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Final Environmental Impact Statement for

Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center

The West Valley Site

Volume 1

(Chapters 1 through 11)

NYSERDA

Availability of the
Final EIS for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center

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Abstract: The Western New York Nuclear Service Center (WNYNSC) is a 1,351-hectare (3,338-acre) site located 48 kilometers (30 miles) south of Buffalo, New York and owned by NYSERDA. In 1982, DOE assumed control but not ownership of the 68-hectare (167-acre) Project Premises portion of the site in order to conduct the West Valley Demonstration Project (WVDP), as required under the 1980 West Valley Demonstration Project Act. In 1990, DOE and NYSERDA entered into a supplemental agreement to prepare a joint EIS to address both the completion of WVDP and closure or long-term management of WNYNSC. A Draft EIS was issued for public comment in 1996: the *Draft Environmental Impact Statement for*

Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center, also referred to as the 1996 *Cleanup and Closure Draft EIS*, DOE/EIS-0226D, January 1996. The 1996 Draft EIS did not identify a preferred alternative.

Based on decommissioning criteria for WVDP issued by NRC since the publication of the 1996 *Cleanup and Closure Draft EIS* and public comments on that EIS, DOE and NYSERDA issued the *Revised Draft Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center* (also referred to as the *Decommissioning and/or Long-Term Stewardship EIS*) in December 2008, revising the 1996 Draft EIS. This *Decommissioning and/or Long-Term Stewardship EIS* has been prepared in accordance with NEPA and the State Environmental Quality Review Act (SEQR) to examine the potential environmental impacts of the range of reasonable alternatives to decommission and/or maintain long-term stewardship at WNYNSC. The alternatives analyzed in this EIS include the Sitewide Removal Alternative, the Sitewide Close-In-Place Alternative, the Phased Decisionmaking Alternative (Preferred Alternative), and the No Action Alternative. The analysis and information contained in this EIS are intended to assist DOE and NYSERDA with the consideration of environmental impacts prior to making decommissioning or long-term management decisions.

Phased Decisionmaking Alternative (Preferred Alternative): Under the Preferred Alternative, decommissioning would be accomplished in two phases: Phase 1 would include removal of all Waste Management Area (WMA) 1 facilities, the source area of the North Plateau Groundwater Plume, and the lagoons in WMA 2. Phase 1 activities would also include additional characterization of site contamination and scientific studies to facilitate consensus decisionmaking for the remaining facilities or areas. Phase 2 actions would complete decommissioning or long-term management decisionmaking according to the approach determined most appropriate during the additional Phase 1 evaluations. In general, the Phased Decisionmaking Alternative involves near-term decommissioning and removal actions where there is agency consensus and undertakes characterization work and studies that could facilitate future decisionmaking for the remaining facilities or areas. Phase 1 activities are expected to take 8 to 10 years to complete. The Phase 2 decision would be made no later than 10 years after issuance of the initial DOE Record of Decision and NYSERDA Findings Statement, if the Phased Decisionmaking Alternative is selected. In response to public comments, the Preferred Alternative has been modified since the Revised Draft EIS was issued.

Public Comments: In preparing this Final EIS, DOE considered comments received during the scoping period (March 13 through April 28, 2003) and public comment period on the Revised Draft EIS (December 5, 2008 through September 8, 2009). Public hearings on the Revised Draft EIS were held in Albany, Irving, West Valley, and Buffalo, New York during the public comment period. In addition, a videoconference with the DOE Assistant Secretary for Environmental Management, the President of NYSERDA, and various stakeholders was held on September 4, 2009. Comments on the Revised Draft EIS were requested during the 9-month period following publication of the U.S. Environmental Protection Agency's (EPA's) Notice of Availability in the *Federal Register*. All comments, including late comments and those presented during the September 4, 2009 videoconference, were considered during preparation of this Final EIS.

This Final EIS contains revisions and new information based in part on comments received on the 2008 Revised Draft EIS. Vertical change bars in the margins indicate the locations of these revisions and new information. Volume 3 contains the comments received during the public comment period on the Revised Draft EIS including late comments, and DOE's and NYSERDA's responses to the comments. DOE will use the analysis presented in this Final EIS, as well as other information, in preparing its Record(s) of Decision (RODs) regarding actions to complete WVDP. DOE will issue ROD(s) no sooner than 30 days after EPA publishes a Notice of Availability of this Final EIS in the *Federal Register*. NYSERDA will use the analysis presented in this Final EIS, as well as other information, in preparing its Findings Statement, which will be published in the *New York State Environmental Notice Bulletin* no sooner than 10 days after the Final EIS is issued.

FOREWORD
THE VIEW OF THE NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

NYSERDA and DOE support the Phased Decisionmaking Alternative as the Preferred Alternative. The agencies agree that during the first phase of this alternative, important work would be conducted that the agencies believe is critical to keep the project moving toward completion. There is disagreement, however, regarding the level of additional analysis related to long-term performance assessment required to support the Phase 2 decisions.

DOE disagrees with many of the points raised in NYSERDA's View. At the core, differences between DOE and NYSERDA center on different views about the nature of analysis required for an EIS and the attendant level of acceptable risk associated with any uncertainties in that analysis as it relates to decisionmaking. The analysis in this EIS meets the requirements of NEPA and SEQR in that, when there is incomplete or unavailable information relevant to reasonably foreseeable significant adverse environmental impacts, this EIS (1) acknowledges the information limitation and its relevance to environmental consequence, (2) summarizes existing credible scientific evidence, and (3) presents an analysis using a theoretical approach that is generally accepted by the scientific community involved in such analyses. This Final EIS contains text boxes in the relevant subject matter areas that acknowledge the differences of opinion between DOE and NYSERDA. In general, DOE's position is that the agency spent much time and effort engaging highly qualified and respected experts in hydrology and hydrological transport, landscape evolution (erosion), human health and environmental risk analysis, and other technical fields, and stands behind the analyses performed for this EIS.

This Foreword to the Final Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center presents NYSERDA's differing opinion, its "View."

FOREWORD

The View of the New York State Energy Research and Development Authority on the Final Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center

Introduction

The New York State Energy Research and Development Authority (NYSERDA) would like to thank you for participating in this very important Environmental Impact Statement (EIS). This Final EIS presents alternatives for the critical next steps in the cleanup of the Western New York Nuclear Service Center and completion of the West Valley Demonstration Project (WVDP), and assesses the environmental impacts from those alternatives. It is important for the agencies and the public to be properly informed of the potential environmental impacts associated with each of these alternatives; and, it is equally as important for members of the public to provide their input to the agencies on the alternatives.

Because of the importance of the decisions that will soon be made regarding the next steps in the cleanup, NYSERDA requested the opportunity to present our agency's view on the analyses and results that are included in this Final EIS.

NYSERDA's Role in the West Valley EIS

NYSERDA owns the Western New York Nuclear Service Center on behalf of New York State, and is a joint lead agency with the U.S. Department of Energy (DOE) in this EIS process. NYSERDA and DOE are joint lead agencies because both agencies are planning to make decisions on the future of the West Valley site. Federal and state regulations require these decisions to be assessed through an EIS.

In terms of the EIS preparation, DOE managed and directed the EIS contractor (Science Applications International Corporation), and NYSERDA provided input on the EIS content, analyses and results through consultations with DOE.

The Preferred Alternative – An Approach to Allow Important Near-Term Work to Proceed

An interagency working group[1] was established by DOE in late 2006 to resolve a number of outstanding technical issues that were identified during agency reviews of early versions of the Draft EIS. The working group was tasked with finding ways to come to concurrence on almost 1,700 comments on the EIS, many of which were related to the long-term analysis of the site. The comments also included input from an independent Peer Review Group that was convened by DOE and NYSERDA in early 2006[2]. Although the interagency working group did not resolve all issues to the satisfaction of all participating agencies, the group did identify a preferred cleanup alternative that would allow the near-term removal of

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[1] This interagency working group, called the Core Team, is composed of representatives from DOE, NYSERDA, U.S. Nuclear Regulatory Commission (NRC), New York State Department of Environmental Conservation (NYSDEC), U.S. Environmental Protection Agency (EPA) and New York State Department of Health (NYSDOH).

[2] This 2006 independent review group, known as the Peer Review Group, documented its findings in a report presented to NYSERDA and DOE dated April 25, 2006 (PRG, 2006). This report is available on the internet at http://www.nyserda.org/publications/westvalleypeerreviewgroup.pdf. Paper copies can be requested from NYSERDA at END@nyserda.org, or by calling Elaine DeGiglio at (716) 942-9960, extension 2423.

several very significant site facilities and areas of contamination (the Main Plant Process Building, the Low-Level Waste Treatment System Lagoons and the source area of the North Plateau groundwater plume). The alternative put forth by the interagency working group also included a period, of up to 30 years, for making decisions for certain other key facilities (e.g., the High-Level Waste [HLW] Tanks[3], the NRC-Licensed Disposal Area [NDA] and the State-Licensed Disposal Area [SDA]). This 30-year time period was considered necessary to allow for, among other things, improvements in the technical basis of the long-term performance analysis. The preferred alternative was presented in the Draft EIS, which was issued in December 2008.

In response to public comments over the length of time that could elapse between Phase 1 and Phase 2 decisions, DOE and NYSERDA have reconsidered the time frame for making Phase 2 decisions. As a result, the Phased Decisionmaking Alternative presented in this Final EIS specifies that the Phase 2 decisions would be made no later than 10 years after issuance of the initial DOE Record of Decision and NYSERDA Findings Statement documenting selection of the alternative.

NYSERDA continues to support the Phased Decisionmaking Alternative because it allows substantial facilities and contamination to be removed from the site in the near term. This removal work represents very important progress in the cleanup of the Western New York Nuclear Service Center and completion of the WVDP. The alternative also provides the opportunity to improve EIS long-term technical analyses so the agencies can be better informed when considering the decision with respect to the remaining facilities. Due to the very large costs associated with removing these facilities and the potential for significant long-term risk from leaving them in place, NYSERDA believes the long-term decision with respect to these facilities must be supported by a thorough and scientifically defensible long-term analysis. We also continue to believe that this scientifically defensible long-term analysis does not exist, even in this FEIS.

Independent Expert Review of the Draft and Final EIS

In the spring of 2008, NYSERDA convened a group of nationally and internationally recognized scientists to review a Preliminary Draft of the DEIS (PDEIS). These distinguished scientists, collectively called the Independent Expert Review Team (IERT), are experts in the disciplines of geology, erosion, groundwater hydrology, nuclear science and engineering, health physics, risk assessment, and environmental science and engineering (see the second-to-last section of this *Foreword* for a list of the members and their respective affiliations). The scope of their review was to assess the technical basis and scientific defensibility of the analyses presented in the PDEIS. The review was initiated in May 2008 and was completed in September 2008[4]. A final report was submitted to NYSERDA on September 23, 2008 (IERT, 2008).

In preparation for the issuance of the Final EIS in October 2009, NYSERDA convened a subteam of the IERT to review an early ("Pre-Concurrence") draft of the FEIS. This IERT subteam was tasked with reviewing the document to identify noteworthy changes since the Draft EIS (issued December 2008), and assessing the implications of these changes to the defensibility and outcome of the analyses.

While the IERT subteam acknowledged the additional work and effort put forth by DOE (and its contractor) to improve the analyses in the FEIS, they also concluded that many of the technical issues identified in the Preliminary Draft EIS, remain valid in the Final EIS. The results of the Independent Expert Review Team's review, along with NYSERDA staff's own review of this Final EIS, allowed

3 The HLW Tanks are referred to in the EIS as "the Waste Tank Farm."
4 The report from the Independent Expert Review Team is available on the internet at: http://www.nyserda.org/publications/westvalleyindependentreview.pdf. Paper copies can be requested at END@nyserda.org, or by calling Elaine DeGiglio at (716) 942-9960, extension 2423.

NYSERDA to develop an overall "view" on the Final EIS analyses and results. The NYSERDA "View" is presented below.

NYSERDA's View on the Final EIS Analyses and Results

NYSERDA's view on the Final EIS analyses and results is as follows:

1. **<u>The Final EIS Analysis of Soil Erosion is Not Scientifically Defensible and Should Not Be Used for Long-Term Decisionmaking</u>**

   The Final EIS soil erosion analysis, which is intended to show how soil erosion by water will impact the site and site facilities over the next 10,000 years, is not scientifically defensible and should not be used for long-term decisionmaking.

   The Final EIS presents the results from a computer program (also called a landscape evolution model) that is used to calculate changes to the existing land surface from soil erosion. The model uses mathematical equations and input parameter values (e.g., rainfall amount and intensity, soil type, vegetation, the slope of the land surface, etc.) to predict how the topography of the land will be shaped by natural erosion processes over very long time frames (i.e., thousands of years). These computer-predicted changes in the land surface were then combined with the conceptual designs for facilities that are proposed to be closed-in-place to determine how critical facilities and areas of contamination would be impacted by the computer-predicted erosion for each of the EIS alternatives.

   NYSERDA recognizes DOE's efforts in trying to develop a defensible erosion analysis, yet it is apparent that the science of landscape evolution modeling is still in its infancy. Although these models are used to recreate many complex individual processes, they necessarily represent nature in a very abstract, simplistic way. While current state-of-the-art landscape evolution models are capable of recreating very basic, gross aspects of a stream network or watershed, they admittedly cannot: (1) predict the location of streams, gullies, landslides, etc.; (2) address the wandering or meandering nature observed in local streams; or (3) explicitly account for the knickpoint erosion that is actively causing downcutting (downward erosion) of stream channels and advancement of gullies. As such, we cannot rely on the results from these models to make decisions regarding the long-term future of the West Valley site.

   The limited graphical information provided to support the long-term modeling results is incomplete and makes it impossible for the general public to distinguish, for example, between areas predicted to erode 25 centimeters or 1700 centimeters. Further, NYSERDA staff believe these results are not only unrealistic, but overly optimistic given the 10,000-year time frame. With the exception of one modeling scenario, the simulation results show **no gully erosion of the South Plateau over the next 10,000 years.** Even more astonishing, these results show streams surrounding the South Plateau filling in with sediment over the same time period. These results are wholly inconsistent with what is being observed at these locations today. The streams themselves are actively downcutting dramatically in some locations, and the stream valley walls contain actively eroding gullies. The modeling results for the North Plateau predict tremendous downcutting (up to 30 meters or 100 feet) on Quarry Creek, which borders the WVDP to the north, yet relatively little gully erosion protruding into the plateau. Again, this predicted landscape is not representative of observed site or regional topography. Where local streams have incised the landscape, deep gullies extend many hundreds of feet into the landscape on either side of the stream. These discrepancies suggest the modeling results are neither meaningful nor reliable.

Also included in the EIS are short-term erosion predictions, based on four separate commonly used computer models that have been used to provide perspective on the reasonableness of the landscape evolution predictions. The results from these models provide very little useful information with regard to erosion rates at the West Valley site because gullies are the principal surface erosion threat at the site, and none of the models are capable of predicting gully erosion.

After reviewing the erosion modeling presented in the Final EIS, the Independent Expert Review Team offered the following observations:

> "While the current version of the EIS (dated October 5, 2009) offers some refinements over the previous version (2008), especially with regard to modeling the surface processes, deficiencies still remain, and these include the following:
>
> (1) A serious disconnect exists between model parameterization and the hydrologic and geomorphic characteristics of the site;
>
> (2) No verification or validation of any models is presented in the context of comparing model output with actual field data;
>
> (3) Many of the model components, especially with regard to the gully erosion and landscape evolution, are unjustifiable and unsupported by scientific evidence; and
>
> (4) No uncertainty analysis of any model predictions is provided."

Based on the IERT subteam's recent review of the erosion modeling work, coupled with NYSERDA staff's review of the Final EIS, NYSERDA believes that the erosion modeling results presented in the Final EIS are unrealistic and not scientifically-based, and therefore should not be used for long-term decisionmaking. Accordingly, predictions of radiation doses to the public and all other site impacts that were calculated using the erosion models presented in this Final EIS should not be used to support long-term decisionmaking for the West Valley site cleanup. Until both lead agencies and the scientific community conclude that a defensible erosion analysis for the site is achievable and has been prepared, decisions will need to focus on actions that are not dependent on having scientifically defensible estimates of erosion impacts over thousands of years.

2. **The Final EIS Analysis of Contaminant Transport by Groundwater Needs Improvement**

The analysis of the potential for transport of contaminants by groundwater, as presented in Appendix E and Appendix G of the Final EIS, needs improvement.

The groundwater transport analyses are presented in the Final EIS in two appendices. Appendix E presents a description of three-dimensional groundwater flow-and-contaminant transport models that were used to estimate the flow of groundwater through the soils and bedrock beneath the site, and to assess the release and transport of contaminants by groundwater from any facilities and contamination that might be closed-in-place. Appendix G describes simpler, one-dimensional groundwater flow-and-contaminant transport models that were used in the calculations of impacts to the public that are presented in other sections in the DEIS.

NYSERDA recognizes the significant effort that was employed by DOE and its consultants to develop and run a three-dimensional flow-and-transport model for this site, and we note that this work represents an improvement over earlier groundwater modeling efforts. In its review of the 2008 Draft EIS, the IERT noted that "the general approach to groundwater flow and transport modeling described in Appendix E is acceptable but could be improved." The IERT also made specific recommendations to improve the model. The recommendations called for (1) a more comprehensive evaluation of uncertainties using a probabilistic approach, and (2) a more convincing demonstration that one-dimensional models in Appendix G are derived from and supported by the three-dimensional models presented in Appendix E.

After completing its review of the 2009 FEIS, the IERT subteam concluded that there are no substantive changes to the 2009 FEIS compared to the 2008 version. There continues to be no compelling argument for why the modelers have chosen to use simplified one-dimensional flow-and-transport models for the purposes of calculating long-term dose (as opposed to the three-dimensional model presented in Appendix E). Similarly, the IERT subteam believes that the deterministic analysis presented in the EIS may not be realistic or conservative. They concluded that it should be possible to propagate uncertainties in the model inputs using Monte Carlo methods to generate a probabilistic range of outcome. Unfortunately, the modelers chose not to perform such calculations.

The Final EIS uses a deterministic approach (i.e., single values are used for model inputs and model parameters), and asserts that these values are conservative[5]. NYSERDA shares the belief of the IERT—that additional documentation is needed to substantiate the assertion that the deterministic treatment of groundwater flow and transport is truly conservative. According to the IERT, the sensitivity analyses presented are a very small subset of the potentially important analyses, and do not provide a comprehensive evaluation of uncertainty in groundwater flow and transport.

Based on the IERT's review of the groundwater modeling work, and on NYSERDA staff's review of the same information, NYSERDA opposes using the groundwater modeling results presented in the Final EIS for long-term decisionmaking. Accordingly, predictions of radiation doses to the public and all other site impacts that were calculated using the groundwater modeling approach presented in the Final EIS should not be used to support long-term decisionmaking for the West Valley site cleanup.

3. **<u>The Final EIS Assumptions Used for the Performance of Engineered Barriers have not been Substantiated and may be Overly Optimistic</u>**

The assumptions used in the Final EIS analysis to predict the performance of engineered features such as caps, slurry walls, grout, and other engineered materials intended to keep contamination physically and chemically bound in place for tens of thousands of years, have not been substantiated and may be overly optimistic. Additional analysis and verification are required for the performance of engineered barriers that are used in the Final EIS site closure alternatives.

In the Final EIS analysis, the physical properties of engineered barriers are assigned a level of performance that is said to represent a degraded condition to account for barrier subsidence, cracking and clogging. The engineered barriers are then assumed to perform at that level, without further reduction in performance, for the duration of the analysis (100,000 years). An important factor for the physical performance of engineered barriers in the Final EIS is the assumption that the barriers used to protect the North Plateau facilities will not be physically disturbed by natural processes (e.g., erosion). Given the presence of significant erosion features (gullies and slumps) that are actively changing and impacting the North Plateau today, this assumption seems implausible, and if this assumption is going to be used in the Final EIS, it must be supported by convincing evidence. Our review of Appendix H shows that this assumption is based solely on the results of the Final EIS erosion modeling, and, as stated above, we believe this modeling is not scientifically defensible. Consequently, the assumption in the Final EIS that the engineered barriers would be physically stable for 100,000 years on the North Plateau is not adequately supported.

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[5] *"Conservative" means that the values chosen would not likely lead to an underestimate of impacts.*

The chemical properties of engineered barriers (which are intended to chemically bind contaminants and prevent their migration) are also said to be assigned degraded values, and are then assumed to remain at that level for the 100,000-year-analysis period without further reduction in performance. The assumption that chemical properties of man-made engineered barriers will remain constant over tens of thousands of years is implausible. Even though a "natural" material may be stable and retain certain properties in one geologic and hydrologic setting, that same natural material may not be stable or retain those same chemical properties indefinitely in another setting, particularly when combined with other natural and man-made materials over time frames as long as 100,000 years. If the Final EIS is going to use this assumption, the Final EIS must also provide adequate references to properly support and defend this assumption.

The IERT noted that text had been added to supporting documents to this Final EIS (see *Sitewide Close-In-Place Technical Report)* stating that "erosion control installations in Western New York had been reviewed to gain a better understanding of the various types of structures used, the successes and failures, and the mechanisms for failure, for these structures." However, the IERT could not find where that information had been used to improve the analyses anywhere in the Final EIS or the supporting documents. They also noted that no engineered barrier uncertainties were accounted for in the Final EIS.

The sensitivity analysis information presented in Appendix H in the Final EIS shows that the assumptions used for engineered barriers in the long-term performance calculations, even in the "degraded" state, are critical to the outcome of performance for facilities that are closed-in-place. As such, it is very important that the Final EIS provide clear support for all assumptions used for engineered barriers, and provide additional information on the impacts from complete- and partial-barrier failure as well as on the importance of engineered barriers in each alternative's ability to meet the decommissioning criteria[6].

Based on the IERT's review of the engineered barrier assumptions, and based on NYSERDA staff's review of the Final EIS, NYSERDA has concluded that the assumptions used for engineered barriers in this Final EIS are not adequately supported, and may lead to underestimates of dose and other impacts. Accordingly, predictions of long-term radiation doses to the public and all other site impacts that were calculated based on the engineered barrier assumptions presented in this Final EIS should not be used to support long-term decisionmaking for the West Valley cleanup.

4. <u>The Uncertainties in the Final EIS Long-Term Performance Analyses are not Adequately Presented or Discussed</u>

The Final EIS does not address uncertainty in a manner that provides decisionmakers with information on the critical contributors to uncertainty, or the importance of uncertainty in site cleanup decisions.

All long-term analyses in the Final EIS are deterministic, which means that they use single models and single values for model input parameters. The IERT subteam, in their assessment of the Final EIS, concluded the following:

> "There have been no significant changes in the approach to uncertainty analysis from the 2008 review. The models are generally void of probability-based information that would be the basis for meaningful uncertainty analysis. The absence of a probability-based uncertainty

[6] Under the WVDP Act, the U.S. Congress required the U.S. Nuclear Regulatory Commission to prescribe decommissioning criteria for the WVDP. Those criteria were issued by NRC in a "Policy Statement" that was published in the Federal Register on February 1, 2002.

> analysis also greatly compromises any attempt at making the assessments risk-informed or having a high level of confidence in the quality of the dose modeling. The approach to considering uncertainty is based on alleged use of conservative assumptions. No attempt was made to quantify the uncertainties."

The IERT noted that the multiple sources of uncertainty inherent in this analysis are largely unacknowledged, and there is no systematic discussion of how uncertainty has been characterized. Impacts of uncertainties on decisionmaking are supposed to be accounted for by conservative choices in scenario selection and modeling, and by limited deterministic sensitivity analyses. In practice, however, the Final EIS does not demonstrate that the deterministic analysis is either conservative, or that it has appropriately incorporated or bounded uncertainty.

The IERT concluded that some potentially significant uncertainties have not been evaluated. In addition, assertions that other uncertainties have been conservatively bounded are not justified. Transparency of the long-term analysis is poor, and it is not possible to independently replicate the analyses or to otherwise understand how the results were derived. Given these observations, the IERT stated that the quantitative results of the long-term analysis presented should not be used to support decisionmaking associated with the Final EIS.

Based on the IERT's review of the treatment of uncertainty, and based on NYSERDA staff's review of the Final EIS, NYSERDA has concluded that the approach used to identify, analyze, and present uncertainty in the Final EIS is not adequate. The sensitivity analyses in Appendix H show that varying the values of certain important parameters could make the difference between whether an alternative meets the decommissioning criteria or fails to meet the criteria. Consequently, a more comprehensive and transparent analysis and presentation of uncertainty is needed to support long-term decisionmaking for the West Valley site cleanup.

5. The Connection between the Final EIS Analyses and the Applicable Regulatory Framework Must be Strengthened

The long-term analysis for the site, as described in Appendix D of the Final EIS, should be closely structured and clearly tied to the NRC's License Termination Rule (LTR). The LTR is the applicable regulatory framework for decommissioning the WVDP and for the termination of the 10 CFR 50 License.

The Final EIS identifies several regulations that were used to develop the framework for the long-term performance assessment analysis. One of these regulations is the License Termination Rule, which is the applicable regulatory framework for the West Valley Demonstration Project cleanup. Another regulation that was relied upon extensively in the development of the Final EIS analytical approach is 10 CFR 61 (Part 61), the NRC's Low Level Waste disposal regulations. We are concerned that using portions of the Part 61 guidance, absent other critical parts of the Part 61 regulations (such as the facility siting requirements), may result in a nonconservative performance assessment.

Part 61 requires a disposal site to be located in a geologic setting that is essentially stable, or alternatively, in an area where active features, events, and processes (such as erosion) will not significantly affect the ability of the site and design to meet the Part 61 performance objectives. The Part 61 performance assessment guidance is intended to be applied to a facility that is sited in accordance with the site suitability requirements. In such a setting, an engineered cap might not be substantially disturbed by natural processes, and it may be reasonable to assume that the cap would provide adequate protection to an intruder for the needed time period. At the West Valley site, however, the facilities were not sited in accordance with the Part 61 site suitability requirements, and as such, the Final EIS analysis should not take credit for site stability and the passive functioning of engineered barriers in perpetuity unless this assumption can be justified.

Although DOE has a standard approach for preparing National Environmental Policy Act (NEPA) documents, the LTR (and its implementing guidance, NUREG-1757), are directly applicable to the West Valley Demonstration Project decommissioning activities and alternatives, and the LTR requirements and guidance should form the framework for the Final EIS analysis. The NRC's West Valley Policy Statement prescribes the LTR as the decommissioning criteria for the WVDP, and states:

> "The environmental impacts from the application of the criteria will need to be evaluated for the various alternative approaches being considered in the process before NRC decides whether to accept the preferred alternative for meeting the criteria of the LTR. NRC intends to rely on the DOE/NYSERDA EIS for this purpose."

While DOE has stated that the Decommissioning Plan, not the EIS, is the proper document to conduct the LTR compliance analysis, it does not seem logical to prepare an EIS to assess the impacts from decommissioning actions that must meet the requirements of the NRC's LTR, and use regulations and guidance that are not part of the LTR regulatory framework to structure the analyses. As such, NYSERDA believes that the Final EIS analyses are not adequately framed to reflect the requirements of the NRC's analytical requirements for decommissioning. The Part 61 guidance should not be used as part of the analytical framework for the Final EIS unless there is a specific reason under the requirements of the LTR or WVDP Act to do so.

6. <u>The Final EIS Approach for Exhumation may be Overly Conservative</u>

The approach described in the Final EIS and its supporting documents for exhumation of the SDA, the NDA and the Waste Tank Farm appears to be overly conservative, and based on extreme conditions, rather than on conditions that are more likely to be encountered during exhumation. As a result, there is significant uncertainty in the cost estimates in the Final EIS for the exhumation of the Waste Tank Farm and the disposal areas.

The SDA and NDA exhumation processes are conducted using very large, hard-walled concrete secondary containment structures. Primary containment structures are located within the larger secondary containment structures. While this may be an effective approach to provide containment, it may also be more containment than what is ultimately needed to safely exhume some or all of the wastes. Further, the Final EIS assumes that 100 percent of the waste resulting from demolition of these massive containment structures must be disposed of as radioactive waste. We believe this assumption to be unnecessarily conservative.

An alternative approach to the use of hard-walled containment structures would be the use of Sprung Structures™, which consist of UV-resistant fabric and PVC membrane over an aluminum support system. Sprung Structures™ have lasted 15-20 years through harsh winters, and they can be fitted with the ventilation and air filtering systems that would be needed to contain contamination within the structure. Similar structures were used at the WVDP in the 1980s during the excavation of the solvent tanks from the NDA, and are currently employed in waste exhumation projects at Idaho National Laboratory and Los Alamos National Laboratory.

NYSERDA acknowledges DOE's efforts to clarify the large uncertainty of the cost for disposal of Greater than Class C (GTCC) wastes. It is projected that approximately 150,000 cubic feet of waste exhumed from the SDA and NDA will be classified as GTCC waste. The disposal cost for GTCC waste will not be known until there is a disposal facility for GTCC waste. In an effort to bound the costs for disposal of GTCC waste, DOE has included a range of costs based on the cost of disposal of TRU waste at the Waste Isolation Pilot Plant (WIPP) and an estimated cost for disposal at a high-level waste repository using cost for disposal at Yucca Mountain.

For the Waste Tank Farm, the IERT questioned the high cost of constructing and operating the Waste Tank Farm Waste Processing Facility. They suggested that by considering alternative exhumation approaches for the tanks, cost savings could be realized.

Based on the IERT's review of the exhumation approach, and based on NYSERDA staff's review of the Final EIS and supporting documents, we believe that the exhumation approaches in the Final EIS could be successful. It is however, recommended that current industry practices and innovations be applied in an effort to lower costs. NYSERDA acknowledges that DOE's revised approach reuses some modular components of the environmental containment to lower waste volumes but we believe these changes do not adequately address the issues previously identified. Significant uncertainty remains in the costs used in the Final EIS for disposing of exhumed waste from the SDA and NDA.

NYSERDA believes that the approach identified in the Final EIS for exhuming the disposal areas and Waste Tank Farm should be reassessed to determine whether less conservative, but still protective, methods of exhumation could be identified that would significantly reduce the cost of exhumation.

7. <u>Current Methods for Assessing Nonradiological Risk from Transportation Have Limitations and are Likely to Overestimate Fatalities</u>

NYSERDA recognizes the DOE's revisions to evaluating human health impacts from transportation. In previous versions of this EIS, DOE relied on national average accident fatality rates to determine the number of predicted fatalities from rail transportation under each decommissioning alternative. In the Final EIS, DOE uses state-specific fatality rates (published for the years 1994 to 1996) along the designated transportation routes shown in Figure J-2 of Appendix J. This change, which is consistent with previous DOE guidance on transportation risk assessment (DOE, 2002), resulted in a 50 percent reduction in predicted rail transportation fatalities in the Final EIS.

While the current approach for assessing nonradiological transportation risk is consistent with DOE guidance and other published DOE Environmental Impact Statements (e.g., the Yucca Mountain FEIS released in 2002), it does have limitations. In its evaluation of nonradiological risk from rail transportation, the Final EIS uses "railcar-kilometers" to assess the number of expected traffic accident fatalities. The main purpose for adopting this approach is that readily available data exists for State-specific accident rates provided in units of fatalities per railcar-kilometer. NYSERDA believes that a better measure for assessing impacts from rail transportation would be train-kilometers that would assume a single shipment consists of multiple railcars. The accident risk would be assigned to the entire train, rather than each individual railcar on the train. In regard to this issue, in 2008, the IERT offered the following observation:

> "The railcar-kilometer metric implies that one or a few waste laden railcars are part of a larger variable construct train. (See Saricks and Tompkins, 1999 cited in Appendix J of the 2008 DEIS for a discussion of variable-construct versus dedicated trains.) If these waste-laden railcars are a small part of a much larger train (Saricks and Tompkins estimate 68 cars in an average train), then the non-radiological risk is already inherently included in the train that would run whether the few additional waste-laden railcars were present or not. This is another difference between variable-construct train and truck risks – the truck would not travel if not for the waste cargo; the same is not true for variable-construct trains. One could argue that the incremental non-radiological rail transportation risk due to an additional waste-laden railcar is negligible."

To further illustrate the point that train-kilometers represent a more accurate measure, it has been reported that approximately half of all rail transportation injuries and fatalities occur at rail crossings in which the lead locomotive is involved in the collision (DOT, 1997). This would suggest that injury and fatality rates are independent of train length (Cashwell et al., 1986).

However, despite the arguments for expressing fatality rates in terms of train-kilometers, NYSERDA recognizes that this is not the common industry practice because statistics on train-kilometers are not readily available. As Saricks and Thompkins (1999) point out, converting a unit railcar rate to a unit train rate requires application of statistical information available only for trains of an average length (estimated to be 68 cars). They advise against this approach because they do not consider it to be statistically defensible. Other uncertainties associated with available transportation statistical data are summarized in Section J.11.5 of the Final EIS. Also mentioned in that section is the more recent trend (based on limited available data for the years 2000 through 2004) toward lower rail transportation fatality rates.

Given the limitations on available statistical data cited above, NYSERDA believes that the calculation of fatalities based on train-kilometers is not, at this time, defensible. Consequently, we believe that the rail fatality rates presented in the Final EIS are adequate for decisionmaking, but are likely to be overestimates of actual fatality rates. This conclusion is supported by the fact that, as stated in the Final EIS, in 50 years of moving radioactive and hazardous materials, DOE and its predecessor agencies have not incurred a single fatality.

8. <u>The Existing Long-Term Performance Assessment is not Adequate to Support the In-Place Closure of the Waste Tank Farm or any Other Facilities</u>

The Final EIS includes an analysis that attempts to quantify and present the impacts from the in-place closure of all major facilities on the site. Much of the discussion in this “View” presents NYSERDA’s concerns with that long-term, in-place closure analysis. As discussed above, NYSERDA believes that the Final EIS long-term performance assessment for the in-place closure alternative is seriously flawed and scientifically indefensible. As such, the Final EIS long-term performance assessment should not be used to support a decision to close the Waste Tank Farm, or any other facilities, in place.

In response to public comments received on the Draft EIS, DOE has stated that they will seek public input prior to a Phase 2 decision regardless of the exact NEPA process utilized. NYSERDA also believes that before a decision is made to close the Waste Tank Farm in place, DOE should prepare and make available for public and agency comment, an EIS with a revised and scientifically defensible long-term performance assessment that would fully analyze, identify and disclose the impacts from this alternative.

NYSERDA’s Quantitative Risk Assessment for the State-Licensed Disposal Area

NYSERDA’s preferred alternative for the SDA is to manage the facility in place for up to 10 more years while we complete needed scientific studies and collect data to make an informed decision on the future of the SDA. At the end of the 10-year period (also referred to as “Phase 1” of the preferred alternative), NYSERDA, with input from the public and stakeholders, will make a decision to either continue active management of the site (under a State-issued permit and license), close-in-place or exhume part or all of the disposal area.

For implementation of Phase 1 of the preferred alternative, NYSERDA is required under the State Environmental Quality Review Act (SEQR) to identify and mitigate potential environmental impacts from that action. Through early discussions with DOE regarding the content of the EIS, NYSERDA learned that the EIS would not include a quantitative analysis of impacts from the in-place management of the SDA for the next several decades. To meet its requirements under SEQR, NYSERDA tasked Dr. B. John Garrick to provide the analysis needed to assess NYSERDA's preferred alternative for the SDA. Dr. Garrick, who is the current Chairperson of the U.S. Nuclear Waste Technical Review Board, and a former President of the Society for Risk Analysis, recommended that the SDA short-term analysis consist of a quantitative risk assessment (QRA).

The Quantitative Risk Assessment for the State-Licensed Disposal Area (QRA 2008) evaluates the risk from continued operation of the SDA for the next 30 years with its current physical and administrative controls. With the current change to the time period between Phase 1 and Phase 2 decisions (10 years versus 30 years) as identified in the Final EIS, NYSERDA determined that a 30-year analysis for the SDA would be bounding and conservative. The scope of this risk assessment is limited to quantification of the radiation dose received by a member of the public, represented by two potential receptors - a permanent resident farmer located near the confluence of Buttermilk Creek and Cattaraugus Creek, and a transient recreational hiker / hunter who traverses areas along Buttermilk Creek and the lower reaches of Frank's Creek.

The study evaluates potential releases of liquid, solid, and gaseous radioactive materials from the 14 waste disposal trenches at the SDA site. It examines a broad spectrum of potential natural and human-caused conditions that may directly cause or contribute to these releases.

The QRA includes detailed models for the mobilization, transport, distribution, dilution, and deposition of released radioactive materials throughout the environment surrounding the SDA site, including the integrated watershed formed by Erdman Brook, Frank's Creek and Buttermilk Creek.

Appendix P of this Draft EIS contains a summary of the QRA for the SDA, and the supporting models, data, and analyses for the QRA are available as a separate document from NYSERDA[7].

The Composition of the Independent Expert Review Team

NYSERDA selected a distinguished group of nationally and internationally recognized scientists and engineers to conduct an independent review of the Draft EIS for the West Valley Demonstration Project and the Western New York Nuclear Service Center. The basis of their selection was to select individuals who have distinguished themselves in the disciplines believed important to the scope of the review. The disciplines included on the IERT are geology, erosion, groundwater hydrology, nuclear science and engineering, health physics, risk assessment, and environmental science and engineering.

Dr. B. John Garrick, Chairman, U.S. Nuclear Waste Technical Review Board and an independent consultant in the nuclear and risk sciences, was named as the initial member and chairman of the Independent Expert Review Team. Dr. Garrick assisted NYSERDA in selecting the review team, and he had the responsibility for integrating the reviews and leading the preparation of the team's report. The full membership and their affiliations are listed below.

James T. Bell, Ph.D., Retired, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Sean J. Bennett, Ph.D., Professor, State University of New York at Buffalo. Buffalo, New York

Robert H. Fakundiny, Ph.D., New York State Geologist Emeritus, Rensselaer, New York

[7] The complete QRA report is available on the internet at http://www.nyserda.org/publications/sdaquantitativeriskassessment.pdf. Paper copies can be requested from NYSERDA at END@nyserda.org, or by calling Elaine DeGiglio at (716) 942-9960, extension 2423.

B. John Garrick, PhD., Chairman, U.S. Nuclear Waste Technical Review Board, Laguna Beach, California

Shlomo P. Neuman, Ph.D., Regents' Professor, University of Arizona, Tucson, Arizona

Frank L. Parker, Ph.D., Distinguished Professor, Vanderbilt University, Nashville, Tennessee

Michael T. Ryan, Ph.D., Principal, Michael T. Ryan Associates, Lexington, South Carolina

Peter N. Swift, Ph.D., Yucca Mountain Lead Laboratory Chief Scientist, Sandia National Laboratory, Albuquerque, New Mexico

Chris G. Whipple, Ph.D., Principal, ENVIRON International Corporation, Emeryville, California

Michael P. Wilson, Ph.D., Professor, State University of New York at Fredonia, Fredonia, New York

As a follow-up to their comprehensive review of the Draft EIS, a smaller team of experts (IERT subteam) reviewed critical chapters and appendices in the Final EIS. The purpose of this review was to identify substantive changes to the EIS (from the draft that was published in 2008), and assess the implications of these changes to the defensibility and outcome of the analyses. Members of the subteam included Drs. Bennett, Fakundiny, Garrick, Neuman, Ryan and Whipple.

References

Cashwell, J. W., et al., 1986, *Transportation Impacts of the Commercial Radioactive Waste Management Program*, SAND85-2715, Sandia National Laboratories, Albuquerque, N.M.

DOE (U.S. Department of Energy), 2002, *A Resource Handbook on DOE Transportation Risk Assessment*, DOE/EM/NTP/HB-01. DOE Transportation Risk Assessment Working Group Technical Subcommittee, July.

U.S. Department of Transportation, 1997, *Accident/Incident Bulletin No. 165*, Federal Railroad Administration, Washington, D.C., Aug.

IERT, 2008, *Independent Review of the Draft Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center*, Independent Expert Review Team, September 23, 2008.

PRG, 2006, *Peer Review of Draft Environmental Impact Statement for Decommissioning and/or Long-Term Stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center*, Peer Review Group, April 25, 2006.

QRA, 2008, *Quantitative Risk Assessment for the State-Licensed Disposal Area*, QRA Team, September 25, 2008.

Saricks and Tompkins, 1999, State-Level Accident Rates for Surface Freight Transportation: A Reexamination, ANL/ESD/TM-150, Center for Transportation Research, Argonne National Laboratory, U.S. Department of Energy, Argonne, Illinois, April 1999.

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ACRONYMS, ABBREVIATIONS, AND CONVERSION CHARTS

ACRONYMS, ABBREVIATIONS, AND CONVERSION CHARTS

A&PC	Analytical and Process Chemistry
ALARA	as low as is reasonably achievable
BCG	Biota Concentration Guide
CDDL	Construction and Demolition Debris Landfill
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CMS	Corrective Measures Study
dBA	decibels A-weighted
DCGL	Derived Concentration Guideline Limits
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	Environmental Assessment
ECL	Environmental Conservation Law
EDE	effective dose equivalent
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EPRI/SOG	Electric Power Research Institute/Seismic Owners Group
FHWA	Federal Highway Administration
FONSI	Finding of No Significant Impact
FR	*Federal Register*
FTE	full-time equivalent
GTCC	Greater-Than-Class C waste
HDPE	high density polyethylene
HEPA	high-efficiency particulate air
HIC	high-integrity container
LCF	latent cancer fatality
LLW	low-level radioactive waste
LSA	Lag Storage Area
M&M	monitoring and maintenance
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	maximum contaminant level
MEI	maximally exposed individual
MLLW	mixed low-level radioactive waste
MMI	Modified Mercalli Intensity
NAAQS	National Ambient Air Quality Standards
NDA	NRC-licensed Disposal Area
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutant

NFA	no further action required
NFS	Nuclear Fuel Services, Inc.
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
NYCRR	New York Code of Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDOL	New York State Department of Labor
NYSERDA	New York State Energy Research and Development Authority
PCB	polychlorinated biphenyl
PGA	peak horizontal ground acceleration
PM	particulate matter
PMF	probable maximum flood
PSD	Prevention of Significant Deterioration
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RFI	RCRA Facility Investigation
RH	remote-handled
ROD	Record of Decision
ROI	Region of Influence
SDA	State-Licensed Disposal Area
SEQR	State Environmental Quality Review Act
SPDES	State Pollutant Discharge Elimination System
STS	Supernatant Treatment System
SWMU	Solid Waste Management Unit
TAGM	Technical Assistance and Guidance Memorandum
TEDE	total effective dose equivalent
TRU	transuranic
TSCA	Toxic Substances Control Act
U.S.C.	United States Code
VRM	Visual Resource Management
WIPP	Waste Isolation Pilot Plant
WMA	Waste Management Area
WNYNSC	Western New York Nuclear Service Center
WVDP	West Valley Demonstration Project
WVNSCO	West Valley Nuclear Services Company, Inc.
ºC	degrees Centigrade
ºF	degrees Fahrenheit

CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Hectares	2.471	Acres	Acres	0.40469	Hectares
Concentration					
Kilograms/square meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/square meter
Milligrams/liter	1 [a]	Parts/million	Parts/million	1 [a]	Milligrams/liter
Micrograms/liter	1 [a]	Parts/billion	Parts/billion	1 [a]	Micrograms/liter
Micrograms/cubic meter	1 [a]	Parts/trillion	Parts/trillion	1 [a]	Micrograms/cubic meter
Density					
Grams/cubic centimeter	62.428	Pounds/cubic feet	Pounds/cubic feet	0.016018	Grams/cubic centimeter
Grams/cubic meter	0.0000624	Pounds/cubic feet	Pounds/cubic feet	16,025.6	Grams/cubic meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F - 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cubic meters/second	2118.9	Cubic feet/minute	Cubic feet/minute	0.00047195	Cubic meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor
exa-	E	1,000,000,000,000,000,000 = 10^{18}
peta-	P	1,000,000,000,000,000 = 10^{15}
tera-	T	1,000,000,000,000 = 10^{12}
giga-	G	1,000,000,000 = 10^{9}
mega-	M	1,000,000 = 10^{6}
kilo-	k	1,000 = 10^{3}
deca-	D	10 = 10^{1}
deci-	d	0.1 = 10^{-1}
centi-	c	0.01 = 10^{-2}
milli-	m	0.001 = 10^{-3}
micro-	μ	0.000 001 = 10^{-6}
nano-	n	0.000 000 001 = 10^{-9}
pico-	p	0.000 000 000 001 = 10^{-12}