502.9 compel preparation of an EIS supplement.

If an agency has made a substantial change in a proposed action that is relevant to environmental concerns, or if there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts, a supplemental EIS must be prepared for an old EIS so that the agency has the best possible information to make any necessary substantive changes in its decisions regarding the proposal. Section 1502.9(c).

C. Excerpts from DOE Regulations

10 CFR 1021.314 Supplemental environmental impact statements.

(a) DOE shall prepare a supplemental EIS if there are substantial changes to the proposal or significant new circumstances or information relevant to environmental concerns, as discussed in 40 CFR 1502.9(c)(1).

(b) DOE may supplement a draft EIS or final EIS at any time, to further the purposes of NEPA, in accordance with 40 CFR 1502.9(c)(2).

(c) When it is unclear whether or not an EIS supplement is required, DOE shall prepare a Supplement Analysis.

(1) The Supplement Analysis shall discuss the circumstances that are pertinent to deciding whether to prepare a supplemental EIS, pursuant to 40 CFR 1502.9(c).

(2) The Supplement Analysis shall contain sufficient information for DOE to determine whether:

(i) An existing EIS should be supplemented;

(ii) A new EIS should be prepared; or

(iii) No further NEPA documentation is required.

(3) DOE shall make the determination and the related Supplement Analysis available to the public for information. Copies of the determination and Supplement Analysis shall be provided upon written request. DOE shall make copies available for inspection in the appropriate DOE public reading room(s) or other appropriate location(s) for a reasonable time.

(d) DOE shall prepare, circulate, and file a supplement to a draft or final EIS in the same manner as any other draft and final EISs, except that scoping is optional for a supplement. If DOE decides to take action on a proposal covered by a supplemental EIS, DOE shall prepare a ROD in accordance with the provisions of §1021.315 of this part.

(e) When applicable, DOE will incorporate an EIS supplement, or the determination and supporting Supplement Analysis made under paragraph (c) of this section, into any related formal administrative record on the action that is the subject of the EIS supplement or determination (40 CFR 1502.9(c)(3)).

10 CFR 1021.330 Programmatic (including Site-wide) NEPA documents.

(c) As a matter of policy when not otherwise required, DOE shall prepare site-wide EISs for certain large, multiple-facility DOE sites; DOE may prepare EISs or EAs for other sites to assess the impacts of all or selected functions at those sites.

(d) DOE shall evaluate site-wide NEPA documents prepared under § 1021.330(c) at least every five years. DOE shall evaluate site-wide EISs by means of a Supplement Analysis, as provided in § 1021.314. Based on the Supplement Analysis, DOE shall determine whether the existing EIS remains adequate or whether to prepare a new site-wide EIS or supplement the existing EIS, as appropriate. The determination and supporting analysis shall be made available in the appropriate DOE public reading room(s) or in other appropriate location(s) for a reasonable time.

(e) DOE shall evaluate site-wide EAs by means of an analysis similar to the Supplement Analysis to determine whether the existing site-wide EA remains adequate, whether to prepare a new site-wide EA, revise the FONSI, or prepare a site wide EIS, as appropriate. The determination and supporting analysis shall be made available in the appropriate DOE public reading room(s) or in other appropriate location(s) for a reasonable time.

Attachment 2. SA to Support an Amended Decision – An Example

In August 2002, the Fourth Circuit Court of Appeals upheld a district court decision that DOE had taken the "hard look" required by NEPA in regard to the Department's surplus plutonium disposition program. The Supreme Court refused to review the appellate court's ruling. The fact that DOE had prepared SAs in support of its decisionmaking played a large part in the outcome of this case.

Background. In April 2002, DOE changed its plans for its plutonium disposition program by (1) canceling one of two parallel tracks for plutonium disposition and (2) accelerating the consolidated storage of surplus, non-pit plutonium from the Rocky Flats site in Colorado at the Savannah River Site (SRS) in South Carolina (67 FR 19432, April 19, 2002).

South Carolina's Governor Hodges filed suit in May 2002 in the U.S. District Court for the District of South Carolina alleging that DOE had violated NEPA and the Administrative Procedure Act in modifying its plutonium disposition plans. The court ruled in DOE's favor. The issue before the court relevant to the SAs was the change from a proposal to construct an Actinide Packaging and Storage Facility (APSF) for long-term storage (up to 50 years) of non-pit, surplus plutonium at SRS to a proposal to modify one of the site's closed reactor buildings to store the plutonium. The modified reactor building is known as the K-Area Material Storage Facility (KAMS).

Four NEPA Reviews

DOE's NEPA compliance strategy for its plutonium disposition program involved a programmatic EIS (PEIS), a tiered project EIS, and two SAs. The courts referred to elements of each of these in their determinations that DOE had satisfied its obligations under NEPA.

- *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement* (DOE/EIS-0229, December 1996) – DOE evaluated alternative strategies and locations both for long-term storage and for disposition of weapons-usable fissile materials (plutonium and highly enriched uranium). In its record of decision (ROD), DOE chose to consolidate storage of surplus, non-pit plutonium at SRS upon completion of an expanded, new storage facility, and DOE chose to pursue plutonium disposition through both immobilization (conversion of plutonium to a form suitable for direct disposal within a matrix of highly radioactive vitrified waste) and use as mixed-oxide (MOX) fuel (62 FR 3014, January 21, 1997).
- *Supplement Analysis for Storing Plutonium in the Actinide Packaging and Storage Facility and Building 105-K at the Savannah River Site* (DOE/EIS-0229-SA1, July 1998) – To accelerate shipment of surplus, non-pit plutonium from Rocky Flats to SRS, DOE prepared an SA regarding use of KAMS for up to 10 years. This would allow receipt at SRS of plutonium before APSF became operational and enhance management flexibility of plutonium in storage at SRS while additional shipments were being received. The SA supported an amended ROD for the Storage and Disposition PEIS (63 FR 43386, August 13, 1998).
- *Surplus Plutonium Disposition Final Environmental Impact Statement* (DOE/EIS-0283, November 1999) – DOE selected SRS as the location for new facilities and associated activities to implement its plan to disposition surplus plutonium through a combination of immobilization and MOX fuel. (See ROD, 65 FR 1608, January 11, 2000.)
- *Supplement Analysis for Storage of Surplus Plutonium Materials in the K-Area Material Storage Facility at the Savannah River Site* (DOE/EIS-0229-SA2, February 2002) – DOE analyzed use of KAMS for storage of surplus, non-pit plutonium for up to 50 years. This made the analysis consistent with the analysis of long-term storage in the Storage and Disposition PEIS and was necessary because the APSF was cancelled. This SA supported an amended ROD for the Storage and Disposition PEIS (67 FR 19432, April 19, 2002).

Court Decisions

The court of appeals, affirming the district court's ruling, determined in this case that through the 2002 SA, which incorporated by reference the other NEPA documents, DOE fulfilled its NEPA obligations to take a "hard look" at the long-term plutonium storage option. The appellate court referred to the Supreme Court's decision in *Marsh v. Oregon Natural Resources Council* (1989) in which the Court held that an agency must prepare a supplemental EIS "[i]f there remains 'major Federal action' to occur, and if the new information is sufficient to show that the remaining action will 'affect the quality of the human environment' in a significant manner or to a significant extent *not already considered*."

Attachment 3. Bonneville Power Administration's Strategic Use of SAs

The Bonneville Power Administration (BPA) annually funds a substantial number of specific projects within each of its three major programs, and must accordingly conduct a large number of NEPA reviews. To make its NEPA process efficient and effective, BPA prepared programmatic EISs for each of these major programs and regularly prepares a large number of project-specific SAs to ensure that appropriate NEPA review has been completed. Although BPA's approach is unique to its programs, other NEPA practitioners may find elements of the strategy useful to their own needs, including those for five-year site-wide reviews.

- BPA's mission under the Wildlife Mitigation Program, as mandated by the Pacific Northwest Electric Power Planning and Conservation Act, is to mitigate the loss of wildlife habitat caused by development of the Federal Columbia River Power System. Specific wildlife conservation projects that BPA supports to satisfy this responsibility are generally developed in a public process managed by the multi-state Northwest Power and Conservation Council (Council). BPA funding of Council-approved wildlife mitigation projects is a Federal action subject to NEPA.
- The Watershed Management Program separately funds projects beneficial to fish habitat.
- The Transmission System Vegetation Management Program maintains the transmission line corridors and substations free from intrusive vegetation that could cause interruptions in power transmission such as from the growth of trees through power lines.

In 1997, BPA completed the *Wildlife Mitigation Program EIS* (DOE/EIS-0246). Until the EIS had been completed, identification and resolution of project management issues occurred at various stages of project planning, sometimes through the NEPA review and sometimes not. In the EIS, BPA identified the universe of activities conceivably funded under the program, generically evaluated their potential environmental impacts, and presented various standards and guidelines − procedural and substantive − to address concerns. The EIS arranged these various standards and guidelines in alternative sets, with one set ultimately adopted in the Record of Decision (ROD). BPA later prepared a very similar EIS for its *Watershed Management Program* (DOE/EIS-0265, July 1997) and a third EIS using a similar NEPA compliance strategy, but with a very different scope and constituency, to create standards and guidelines for its *Transmission System Vegetation Management Program* (DOE/EIS-0285, May 2000).

For application to specific wildlife and watershed projects proposed for funding, and for specific transmission system vegetation management treatments, BPA developed user-friendly checklists derived from the respective program ROD. The appropriate program checklist, which asks questions requiring narrative answers, is completed by each project proponent (or regional transmission maintenance staff) and used as the evidentiary basis for an SA.

BPA environmental staff reviews each project checklist for completeness and independently evaluates the environmental issues present. Through this review and evaluation, BPA staff determines (1) whether the proposed project is substantially consistent with actions identified in the EIS (and the applicable the standards and guidelines) and (2) whether there are significant new circumstances or information relevant to environmental concerns. The findings and the analysis supporting them are recorded in an agency memorandum attaching the completed checklist, approved by the designated NEPA compliance authority, and made public by way of printed notice in BPA's widely-distributed monthly public periodical and also on BPA's Web site (*www.efw.bpa.gov* under Environmental Services then Environmental Policies and Planning) and the DOE NEPA Web site (*www.eh.doe.gov/nepa* under DOE NEPA Documents). BPA staff find these procedures provide project, public, and agency efficiencies and that they help incorporate environmental protection features early in project planning.

Attachment 4. Examples of Determinations Based on SAs

Concluding paragraph and determination both contained in the SA

Example 1:

From: *Supplement Analysis for Disposal of Polychlorinated Biphenyl-Commingled Transuranic Waste at the Waste Isolation Pilot Plant* (DOE/EIS-0026-SA-2, June 2004)

In summary, DOE has conservatively reviewed the impacts that would be expected from preparing and transporting up to 2,500 cubic meters (88,000 cubic feet) of PCB-commingled TRU waste from the five sites where it is currently stored and projected to be generated and disposing of this waste at the Waste Isolation Pilot Plant (WIPP). The volume of this waste is within the total volume analyzed in the Supplemental EIS II (SEIS-II) Proposed Action. DOE estimated the maximum impacts that could be associated with the addition of PCBs to the hazardous organic compounds analyzed in Action Alternative 2. These impacts would be so small that in no instance would the presence of PCBs increase the impact results beyond those presented in the SEIS-II.

Determination

Based on the analyses of the potential impacts on land use, geology, hydrology, biological resources, air quality, socioeconomic conditions, noise, cultural resources, environmental justice, waste handling and characterization, transportation, and long-term performance of the WIPP repository for disposal of PCB-commingled TRU waste discussed in this Supplement Analysis, DOE concludes that the Proposed Action is not a substantial change to the proposal analyzed in the SEIS-II. Further, there are no significant new circumstances or information relevant to environmental concerns and bearing on the Proposed Action or its impacts. Therefore, a supplement to the SEIS-II is not needed.

Approved in Washington, DC, on this _____ day of _____, 2004.

[Signature of Approving Official]

Example 2:

From *Supplement Analysis for Storage of Surplus Plutonium Materials in the K-Area Material Storage Facility at the Savannah River Site* (DOE/EIS-0229-SA-2, February 2002)

The results of this SA indicate that the activities and potential environmental impacts associated with the storage of surplus plutonium materials in the KAMS facility at SRS are encompassed within those activities analyzed in the NEPA and supporting documentation described above. Storage of these materials would not constitute a substantial change in actions previously analyzed and would not constitute significant new circumstances or information relevant to environmental concerns and bearing on the previously analyzed action or its impacts. Therefore, DOE does not need to undertake additional NEPA analysis.

Issued in Washington, DC, [date].

[Signature of Approving Official]

Attachment F: U.S. Department of Energy, Office of NEPA Policy and Compliance, *Lessons Learned Quarterly Reports: December 1994 to September 2005*, October 2005 (excerpt)

NEPA

National Environmental Policy Act

LESSONS LEARNED

Mini-guidance Articles from *Lessons Learned Quarterly Reports*

December 1994 to September 2005

Office of NEPA Policy and Compliance
U.S. Department of Energy

October 2005

Preface

This is a collection of mini-guidance on DOE NEPA issues published in the *Lessons Learned Quarterly Report* (*LLQR*) from December 1994 to September 2005. It expands and updates a collection first issued in November 2000.

The articles in this collection, organized by topic, contain procedural interpretations and recommendations developed by the Office of NEPA Policy and Compliance in consultation with the Office of General Counsel, the DOE NEPA Community, and others. They constitute a deep, varied, and experience-based resource. The mini-guidance articles were developed to address problems identified in the course of preparing, reviewing, and issuing NEPA documents – often in response to specific requests from DOE's diverse NEPA practitioners.

The mini-guidance articles are reprinted as they originally appeared in *LLQR*, except as noted in a small number of articles. However, contact information and references, including Web sites, have been updated without highlighting such changes.

This mini-guidance and other DOE NEPA guidance referred to herein are available on the DOE NEPA Web site (*www.eh.doe.gov/nepa*) under Guidance. A complete archive of *LLQR* is available on the DOE NEPA Web site under Lessons Learned Quarterly Reports.

To comment on this collection or for more information on the content of the mini-guidance, please contact the DOE NEPA Office at 202-586-4600.

Printed on recycled paper.

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Using Bounding Analyses in DOE NEPA Documents

DOE NEPA documents sometimes estimate impacts by means of a "bounding" analysis; i.e., an analysis that uses simplifying assumptions and analytical methods that are certain to overestimate actual environmental impacts. While bounding analysis can be efficient, and is sometimes necessary, DOE should take care to use that approach only in appropriate circumstances; i.e., where the differences among alternatives would not be obscured. The purpose of this mini-guidance is to describe appropriate and improper uses of bounding analysis.

Neither the Council on Environmental Quality (CEQ) NEPA implementing regulations (40 CFR Parts 1500-1508) nor the DOE NEPA regulations specifically address bounding analyses in NEPA documents, but there are situations where the bounding approach is helpful. These situations include:

- Where information relevant to reasonably foreseeable significant adverse impacts cannot be obtained because the overall costs of obtaining it are exorbitant or the means to obtain it are not known (See 40 CFR 1502.22), bounding analysis may provide an efficient, practical solution. In such cases, DOE must make reasonable, conservative assumptions for purposes of analysis, which should produce estimates that bound the impacts to a reasonable degree. For example, cumulative impacts would need to be bounded in a site-wide EIS for a site that is being considered in another EIS as an alternative (i.e., not proposed/ preferred) location for a new activity. Including the best available information regarding the impacts of the potential new activity in the cumulative impacts for the site would account for all reasonably foreseeable actions, but would overstate the probable impacts. The EIS being prepared for operations of the Pantex Plant, for example, includes in its cumulative impacts analysis several functions for Pantex that are being considered (short of being preferred) in several other EISs that are in preparation.
- Where DOE is evaluating the potential environmental impacts of a program or a broad agency action, simplifying assumptions may be necessary to perform the analysis. While the assumptions may be conservative and the impacts estimated may be substantially higher than those that would actually occur, the relative differences in the impacts among the alternatives should be discernible for the analysis to be useful in informing the choice among alternatives.
- Where a simple conservative analysis is sufficient to show that an impact is insignificant and doesn't warrant further investigation, bounding analysis may be efficient, though not necessary. This approach is useful for both EAs and EISs.

In sum, using conservative assumptions and analytical methods to bound an impact may be appropriate and even necessary in some cases. Nevertheless, bounding analyses should not be used where more accurate and detailed assessment is possible and would better serve the purposes of NEPA. Therefore, when using bounding analysis:

- DOE must ensure that the analysis is not so broad and all-encompassing as to mask the distinctions among alternatives, or to hinder consideration of mitigations.
- Even where overall impacts are small, detailed analysis for each alternative may be needed where differences in impacts may help to decide among alternatives or to address concerns the public has expressed, as sometimes applies when DOE must select sites or transportation routes and methods for conducting its operations.
- It is never appropriate to "bound" the environmental impacts of potential future actions (not yet proposed) and argue later that additional NEPA analysis is unnecessary because the impacts have been bounded by the original analysis. LL

December 2000