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*

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Preface

This peer review of the *Draft Environmental Impact Statement for Decommissioning and/of Long-Term Stewardship at the West Valley Demonstration Project and Western News York Nuclear Service Center* (DEIS) was managed by the New York State Energy Research and Development Authority (NYSERDA), with support from the U.S. Department of Energy.

The peer review began in late October 2005 and was largely completed by the time the results were presented orally on February 23, 2006. A site tour and kickoff meeting were held November 7-8. The Peer Review Group (PRG) thanks Paul Bembia, who served as NYSERDA's project manager for organizing and managing the review. Given the relatively short time available for the review and the lack of familiarity with the site and facility on the part of four of the five PRG members, Paul's assistance was instrumental in getting us off to a fast start and in providing us with documents and answers to questions throughout the review. We also thank Paul Piciulo, Colleen Gerwitz, and Hal Brodie of NYSERDA, Dan Sullivan and Robert Warther of DOE, and Vernon Ichimura, a consultant to NYSERDA, for their helpful participation in meetings and on conference calls.

Shortly before the peer review began, the USNRC's Advisory Committee on Nuclear Waste held a meeting at West Valley to hear about and discuss aspects of the DEIS. Documents from this meeting were made available to the PRG. In addition, during the period while the peer review was being prepared, the PRG was invited to listen in on several USNRC-DOE conference calls regarding aspects of the performance assessment.

During the review of the Draft EIS and DEIS Appendices, a number of questions arose about how the analyses were done. These questions were compiled and sent to the primary author of the performance assessment (PA), Joseph Price of SAIC, with copies to NYSERDA and DOE personnel. A meeting was held to discuss the questions and the details of the performance assessment on December 19-20 at the SAIC offices in Germantown, MD. James Hammelman, John Eichner, and Sandra Doty of SAIC also participated in this productive meeting.

The PRG met again on February 23 in Buffalo. At this meeting, the PRG's tentative findings were presented orally. The meeting was to provide the various parties an opportunity to get a sense of the major technical aspects of the review and to identify errors or misinterpretations that could be corrected by the March 10, 2006 due date of the draft peer review report. Aside from the three meetings described here, the PRG communicated by emails and conference calls.

In March 2006, the PRG received comments on the March 10 draft report from NYSERDA and from DOE. We also received copies of comments on the DEIS from NYSERDA, the New York Department of Environmental Conservation, the USEPA and the USNRC. These comments, particularly those that addressed the Draft Peer Review Report, were considered in the revision of the Draft Peer Review Report into this Final Report.

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Introduction

The Peer Review Group (PRG) was charged with reviewing the radiological performance assessment being conducted as part of a Draft Environmental Impact Statement (DEIS) to assess decommissioning and/or long-term stewardship at the West Valley Demonstration Project and Western New York Nuclear Service Center. This report is a review of the Draft EIS dated September 15, 2005. During the course of the review, we learned that some work on aspects of the analysis is still evolving. While we note some instances where that is apparently the case, our task is to review the September 15 Draft EIS as written.

The analysis that we reviewed is unusual in comparison to many risk assessments by the need to consider and model how erosion, due mainly to creek downcutting and migration, might affect the evolution of the site landscape into the future. This is not a mature area of science, and while a model designed for such purposes was used, the ability of the model to predict landscape evolution is not well established or accepted. In comparison to the other aspects of the analysis, methods for predicting how erosion would affect the site are limited at best, being prone to large uncertainties that are difficult to quantify and which have not been articulated in the DEIS. Our comments below concerning erosion should be considered with this fundamental limitation in mind.

The Draft EIS includes five alternatives: under Alternative 1 all waste at the site would be removed to offsite disposal locations; Alternative 5 is the no action alternative; and Alternatives 2, 3, and 4 involve scenarios under which some wastes would be removed and other wastes left on site. These alternatives also involve various sorts of barriers to protect the waste disposed of on site. None of the alternatives is identified as the preferred alternative.

The DEIS that we reviewed was a draft that is still undergoing change and is not publicly available at this time. It indicates that to prepare the EIS for public distribution, the U.S. Department of Energy (DOE) and New York State Energy Research and Development Authority (NYSERDA) will determine whether additional analyses are needed to support the decision-making process and to select a preferred alternative. In addition, the cooperating regulatory agencies must determine if additional analyses are required to support their determinations of compliance. Finally, New York State Department of Environmental Conservation will evaluate aspects of the RCRA Corrective Measures Study, and DOE will revise the Draft in response to inputs from the cooperating agencies.

Summary of Findings

- The PRG is pleased to observe that the DEIS has estimated peak dose rates and their times of occurrence even if the peak occurred after 1,000 years, consistent with US NRC guidance.

- A significant effort was made to estimate the residual radionuclide inventories of the waste tanks. A combination of analyses, measurements and calculations were used for what the PRG views as a difficult and challenging task. It is important to recognize that the range between the “best” and “worst” case estimates is relatively large – ranging from a factor of 1.6 up to 6 for all 18 radionuclides, and that this range was not included in the uncertainty analyses of the DEIS.

- For Alternative 1, the total effective dose equivalents (TEDE) for workers in different labor categories were based on commercial construction cost estimating information and exposure data available through Department of Energy reports. Site-specific data were used when available; however such data were quite limited. The generic data for exposures to workers across the DOE complex was not filtered based on the similarity of facilities or operations to those proposed for Alternative 1.

- The assumptions made under “conditions expected to occur” are in our view highly unlikely to be fulfilled. The DEIS expects institutional controls to be successfully maintained into the indefinite future such that all engineered barriers and erosion control structures would be kept fully functional, contamination would be monitored and remediated as needed, and access to the site would successfully be prevented. While predicted doses under these conditions are low, this is due in part to receptors being located at least several miles from the site and the assumption that engineered barrier systems remain unaffected by erosion or other disrupting processes. In addition, dose predictions are based in part on calculations of contaminant transport by groundwater that, for reasons summarized below, the PRG considers to be neither reliable nor conservative.

- Conditions under which institutional control of the site would be lost, allowing access to the site and loss of functionality of the engineered barrier systems, are “not expected to occur” in the DEIS. The PRG considers it to be highly likely (and therefore expected) that institutional control of the site would be lost sometime during the first few hundred years of the initial 1,000 year regulatory period, allowing uncontrolled access to the site and gradual failure of the engineered barrier system due to erosion and other disruptive processes.

- Dose calculations are provided for the well driller and home constructor for each waste area. Doses rate estimates are also provided for a resident farmer who uses contaminated groundwater, and whose garden contains contaminated soil. These calculations assume that various engineered barriers continue to offer protection against some types of direct contact. However, the dose rates from the use of groundwater at the SDA or NDA exceed the license termination limits for Alternatives 2 through 5. The dose rate from the remainder of the Process Building exceeds the limits for Alternatives 3 through 5.

- For the case where erosion exposes waste, the nearest receptors are assumed to be an onsite hiker and a Buttermilk Creek resident farmer. The farmer is at some distance from the SDA and NDA. The rationale given for not choosing a closer location for this case is that erosion would create steep slopes unsuitable for home construction and farming. This ignores the possibility that such residency might be possible under less severe erosion scenarios, as is the case today according to photographic documentation provided to us by NYSERDA (2006).

- Analyses related to performance assessment are not described fully and clearly in the DEIS and are sometimes contradictory, hence the analyses were often difficult for members of the PRG to understand without further information and clarification. Assumptions, modeling procedures and parameters are not presented in sufficient detail to allow independent assessment of the results.

- The DEIS performance assessment is largely deterministic, including only a partial analysis of uncertainties done to support some deterministic groundwater flow and transport analyses *a posteriori*. The PRG believes that uncertainties of many kinds loom large at this complex site and merit a comprehensive analysis. The PRG is of the opinion that uncertainties must play a primary role in PA. We especially urge the authors of the DEIS to account in a comprehensive manner for uncertainties related to (1) conceptualization and mathematical representations of erosional processes, groundwater flow and contaminant transport; (2) uncertainties in model parameters and forcing terms (initial and boundary conditions, source terms); (3) uncertainties arising from measurements and data processing; and (4) scenario uncertainties. Whereas the DEIS accounts in a cursory manner for uncertainties in selected model parameters, it neither articulates nor quantifies uncertainties due to other factors, which the PRG considers to be potentially of equal or even greater significance.

- In the opinion of the PRG, the science behind landscape evolution models such as SIBERIA is not mature enough to justify relying on these models to provide long-term predictions of erosional processes and rates in glaciated terrains of the northeastern United States. In our view, a less sophisticated but more credible alternative would be to judiciously extrapolate observed short and long-term patterns and rates of erosion at the site and the surrounding region into the future, considering such patterns and rates recorded in similar terrains elsewhere, and quantifying the associated predictive uncertainties (which we expect to be very large).

- As presented in the DEIS, SIBERIA does not consider commonly accepted erosion processes such as knickpoint (gully cutting) migration. SIBERIA has predicted future landscapes for the site that the PRG considers unrealistic and hence not credible. The PRG notes that it might be possible to produce more realistic future landscapes with SIBERIA by (a) modifying the grid, parameters and inputs of the model and (b) calibrating it against geologic and geomorphic indicators of erosion in the past 10,000 – 15,000 years. Though this could improve the model's predictive capability, its reliability as a predictor would still remain highly uncertain. This is due in part to the principle of equifinality according to which varied conceptual models, parameters, initial conditions and forcing terms might produce final landscapes that are statistically similar to the current one. Aside from the use of low/medium/high values for some parameters, no attempt has been made to quantify the uncertainty in SIBERIA predictions quoted in the DEIS.

- Deterministic dose predictions associated with erosion scenarios are categorized in the DEIS as representing "favorable," "best estimate" or "unfavorable" cases. It is not clear to us what renders these cases favorable, best estimate or unfavorable; it appears to us that a more apt description of these cases would be conservative, nominal and non-conservative. Whereas the DEIS considers presenting three sets of cases to constitute an analysis of uncertainty, the PRG views it at best as a deterministic sensitivity analysis. The latter cannot substitute for a comprehensive uncertainty analysis of the kind we proposed earlier.

- Scenarios that consider groundwater flow and contaminant transport under "conditions expected to occur" ignore erosion, and scenarios that consider erosion under "conditions not expected to occur" ignore groundwater flow and contaminant transport. If and when institutional controls eventually fail, then erosion would start gradually impacting groundwater flow and contaminant transport, a case the PRG considers important and highly likely. The analysis of the exposures due to ground water flow and transport with erosion is not included among any of the scenarios presently analyzed.

- The analysis of existing groundwater flow conditions at the site in Appendix E is unreliable, ignoring basic principles of groundwater balance and hydraulics. The analysis is neither realistic nor conservative, failing to represent adequately spatial variations and uncertainties in key hydrogeologic parameters, most notably the overall hydraulic conductivity and advective porosity of the ULT. The underlying premise that current groundwater flow conditions would remain unchanged in the indefinite future ignores the potential influence on these conditions of site alterations due to closure activities, future climate changes, erosional processes and human activities at and around the site.

- For purposes of performance assessment (PA), groundwater flow is quantified in Appendix G using one-dimensional flow tubes that are quite arbitrary and fail to capture adequately the full three-dimensional nature of subsurface flow conditions at the site. In particular, the flow tube network model is not capable of accounting for potential leakage into and out of waste enclosures through fractured ULT under slurry walls, convergent flow to French drains and active wells, and lateral as well as vertical flow around disposal holes and trenches within the ULT. Flow rates in the ULT are ignored unjustifiably on the North Plateau and most likely underestimated on the South Plateau, disregarding (a) the potential impact of fractures, pods and lenses of relatively coarse material, collapsed boreholes at the SDA, and steel piles prone to corrosion under the Process Building on the effective permeability of the ULT and (b) elevated vertical hydraulic gradients under deep disposal holes at the NDA.

- The flow tube network model of groundwater flow in Appendix G is by its very nature difficult to reconcile with actual or expected groundwater flow conditions at the site. In particular, the model is not amenable to proper calibration against existing water level data and does not represent adequately temporal variations in present and future hydrologic conditions at the site. This leads to an inherent inconsistency between the PA in Appendix G and groundwater flow analyses in Appendix E.

- In the opinion of the PRG, groundwater flow analyses in the EIS should be conducted using state-of-the-art numerical models that conserve water balance and allow the representation of key spatial and temporal aspects of current and anticipated groundwater flow conditions realistically, consistent with all relevant site data. Such models, if reasonably but not excessively detailed, can be at once realistic and computationally efficient in a way that renders them suitable for either deterministic or stochastic analysis of transient three-dimensional groundwater flow at each plateau. The argument that one-dimensional flow tube network models have been traditionally employed by the US DOE for environmental assessments at other radioactive waste sites, and that they have been accepted as valid by regulatory agencies such as the US NRC, is in our view not relevant to the unique and complex conditions at and around the WVDP.

- Contaminant releases from buried wastes to groundwater, and contaminant transport by groundwater, depend critically on the underlying representation of groundwater flow. As this flow is not represented accurately in the DEIS, the PRG sees no basis for confidence in long-term DEIS predictions of contaminant concentrations and doses presented under “conditions expected to occur.” This is especially true considering that the DEIS does not recognize the possibility of vertical migration and dispersion of contaminants from the shallow saturated zone to the unsaturated zone and the soil surface. We consider this to be a likely contaminant transport mechanism due to the following facts: (a) the water table fluctuates seasonally by several feet at each plateau; (b) the water table is in places quite shallow; and so (c) contaminants at and below the water table could come into contact with shallow soils, appear in shallow excavations, be taken up by plant roots or seep vertically to the surface.

- The authors of the DEIS expressed to us orally their opinion that the groundwater flow and contaminant transport modeling approach they had adopted in the DEIS is adequate for a comparative PA of the various site decommissioning alternatives. We respectfully disagree for the following two reasons:
    a. The PA is intended to provide a credible analysis of actual rather than just relative long-term environmental impacts that may be expected upon selection of any of the planned alternatives. Considering our opinion that the PA models used in the DEIS are not reliable, we do not have confidence in their ability to provide a credible prediction of actual long-term impacts.
    b. We likewise see no reason to have confidence that PA models, which we consider to be unreliable, would provide a credible basis for a comparative analysis of such impacts among the various alternatives.

- For the above reasons, the PRG questions the suitability of the DEIS to serve as a basis for an informed selection of a preferred site closure or decommissioning alternative. Considering our skepticism about the manner in which erosion, groundwater flow and contaminant transport were accounted for in the DEIS, we cannot be sure that contaminant concentrations and doses predicted on the basis of these analyses in the performance assessment are either reliable or conservative. As such, these doses and concentrations cannot, in our view, reliably be used to decide whether or not the various decommissioning alternatives would meet the dose limits of the License Termination Rule, or to rank the alternatives on the basis of predicted concentrations and doses. Whereas the DEIS emphasizes so-called “conditions expected to occur,” we believe that for purposes of selecting a suitable alternative the emphasis should be on long-term performance assessment under what the DEIS considers “conditions not expected to occur.” Whereas the DEIS emphasizes the results of deterministic performance assessment, we believe that the emphasis should be on a comprehensive assessment of uncertain environmental impacts of at least Alternatives 2 – 4.

<u>Overview of the DEIS and Performance Assessment</u>

Sources and Source Areas

Because the site is described in various project documents including the Draft EIS, it will not be described here in much detail. However, among site features relevant to performance assessment (PA) is the presence of five principal source areas, three on the North Plateau and two on the South Plateau.

The principal sources on the North Plateau are the waste tanks, the waste lagoons, and the former process building. There are four underground waste tanks that were used to store the liquid effluents from spent fuel reprocessing. The wastes from these tanks have been retrieved and vitrified, but some residual activity remains. There are five waste lagoons in the low-level waste treatment area; of these, lagoon 1 is inactive and lagoons 2-5 are operational. Among them, almost all of the activity is in lagoon 1. The process building is where waste reprocessing occurred and where the vitrified high-level waste is stored awaiting shipment offsite for disposal. For purposes of defining the inventory of radioactive materials onsite, the process building is sometimes described in terms of above-ground and below-ground activity. In addition to these facilities, the North Plateau includes a groundwater plume containing mainly strontium. It also includes the cesium prong, an area of surface soil contamination that extends to the northwest from the process building stack.

The South Plateau includes two waste disposal areas, the NRC-licensed Disposal Area (NDA) and the State-licensed Disposal Area (SDA). The NDA disposal area measures about 400 by 600 feet, and contains solid wastes from reprocessing in disposal pits and trenches. The SDA operated as a commercial low-level waste disposal facility from 1963 to 1975, and accepted approximate 68,000 cubic meters of waste. These wastes reside primarily in disposal trenches. Although the SDA disposal areas are now covered by a geotextile membrane to prevent infiltration, a considerable amount of leachate has collected in the disposal holes and trenches. The SDA disposal area is roughly three times that of the NDA.

Table 1 lists the estimated inventory of activity in the above waste areas that was used as the basis for the PA. It is based on residual inventory reports made available to the PRG via the West Valley Electronic Library System, and matches the quantities reported in Appendix C.

The purpose of this table is to provide a perspective on the relative amounts of inventory in each source area. However, while it is instructive to obtain an overall sense of what activity exists at the site and where, the PRG is aware that activity is not a surrogate for the risk posed by such materials. Instead, the risk depends on additional factors such as the mobility of specific radionuclides, the exposure scenarios considered, etc.

As noted, Table 1 identifies an area of surface soil on the north plateau known as the cesium prong. While the DEIS or inventory reports do not provide an estimate of total activity in the cesium prong, we note that only under the most stringent cleanup alternative (Alternative 1) is sampling and removal of hotspots proposed. Under Alternatives 2 through 5, the DEIS indicates that institutional controls would allow for the decay of the cesium prong. Section 3.3.2 of the DEIS indicates that about 61,000 cubic meters of soil would need to be removed to meet a 25 mrem per year dose limit. The criterion for this dose rate for Cs-137 in surface soil is 10.9 pCi per gram; Chapter 3 reports that the highest concentration measured in the cesium prong was 44 pCi per gram. This suggests that there is between one and four curies of cesium in the soil that exceeds the concentration limit. This calculation, coupled with the fact that the plan for the cesium prong under Alternatives 2 through 5 is to allow for decay, and with the relatively low dose rates reported in Tables 4-37 and 4-38 and in Table H-51, implies that the amount of activity in the cesium prong is not great.

Table 1. Current and Future* Activity by Waste Area

Source Area	Present Activity, Ci	Future Activity, Ci*
North Plateau		
WM-1 Process Building	11,548	1,024
Process Building below grade	7,021	564
WM-2 Lagoons	1,029	29
WM-3 Tanks	382,519	744
Plume	~ 100**	
Cesium Prong	Not reported	
South Plateau		
NDA	114,736	4,209
SDA	129,206	29,179
Total	~ 640,000	~ 35,000

* We estimated the future activity by subtracting the activity from Cs-137, Sr-90 (half-lives about 30 years), U-232 (half-life 72 years) and other short-lived radionuclides, and by converting the activity from the 14.4 year half-life Pu-241 into the amount of Am-241 it will decay into. The future activity is roughly that which will be produced by the present inventory several hundred years from now.
**Based on a PowerPoint presentation prepared by SAIC titled *West Valley EIS Multi-Agency Review Summary of Human Health Impacts for Onsite Receptors*, November 17, 2005.

Estimation of Radionuclides in Waste Tanks

The design of the waste tanks is described in the Closure Engineering Report for Alternative 1 (WSMS-WV-05-0001, September 2005). These tanks will not be described here. The focus of this discussion is the estimation of the residual radionuclide contents of the waste tanks. This task is very complex and provides a number of challenges. There were several approaches taken in order to provide the best possible estimates of the radionuclides present and their total activities. The approaches taken are outlined in some detail in the data collection and analysis plan (Fazio, 2001). Additional information was presented in a supplemental report issued in February 2005 (no citation or identification number available). This latter document was intended to consolidate the previous three radionuclide inventory reports into a single document (these three documents were not reviewed). The report states that estimates are provided in three categories; best estimate, conservative estimate, and worst estimate. It is the intent that the “conservative case” be used for demonstrating compliance with the NRC’s final policy statement on cleanup criteria for the WVDP.

In this analysis only 18 radionuclides were considered to be important in estimating the residual radionuclide inventories in the waste tanks. These were selected from a list of 30 radionuclides identified in the draft environmental impact statement prepared in

1996. The original scoping studies conducted by SAIC evaluated a total of 71 radionuclides.

Three types of measurements were made in this effort; grab samples, radiation measurements, and burnishing samples. However, not all measurement methods were used in all the tanks. Grab samples were collected in waste tanks and other systems from July 1986 through July 2003. These samples were used more to characterize the mobile inventory in the tanks, establish the residual (fixed) inventories, and to provide scaling factors.

Samples of high-level waste transferred from Tank 8D-2 to the concentrator feed makeup tank (CFMT) were also used to establish radionuclide inventories. Data from the six CFMT samples presented in tabular form show clearly that the dominant radionuclides are Cs-137 and Sr-90. In addition, vitrification analytical samples were used to establish the both mobile and non-mobile inventories in all the waste tanks. In reporting these concentration estimates (in μCi/g), it is curious that daughter radionuclides are not included in the tables. For example, in the tables reporting concentration estimates of radionuclides in the tank show data for Sr-90 but no data are given for the Y-90 daughter, even though it is almost certain that these two radionuclides would be in secular equilibrium.

Radiation measurements taken in the waste tanks were used to provide estimates of the residual radionuclide inventories using dose rate to activity modeling techniques. Two beta-gamma detection systems were used to measure the beta and gamma activities. These detectors were used in vertical scans down the interior of the tank wall. These detector systems are described elsewhere. These detector systems were described in the data collection and analysis plan (Fazio, 2001) as well as in the supplemental report mentioned above. Measurements were made inside Tanks 8D-1 and 8D-2 and outside of Tank 8D-4. The computer code MICROSHIELD was used in the dose rate-to-activity modeling. In addition, for Tank 8D-4, the Cs-137 estimates obtained using MICROSHIELD were compared with results obtained using a Monte Carlo code, MCNP-5.

For the combined beta/gamma measurements, the exposure rate was assumed to be proportional to the beta activity. Results obtained with a “gamma only” detector were found to be about three orders of magnitude below the combined beta/gamma results. Initially, it was established that there were 18 radionuclides of importance in the residual inventory. However, the dominant radionuclide was found to be Cs-137 and the assumption was made that the measured dose rates were due solely to this radionuclide. A dose rate-to-activity model was used to estimate the Cs-137 activity and the activities of the other 17 radionuclides were estimated using scaling factors. The methods used to scale the radionuclides were described in the supplemental report.

Physical samples were collected from the internal surfaces of Tank 8D-2 in an effort to obtain data for the fixed waste inventory. A burnishing sampler was used to collect samples of the internal wall. The area sampled was a 0.5-inch diameter circle and the average sample weight collected was about 0.5 grams. A total of 66 samples were collected; 35 samples before washing the interior surface of the tank and 31 samples after washing the tank. Some samples were eliminated from consideration through an analysis of beta activity concentration versus iron concentration in the sample. In all a total of 46 samples were considered "reliable." Of these, only 21 samples were obtained after Tank 8D-2 was washed.

Mobile and fixed radionuclide estimates are provided for each waste tank for the 18 radionuclides of interest. As stated above, these estimates were provided in three categories; best estimate, conservative estimate, and worst estimate. In addition, the Executive Summary provides a table of the total residual activities of the 18 radionuclides estimated to be in the waste tanks. For radionuclides with high activities (e.g., Cs-137 and Sr-90), the "best" estimates and "worse" estimates differ by a factor of two and, in some cases, range up to a factor of five.

It is clear that a significant effort has been devoted to establishing residual radionuclide inventories and that a combination of analyses, measurements and calculation were used to arrive at these estimates. This was a very difficult and challenging task. It is important to recognize that the range between the "best" and "worst" case estimates is relatively large – ranging from a factor of 1.6 up to 6 for all 18 radionuclides. Thus, these estimates should be used carefully because of these large uncertainties. Nevertheless, this review did not find any apparent weaknesses in the approaches taken – even though the documentation trail was very difficult to follow.

Summary of Alternatives Considered in the DEIS

The DEIS evaluates five decommissioning alternatives, described clearly in Table 2-2 and subsequent pages in the DEIS. Details of how each alternative would be implemented are given in corresponding Closure Engineering Reports. A brief description of each alternative follows.

- Alternative 1 (removal) involves the most extensive remediation activities among all five alternatives; it entails the virtual removal of all radionuclides so that the entire site would meet dose and chemical criteria for unrestricted use. In addition to removing major facilities (process building, tanks and vaults, lagoon sediments, SDA and NDA), this alternative also entails exhuming soils contaminated by the North Plateau groundwater plume, and sampling to determine where soil in the cesium prong should be removed.

- Alternative 2 (removal and decay) involves extensive remedial operations on the North Plateau with the goal of meeting license termination criteria for unrestricted use in that area of the site. Under this alternative, both above ground and below ground parts of the process building would be removed as would the underground tanks and associated process lines (the vaults would be left in place). Sediments and wastes from lagoons 1-3 would be removed, as would the contents of the construction and demolition debris landfill. Whereas the source area of the groundwater plume would be removed, the remainder would be allowed to decay assuming a 200 year institutional control period. No action would be taken regarding the cesium prong. On the South Plateau, "The NDA and SDA would be managed under geomembrane covers for approximately 100 years (Year 15 to Year 115). Geomembrane covers, erosion control, monitoring equipment, and security equipment would be installed at the NDA and SDA during the first 2 years. Engineered multi-layer covers would be installed in-place of the geomembrane covers in Years 115 and 116." The use of slurry walls and French drains on the South Plateau is described in the Alternative 2 Closure Engineering Report. Institutional control on the South Plateau is assumed to extend indefinitely.

- Alternative 3 (prompt in-place closure) is intended to meet license termination criteria for restricted use on the North Plateau. The closure would include an engineered barrier system to control releases from the tanks and the below-ground portion of the process building, which would also provide containment for the source area of the groundwater plume. The above-ground portion of the process building would be demolished and the high-level waste canisters stored in a new facility onsite until a repository became available. Wastes from lagoons 1-3 would be exhumed. The SDA and NDA would be protected by the installation of French drains and through the use of grout injection, followed by the installation of engineered multilayer cover systems. Monitoring wells would be installed and erosion control structures constructed. Institutional control on the South Plateau is assumed to extend indefinitely.

- Alternative 4 (delayed in-place closure) is similar to Alternative 3 in that its goal is to meet conditions consistent with restricted use on the North Plateau, but the demolition of the above-ground portions and engineered containment of the below-ground portions of the process building would be delayed until the high-level waste is shipped offsite. On the South Plateau, the SDA and NDA would remain under regulatory control and slurry walls and French drains would be installed. Unlike Alternative 3, a geomembrane cover would be used for these areas instead of grout injection or an engineered multilayer cover. Monitoring wells would be installed and erosion control structures constructed. Institutional control on the South Plateau is assumed to extend indefinitely.

- Alternative 5 (no action alternative) is included for comparison as required by NEPA, but the DEIS makes clear that this alternative is not a *bona fide* decommissioning plan but rather a plan for continued site monitoring and maintenance. Under this alternative, no portion of the Project Premises or the Western New York Nuclear Service Center would be released for use. The effect of facility failures over time is evaluated; it is assumed that when such failures occur, action would be taken to mitigate them. Institutional control on the South Plateau is assumed to extend indefinitely.

To summarize the main features of Alternatives 1 through 4: We note that under Alternative 1, the entire site would be remediated to meet criteria for unrestricted use and all significant radiological sources would be removed from the site. Under Alternative 2, the North Plateau would be cleaned up to meet unrestricted release criteria and the principal radiological sources on the North Plateau would be removed or managed through decay. Under Alternatives 3 and 4 the North Plateau would be engineered to meet restricted release criteria through the installation of a barrier system to isolate the tanks and below-ground portions of the process building; the main differences between Alternatives 3 and 4 are the time at which the process building would be demolished and the isolation of the groundwater plume source under Alternative 3. Under Alternatives 2, 3, and 4, the South Plateau would be engineered to isolate wastes on site, remaining under institutional control and management for an indefinite time period. Slurry walls and French drains would be installed, as would erosion control structures. While cover designs for the SDA and NDA differ in some details, the overall closure schemes of the South Plateau in Alternatives 2 – 4 are similar; in all three cases, the ultimate disposition of the South Plateau is deferred to the indefinite future. Alternative 5 would essentially defer the decommissioning decision; maintenance and monitoring of the site would continue and institutional controls would preclude access to the site.

Scenarios

The term scenario is used in the DEIS to describe the combination of features, events and processes that can lead to an exposure to hazardous materials. A scenario typically includes the specification of a source, a set of assumptions about the manner in which contaminants might be released and come into contact with potential receptors, the location and characteristics of the receptors such as duration and mode of their exposure to contaminants and, for off-site receptors, an analysis of contaminant transport from the source to the receptors.

In Section 4.1.5, the exposure scenarios pertaining to Alternative 1 are described separately from those pertaining to Alternatives 2 - 5 because under the former the entire site would be cleaned up to levels meeting the criteria for unrestricted use. Under Alternative 2, the North Plateau also would be cleaned up to unrestricted use levels but some wastes would be stabilized in place. Under Alternatives 3 and 4, it would be cleaned up only to levels permitting restricted use of the North Plateau. Under Alternatives 2 - 4, the South Plateau (and under Alternative 5 also the North Plateau) would be engineered to isolate wastes on site, remaining under institutional control for an indefinite time period.

- Alternative 1 scenarios, DCGLs and analysis

For Alternative 1, radionuclide-specific derived concentration guidelines (DCGLs) are derived to define concentrations that would produce an annual dose of 25 mrem, the criterion in 10 CFR 20.1402 for unrestricted release. Tables 4-19 and 4-20 (as well as Tables H-17 and H-18) list DCGLs for the residential agriculture and recreational hiker scenarios. As described on page 4-36 (and on page H-16), a sum-of-the-fractions rule is used to account for exposures to a mixture of radionuclides. No dose or risk estimates are provided for Alternative 1, presumably because the site would be remediated to conditions consistent with a 25 mrem per year dose rate.

The intent to survey the full site, including areas outside the West Valley Demonstration Project boundary, as part of the closure process is indicated by the comment on page 156 of the Closure Engineering Report for Alternative 1: “After the source(s) of contamination are removed, a MARSSIM Final Status Survey would be performed to verify that residual radioactivity levels do not exceed the established DCGLs.” MARSSIM is typically used to design sampling plans for surface contamination. Subsurface contamination at the defined facilities such as the tanks, process building, SDA, NDA, etc, would be excavated. With the exception of the North Plateau groundwater plume, the conceptual model behind the DEIS assumes that little waste has moved from any of the source areas, so that exhuming the principal source areas would be sufficient to render the site suitable for unrestricted release. The extent to which this assumption is supported by monitoring data is not clear. In addition, Alternative 1 calls for removing the source of the groundwater plume. The approach would be to remove soils and groundwater from areas of high concentration down to predetermined thresholds. The Alternative 1 Closure Engineering Report indicates that under this alternative, the groundwater plume would be remediated based on EPA drinking water criteria for radionuclides, as specified in 40 CFR 141. The CER indicates that the 4 mrem per year dose limit in the regulations translates into a concentration limit of 42 pCi/L for Sr-90, which apparently assumes that no other radionuclides are present. However, it indicates that a 10 pCi/L limit for gross beta would be the criterion actually applied.

PRG Assessment of DCGL Estimation for Alternative 1

DCGL estimation and treatment of uncertainty. The discussion of how the DCGLs were obtained to account for exposures from both contaminated soil and groundwater is unclear from the information provided in the DEIS. Specific bullets on the top of page H-8 address water-dependent and water-independent pathways in a way that is difficult to understand. The DCGLs refer to soil concentrations; the corresponding concentrations of radionuclides in groundwater are not reported. The DCGLs were derived using the RESRAD model in which both water-dependent and water-independent pathways had been included. The details of how this was done are difficult to extract from the DEIS.

Supplemental information regarding how the DCGLs were derived was provided to the PRG by SAIC and forms a partial basis for the following discussion. We note that such supplemental information does not constitute a revision of the DEIS but simply a clarification of analyses already described (though not clearly enough) in the document.

Our understanding is that, for locations at which contaminants are present in surface soil, the model derives a corresponding contaminant concentration in groundwater that would result from precipitation and recharge through the contaminated soil. RESRAD uses a simple equilibrium approach to relate soil and groundwater concentrations. Conversely, where there is contaminated groundwater but initially clean surface soil, the model calculates the buildup of radionuclides in surface soil that would result from use of groundwater for irrigation. In this case, where groundwater is the initial source of contamination, the drinking water dose rate to an individual is based on the groundwater concentration. All other water-dependent exposures, e.g., from consumption of crops irrigated with contaminated groundwater, are computed using RESRAD. Drinking water exposures are calculated separately from other water-dependent pathways because RESRAD does not handle well situations in which groundwater and surface soil concentrations are not in equilibrium.

In addition to not providing a clear description of how the DCGLs were derived, the DEIS fails to (a) discuss the limitations that RESRAD places on these derivations and (b) to quantify the associated uncertainties.

- Alternatives 2 - 5 under "conditions expected to occur"

For Alternatives 2 – 5 which assume perpetual institutional control of the South Plateau, the assumed controls would preclude scenarios such as an on-site resident farmer. Four receptors are considered under "conditions expected to occur": a resident farmer located at Cattaraugus Creek – Edies Road/Mill Street; residents of the Seneca Nation Indian Reservation; and users of municipal water systems drawing water at Sturgeon Point near Derby, NY, and from the Niagara River. All of these locations are outside the Western New York Nuclear Service Center boundary. The closest location considered, Cattaraugus Creek – Edies Road/Mill Street, is about 2 ½ miles from the northern boundary of the WVDP. It is roughly 20 miles to the Seneca Nation and 30 miles to the Lake Erie water users. Only one set of deterministic results is reported for "conditions expected to occur" under Alternatives 2 - 5. In contrast and as described below three sets of "favorable," "best estimate" and "unfavorable" deterministic results are provided for "conditions not expected to occur" under these alternatives.

The reason for not placing receptors on or near the North Plateau under Alternative 2 is not clear to us. Under this alternative, the North Plateau is to be remediated to levels appropriate for unrestricted use. It is in our view inconsistent to exclude receptors from a site that has been released for unrestricted use.

Under "conditions expected to occur," the estimated doses are quite low for all receptors under Alternatives 2 - 4. For the Cattaraugus Creek receptor, the estimated dose rate under all four alternatives is 0.15 mrem per year, due almost entirely to releases from the SDA through groundwater flow to Frank's Creek and Buttermilk Creek. Drinking creek water and fish consumption are the primary pathways. Under Alternative 5, the estimated dose rate is 1.3 mrem per year, due mainly to the high level of contamination in waste tanks. Unlike the 20,000+ year time to peak dose for Alternatives 2 - 4, the peak dose under Alternative 5 occurs at about 300 years. The finding that the peak dose is due to releases from the SDA is consistent with the estimated future inventory in Table 1.

The doses calculated for receptors at the Seneca Nation Reservation are similar to but slightly higher than those for the Cattaraugus Creek receptor. Although the distance to the Seneca Nation receptor is larger than to the Cattaraugus Creek receptor, the rate of fish consumption assumed for the Seneca Nation receptor is significantly higher than that for the Cattaraugus Creek receptor. The fish consumption estimates used in the DEIS correspond to the 95th percentile upper estimates in the EPA Exposure Factors Handbook. As with the Cattaraugus Creek farmer, the estimated doses to the Seneca Nation receptors are due mainly to releases from the SDA under Alternatives 2 - 4 and to the waste tanks under Alternative 5.

As one might anticipate, the estimated individual dose rates to distant water users are very low. At Sturgeon Point, the estimated dose rate is 0.041 mrem per year for Alternatives 2 - 4; for Alternative 5 the estimate is 0.42 mrem per year. For Niagara River water users the estimates are lower than for Sturgeon Point water users by almost a factor of 300. As is appropriate for a situation in which individual dose rates are very low but a large number of people may be exposed, the assessment also reports the estimated population dose for the water user scenarios. An estimated peak annual population dose for Lake Erie water users of about 16 person-rem per year is estimated to occur roughly 20,000 years into the future under Alternatives 2 - 4. Under Alternative 5, the peak population dose rate is estimated to be 170 person-rem per year 200 years into the future. The DEIS also reports the estimated population dose to Lake Erie water users integrated over 10,000 years. This apparently refers to the first 10,000 years, even though the peak population doses are estimated to occur about 20,000 years into the future under Alternatives 2 - 4. The integrated population doses are in the 12,000-13,000 person-rem range for Alternatives 2 - 4 and about 100,000 person-rem for Alternative 5.

Table H-16 notes that the assumed fish consumption rate for Lake Erie water users is very low – 0.1 kg per year – in contrast to the assumed rate for Cattaraugus Creek and Seneca Nation residents, which are 9 and 63 kg per year, respectively. A footnote to this table explains that “The 0.1-kilogram per year is based on a five-year average New York fish yield from Lake Erie (102,000 kilograms) distributed over the population that uses the water.” For the population dose calculation, it is appropriate to consider the total amount of fish taken from the lake. However, it appears that this value was also used for the individual dose rate calculation. While the dose estimates for Cattaraugus Creek and the Seneca nation receptors are based on the 95th upper percentile of the consumption distribution, the estimates for individual doses to Lake Erie water users are not comparable. This technical comment does not bring into question the finding that dose rates to individuals who drink water from Lake Erie sources are very low.

PRG Assessment of Scenarios and Receptors Considered for Alternatives 2 - 5 under "Conditions Expected to Occur"

Long-term effectiveness of institutional controls: The terminology used to describe the future scenarios is considered by the PRG to be misleading. One specific concern is with the use of the term "conditions expected to occur." As used in the DEIS, "conditions expected to occur" assume that institutional controls would prevent people from living or even hiking on the site at any time in the future, and would ensure that erosional forces remain in check. Given that estimated peak doses for Alternatives 2 - 4 occur over 22,000 years into to future under "conditions expected to occur," the assumption that access to the site is avoided and erosion controls remain effective over this long period does not appear credible to us. Even if the period of concern is limited to the 1,000 year regulatory time frame, it would in our view not be reasonable to assume that institutional controls remain effective for this long. In the opinion of the PRG, long term dose rates predicted under this scenario form a questionable basis for a decision about which among the five alternatives to select.

Our opinion is reinforced by the assumption in the Closure Engineering Reports that the following activities would be required to maintain erosion control, monitor and remedy site contamination, and prevent access to the site:

a) 25 percent of erosion control structures would require repairs every 25 years.
b) 25 percent of erosion control structures would be replaced every 25 years.
c) Each groundwater monitoring well and piezometer would be replaced every 25 years.
d) Each stream sampler would be replaced every 25 years.
e) French drains at both WMA 7 and WMA 8 would need to be repaired every 25 years.
f) Security systems, including fencing, would require complete replacement every 35 years.
g) All engineered closure structures and environmental monitoring installations would be continuously inspected and repaired as needed.
h) Monitoring wells and piezometers would be periodically subjected to hydraulic testing.
i) Groundwater and surface water would be continuously monitored and sampled.
j) Annual reports would be prepared providing data summaries and trends, highlight data points above regulatory or site-specific action levels, conclusions, and recommendations for interim action, if appropriate. Site conditions and the need for remedial action would be reviewed once every 5 years.
k) One security officer would be performing on-site inspections 2 hours a day, 5 days a week.

In the opinion of the PRG, there is little reason to assume that such activities could be carried out indefinitely at the site.

The US Nuclear Regulatory Commission's License Termination Rule (LTR) discusses institutional controls but does not specify a duration over which they may be relied upon. The LTR does anticipate that such controls could fail and provides dose limits for the unanticipated failure of such controls. However, the LTR does not discuss whether the failure of such controls over time periods extending for 1,000 or 22,000 years into the future can be described as unanticipated. The specific dose requirements of the LTR are:

> Briefly stated, for unrestricted release, the LTR specifies a dose criterion of 25 mrem/yr total effective dose equivalent (TEDE) to the average member of the critical group plus as low as reasonably achievable (ALARA) considerations (10 CFR 20.1402). For restricted release, the LTR specifies an individual dose criterion of 25 mrem/year TEDE plus ALARA considerations using legally enforceable institutional controls established after a public participatory process (10 CFR 20.1403). Even if institutional controls fail, individual doses should not exceed 100 mrem/yr TEDE . If it is demonstrated that the 100 mrem/yr TEDE criterion in the event of failure of institutional controls is technically not achievable or prohibitively expensive, the individual dose criterion in the event of failure of institutional controls may be as high as 500 mrem/yr TEDE.

Though the future duration of institutional controls is uncertain, at least two committees of the National Academy of Sciences have addressed the issue (National Research Council 2000, 2003). The same issue has also been considered in great detail in connection with the DOE-operated, EPA-licensed Waste Isolation Pilot Plant. It is fair to characterize the results of these three activities as supporting the PRG view that institutional controls may be not be relied upon for more than a few hundred years.

- Alternatives 2 - 5 scenarios under "conditions not expected to occur"

The analyses for "conditions not expected to occur" are divided into the analysis of erosion impacts and the groundwater analysis. We address the erosion analysis first.

As discussed on page 4-45, three conditions not expected to occur are analyzed: (1) loss of institutional control leading to an unmitigated erosion scenario, (2) loss of institutional control leading to a loss of active control measures at the site and intruders onto Buttermilk Creek, and (3) loss of institutional controls leading to intruders on the North and South Plateau. These assumed conditions do not affect Alternative 1 because all significant waste sources would have been removed before the loss of control under this alternative.

The risks from unmitigated erosion are calculated for a recreational hiker, to a resident farmer along Buttermilk Creek, and to the offsite receptors considered under "conditions expected to occur," that is, a resident farmer near Cattaraugus Creek, members of the Seneca Nation, and Lake Erie water users. The analysis is described in three places: Chapter 4 Section 4.1.5.2; Appendix D and in particular Table D-4; and Appendix H

Sections H.1.2.2 and H.2.2.2. The onsite residential receptor is further described by three situations: home construction, well-drilling, and a residential lifestyle.

Unlike the single exposure estimates provided for each of the various receptors under “conditions expected to occur,” estimates under “conditions not expected to occur” are categorized as being “favorable,” “best estimate” and “unfavorable.” This categorization is related to assumptions about which erosion processes would take place at what rates.

Estimated peak annual dose rates to a recreational hiker under each of the three categories and four remediation alternatives at the four major waste management areas are listed in Table H-40. We find it interesting that the dose estimates are identical for the NDA and SDA in each case. This suggests that differences in engineered barrier systems at the South Plateau between the alternatives lose significance once institutional controls are lost.

Under Alternative 2, wastes from the North Plateau would be removed or, in the case of the groundwater plume, managed to allow for decay. For Alternatives 3 and 5 (Prompt In-place Closure and No Action, respectively) the Process Building is the dominant source in the favorable and best estimate cases (73 mrem per year after 9,230 years and 91 mrem per year after 4,100 years, respectively). The estimated peak dose rate under these alternatives in the unfavorable case is 270 mrem per year at 650 years. The DEIS (page H-64) indicates that the Process Building produces the largest estimated doses for Alternatives 3 and 5 due to plutonium isotopes in the rubble piles. Under Alternative 4 (Delayed In-place Closure), the Process Building contribution is estimated to be lower at 9.3, 12, and 34 mrem per year in the three cases. In no case and under no alternative does the estimated peak annual dose from erosion processes affecting the waste tanks exceed 10 mrem.

Estimated doses to a residential farmer near Buttermilk Creek, reported in Table H-41, are similar to those for a recreational hiker. Peak annual doses under the four alternatives are almost identical. The estimates are 30-31 mrem per year after about 3,000 years in the favorable case, 100 mrem per year after about 1,000 years in the best estimate case, and 4,500 mrem per year after 125 years in the unfavorable case.

Under the “conditions not expected to occur” scenario, dose analyses are also performed for waste management area intruders. These analyses include dose rate estimates for a well driller, home constructor, and resident farmer who uses contaminated soil and who uses contaminated groundwater. These cases do not consider the effect of erosion.

PRG Assessment of Scenarios and Receptors Considered for Alternatives 2 - 5 Under “Conditions Not Expected to Occur”

Description of key assumptions: The exposure assumptions behind the hiker scenario are not described in detail, other than identifying pathways in Table D-4 and providing exposure time and duration in Table H-14. In Table H-14 exposure frequency is 365 days a year, exposure duration is 30 years and assumed hiking velocity is 1.6 km per hour (1 mile per hour). There is no explanation of how the hiking velocity enters into the dose calculation nor are the exposure factors that typically determine exposures for such scenarios, e.g., incidental soil ingestion and surface water ingestion, given. The report does not indicate how many hours per day are spent hiking, without which it is not possible to interpret the significance of a 365 day per year exposure frequency. The numbers of hours per day would affect calculations of doses received externally, that is, from simply walking on soil that contains gamma emitting radionuclides. The assumption that exposure duration is 30 years does not affect the peak annual dose rate but does affect the calculation of lifetime risk. However, no estimates of lifetime risks to a recreational hiker are reported.

The finding that estimated peak dose rates from the SDA and NDA are identical under Alternatives 2 through 5 is reasonable in light of reliance on similar erosion control and engineered barrier systems in all four cases.

Residential farmer scenario for the erosion case: Curiously, for the erosion case, the risks estimated for a hiker are quite similar to those for a Buttermilk Creek resident. Depending on the alternative considered, the peak dose rate to a hiker ranges from 60 to 100 mrem per year under Alternatives 2 - 5 (Table 4-30) while the peak dose rate to the Buttermilk Creek resident farmer is estimated to be 100 mrem per year under each of these alternatives (Table 4-31). In the experience of the PRG, it is unusual to obtain similar exposures for a hiker and a residential farmer because the farmer’s production of locally grown food would typically lead to significantly higher dose and risk estimates than would be obtained under a recreational use scenario. A section of Appendix D (on page D-12) titled “Receptors inside the Current Western New York Nuclear Service Center Boundary” helps to explain this result:

> Each of the three types of individual receptors may be located onsite on the North Plateau or along Buttermilk Creek, but location and activities are constrained by topography, groundwater availability, and waste form location. In particular, direct intrusion into buried waste is assumed not to occur in the erosion case, because exposure of the waste involves development of steep slopes and concentrated flow as the area moves within the rim of a creek. These conditions are less favorable to utilization than settling of nearby areas outside of the creek channel. For erosion scenarios, intrusion involves a hiker walking along the contaminated creek bank and coming into direct contact with waste for a limited period of time.

The presumption that the eroded slope is too steep for a resident farmer to build and farm onsite may be reasonable for the situation in which erosion has disrupted the engineered barriers and exposed the waste.

Waste management area intruders: The situation in which a well driller, home constructor, or resident farmer is located on a waste area prior to it being affected by an eroding creek is covered by the calculations for the intruders onto waste management areas. These results are interesting in several respects. First, it is assumed that the SDA and NDA would have thick caps under Alternatives 2 and 3 but not Alternatives 4 and 5. The results for Alternatives 4 and 5 indicate that absent such caps, doses to workers or to a resident farmer using contaminated soil or groundwater would be far above what the USNRC requirements would allow. For the Alternatives 2 and 3, the doses to workers would be slightly above the 25 mrem per year decommissioning criterion, and groundwater doses to a resident farmer would approach 1,000 mrem per year.

On the North Plateau, the dose rate to a resident farmer from the groundwater plume is reported to be 220 mrem per year after 100 years. This result suggests that more than 200 years is needed for the plume to decay to levels that would not cause groundwater use from the plume area to exceed dose limits.

The estimated dose rates from the Process Building and waste tanks are above the dose limit for Alternatives 3 through 5. The text observes, in reference to the estimated dose rate of 1,340 mrem per year to a worker intruder from the Process Building under Alternatives 3 and 4 “While this dose is considered high, it is within limits for trained radiation workers.” We do not understand why dose limits for radiation workers are relevant to a well driller or home constructor. Also, the dose rate to a resident farmer whose garden contains contaminated soil is also well above the closure criteria.

In short, if the waste management area intruder scenarios are judged to be credible, then only Alternative 1 meets the dose criteria for the full site. Alternative 2 would allow the dose criteria to be achieved for the North Plateau, provided institutional controls prevent the use of groundwater from the plume for several hundred years. Under all of the other combinations, that is, Alternatives 3 through 5 for the North Plateau and Alternatives 2 through 5 for the South Plateau, the dose rates would exceed regulatory limits.

Impact of erosion on groundwater flow and contaminant transport: The scenarios under “conditions not expected to occur” consider separately intruder and erosion scenarios. Under both scenarios, receptors come in direct contact with the waste form or contaminated surface water, but not with contaminated soil or groundwater affected by erosion. More generally, scenarios that consider groundwater flow and contaminant transport under “conditions expected to occur” ignore erosion, and scenarios that consider erosion under “conditions not expected to occur” ignore groundwater flow and contaminant transport.

If and when institutional controls eventually fail, then erosion would start gradually impacting groundwater flow and contaminant transport, a case the PRG considers important and highly likely which however is not included among any of the scenarios presently analyzed.

Evaluation of peak dose rates after the LTR regulatory period: The USNRC license termination rule (LTR) (Federal Register, Vol. 67, No. 22, February 1, 2002, pages 5003-5012) is based on and consistent with the requirements of Subpart E of 10 CFR 20. These decommissioning requirements take the form of dose limits applicable to the total effective dose equivalent (TEDE) to the average member of a critical group within 1,000 years after decommissioning. In the discussion of comments received on the NRC draft policy statement concerning the LTR, the NRC notes:

> In the development of the LTR, the Commission considered comments seeking a time period for dose analysis longer than 1000 years. Section F.7 in the LTR ‘‘Statement of Considerations,’’ 62 FR 39058 (July 21, 1997). The Commission concluded that for the types of facilities and source terms considered, it was reasonable to use a 1000-year period. However, the West Valley site presents some unique challenges in that significant quantities of mobile, long-lived radionuclides are present on site. Because under NEPA an evaluation of reasonably foreseeable impacts is required, the Commission believes that an analysis of impacts beyond 1000 years should be provided in the DOE/NYSERDA EIS. Thus, information will need to be evaluated to determine if peak doses might occur after 1000 years and to define dose consequences and impacts on potential long-term management of residual radioactivity at the site. Depending upon the outcome of the EIS review, the Commission may need to consider the need for environmental mitigation.

The PRG is pleased to observe that the DEIS has estimated peak dose rates and their times of occurrence even if the peak occurred after 1,000 years, consistent with this NRC guideline.

<u>Sensitivity and Uncertainty Analyses</u>

In the main body of the DEIS, the results of the analyses are presented in tables showing the estimated peak dose rates and on graphs that display the estimated dose rates versus time for the various source facilities and exposure scenarios. These are given as point estimates rather than as ranges or distributions, and for “conditions not expected to occur” refer to “best estimates.” The DEIS performance assessment is largely deterministic, including only a partial analysis of uncertainties done to support some deterministic groundwater flow and transport analyses *a posteriori* (more on this later). All performance assessment results presented in the main body of the DEIS (primarily in Chapter 4), for example in tables of estimated peak dose rates and graphs of estimated dose rates versus time for various sources under diverse exposure scenarios, are strictly deterministic. Deterministic results presented under “conditions not expected to occur” include only “best estimates.” Only in Appendix H is a distinction made between these and "favorable" or "unfavorable" deterministic results (e.g. Table H-40) obtained by varying some model parameters about their nominal (“best estimate”) values in what the DEIS terms a “sensitivity analysis.” The last seven pages (H-81 through H-87) of Appendix H also include some results of an uncertainty analysis whose primary aim is to buttress probabilistically, *a posteriori*, the choice of some deterministic "best estimate" groundwater flow and transport parameters.

Tables H-52 through H-57 in Section H.3 of Appendix H provide a summary of the sensitivity of peak dose to the following factors:

- Hydraulic conductivity of the engineered cap for the Process Building;
- Hydraulic conductivity of the engineered cap for the SDA;
- Hydraulic conductivity of the slurry wall for the Process Building under Alternative 4;
- Hydraulic conductivity of the slurry wall for the NFS Hulls Area under Alternative 3; and
- Annual rate of precipitation.

The manner in which uncertainty analyses were performed and some of the results are described briefly in Section D.3.2.3 of Appendix D and in greater detail in Appendix G (Section G.3.5 and Figure G-19) and Appendix H (starting with Section H.3 and continuing to the end of the appendix). According to Appendix H, the approach to probabilistic analysis of parameter uncertainty involves:

- Listing of parameters appearing in the models,
- Screening of the list to identify sensitive parameters,
- Selection of sensitive parameters for representation as random variables,
- Development of frequency distributions for the random variables,
- Sampling of the frequency distributions to construct multiple sets of values of the random variables,
- Execution of the model to calculate a time series of dose for each set of values of the random variables,
- Calculation of dose averaged over the sets of values of the random sample (mean dose) for each year of time (time series of mean dose),
- Identification of the peak dose in the time series of mean dose, and
- Calculation of the frequency distribution of dose for the year of peak mean dose.

Tables H-58, H-59 and H-60 list variables whose values are varied at random during Monte Carlo analyses of conditions across the entire site, for the Process Building and for the SDA, respectively. Included among the variables are hydraulic conductivities of various geologic and boundary materials, distribution coefficients specific to various radionuclides, the drinking water intake rate and the fish consumption rate.

Tables H-61 and H-62 list median, mean, 95th percentile and maximum doses for the year of mean peak dose, as well as the corresponding year, for different numbers of Monte Carlo runs. Results based on 400 runs are presented graphically in Figure H-59 (showing how mean dose varies with time for an onsite receptor due to groundwater releases from the Process Building), Figure H-60 (displaying the corresponding cumulative frequency distribution of annual dose for the year of peak mean dose), and Figures H-61 and H-62 which provide analogous results for the SDA.

PRG Assessment of Sensitivity and Uncertainty Analyses

Sensitivity and uncertainty assessments: Results of parameter sensitivity and uncertainty analyses are presented only for a few selected cases among those considered in the DEIS. The PRG believes that uncertainties of many kinds loom large at this complex site and merit to be accounted for in a much more comprehensive manner than has been done in the DEIS. Presently, sensitivity and uncertainty analyses play at best a supportive role in the DEIS, which emphasizes a nominal ("best estimate") set of deterministic results. We think that sensitivity and uncertainty analyses should be the primary focus of performance assessment. We note in passing that the term "best estimate," as used in the DEIS, is misleading in that it does not represent a best estimate in the usual sense of the phrase (e.g. the mean of a distribution or some other optimum). Instead, it represents a nominal case considered to be conservative by the authors and we therefore propose referring to it as the "nominal case."

The few probabilistic analyses conducted in the DEIS clearly illustrate the importance of accounting more thoroughly for the effect of uncertainties on performance assessment. To provide an example, we summarize in Table 2 the last two lines of Table H-62 which clearly demonstrates the large uncertainty in estimated annual dose for the year of peak mean dose, and the futility of attempting to capture this uncertainty by means of a single deterministic outcome.

Table 2. Summary of Results in Table H-62 for 400 and 600 Realizations.
Units are peak dose rates in mrem per year.

	400 Realizations	600 Realizations
Median	0.01	0.01
Mean	214	403
95th Percentile	57	51
Maximum	81,640	224,400

As many fewer such analyses have been conducted than the number of deterministic outcomes presented in the DEIS, we feel that the authors are not justified in concluding that their deterministic outcomes are generally conservative based on a few instances in which this was found to be the case, as in the following example (Appendix H):

> The probabilistic analysis for the Process Building and the SDA with deterministic dose at the 70th and 99th percentiles and median doses that are small fractions of mean doses (Tables H–61 and H–62) supports the position that the deterministic calculations provide conservative estimates of dose.

We draw a different conclusion from the results indicated in Table 2. The mean dose estimate is evidently quite sensitive to rare realizations that produce extremely high dose rate estimates. The combination of parameter values that produce such results should be considered carefully to establish that they reflect unlikely but possible conditions, and to see if the estimate can be refined.

Number of Monte Carlo runs: Tables H-61 and H-62 clearly indicate that the maximum number of Monte Carlo runs conducted in the DEIS, 600, was not sufficient for key statistics of computed dose to stabilize; many more runs would evidently have been required for this to happen. Without such convergence, the results of uncertainty analyses in the DEIS cannot be fully trusted.

Sources of uncertainty and variability: The uncertainty analysis in the DEIS is limited to some aspects of groundwater flow and transport which is discussed in some detail later. Here we emphasize the need to account for conceptual model uncertainty and for uncertainties associated with contaminant inventory estimates at source locations. Variability and uncertainty in exposure factors other than water and fish consumption rates need to be considered. For example, it is common in risk assessments done to EPA guidance to consider uncertainties in the soil ingestion rate, which may be important where exposures to children may occur because children typically ingest more soil than do adults.

Transparency of uncertainty assessments: As mentioned above, the parameters that were included as variables in the Monte Carle analysis are listed in Tables H-58 through H-60. However, the ranges and functional forms of the probability distributions associated with these parameters and the sources of data on which these are based are not specified with the exception of hydraulic conductivities for some of the hydrogeologic units at the site.

Uncertainties in erosion predictions: The erosion analysis is included under "conditions not likely to occur" and further categorized as "favorable," “best estimate,” and “unfavorable." However, this categorization is strictly deterministic and no attempt is made in the DEIS to quantify statistically the uncertainty associated with the given predictions of erosional impacts. If this uncertainty is anything like that associated with groundwater flow and transport analyses, as discussed earlier and illustrated in Table 2, one may expect the probability distributions of erosional impacts to be highly skewed. As Table 2 illustrates, even a 95th percentile estimate may be significantly below the mean. Hence if the “best estimate” refers to a mean or a median value as is customary in estimation theory and practice, then it is equally important to provide additional information about the probability distribution of the dose estimation errors such as variance, skewness and/or quantiles. Whereas the report cites future dose rates that greatly exceed those specified in the LTR, it does not quantify or comment on their likelihood of occurrence.

In our understanding, the only difference between “favorable,” “best estimate” and “unfavorable” erosional impacts cited in the DEIS is in the choice of selected deterministic model parameters. Whereas the “best estimate” represents a nominal condition, the “favorable” and “unfavorable” cases represent non-conservative and conservative conditions, respectively. Considering that the science of predicting landscape evolution into the distant future is in its infancy (see below), it would be at least equally if not more important to consider several alternative conceptual models of landscape evolution and driving terms such as initial and boundary conditions, and quantify their predictive uncertainties relative to each other. This is discussed in greater detail below.

Erosion – Comments on Erosion Modeling in Appendix F

The DEIS attempts to model future landscape evolution of the WNYNSC throughout the next 10,000 years by employing the SIBERIA finite-difference model. The purpose of this modeling is to estimate where, when, and the extent to which facilities left in place or engineered at the site are altered or removed by erosion. The modeling relies to some degree on earlier studies and models that include past geology and engineering geology investigations, which may or may not be directly relevant to the SIBERIA modeling effort. Observed erosion rate estimates are discussed in Section F.2, but such estimates were apparently not the basis for erosion modeling. Erosion-rate-prediction models that are discussed in the DEIS include the Universal Soil Loss Equation (USLE), Sediment Distributed Model Treatment (SEDIMOT II), Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS), and the Water-Erosion Prediction Project (WEPP). What aspects of these modeling studies have been incorporated into the SIBERIA modeling effort is unclear. Confusion on this account is compounded by statements such as that on page F-4 of Appendix F:

> All of these measurements were collected before the current long-term erosion modeling effort was initiated and, therefore, were not designed as calibration measurements with quantifiable uncertainties. Thus, specific measurements reported in this section were not directly used in the modeling projections discussed in Section F.3, with the exception of the carbon-14 age-dating data.

Scientific Basis for Long-Term Predictions of Erosion

We offer below extensive comments about how the SIBERIA model was used in the DEIS, and how this modeling could be improved to produce a greater correspondence between past, current, and future landscape conditions at the site. These comments not withstanding, the PRG believes that the science behind landscape evolution models such as SIBERIA is not mature enough to justify relying on these models to provide long-term predictions of erosional processes and rates in glaciated terrains of the northeastern United States. The limits of SIBERIA are recognized by the developer of the code, Garry Willgoose, who states the following in his review summary (Willgoose, 2005, 443-459):

> Engineering applications require a guarantee that predicted geomorphic behavior in the future will follow from processes that the model is calibrated to. This requires quantitative testing of modeling predictions. The earth science community has not been good at model validation,

> mainly because testing requires an ability to (a) make predictions for case studies that are independent of where the model was developed/calibrated; (b) determine error bands on those predictions (and potentially on observed data), so that it is possible to objectively assert that an incorrect model should be rejected; and (c) repeat experiments. All three of these requirements are difficult to achieve … We are still some way from having a complete and comprehensive model of landform evolution … The science challenge is to identify under what conditions they do not work (by comparing with data) and addressing these deficiencies.

We believe that this is especially true for SIBERIA which does not model relevant processes (e.g. sheet and rill runoff) directly but through semi-empirical "effective" equations and parameters. These parameters cannot be measured directly but must be estimated indirectly through the calibration of SIBERIA against observed runoff and erosional data. SIBERIA does not compute stream downcutting, but rather requires a uniform stream downcutting rate as an input. It represents all soils and geology as a single uniform material. Though SIBERIA may handle non-uniform runoff, only uniform runoff was considered in the DEIS.

In our view, extrapolation based on qualitative geomorphologic analysis of the topography and geology and their past evolution, and currently estimated rates of erosion, would likely provide a more defensible prediction of future landscape evolution than is presently possible with SIBERIA. However, the associated uncertainty may be so large as to suggest that any alternative that leaves significant quantities of waste in place could lead to doses that exceed those of the LTR.

Prediction of Landscape Generated by Siberia

Some of the landscape predictions generated using SIBERIA in the DEIS are unrealistic, compounding our lack of confidence in these predictions:

1. A striking feature of the SIBERIA predictions in Figures F-14, 15, 20, 21, 22, 23, 25 is that stream channel headcuts (most upstream points) appear to be frozen in time instead of retreating gradually upstream (headward).

2. Another striking feature, evidently related to the first, is that ravines and gullies are gradually obliterated rather than forming and retreating in a similar manner. In reality, gullies at the site are known to have retreated headward at rates of 0.4 – 0.7 meter per year (Table F-4).

   It may be relevant to note that of 15 gullies studied by Vandekerckhove et al in southeast Spain (*Catena*, 50, 329-352, 2003), 12 have been retreating at rates ranging from 0.07 to 0.86 meter per year (Table 2). The authors note that higher gully-head retreat rates are obtained at the medium-term time scale (5 – 50 years) compared with the short-term scale (1 – 5 years) but the differences are not significant. They found medium-term volumetric gully-head retreat rate to be a power of the drainage-basin area, with an exponent that increases from the short-term, over the medium-term to the long-term (more than 50 years) time scales, expressing the increasing importance of drainage-basin area in gully development with time. The authors explain that increasing the time scale implies (a) a decreased variability in measured erosion rates as the effects of tension cracking and spatially variable rainfall intensities average out at a longer term; and (b) an increased contribution of extreme rainfall events whereby the role of drainage basin in the erosion process becomes more pronounced, as runoff is produced from the entire catchment and transmission losses are much lower than at low intensity events.

A problem with the Vandekerckhove and others (2003) paper on the analysis of gully-headcut retreat rates is that they find a power function that relates the headcut retreat rate to the size of the drainage basin, but do not discuss or refute other studies that find a relation between headcut retreat and the length of the "ordered" streams. Gully headcut retreat rates appear to be different for different side creeks (2nd, 3rd, etc. orders) to Buttermilk Creek and to Buttermilk Creek (a 1st or 2nd order creek, depending on whether we count Cattaraugus Creek as part of the ordering sequence), itself. Whatever the power function is for the relations of headcut gully migration to either area of subdrainage basins or of creek length, these relations must be measured and included in the modeling process for the Buttermilk watershed.

We propose that it might have been more appropriate, and conservative, to adopt such measurements and empirical relations in the long-term PA than to rely on counter-intuitive predictions of unknown reliability obtained with SIBERIA. However, we expect the resultant uncertainty to be high.

3. Yet another striking feature of the SIBERIA results, evidently related to the above, is that they do not include any cases of stream or gully capture by headward retreat and only one ambiguous example of valley capture by another via sideway widening of the latter (Figure F-26). Various tables give gully-headcut migration rates that imply stream capture of Frank's Creek by a gully heading southwest off of Buttermilk Creek within a century or so.

Another characteristic of the SIBERIA predictions is that landscapes appear to become smoother as topographic elevation contrasts increase with channel downcutting, rather than becoming rougher as is generally observed in areas of active channel incision (for illustration see Figures 10 and 14 in Hancock and Willgoose, 2004 and Figure 3 in Willgoose, 2005). The use of erosion by sheet and rill flow in the hillslope mode of SIBERIA leads to a final sculpted landscape that looks as if it were produced by equal shaving of the topography at each node, much like peeling an onion. The 10,000 year prediction results in rolling, convex-upward knolls with few remaining incised gullies. This is contrary to all of the erosion features produced within the last 15,000 years in the

Buttermilk Creek watershed and all of the other watersheds of central and western New York State.

Potential Artifacts of Siberia Application in DEIS

We suspect that these counter-intuitive SIBERIA predictions may in part be artifacts of how the code has been applied in the DEIS. The artifacts may stem from the following modes of application:

1. As applied in the DEIS, the code never switches from hillslope to channel mode (only the reverse, line 866, page F-43) in mid-run. We suspect that this effectively eliminates the possibility of channels extending beyond their initial headcuts and of new branches or channels/gullies developing with time (we note that according to page 466 in Hancock and Willgoose, 2004, high rainfall catchments have been found experimentally to develop small gullies or incisions at random positions dictated by concentrated flow and weakness in the erodible material). Weakness in the erodible material is in part related to the geographic positioning of systematic joints and irregular cracks. These are the empirically observed controlling factors in the erosion patterns in Buttermilk Creek drainage basin.

2. It would be useful to check whether or not the diffusion coefficient adopted in the DEIS applications, which is based on landslide data (lines 881-889, page F-44), might be too high and thus artificially smooth out (obliterate) incipient channels and/or gullies (as illustrated in Figure 18 of Hancock et al., 2002). We believe that the gully headcutting migration rate is a function of the knickpoint migration process. Knickpoint migration is a function of creek flow, erodability of the material type on the bottom of the creek, stratigraphy in the gully walls and bottom, amount of material and grain sizes being supplied by the creek from the sides, land-use practices, among possibly many other factors, whereas, the gully-rim widening rate is a function of slope stability and the ability for the creek flow to remove slumped material at the base of the slope. The concept that a 21-degree valley wall slope represents a stable slope, as presented on page F-9, and thus, can be considered a relation between downcutting and gully-rim widening is illogical. All downcutting and gully-rim widening is occurring where the gully walls are not stable, and probably have greater than 21° slope.

3. The grid cell sizes of 50’ by 50’ adopted in the DEIS are too large to accommodate small-scale features such as incipient gullies and ravines. Indeed, the authors have demonstrated to us that by employing a finer grid of 4’ by 4’, such features are represented more accurately. In fact, the authors have observed (bottom of page F-36) that smaller grid sizes are required when dependence of fluvial sediment transport on discharge becomes strongly nonlinear. We also note that according to Hancock and Willgoose (2004. page 467) SIBERIA is able to predict small gully development where the initial surface

roughness is sufficiently representative of small-scale spatial heterogeneity, which is not presently the case in the DEIS.

Calibration of Siberia

It is seen that, as used in the DEIS, SIBERIA has predicted future landscapes for the site that the PRG considers unrealistic and hence not credible. The PRG notes that it might be possible to produce more realistic future landscapes by (a) modifying the grid, parameters and inputs of the model and (b) calibrating it against geologic and geomorphic indicators of erosion in the past 10,000 – 15,000 years. Although this could improve the model's predictive capability, its reliability as a predictor would still remain highly uncertain. This is due in part to the principle of equifinality (e.g. Beven, 1993, Beven and Freer, 2001) according to which multiple sets of conceptual models, parameters, initial conditions and forcing terms might produce final landscapes that are statistically similar to the current one.

Little has been done to quantify the uncertainty in SIBERIA predictions quoted in the DEIS. Three of the SIBERIA model parameters have been estimated by regression against predictions generated using WEPP, which in turn has been calibrated against short-term site data. Other SIBERIA parameters have been assigned in what appears to be an arbitrary manner. We see little basis for confidence in these parameters considering the following:

1. The DEIS provides no information (such as error estimates and/or confidence intervals) about the uncertainty of the WEPP parameter estimates. How unique and accurate are the WEPP parameter estimates considering their large potential range, as stated at the bottom of page F-38 and the cited tables? Could other sets of WEPP parameters have produced equally good matches with measurements? If so, what is the range of possible WEPP predictions associated with such alternative parameter sets?

2. The DEIS provides no information (such as error estimates and/or confidence intervals) about the uncertainty of SIBERIA parameter estimates obtained by regression against short-term WEPP predictions. How unique and accurate are SIBERIA model settings (e.g. nodal switches from hillslope to channel mode) and parameters (those obtained by regression and those assigned)? Might other combinations of model settings and parameters have produced equally good matches with WEPP predictions? If so, what is the range of possible SIBERIA predictions associated with such alternative model setting and parameter sets, considering further a plausible range of future climatic conditions driving the model?

3. The five SIBERIA parameters β_1, β_3, O_t, m and n are said (line 810, page F-38) to depend in a complex manner on precipitation rate, soil properties and topography. If so, should they not be changing with time as the landscape evolves (topography changes) and climate varies (affecting precipitation rate and

soil properties)? If so, on what basis would such changes be introduced? If the parameters are kept constants, how does this affect the reliability of SIBERIA long-time predictions? What is the meaning of setting $O_1 = 1$ (line 851, page F-42)?

4. The DEIS does not explain how SIBERIA was calibrated “on an area-by-area average basis” so as to result in “local variability” (line 1007, page F-55).

5. The DEIS fails to include a check of how closely the calibrated SIBERIA model reproduces the WEPP predictions against which it has been calibrated.

Sensitivity Analysis of Siberia

In our view varying SIBERIA parameter estimates obtained by regression does not constitute a valid sensitivity analysis (page F-55). A proper sensitivity analysis would examine the manner in which SIBERIA predictions vary with each of its parameters.

Effect of Future Climate Changes

As stated elsewhere, the analysis does not consider the impact of potential future climate changes on erosion. We do not understand the rationale for ignoring such changes. In our view, future changes in climate could bring about, in a time frame of thousands to several hundred thousand years, (a) precipitation and flooding in excess of those considered in the conceptual design of erosion control structures, and their consequent inability to function as designed, and (b) precipitation, flooding and/or glaciation that might significantly alter the mechanisms and rates of erosion considered, and predicted, in the DEIS.

Conceptualization of Erosional Processes

The Overview section F.1 sets up the erosion study by placing emphasis on the north and south plateaus. We believe, rather, that the entire Buttermilk Creek drainage basin should have been considered in the modeling, if not neighboring drainage basins, such as the Connoisarauley drainage basin. Indeed, a study of the geomorphological development of the neighboring regions to the east and north reveal topography that has been little altered over the last 15,000 years, except for gully downcutting and gully-headcut retreat (migration), and may add insight to the local landscape study.

The introductory paragraph of Appendix F lists only four of the many processes that modify the topography at the WNYNSC, failing to include frost heave, wind erosion, and man-created earth excavations and surface modifications. Although these other processes are in effect at different levels of influence on the site’s topography, they should be included. The processes of “sheet erosion” and “rill erosion” are not defined nor described well, and thus, it is difficult to understand how their parameters can provide a reasonable weighting in the SIBERIA modeling. The process of sheet flow, as opposed to the beginning text book definition given within Appendix F, line 34, has more complexity and is a short-termed, infrequent erosion event. Sheet flow does not have to be a continuous film, nor does it have to flow over smooth surfaces. It is the result of such excess precipitation that rivulets can not contain the flow, and thus, the intervening ground is flooded. The effect of this process is most dramatically displayed on the bahada alluvial fans of the southwestern U.S. deserts. This style of topography is not present in the Buttermilk Creek watershed. Buttermilk Creek watershed displays a sub- to pro-glacial lake bottom with “hanging” beach lines around the basin at several elevations that reflect progressively earlier lake stands for higher beach terraces. This rather smooth topography was incised during and after the proglacial lakes declined by draining through outlet channels as retreating ice uncovered them. Gullies incised this topography along straight line segments that replicate the joint distribution of the exposed bedrock of the area, implying that erosion began as gullies incised along pre-existing joints within the Lavery Till. The relation of gully directions and joint patterns has been demonstrated in the studies performed at the West Valley Nuclear Service Center by the New York State Geological Survey in the 1970s and 1980s. The New York State Geological Survey noted that farming was the last land use at the WNYNSC prior to the installation of the reprocessing plant and burial trenches at the SDA and holes and trenches at the NDA. Thus, the soils on the north and south plateaus are primarily plowed ground and material that was disturbed by road building and drainage control among other agricultural practices. One of the gullies at the north end of the SDA was initiated by bulldozing to establish a farm road across Erdmans Brook.

Rill flow is described in Appendix F, line 34, as a series of small rivulets connecting one water-filled hollow with another on the rougher terrain. The very existence of water-filled hollows implies a “youthful” topography or relatively uneroded ground. Thus, neither sheet flow nor rill flow can be a significant, long-term erosion process in the Buttermilk Creek drainage basin. The second paragraph of the Overview adds stream valley-rim widening to the list of original four in the first paragraph. It should be noted that the final SIBERIA modeling describes gully-rim widening as being a more dominant erosion process than gully-head migration. We believe that both processes are related to a number of factors that include slope stability, base-level change, stream flow, land-use practices, sapping by groundwater flow, and erodability of the channel floor, among others.

The simple statement on page F-4, lines 41-50: “The three small streams (Erdman Brook, Quarry Creek, and Frank’s Creek), that drain the Project Premises and SDA are being eroded by the stream rim widening process…” adequately describes the erosion processes at the site. This is not consistent with running SIBERIA in hillslope mode, as done in the DEIS.

Paragraph 5 of the Overview, starting on line 51, lists gully advance (presumably gully-head cutting retreat or migration) as a third type of erosion, which it is not, but only one of the three phenomena that operate together: gully-bottom erosion, gully-head cutting migration (knickpoint migration), and gully-rim widening.

Nowhere in the modeling process is the stratigraphy of the exposed glacial deposits factored into the SIBERIA model. Through time, erosion will cut through glacial deposits of greatly differing engineering properties, especially erodibility. See the discussion below regarding how the stratigraphic differences between the north and south plateaus may affect erosion rates.

The SIBERIA model uses soil-property values derived from review of site conditions and published values for soils with equivalent soil textures, especially from USDA, 1995, and Meyer and Gee, 1999 (page F-38). The PRG assumes that "by review of site conditions" means the soil parameters measured by Albanese and others, 1984, or erosion-frame data, or sediment yield from stream water. Neither of the first two provide data that applies to the entire site; the second is found to be irrelevant as indicated on page F-4, even though discussion of these studies is given on page F-5; the third is fraught with problems, such as sampling techniques. The sources of these data are needed to determine whether they are relevant to the modeling process. Appendix F states that the SIBERIA model used the values of physical properties in the WEPP model, which were selected from surrogate data appropriate for soil types catalogued for the WNYNSC. Discussion is required as to how "appropriateness" of surrogate data was determined. The source of WEPP values for soil erodibility is not provided, especially the values presented in Table F-10 for interrill and rill erodibility. Also not clear is why the values for those two factors in Table F-10 have different dimensions. The SIBERIA model uses parameter values that may have been derived from SEDIMOT II analysis, WEPP model analyses, USLE, and CREAMS, some of which are short-term approaches while others are long-term approaches, and some use second-hand data from others. Moreover it is unclear which data sets from which modeling approaches are used in the final SIBERIA runs. Also unclear is whether the values for erodibility of both the interrill and rill parameters used disaggregated grain-size characteristics without regard for the cohesiveness of the soils and their in situ properties for withstanding erosion. That information which is given is provided on page F-15, where it is stated that "Soil erodibility values were based on standard U.S. Department of Agriculture (USDA) grain-size classifications of each soil unit, as defined in site-specific studies." Nothing is stated about their state of disaggregation. These issues need to be clarified and explained.

Any modeling of future erosion in Buttermilk Creek must include the same processes that operated during the last 15,000 years, that is an element of minor erosion on the plateau top surfaces, and substantial erosion concentrated within the stretches of incision and gully head cutting, with major supply of sediment from gully-wall creep, sapping, landsliding and collapse.

Regardless of the style of erosion at the WNYNSC, erosion of a similar nature and rate will occur at both the north and south plateaus, except for the variation resulting from the sand and gravel unit capping the north plateau. The upper sand and gravel unit does not have a counterpart on the south plateau near the SDA and NDA. The sand and gravel unit on the north plateau extends to the plateau edge, whereas, the south plateau has only the weathered Lavery Till away from bulldozed ground at and near the low-level waste burial trenches. Erosion of the sand and gravel unit on the north plateau might be more rapid than within the south plateau's weathered soil. The erosion of the sand and gravel unit would most likely release the groundwater flowing within it, and possibly quicken the erosion rate there. This positive-feedback mechanism, wherein erosion of an aquifer releases drainage that can quicken the erosion, should be factored into any erosion model.

It is in our view not sufficient to rely on published papers by Willgoose in which existing landscapes at other sites have been reproduced using SIBERIA, as suggested to us by the authors of the DEIS.

Base Level Changes and Knickpoint Migration (Gully-Head Cutting)

Appendix F does not consider the effect of base-level changes on the erosion rates within the Buttermilk Creek drainage basin. The current long-term base level is presumed to be the elevation of Lake Erie. Even Erie's base level is somewhat ephemeral, being related to the fate of Niagara Falls. As local and regional base levels change, mostly downward, the erosion rates of the gullies within Buttermilk Creek drainage basin will vary. Base level drop is equivalent to tectonic uplift upstream, which was not factored into the SIBERIA model for Buttermilk Creek in a modeling sense in the DEIS.

Erosion Frame Data

Sheet and rill erosion measurements from erosion frames at 23 locations along Erdman Brook, Frank's Creek, and Quarry Creek, are reported in the EID III, Part 3. These measurements were not used as calibration points in the modeling, and do not convincingly represent actual erosion rates. All locations were near or within the gullies and not from the plateau upper surfaces. The results of the original study indicate that the ground surface was closer to the frames for most sites during the winter. The interpretation that this puffing up of the land surface below the frames could be the result of ground freezing and consequent expansion is presented in the EID but appears to be ignored in the DEIS. The fact that hardly any soil transport, and consequently deposition, occurs in the dead of winter, makes this data set of questionable relevance to the DEIS.

The largest measured erosion rate over the 11-year study period was 4.6 feet per 1000 years, as mentioned in the text. This site is probably at station EF-17 on the eastern slope of Frank's Creek at a location that is less than 30 feet below the 15,000 year-old plateau surface. Several interpretations, some possibly erroneous, can be concluded: (1) the frame sites have only been eroding over the last 6,000-7,000 years, either because erosion rates were much different before this time, or that this was when a major knickpoint migrated through, (2) the frame study did not measure the true erosion/deposition rates, or (3) the frames were disturbed by some process, such as frost heave. We prefer to accept the third explanation. How SIBERIA (page F-36) uses the "first-order, explicit integration" scheme in the verification process to relate elevation change to sediment transport rates is not clear, and also unclear is whether these relations were consistent with the insights thought to be gained by the erosion-frame studies that are described on page F-5.

Consideration of Base-Level Changes in the Cattaraugus Creek Watershed

Gully deepening is ultimately controlled within the drainage basin by the base level of each creek segment. Base level (analogous to the parameters of SIBERIA for tectonic uplift or sinking) is not considered in the SIBERIA modeling presented in Appendix F. Long-term downcutting rates are presented in Appendix F as 20 ft/1,000 years on the basis of the C-14 age-dating study. This rate is supposedly used in the SIBERIA analysis and would require that the elevation of the confluence of Erdman's Brook with Buttermilk Creek be at least 200 ft lower than present, yet comparison of Figures F-24, where the confluence is given to be 1160 ft, and F-25, where the elevation of the confluence is not clear, but appears to be about 1140 ft, which would give a 10,000-year total downcutting of 20 ft! In contrast, comparison of Fig F-13 with F-15 reveals a total downcutting of the confluence of Frank's Creek and Erdman's Brook of 260 ft (1,300 ft - 1,040 ft). Reconciliation of long-term and short-term estimates, as well as discrepancies between the 10,000-year projections of erosion of individual sites must be clarified, especially in the context of base-level changes.

The first discussion of downcutting in F.2.2.1 revisits the work of LaFleur (LaFleur 1979), and Boothroyd, Timson, and Dana, (Boothroyd et al 1979) who calculated an average downcutting rate for Buttermilk Creek of 18 feet per 1,000 years. Downcutting is directly related to drops in base level. The base level for Buttermilk Creek is its confluence with Cattaraugus Creek, and its history is related to the downcutting of Cattaraugus Creek. The mouth of Buttermilk Creek is protected by a bedrock lip that would have influenced the downcutting rate of Buttermilk Creek once the stream eroded through the overlying glacial deposits. This stuttering of the downcutting rates and the possibility of more fluctuations as a result of stratigraphic changes in stream-bottom material is not considered in the SIBERIA model. The authors should inspect the landscape in the Connoisarauley drainage basin immediately to the west of Buttermilk basin where base level is controlled by a similar bedrock lip, which has yet to be eroded through.

The next consideration of rim widening relates the widening to a geometric relation of 21 degrees of slope for stable gully walls. The approach assumes that the gully slopes are stable, which they are not, or else erosion would cease. This concept ignores the situation that occurs in Quarry Creek where the gully bottom is cut on bedrock and the slopes are being eroded sideways along the contact. This process may be helped by sapping from groundwater emerging along the bedrock-glacial deposit contact within the reported soil or brecciated zone at the top of the bedrock subcropage This concept also ignores the estimated acceleration of soil removal at the base of Lavery Till slopes where meander loops impinge.

The downcutting rate provided by the longitudinal profile survey conducted by Dames and Moore (West Valley Nuclear Services Co., 1993) on a section of Frank’s Creek gives 200 feet/1,000 years, or 2,000 feet per 10,000 years, the time period covered in the modeling. These data have to be modified to include the fact that unless sea level drops considerably, 2,000 feet of incision is not possible. The Erdman Brook estimate of 2 feet/ 10 years provides the same answer. One possible alternative conclusion is that since base levels will most probably stabilize over the next 10,000 years, gully formation processes – deepening, gully-head migration, and rim widening – will slow.

Rim-Widening Estimates and Stream Capture

The rim-widening rate of 16 to 19 feet per year, or 190,000 feet (36 miles) per 10,000 years is not only unimaginable, but by our calculations would allow Buttermilk Creek to capture Frank's Creek by rim widening within 100 years from today. Albanese and others (1984) estimated the Buttermilk Creek would widen by about 5,000 feet in 10,000 years, such that it would take about 3,000 years for Buttermilk’s rim to capture Frank’s Creek. The DEIS uses a figure of about 200 ft of erosion per 10,000 years on the basis of the downcutting rate estimated by LaFleur, 1979, and then assumes a rim-widening rate on the basis of a 21° stable gully-wall slope. The gully-wall slopes of Buttermilk Creek are not at the stable angle of 21°. This angle was measured on the upstream profiles of Erdman"s Brook and Frank" Creek above the major upstream-migrating knickpoint. All gully slopes below this major knickpoint are most likely in a state of disequilibrium, as evidenced by ubiquitous landslides and slumps (see Fig. 2-21 of the EID III, part 3, page 110), and this instability of slopes may continue for thousands of years. The rim-widening rate for these slopes, given as 16 to 19 ft per year may have justification. This rate must be factored into the long-term landscape-evolution model, with some estimate of its propensity to last into the future. The concept of slopes achieving equilibrium in the next 10,000 years is not supported by landscape evolution over the last 15,000 years where paleoterraces have been dissected by post-glacial gully cutting, but themselves not eroded on their preserved flat tops. The SIBERIA parametric values reflect a bias toward the "onion-skin" erosion concept, but are not supported by landscape evolution in any part of the glaciated Appalachian Plateau.

Gully-Head Cutting Advance Rates and the Hillslope Mode

Section F.2.2.3 states that “If gully advancement processes proceed without mitigation, the gully heads could cut into the disposal areas.” This statement contradicts the SIBERIA modeling result that in the hillslope mode gully-rim advancement will overtake gully-head cutting. The processes that modify the north and south plateau landscape must be well understood to predict the timing and type of encroachment into the burial trenches, lagoons, underground barriers and tanks, and surface facilities, and consequently the exposure scenarios.

Significance of Analog Sites

The two analog streams that were used in Section F.2.3 are probably irrelevant, because their stream profiles are greatly different from the Cattaraugus-Buttermilk river basin and in different states of equilibrium. Table F-5 with a range of incision rates from 0.1 to 1,000 millimeters per 1,000 years is most probably irrelevant to any rates measured for Buttermilk Creek. No discussion is given about any of the factors that may influence the incision rates of the rivers of Table F-5.

One interesting note in the discussion of the Winooski drainage basin, on line 272, is that the study concluded that the drainage downcutting was a result of base-level drop and knickpoint migration, two factors apparently not considered in the SIBERIA modeling.

Erosion-Rate Prediction Methods

The conclusions derived about the Universal Soil Loss Equation in Section F.3 have many flaws, and the final conclusion of an average loss of 0.04 feet per 1,000 years reflects these. Subwatersheds are designated because they were conveniently available from a hydrologic modeling study, but their boundaries and differing characteristics are not justified in Appendix F. No discussion is given as to whether these subwatersheds have differing or similar soils, slopes, and other characteristics that might influence erosion rates. Table F-7 does not define terms, nor indicate how they are used in the equation. A serious flaw is to assume that the disaggregated grain size characteristics of the Lavery Till and its derived soils are correlative with erosion resistance of the intact, coherent *in situ* material.

The CREAMS study area on the south plateau used data from a one-year study (Dames and Moore, 1987). This area is one where multiple land uses have been employed next to the railroad track, where roads have crossed the site, earlier farming practices occurred, and where the tumulus now stands. One factor that presents confusion on the reliability of the data in Table F-9 is that is assumes one soil type on the CREAMS site, whereas, Figure F-5 depicts two different subwatersheds (E4 and F4) within the boundaries, each of which has different soil-loss factors.

Whether Positive and Negative Feedback Mechanisms Were Considered

The statement on line 485 to the end of the paragraph indicates that the modelers were aware of process interactions, where some processes could deter others. For example, added landslide debris could retard the downcutting rate. The possible positive and negative feed-back mechanisms within the modeling are not clear.

Understanding of Geological Processes

We are worried that the erosion modeling drove the formation of erosion concepts of the authors of Appendix F. The statement on page F-30, starting with line 597 that “Erosion modeling objectives at WNYNSC are to develop an understanding of erosion processes occurring at the site and the manner in which the processes may develop over a long period of time…" The modeling should not be used to attempt understanding of geological processes. Rather, the understanding of the dynamics of past geologic activity and past scenarios are to be used to model what future geologic results will be obtained.

Insufficiently Precise Topographic Data

The topographic surface at the West Valley site is modeled with contours of 10 feet. We advise that careful study of the topographic changes must be based on a finer detail of topographic mapping than can be obtained from digitized and computer-processed old 20-foot contour maps. A LIDAR image taken over the entire Buttermilk Creek drainage basin and its neighboring basins is advised. Connoisarauley Creek drainage basin appears to be at an erosion state that Buttermilk Creek drainage basin was a few thousand years ago, since its base level is a bedrock-bolstered falls that is analagous to a former state of the eroded bedrock lip near the mouth of Buttermilk Creek.

Siberia Modeling Topography

The SIBERIA model philosophy assumes that erosion at a node is only dependent upon the parameters that reflect isolated action at that site, and not the influence of changes in elevations at nodes upstream or downstream from that point as a result of changes in creek longitudinal profiles or base-level, the exception being local slope. That result is integrated through time to produce a predicted future elevation for each node. The technique does not consider base-level influences on knick-point size or migration rate upstream. This DEIS approach is reflected in Figures F-13 and F-15 where the 1,300 ft contour has moved frmm its present location at the confluence of Frank's Creek and Erdman's Brook (F-13) to the center of the northern trenches of the SDA (F-15), yet with no advancement of the gully head for Frank's Creek west of the southern end of the NDA. Such an approach contributes to the elimination of side gullies, such as the one between the SDA and the NDA. Figure F-13 attempts to model both the north and south plateaus and the influence on topographic changes of erosion processes within the three creeks that border the two plateaus. It does not include the entire drainage for each of the bordering creeks, nor their first major base level, the confluence of Frank's Creek with Buttermilk Creek. Moreover, the model does not factor in the influence of the runoff from the mantled, membrane-covered burial trenches on local erosion. Likewise, the model pays respect to the sensitive erosion characteristics of soils, but does not factor in the "hard" facilities, such as erosion-resistant trench covers, buried slurry walls and groundwater-retention structures, buried tanks, foundations, and retention ponds, and the probably "softer" French drains, intercepted drill holes, covered holes and trenches at other localities, such as the research trenches on the plateau between Buttermilk and Frank's Creeks.

The runs of SIBERIA depicted in Figures F-14, F-15, F-20, and F-21 were performed in the hillslope mode, and reveal an evolving topography or landscape evolution that emphasizes rim-widening over gully-headcut migration. This picture is inconsistent with the landscape evolution of Buttermilk Creek over the past 15,000 years, as demonstrated by “hanging” pro-glacial lake beach lines. Certainly the topography depicted for 10,000 years from now on Figure F-25 cannot be obtained because in that modeling effort Buttermilk Creek has not been allowed to erode at its mouth at all, still lying at above 1,100 feet above sea level in this run. Figure F-26, the unfavorable case, depicts topography that has resulted from the removal of most of the plateau between Buttermilk Creek and Frank’s Creek, but left the topography with a constant slope (close to 21 degrees?) and no gullies. In this story the mouth of Buttermilk Creek is about 900 feet above sea level or just 300+ feet above Lake Erie.

Comments on Section G-5, Erosion Collapse Scenario Models.

The section assumes that each of the trenches in the SDA and NDA are physically and hydrodynamically isolated from each other and that contaminants will be released in an orderly fashion beginning with the trenches closest to eroding gully rims. This assumption cannot be made because it has been reported that fluid connection has occurred between some of the northern SDA trenches, and could also result in the future among those in the southern tier of trenches and in the NDA, if it has not already occurred. Septa (internal trench walls) collapse, sand and gravel pods, and joints within the septa provide potential avenues of fluid flow between trenches. Thus, once a trench is ruptured by erosion, it should be assumed that contaminants from all the trenches are released. A slug of water, possibly from many or all of the trenches, could flood the lower reaches of Franks and Buttermilk Creeks almost instantaneously once the SDA trenches are breached, assuming no functioning institutional engineering controls are in place. Solid material within the trenches will be exposed to the atmosphere and slowly, but inexorably, erode and eventually be transported downstream.

<u>Groundwater Flow And Contaminant Transport</u>

Description of Groundwater Flow and Transport Analyses

Groundwater plays a key role in environmental assessment of the five alternative plans of action at the WVDP site. A brief description of groundwater flow and transport analyses conducted in support of this assessment is provided in Chapter 4 and Appendix D; more extensive descriptions are included in Appendices E and G. We found these descriptions to be incomplete and difficult to comprehend fully. We have developed a more complete understanding of these issues after having discussed them orally with the authors of the corresponding DEIS sections during a meeting in Germantown, MD, on December 19 – 20, 2005. The following comments reflect our consequent understanding of how groundwater flow and transport were analyzed in the DEIS.

Reference to Previous Three-Dimensional Groundwater Flow Modeling

Throughout the DEIS (e.g. Figure 3-16, lines 235-240 and 578-580 in Appendix D) reference is made to a three-dimensional groundwater flow model previously developed and calibrated against observed groundwater levels at the site, and used to generate input into “one-dimensional models appropriate for long-term impact analysis.” The DEIS does not provide any description of this three-dimensional model (other than its lateral outline and some computed groundwater levels in Figure 3-16) or the process used to extract from it input information for the one-dimensional models actually used. We heard from the authors that the three-dimensional model, described in a 1996 draft of the EIS, has been used to guide groundwater flow analyses qualitatively in the current DEIS.

In our opinion, the DEIS should not rely on a groundwater flow model developed in documents that are not an integral part of the DEIS and are thus not subject to a formal review of the DEIS. We are unable to comment on the quality of the model and its relevance to the DEIS. To the best of our understanding the DEIS does not rely in any meaningful way on any three-dimensional groundwater flow model. Instead, it presents graphical analyses of groundwater flow in Appendix E and separate analyses of groundwater flow and contaminant transport in Appendix G based on networks of one-dimensional flow tubes. For reasons described below, we consider these analyses to be problematic and urge the authors to replace or support them quantitatively by well reasoned and documented three-dimensional flow and transport models in future versions of the EIS. We are particularly puzzled by a summary statement in Appendix E (lines 1287-1289) that the analysis in the Appendix is consistent with modeling results presented in the 1996 EIS; no such consistency has been demonstrated in the DEIS.

Groundwater Flow Analysis in Appendix E

All groundwater flow analyses concerning higher-permeability units in Appendix E are based on horizontal flow nets derived from interpolated water level data, such as those presented in Figures E-20, E-25, E-30, E-37, coupled with hydraulic conductivity maps such as those presented in Figures E-10, E-22, E-28, E-34. These maps were drawn from the field data using a geographic information system contouring package, ESRI ArcGIS software. Horizontal groundwater velocities in these units were computed as follows: (a) Groundwater level contours were drawn based on time-averaged water level data for the years 1995 - 2003, and interpreted to represent vertically-averaged long-term steady state hydraulic heads in each unit; (b) a set of streamlines was drawn using the “steepest path” tool of the ArcGis software originating from sample starting points (c) hydraulic gradients were calculated along the streamlines, and the arithmetic and harmonic velocities along each flow path calculated.

1. Groundwater balance

The analysis does not insure that groundwater mass (or, equivalently, volume if one considers groundwater to be virtually incompressible) is conserved, raising a serious question about its validity. To conserve mass in a three-dimensional system of hydrogeologic units having spatially (laterally and vertically) varying hydraulic conductivities, one may have to discretize the system into a three-dimensional network of cells; write an equation of water balance coupled with Darcy's law for each cell, account for the possible presence of sinks and sources such as wells; write appropriate boundary equations (prescribed head, prescribed flux, head-dependent flux) for cells lying at the system boundary, including vertical recharge at the water table; and solve these equations jointly in a way that reproduces (as closely as possible) observed water levels in wells, piezometers and hydraulically connected surface bodies such as seeps, ponds, lagoons and creeks. Such a set of equations would constitute a three-dimensional groundwater flow model, and rendering it capable of reproducing observed water levels would constitute model calibration against such data.

The graphical analysis in Appendix E does not do so and therefore does not guarantee the preservation of water balance either locally (within each cell) or globally (within a given hydrogeologic unit or across an entire system of several such units). In particular, the flow nets in Figures E-20, E-25, E-30, E-37 appear to be arbitrary and to violate basic principles of groundwater hydraulics:

1. One of these principles is that streamlines converge when they encounter a zone of elevated hydraulic conductivity (or, in the case of purely horizontal flow of the kind represented in the above figures, transmissivity, the product of horizontal hydraulic conductivity and saturated aquifer thickness) and diverge when they encounter a zone of reduced hydraulic conductivity. As the groundwater level contours and streamlines in the above figures were drawn independently of any available information about hydraulic conductivity distributions within the various units (this information having been used only *a posteriori* for the purpose of computing fluxes and velocities, but not *a priori* for the purpose of drawing the flow net, as it should have been), they tend to violate this principle.

2. Another principle is that the total rate of inflow across the upstream boundary of a cell, minus the total rate of outflow across its downstream boundary, be equal to the total rates of recharge or leakage (to/from overlying/underlying units) across the area of the cell, from above and/or from below. As the flow nets were drawn without consideration of recharge or leakage (which were computed from the network *a posteriori*, rather than being prescribed *a priori* or computed jointly with the heads and fluxes across the units), they tend to violate this principle as well.

3. Yet another hydraulic principle potentially violated by the above flow nets is that fluxes, computed from it at unit boundaries, be consistent with available information or expectation (say of no-flow across an impermeable boundary) of what their boundary values actually are. For example, the surficial S&G unit (line 160, Appendix E) and the KRS (line 172) are said to be recharged in part by lateral inflows from direct contact with fractured bedrock west of the site: It would have been prudent to insure that fluxes obtained at these and similar contacts from flow net analyses are consistent with those computed independently in the

neighboring fractured bedrock, based on groundwater levels and hydraulic conductivities measured directly within this bedrock. The DEIS neither includes such consistency checks nor defines the conditions that prevail along flow net boundaries. No flow analysis is complete without a clear definition of these conditions.

2. Additional issues

The graphical groundwater flow analysis in Appendix E poses some additional difficulties:

1. **Long-term steady-state flow assumption:** The analysis considers water level data collected from 1990 through Spring 2004 to represent long-term historical flow conditions (line 1246, Appendix E) and to constitute a good predictor of long-term groundwater flow pattern (line 738, Appendix E). The authors of the DEIS support their premise with some well hydrographs (Figures E-15, E-16, E-17, E-18, E-19, E-29, E-36) which suggest that water levels in the corresponding wells have fluctuated about relatively flat average temporal trends during the above 13-year period (though some of the trends point up and some down). Yet groundwater levels at the site have been influenced by man-made alterations of surface conditions (construction of pavements and buildings that alter infiltration and evapotranspiration patterns) and subsurface conditions (excavation of lagoons and foundations, surface and subsurface liquid disposal, leachate accumulation in trenches and boreholes, pumping) as evidenced most conspicuously by Figure E-27. Regardless of observed 13-year long trends in selected boreholes, conditions of the kind depicted in Figure E-27 cannot conceivably represent a steady state flow regime. One should further expect future site decommissioning and waste closure activities under Alternatives 2 – 4 to significantly alter groundwater flow patterns across the site. Once the site is partly decommissioned, pumping by resident farmers at or near the site may likewise alter groundwater flow patterns in the area. At present, residences surrounding the site are served almost exclusively by privately owned wells located upgradient from the facility (lines 278-279, Appendix E); one should expect future changes in upstream water use to have some impact on groundwater flow within the facility downstream. Natural future influences on groundwater flow at the site include potential changes in climate and alterations of site topography by erosion. We expect such anthropomorphic and natural factors to cause temporal variations in groundwater flow patterns that cannot be validly averaged out over the long time periods considered in the DEIS, and might necessitate modeling groundwater flow as a transient (as opposed to steady state) phenomenon over these time periods.

2. **Impact of seasonal water-level fluctuations:** The well hydrographs in Figures E-15, E-16, E-17, E-18, E-19, E-29, E-36 show seasonal fluctuations in groundwater levels at the site of up to about 7 feet; well hydrographs in EID Vol. III Part 4 show fluctuations of up to 10 – 15 feet in both shallow and deeper units.

Considering the relatively shallow water table conditions that prevail across wide areas of the site (depth to water table, according to line 197 in Appendix E, being 0 – 5 m in the S&G), we expect such seasonal fluctuations to constitute a likely mechanism of spreading contaminants in flowing groundwater vertically through the vadose zone, bringing them in direct contact with shallow soils and plant roots, even causing them to seep vertically up to the soil surface. Presently, the DEIS does not consider this vertical transport mechanism, which we believe introduces a non-conservative bias into the performance assessment (PA).

3. **Analysis of hydraulic conductivity data:** The hydraulic conductivity maps in Figures E-10, E-22, E-28, E-31, E-34 depict discrete zones of values within given ranges. The data was contoured using the AcrGIS software. To render these maps more convincing it would help including in them all the underlying conductivity data (even those considered by the authors to be outliers) using different symbols for data based on laboratory and on disparate field tests or methods of test interpretation. It would likewise help demonstrating to the reader than all cited data represent undisturbed natural materials as opposed to artificial fill. Distinguishing between different types and scales of hydraulic conductivity data is important because, in general, conductivities derived from laboratory tests tend to be lower (often by orders of magnitude) than those derived from field tests (e.g. Neuman and Di Federico, 2003); the DEIS does not appear to draw a distinction between these two sets of data, thereby potentially biasing the hydraulic conductivity estimates toward lower (less conservative) values.

4. **Role of high-permeability features in ULT:** We are concerned that the Unweathered Lavery Till (ULT) might have been assigned hydraulic conductivities that are too low for purposes of PA and thus non-conservative. We are particularly concerned that pods and lenses connected by bedding planes may, together with horizontal fractures, form preferential horizontal pathways from waste buried in holes and trenches within the ULT toward vertical fractures and abandoned boreholes forming vertical pathways down to a depth of about 50 feet. This might reduce considerably the thickness of intact, unfractured Lavery Till in comparison to that presently assumed to form an effective low-permeability barrier to flow in the DEIS. Our concern stems from the following:

   a) **Role of high permeability natural material in ULT:** As pointed out by Dana et al, (1979) one finds throughout the Lavery Till discontinuous, distorted, heterogeneous, randomly distributed pods and lenses of silt, sand and gravel having irregular shapes tending toward ellipsoidal with the longest axis horizontal. The pods and lenses are often in contact with extensive horizontal or subhorizontal bedding planes. The presence of high-permeability inclusions within the ULT is recognized on page E-53 of the DEIS, but their potential to elevate the overall permeability of this unit is not recognized. The PRG notes that the presence of high permeability features in the till, even if disconnected, may enhance its overall permeability; this has been demonstrated numerically for disconnected fractures in a porous matrix (Berkowitz and Scher, 1996).

b) **Role of fractures in ULT:** Contrary to the impression conveyed to the reader by lines 241-251 in Appendix A, the DEIS provides very limited information about fracturing of the till and the bedrock on the local scale of the WVDP site. If we accept the finding in NUREG/CR-0644 (Fickies et al., 1979) that plastic behavior of the ULT would tend to heal fractures at depths exceeding 50 feet, cited on page 3-1 of the DEIS, one faces the following dilemma: Virtually all hydraulic conductivity values cited for the ULT are derived from laboratory or borehole packer tests, which are known to yield local-scale values (e.g. Neuman, 2005). According to Fakundiny, (1985) the horizontal spacing of vertical cracks at a depth of 6 – 15 m in the unweathered till ranges from 1 to 3 m (Table 1, see also Figure 9). Hence it is very likely that most core samples subjected to conductivity testing, and most packer-tests, would reflect the local properties of unfractured till rather than the effective (larger-scale) bulk properties of fractured till. It is thus highly likely that the bulk horizontal and vertical hydraulic conductivities of the ULT have been significantly underestimated in the DEIS.

According to Zadins, (1997), NDA deep disposal holes were excavated to a maximum depth of 17 m in the Lavery Till while NDA special holes and SDA trenches were excavated down to approximately 6 m. Assuming that the Lavery Till is 24 m thick at these two facilities, this in Zadin's view leaves approximately 7.6 m of till separating the waste from the underlying Kent Recessional Sequence under the deep disposal holes and 24 m under the special holes and trenches. The PRG is concerned that this reduction in ULT thickness at locations where it matters most has not been adequately accounted for in the DEIS. We are further concerned that by reducing the overburden stress on the ULT as a result of excavating and filling the holes and trenches with loosely packed waste material and soil, and exposing them to atmospheric air and precipitation as well as waste material and leachate, the integrity of the ULT near and under the disposal holes and trenches could have been compromised and would likely be compromised further in the future (most notably under the deep disposal holes at the NDA). This has not been accounted for the DEIS.

c) **Role of abandoned boreholes in ULT:** According to Prudic (1986), several test holes were augered by a local contractor adjacent to the SDA burial trenches in 1973-74, as indicated by small black circles on Figure 7 of Prudic's report. The fate of most of these test holes is not known but apparently, most were allowed to collapse naturally upon withdrawal of augers or driller's casings. Location maps and logs of all the 1973-1974 borings can be found in Giardina et al. (1977), Matuszek et al. (1976) and Duckworth et al. (1974); most but not all of them having been noted on

Figure 7 of Prudic. The first ten borings, drilled in November and December of 1973, were 50 feet deep and the rest, drilled in March 1974, appear to have been 25 feet deep. The ten 50-foot borings extend down to a considerable depth below the bottom of the SDA trenches.

If one accepts the aforementioned finding in NUREG/CR-0644 that plastic behavior of the ULT would tend to heal fractures at depths exceeding 50 feet, one must consider it likely that the abandoned boreholes (which are shallower) would have healed at most partially and would therefore constitute preferential pathways for vertical flow in the immediate vicinity of the SDA trenches down to a depth of 50 feet.

Another related issue that we believe needs to be addressed in the DEIS, but is presently not mentioned, concerns 476 steel H-piles driven through the upper sand and gravel layer, through the Lavery Till, into the Kent Recessional Sequence beneath the Process Building on the North Plateau. Each pile is said to have a surface area of over 15 square inches. Some of these piles were reportedly driven out of plumb and then straightened by pulling on their top using a cable attached to a bulldozer. According to a WVDP Fact Sheet this might have caused the upper portion of such a pile (in the sand and gravel) to bend but the bottom would not slice through the till. According and the same Fact Sheet, the till would have sealed around each pile shortly after it was initially driven. In the view of the PRG the aforementioned finding in NUREG/CR-0644 (Fickies, 1979) provides no reason to suppose that such sealing would have been effective at depths shallower than 50 feet. We further believe that the DEIS must give serious consideration to suggestions, previously made by others, that all 476 piles could potentially degrade with time and develop into preferential pathways for vertical migration of contaminants across the entire thickness of the ULT.

The literature describes several case studies demonstrating that low-permeability aquitards (such as the ULT) separating more permeable aquifer-type units (such as the shallow S&G or WLT and the deeper KRS) have much larger bulk permeabilities than one would surmise from local measurements. Consider for example two aquitards consisting of clay (including the swelling mineral montmorillonite) and silt that separate three aquifers in the coastal groundwater basin of Oxnard Plain, Ventura County, California (California Department of Water Resources, 1971). Laboratory measurements of the “coefficient of permeability” (hydraulic conductivity) of undisturbed samples from these aquitards are listed in the following table:

Table VI-7. Permeability of undisturbed samples of aquitard sediments

Sample Depth ft.	Soil Type	Water Content %	Effective Overburden Pressure kg/cm^2	Coefficient of Permeability[1]	
				cm/sec	gpd/ft^2
66.5	Clayey silt	45.0	2.0	1.93×10^{-7}	4.1×10^{-3}
69.3	Silty fine sand	26.0	2.0	1.09×10^{-5}	2.3×10^{-1}
72.1	Clayey silt	40.0	1.7	3.37×10^{-7}	7.1×10^{-3}
77.8	Clayey silt	45.0	1.9	1.31×10^{-7}	2.8×10^{-3}
80.2	Clayey silt	54.0	2.0	0.48×10^{-7}	1.0×10^{-3}
83.0	Clayey silt	36.7	2.0	0.40×10^{-7}	8.5×10^{-4}
91.0	Clayey silt	27.0	2.3	0.89×10^{-7}	1.9×10^{-3}
95.5	Silt	29.0	2.3	0.82×10^{-5}	1.7×10^{-1}
97.0	Clayey silt	43.0	2.4	0.80×10^{-7}	1.7×10^{-3}
98.0	Clayey silt	38.0	2.5	1.67×10^{-7}	3.4×10^{-3}
103.0	Stiff clay	32.0	2.5	0.26×10^{-7}	5.5×10^{-4}
103.4	Stiff clay	36.4	3.1	1.06×10^{-7}	2.3×10^{-3}
202.5	Silt	21.6	4.0	5.60×10^{-6}	1.2×10^{-3}
219.0	Sand with clay	23.5	5.25	8.81×10^{-6}	1.9×10^{-1}
221.1	Silty clay	31.2	6.0[2]	1.35×10^{-7}	2.9×10^{-3}
223.6	Silt	25.5	5.44	4.48×10^{-6}	9.5×10^{-2}
225.9	Clay	32.4	6.77	1.05×10^{-7}	2.2×10^{-3}
226.0	Clay	32.0	8.0[2]	0.16×10^{-7}	3.4×10^{-4}
226.4	Clay	27.0	5.49	0.39×10^{-7}	8.3×10^{-4}

[1]Average of at least two determinations on samples reconsolidated to effective in-situ overburden pressure and saturated using back pressure.

[2]Actual effective stress corresponding to value of permeability given.

All but two of the upper (shallower) aquitard samples have hydraulic conductivities in the range 0.26 – 3.37 $\times$ 10^{-7} cm/sec; those in the lower (deeper) aquitard lie within the range 0.16 $\times 10^{-7}$ – 8.81 $\times$ 10^{-6} cm/sec. The harmonic average conductivity (similar in principle to the kind employed for the ULT in the DEIS, in which however high value have been discarded as “outliers”) of all 12 upper aquitard samples is 8.61 $\times$ 10^{-8} cm/sec and that of all 7 lower aquitard samples is 6.63 $\times$ 10^{-8} cm/sec.

The next table lists bulk or equivalent hydraulic conductivities for the bottom 11 and 21 feet of the upper aquitard, and the top 6 feet of the lower aquitard, as determined on site from a large-scale (spanning the three aquifers and two aquitards), long-term (one month duration) pumping test by the ratio method of Neuman and Witherspoon (1972). These bulk values lie in a narrow range (1.11 - 2.66 $\times$ 10-6 cm/sec) that exceeds the harmonic averages of the laboratory samples by considerably more than one order of magnitude. We note that this is so even though the aquitards are unconsolidated and hence unfractured, in addition to containing swelling clay (montmorillonite).

Table V-5. Hydraulic properties of aquitard layers

Layer	Section tested	Spec. Storage, S_s'		Permeability, K'	
		cm^{-1}	ft^{-1}	cm/sec	gpd/ft^2
Upper Aquitard	Bottom 21 ft	7.88×10^{-6}	2.4×10^{-4}	1.11×10^{-6}	2.45×10^{-2}
	Bottom 11 ft	7.88×10^{-6}	2.4×10^{-4}	2.66×10^{-6}	5.85×10^{-2}
Lower Aquitard	Top 6 ft	3.28×10^{-6}	1.0×10^{-4}	1.89×10^{-6}	4.17×10^{-2}

Another example is provided by the Pierre Shale aquitard that overlies the Dakota Sandstone aquifer in South Dakota where the laboratory values of hydraulic conductivity were two orders of magnitude lower than those determined for the aquifer system through modeling of the entire system (Bredehoeft, et al., 1983). The discrepancy between the laboratory and the larger scale model analysis is best explained by fractures that penetrate the Pierre Shale aquitard but are not represented in the laboratory samples. A similar finding has been reported recently by Hart et al. (2006) with respect to the Maquoketa Formation, a shale aquitard in southeastern Wisconsin.

The PRG therefore deems it reasonable to expect that the ULT has a much larger bulk vertical permeability than that assigned to it in the DEIS, which probably exceedes the latter by at least one and in places (near abandoned boreholes at the SDA, under and around deep disposal holes at the NDA, ultimately under the Process Building) perhaps two or three orders of magnitude.

5. **Estimation of groundwater velocities in ULT:** Groundwater velocities are evaluated according to equation (E-1) upon dividing fluxes obtained from Darcy's law by advective porosities (termed "effective porosities" in the DEIS, and listed in Table E-5) determined on small sediment samples in the laboratory. We are not aware of any field determinations of advective porosity as alluded to in line 569 of Appendix E. We are likewise unclear how the laboratory values of advective porosities were determined. The only valid method of determining advective porosities that we are aware of is by using tracer tests, but no such tests have been reported for the site, either at the laboratory or at the field scale. Table E-5 lists a single value of advective porosity for each unit (the value listed for the S&G exceeds the listed range of total porosities and must therefore be in error), but advective porosities (especially those associated with small laboratory samples of the kind reported in Table E-5) can vary significantly, a fact not

considered in the DEIS. A single value of 17% is listed for the ULR. In the view of the PRG, this reflects at best the local porosity of intact till, disregarding the effect of fractures and other preferential pathways on advective porosity. We expect the advective porosity of preferential pathways to be much smaller than that of unfractured till, and hence groundwater velocity (for a given Darcy flux) to be potentially larger through these pathways than in intact till. It is thus highly likely that groundwater velocities within the ULT have been significantly underestimated in the DEIS, which (as we point out later) would have biased the groundwater flow and transport PA computations in Appendix G toward non-conservative outcomes.

Porosity is not a single valued parameter as indicated in Table E-5. It too is a parameter with a distribution of values much like hydraulic conductivity. The PRG considers it a mistake to treat porosity as single valued. As indicated above, the advective porosity is difficult to determine; it usually requires transport of some chemical constituent to determine advective porosity. Much of the groundwater flow at the site may be dominated by fractures. In this case the advective porosity will be much lower than the matrix porosity of the material. The uncertainty associated with the advective porosity emphasizes the fact that porosity should not be treated as a single valued parameter.

6. **Accounting for uncertainty due to spatial variability of hydraulic conductivities:** It is not clear to us why no attempt has been made to analyze the available hydraulic conductivity data geostatistically. Such an analysis appears to be justified by the tendency of measured hydraulic conductivities to vary by several orders of magnitude, in an apparently random manner, from one location to another within each hydrogeologic unit at the site. A geostatistical estimation of (log, as is commonly and justifiably done in most cases) hydraulic conductivity variations in the horizontal direction within each unit, as well as in the vertical direction within the ULT, might have (a) eliminated the need for what to us appears to be rather arbitrary screening and averaging of the available hydraulic conductivity data, as described in lines 537-544, 802-810, 936-938, 1018-1033, 1129-1130 of Appendix E; (b) eliminated the need for artificial zoning of this important parameter, yielding instead a continuous estimate amenable to contouring within each unit; (c) allowed quantifying spatial variations within each unit in terms of geostatistical parameters such as variance, spatial correlation (integral) scale and nugget; (d) yielded contours of estimation error variance, thereby quantifying the associated uncertainty as a function of spatial location; (e) allowed generating random realizations of hydraulic conductivity within each unit in a manner that is statistically consistent with the available data; (f) allowed numerical Monte Carlo simulation of flow and transport in the system by means of suitable three-dimensional models, applied to each realization, optionally calibrated against measured water level data; (g) yielded statistical predictions of hydraulic head, groundwater flux, advective velocity, contaminant concentration, mass flux, and breakthrough of contaminants at points of interest; (h) yielded measures of predictive uncertainty for each of these variables; and (i) allowed

translating these results into statistical predictions of dose associated with groundwater receptors, including measures of predictive uncertainty. Not doing so is, in our view, a missed opportunity to conduct the groundwater component of the PA within a defensible uncertainty framework. Instead, the graphical flow analysis in Appendix E is purely deterministic, lacking any quantitative indication of its reliability (in terms of potential statistical bias and uncertainty).

7. **Possible effect of unsaturated flow:** The DEIS does not address the potential influence that an unsaturated zone, often found within the Kent Recessional Sequence (KRS) beneath the ULT (as well as within the Lavery Till Sand or LTS, Figures E-5, E-6), could potentially have on flow and contaminant transport through the ULT and KRS complex. The DEIS conceptualizes flow through the KRS as occurring under fully saturated conditions, an approach the authors consider to be conservative. It would, in our view, be worth examining the extent to which unsaturated conditions within the KRS could retard flow and transport out of the ULT, causing contaminants to accumulate within this unit and thus form a long-term source, feeding pollutants into the KRS (eventually reaching seeps and creeks intersected by this unit) over a longer time period and at less diluted concentrations than would be predicted upon neglecting unsaturated flow. It should be relatively easy to address this issue generically with the aid of a two-dimensional saturated-unsaturated flow and transport model in the vertical plane. As water levels within the KRS and LTS fluctuate, the thickness of the unsaturated zone within each of these units varies with time (lines 971-976 and page E-61, Appendix E), suggesting that the analysis should be transient rather than steady state.

8. **Correspondence with previous studies:** In light of the above, we are puzzled by the unsubstantiated statement in line 1115 of Appendix E that computed flow conditions in the ULT show a close match with earlier studies.

Correspondence between groundwater flow analysis in Appendix E and PA in Appendix G

The purpose of the graphical flow analysis in Appendix E is not entirely clear to us, considering that there is only minimal correspondence between this analysis and the PA in Appendix G:

1. Flow tube network models developed for purposes of PA in Appendix G (discussed later) bear little direct relationship to those developed in Appendix E, with the possible exception of the vertical flow net developed in Appendix E for the ULT (which however does not appear to reflect accurately flow conditions around and below the deep disposal holes at the NDA). This is due to at least four factors:
   a) The flow nets in Appendix E represent only one hydrogeologic unit whereas those in Appendix G account for flow in more than one unit;

b) The flow nets in Appendix G take account of planned engineered structures that do not presently exist, whereas those in Appendix E are taken to represent existing conditions;
c) The flow nets in Appendix G conserve water balance, whereas those in Appendix E do not; and
d) The flow nets in Appendix E are based on actual data, whereas those in Appendix G are largely computed.

2. None of the hydraulic conductivity maps developed in Appendix E appears to have been used for purposes of PA in Appendix G.

3. None of the velocity profiles obtained along flow lines in Appendix E appears to have been used for purposes of PA in Appendix G.

Conclusion: It thus appears that much of Appendix E is of little direct relevance to PA; as we point our below, the only information in Appendix E that is adopted for PA in Appendix G are average hydraulic conductivities and advective porosities for the various units and the total head drop across each unit. On the other hand, had a three-dimensional groundwater flow model that accurately represents all significant hydrogeologic and (existing or planned) engineered components of the system been developed and properly calibrated (with existing engineered components) to available site data, it could (and we believe should) have served as a basis for either full 3D or suitably simplified flow and transport analyses in PA (Appendix G).

Statistical hydraulic conductivity analysis in Appendix E

In addition to a graphical analysis of groundwater flow, Appendix E also includes a univariate statistical analysis of hydraulic conductivity data from the various hydrogeologic units at the WVDP site. One objective of this analysis is said to be the estimation of “representative and conservative” deterministic values for PA (e.g. lines 1148-1149) or “conservative means” (line1254); we find it difficult to understand how given conductivity estimates can be at once representative and conservative, and how the mean of a statistical distribution can be conservative. We have several concerns about this analysis:

1. **Sole focus on hydraulic conductivity:** The statistical analysis focuses solely on hydraulic conductivities, for which numerous measurements are available. There should also be a discussion of uncertainties related to other groundwater flow parameters affecting contaminant transport, most notably advective porosity (which is treated deterministically throughout the DEIS), water levels (which exhibit significant fluctuations that the DEIS illustrates but does not otherwise consider), recharge rates and their spatial distribution (whereas Appendix E says nothing about recharge, in Appendix G recharge is considered to be spatially and temporally uniform over each plateau, being computed with a flow tube network model in a way that we consider to be unreliable, for reasons enumerated later).

2. **Issue of spatial variability:** In contrast to a geostatistical analysis of the kind we advocate for these data (which is multivariate in that each datum is considered to be a sample from a probability distribution that may vary from one spatial location to another), a univariate analysis ignores the spatial distribution of the data, treating all of them as a sample from a single probability distribution.

3. **Relationship to graphical flow analysis:** There is no obvious relationship between this statistical analysis and the aforementioned graphical analyses of groundwater flow in Appendix E; the two seem to be disconnected from each other.

4. **Sampling of hydraulic conductivity data:** The only similarity we notice between these two disparate analyses is that neither makes a clear distinction between different types and scales of hydraulic conductivity data, thereby potentially biasing the analysis toward lower (less conservative) values.

5. **Porosity data:** Comments similar to those pertaining to the hydraulic conductivity can be made concerning the porosity data, especially the effective porosity data. These data are not single valued as Appendix E suggests, but are also uncertain and should be treated much as the conductivity data.

6. **Role of high-conductivity features in ULT:** In both cases, the ULT appears to have been assigned hydraulic conductivities that are too low for purposes of PA and thus non-conservative. As mentioned earlier, this may stem from the authors' tendency to disregard (a) high conductivity values (considering them to be "outliers"), which however could admittedly be associated with high-permeability inclusions within the ULT and (b) the potential influence of high-permeability features (fractures, inclusions of coarser material, abandoned boreholes at the SDA, altered conditions around and under deep disposal holes at the NDA, ultimately corroded H-piles under the Process Building) on larger-scale bulk conductivities of the ULT. We reiterate our opinion that most core samples subjected to conductivity testing, and most packer-tests, are very likely to reflect the local properties of intact till rather than the effective (larger-scale) bulk properties of fractured or disturbed till. It is thus highly likely that the bulk horizontal and vertical hydraulic conductivities of the ULT have been significantly underestimated in both analyses, which (as we point out later) would have biased the ground flow and transport PA computations in Appendix G toward non-conservative outcomes.

Analysis of Groundwater Flow for PA in Appendix G

For purposes of PA, groundwater flow through the various hydrogeologic units and saturated engineered components of the closure system, including the waste form, is represented by networks of interconnected "flow tubes" in each of which flow is taken to be one-dimensional and steady state (Figures G-6 through G-8). The edges of the flow tubes form the nodes of a network. Each flow tube is assigned a conductance parameter equal to the product of a specified height, width and saturated hydraulic conductivity, divided by a specified length. Taking arithmetic averages of conductances associated with flow tubes connected to a pair of nodes in parallel and harmonic averages of conductances associated with flow tubes connected to each other in series, one can replace each set by a single effective or equivalent flow tube. Upon continuing to take arithmetic averages of conductances associated with primary or effective flow tubes connected to a pair of nodes in parallel, and harmonic averages of conductances associated with primary or effective flow tubes connected to each other in series, one ultimately obtains a single equivalent algebraic flow equation for the entire system in terms of its overall conductance and hydraulic heads as well as flow rates at boundary nodes.

Though the approach is explained only in a cursory and incomplete manner, we understand (based partly on oral and written explanations provided to us by the authors) that this equivalent flow equation is used to compute a single (spatially uniform) vertical infiltration rate from above by assigning numerical values to all remaining variables in the equation. In particular, the authors

a) Set lateral inflow into the system at its upstream node (representing the upstream boundary of a shallow permeable unit, S&G on the North Plateau or WLT on the South Plateau) equal to zero (which is equivalent to disregarding lateral recharge into this unit);
b) Assign a numerical value to hydraulic head at the upstream node based on hydraulic head contours presented for shallow permeable units (S&G, WLT) in Appendix E;
c) The DEIS provides contradictory information about how downward flow through the ULT is handled on the North Plateau. Lines 440-442 and 562-570 (among other) imply that downward flow rate through the WLT and ULT toward the KRS on either the North or the South Plateau is computed along four parallel equivalent flow tubes by (i) assigning a unit vertical hydraulic gradient across each tube based on vertical flow nets developed in Appendix E, (ii) treating the ULT as being spatially uniform on the North Plateau, and (iii) treating it as consisting of an upper disturbed layer and a lower undisturbed layer on the South Plateau, assigning to it a vertical hydraulic conductivity equal to the harmonic mean of uniform values ascribed to each of the two layers. In contrast, lines 428-429 imply that for the North Plateau, only horizontal flow through the Surficial Sand and Gravel unit is considered in the DEIS; this has been confirmed by an e-mail dated April 5, 2006, from Joseph Price of SAIC. The PRG thus understands that the PA in the DEIS ignores (vertical or horizontal) groundwater flow beneath the surficial S&G unit on the North Plateau, effectively setting it equal to zero;
d) Assign a numerical value to hydraulic head at a single remaining downstream node (representing the downstream boundary of the S&G on the North Plateau or the WLT on the South Plateau) based on hydraulic head contours presented for these shallow permeable units in Appendix E;

e) Compute vertical infiltration rate as the only remaining unknown in the global (single equivalent flow tube) equation (one need not know lateral discharge rate from the system at the downstream node to complete this calculation);
f) Write a system of algebraic water balance equations for all interior nodes of a network in terms of flow rates through the primary flow tubes;
g) Express the flow rate in each flow tube using Darcy's law;
h) Solve the resulting system of algebraic flow equations for unknown heads at the interior nodes;
i) Use these heads to compute the flux through each primary flow tube (including those connected to discharge boundaries) by means of Darcy's law; and
j) Divide the flux by a specified advective porosity to obtain a groundwater velocity for each flow tube.

To estimate infiltration through the tumulus, flow across its components was assumed to be vertical, steady state and saturated. Upon disregarding evapotranspiration, ignoring resistance to flow in the upper soil layer, setting the vertical head drop across the tumulus along each flow path equal to its height, and allowing a predetermined portion of the infiltrating water to leave the tumulus laterally through a drainage layer (lines 467-468, Figure G-5), the authors were able to compute total infiltration rate through the tumulus. If the computed infiltration rate was lower than the annual precipitation rate, it was adopted for the analysis; otherwise it was reset to the annual precipitation rate. To check the way in which flow was divided between a vertical component through the bulk of the tumulus and a lateral component through the drainage layer, the authors solved a linearized version of the one-dimensional Richards' equation of unsaturated flow through components of a flow net representing the tumulus and waste form (Figure G-5). The details are insufficient for the PRG to understand how this check was performed; it is not clear to us how a one-dimensional solution of this kind could in principle be used to verify a two-dimensional (vertical and lateral) concept of flow through the tumulus.

Flow through any cylindrical tank closure system on the North Plateau (Figure G-12) is represented by and equivalent rectangular flow system (Figures G-13, G-14).

We have serious reservations about the above groundwater flow approach to PA for the following reasons:

1. **Flow beneath surficial unit on North Plateau:** Ignoring groundwater flow beneath the surficial S&G unit on the North Plateau is in our view entirely unjustified for reasons that should be amply clear from comment 6 on page 50 and comment 12 on page 56 of this report as well as the rest of our discussion. It renders the flow and transport PA calculations for the North Plateau invalid.

2. **Role of multidirectional flow:** The approach does not account simultaneously for multidirectional flows within any component of the system. Although the authors claim an ability to account simultaneously for horizontal and vertical flows within the waste form by superimposing the results of separate analyses in each

direction (lines 444-446), they neither explain nor demonstrate how and in what context this has been accomplished. We consider the simultaneous treatment of flows in multiple directions to be important in and around the engineered components of the system where flow would most likely be three-dimensional, and in the vicinity of active wells. In particular, we expect that:

a) Flow in the tumulus would take place both laterally and vertically due to the layered and inclined nature of this structure; presently, lateral flow is disallowed in any but the drainage layer (lines 467-468. Figure G-5).
b) Flow would take place from shallow permeable units (S&G on the North Plateau, WLT on the South Plateau) into areas enclosed (fully or in part) by slurry walls, and vice versa, not only through but also underneath (and where possible around) these vertical barriers, considering (i) the current plan (according to the relevant CERs) to construct the walls so they extend vertically only three feet into the ULT and (ii) our previous suggestion that the upper parts of the ULT are likely to be fractured and effectively more permeable than is presently assumed in the DEIS. Such three-dimensional leakage underneath vertical engineered barriers is presently disallowed in the DEIS.
c) Flow within areas enclosed (fully or partially) by slurry walls (including the waste form) would be fully three dimensional due to infiltration from above, leakage into and out of these area through their bottom, as well as lateral inflow and outflow not only in the mean direction of flow but also from the sides (especially on the North Plateau where both the internal and the external chevron-shaped slurry wall are designed to enclose the waste form on at least three sides). The present PA model disregards important aspects of this three-dimensional flow pattern.
d) French drains are represented in the PA model by high-permeability flow tubes (lines 425-427) connected to a discharge boundary (Figure G-7). If properly constructed and maintained, water would converge toward the drains not only from the upstream side, as in Figure G-7, but also from the downstream side as well as from above and below. This important multidimensional flow pattern is lost in the flow tube network model presently employed for PA.
e) Flow through and around cylindrical tank closure systems would be multidimensional; it is not clear that the equivalent rectangular flow system representation adopted in Figures G-13 and G-14 adequately captures the effect of such multidimensional flow on groundwater velocities, and ultimately contaminant transport, through this system. We are particularly concerned about the rationale (which to us appears to constitute circular reasoning) for, and accuracy of, first replacing multidimensional flow through the system by a network of one-dimensional flow tubes (Figure G-13) and then translating the computed velocity back into radial and angular components for purposes of contaminant release modeling according to equation G-56.
f) Flow through and around waste buried in trenches and holes will take place not only horizontally where they penetrate shallow permeable units

(S&G or WLT, as presently assumed in the PA) but also horizontally and vertically where they penetrate the less permeable (but potentially fractured and/or disturbed) ULT (e.g. Figure 3.2-13 in CER for Alternative 3). Such multidimensional flow through and around significant portions of the wasteform on the South Plateau is not presently accounted for in the DEIS, yet it may significantly impact the release of contaminants from this wasteform and their subsequent transport.

g) Flow within the ULT is considered to be strictly vertical under a unit hydraulic gradient (representing pure gravity flow). However, the PRG expects the vertical hydraulic gradient under deep disposal holes at the NDA to be at least twice as large because the waste within these holes is relatively permeable and so close to hydraulic equilibrium with the shallow WLT at the site. The vertical gradient would thus be given approximately by the difference between head in the shallow WLT and the elevation of the ULT bottom, divided by the distance between this bottom and that of each disposal hole.

h) Flow in the vicinity of any active well would converge or diverge radially toward or away from the well, thus taking place in all horizontal directions. Flow would also converge/diverge toward/away from the well vertically from above and/or below. Though active wells are an integral part of the conceptual PA flow and transport model (Figure G-2), they cannot be (and are not) validly included in a flow tube model that allows only one-dimensional flow within each tube. Instead, the effect of active wells on flow is ignored in the PA, an approach that we view with some concern.

3. **Definition of flow tubes:** The definition of flow tubes in the PA appears to be quite arbitrary and to bear little direct relationship to those that might develop if a steady state flow regime was actually established at the site under any of the five alternative site decommissioning plans. We see little relationship to existing flow conditions at the site, as described in Appendix E, and do not fully understand how specific engineering structures and waste forms under the various alternatives are being represented (how for example is the chevron-shaped slurry wall, planned for the North Plateau under Alternatives 2 – 4, treated? It does not appear to be represented in Figure G-6). In our view, a defensible flow net (if at all necessary, a proposition we question below) could be established only on the basis of a more complete, three-dimensional groundwater flow model properly calibrated to available site data and subsequently augmented to include in a realistic manner all significant engineered components and waste forms planned under each alternative.

4. **Choice of modeling approach:** We are of the opinion that, in recent years, most computer- or software-related obstacles to the use of three-dimensional groundwater and contaminant transport models for purposes similar to those we deem advisable for PA at the WVDP site have been largely eliminated. We therefore question the continued reliance on flow tube models at the virtual exclusion of more realistic models in PA, considering their limited power and

validity. The argument that such flow tube models have been traditionally employed by the US DOE for purposes of PA at radioactive waste sites, and that they have been traditionally accepted as valid by regulatory agencies such as the US NRC, is in our view not relevant to the unique and complex conditions of the VWDP.

5. **Role of lateral recharge:** In Appendix E (line 160) the surficial S&G unit on the North Plateau is said to be recharged in part by lateral inflow from direct contact with fractured bedrock west of the site; in the PA model of Appendix G this lateral recharge must be disregarded in order to allow computing a single uniform value of vertical infiltration into the unit. The same is probably true with respect to lateral recharge into the WLT unit on the South Plateau. We believe that rather than sacrificing available information about the flow system in order to accommodate the limitations of a questionable flow tube network model, it would be more accurate to work with a valid groundwater flow model which does not require excluding relevant data.

6. **Spatial variations in vertical recharge:** We likewise believe that rather than having to treat vertical infiltration as uniform across each plateau, it would be more accurate to consider spatial variations in infiltration due to spatial variations in the permeability of surficial soils and graded surfaces, and the distribution of paved surfaces and structures, by adopting a valid groundwater flow model that can admit such information.

7. **Correspondence between computed and measured heads:** It is generally not possible to insure that hydraulic heads assigned to boundary nodes, or computed at interior nodes, of a flow tube network model are consistent with measured heads in the system. Prescribing numerical head values to one upstream and one downstream node, as described earlier, does not allow representing known heads at other points along the system boundaries; this is important if heads along the boundaries are not uniform, as they are at the VWDP site. Due to the coarse and somewhat arbitrary designation of flow tubes, it is difficult to associate interior nodes with specific spatial locations within the system, rendering it equally difficult to validly compare head values computed at these nodes with measured water level data. This precludes any meaningful calibration of the flow tube network model against such data, leaving its reliability open to question.

8. **Role of temporal head variations:** Water level data assigned at the upstream and downstream nodes of the equivalent (global) flow tube network model, taken from Appendix E, represent at best a period from 1990 through Spring 2004. We explained earlier that these data cannot conceivably represent a long-term steady state flow regime, as is assumed in the DEIS. We also explained why, in our view, groundwater flow may have to be modeled as a transient phenomenon over the long time periods considered in the PA. Under transient conditions, streamlines vary with time and therefore an approach based on fixed flow tubes

becomes inapplicable. Only a standard groundwater flow model, capable of resolving both spatial and temporal variations in hydraulic heads and fluxes across the entire system, can validly be used for this purpose. We therefore urge the authors to adopt such a model in lieu of their flow tube network model.

9. **Vertical contaminant transport above water table:** We explained earlier the reasons why we expect seasonal fluctuations in groundwater levels to constitute a likely mechanism of spreading contaminants in flowing groundwater vertically through the vadose zone, bringing them in direct contact with shallow soils and plant roots, even causing them to seep vertically up to the soil surface. Presently, the flow tube network model in Appendix G does not consider this vertical transport mechanism, which we believe introduces a non-conservative bias into the PA.

10. **Role of spatial variations in hydraulic conductivity:** Measured hydraulic conductivities are known from Appendix E to vary by several orders of magnitude within each hydrogeologic unit at the site. Though the DEIS does not mention it, we understand from discussions with the authors that flow tubes representing portions of a hydrogeologic unit are assigned the overall geometric average conductivity of that entire unit. We believe that it would be considerably more accurate to represent the spatial variability of hydraulic conductivities (and/or transmissivities) within each unit geostatistically and account for it explicitly in a three-dimensional groundwater flow model.

11. **Use of hydraulic conductivity data:** The geometric (or any other) average hydraulic conductivities, employed in the flow tube network model, are based on a mixture of laboratory and field data obtained by different methods on disparate scales of measurement (please refer to our earlier discussion of Appendix E). It appears that few if any of these data account for the effect of fractures, high-permeability inclusions, collapsed open boreholes and corrodible H-piles under the Process Building in the ULT down to 50 feet on the bulk (larger-scale) horizontal and vertical hydraulic conductivities of this unit. We are concerned that by including laboratory values and failing to consider the impact of preferential pathways, the conductivity values used for each hydrogeologic unit in the model are biased downward toward non-conservative values.

12. **Effect of preferential pathways on advective porosity in ULT:** As in Appendix E, here too groundwater velocities are computed upon dividing fluxes obtained from Darcy's law by advective porosities (Table E-5) determined on small sediment samples in the laboratory (as already stated, we are not aware of any field determinations of advective porosity, alluded to in line 569 of Appendix E). It is highly likely that most such samples reflect the local porosity of intact till rather than that of preferential pathways such as fractures and collapsed open boreholes. We expect the advective porosity of preferential pathways to be much smaller than that of intact till, and hence groundwater velocity (for a given Darcy flux) to be potentially larger in fractured or disturbed than in intact till. It is thus

highly likely that groundwater velocities within the ULT have been significantly underestimated in the DEIS, which would have biased the groundwater flow and transport computations in the PA toward non-conservative outcomes.

13. **Description of flow modeling in KRS:** The flow tube network models described in Appendix G (Figure G-6, G-7) do not explicitly contain the KRS, even though the latter is part of the conceptual framework in Figure G-4. It is conceivable that flow through this unit is modeled separately, using computed vertical inflow through the WLT and ULT via four parallel equivalent flow tubes, as input but we were unable to find any description of such a separate KRS flow tube model within the DEIS.

14. **Possible impact of unsaturated flow on transport:** As already mentioned in connection with Appendix E, the DEIS does not address the potential influence that an unsaturated zone, often found within the KRS beneath the ULT (as well as within the LTS), might have on flow and contaminant transport through the ULT and KRS complex. The DEIS conceptualizes flow through the KRS as occurring under fully saturated conditions, an approach the authors consider to be conservative. It would, in our view, be worth examining the extent to which unsaturated conditions within the KRS could retard flow and transport out of the ULT, causing contaminants to accumulate within this unit and thus form a long-term source, feeding pollutants into the KRS (eventually reaching seeps and creeks intersected by this unit) over a longer time period and at less diluted concentrations than would be predicted upon neglecting unsaturated flow. It should be relatively easy to address this issue generically with the aid of a two-dimensional saturated-unsaturated flow and transport model in the vertical plane. As water levels within the KRS and LTS fluctuate, the thickness of the unsaturated zone within each of these units varies with time, suggesting that the analysis should be transient rather than steady state.

Analysis of Contaminant Transport for PA in Appendix G

Once groundwater velocities in each flow tube of a network have been computed in the aforementioned manner, it is possible to route contaminants through the network by advection. To avoid excessive dilution by mixing as a contaminant migrates out of a wasteform (including the groundwater plume on the North Plateau) into a downstream flow tube, its downstream concentration is computed by assuming that the contaminant continues to occupy a cross-sectional area not larger than that of the waste form. Dilution occurs by mixing with surface water at an exit point from the system or at a well (lines 311-325, Appendix G). Mixing at a well is specified independently of any flow model by considering the minimum daily requirement for a family living at the site and engaging in agriculture. If aquifer flow is below the minimum required well production rate, the entire plume is taken to be captured by the well and concentrations are diluted by mixing into a volume equal to the productivity of the well; otherwise, dilution is assumed not to take place within the well. The authors also account for longitudinal dispersion and diffusion, retardation and radioactive decay (line 53) or chemical decomposition (line 583) by specifying numerical values for a corresponding dispersion coefficient, distribution coefficient and decay or decomposition rate. They then solve linear ordinary differential equations of transport representing these processes, for the most part analytically, along one-dimensional flow paths defined by flow tube network models.

In the case of localized wasteforms contaminant release rates to, and initial concentrations in, groundwater are computed by means of corresponding release modules by superposition of solutions corresponding to a sequence of stepwise pulses (Figure G-9); in the case of distributed wasteforms such as the North Plateau groundwater plume, the initial concentration is specified as a function of location (lines 361-381). Release modules consist of a one-dimensional analytic model for a rectangular source oriented perpendicular to groundwater flow (line 419), a one-dimensional finite difference model for a rectangular source, and a two-dimensional finite difference model in radial coordinates for a cylindrical source (lines 406-412).

We have serious misgivings about the above contaminant transport approach to PA for the following reasons:

1. **Transport under surficial unit on North Plateau:** The DEIS ignores transport of contaminants through the ULT on the North Plateau. This, for reasons explained earlier in connection with flow (which is likewise ignored), is considered by us to be entirely inappropriate and to invalidate the corresponding PA transport modeling results.

2. **Representation of advective velocities:** Any analysis of contaminant transport in groundwater depends critically on the underlying advective velocity field; it is a key parameter in any transport equation. For purposes of PA the velocity field is computed using a flow tube network model which (as explained earlier) we deem to be inadequate for this task. As the PA yields an unreliable representation of advective velocity, the corresponding analysis of contaminant transport and resulting impacts are equally unreliable. In effect, every deficiency of the flow tube network model that we have identified earlier is also a deficiency of the contaminant transport model built upon it in the PA.

3. **Specification of contaminant dilution rates in wells:** The inability of the PA model to incorporate wells explicitly forces the authors to prescribe contaminant mixing at wells rather than compute it as an integral part of the modeling process. It is not clear that the resulting dilution rates are consistent with what a more complete three-dimensional model would have predicted.

4. **Role of transverse diffusion:** The transport analysis disregards molecular diffusion transverse to advective flow; it also disregards it parallel to flow in cases where longitudinal dispersion is suppressed (e.g. lines 581-582 where contaminants are taken to move through the waste form in plug flow manner). Yet diffusion is sure to take place in multiple directions, and be potentially

important, through any waste form (affecting release rates and concentrations) or low-permeability barrier including the ULT matrix (affecting transport rates and concentrations).

5. **Role of transverse dispersion:** The transport analysis disregards transverse dispersion which may act to spread contaminants in flowing groundwater horizontally and vertically perpendicular to flow.

6. **Modeling of contaminant release from tanks:** As mentioned previously, flow through and around cylindrical tank closure systems is represented by an equivalent rectangular flow system (Figures G-13 and G-14) which we suspect may not adequately capture actual flow and transport through and around these systems. The corresponding contaminant release model translates velocities obtained from the equivalent rectangular representation into radial and angular velocity components to allow developing a two-dimensional contaminant release model for the system in cylindrical coordinates (equation G-56). We consider this approach to constitute circular reasoning the accuracy of which has not been demonstrates and remains in doubt.

7. **Vertical contaminant migration above water table:** As already stated, the water table on each plateau fluctuates seasonally with an amplitude that in places is of the same order as the thickness of the overlying unsaturated zone. This may bring contaminated groundwater in contact with overlying shallow soils, plants roots penetrating these soils, and perhaps even to seep out vertically. We suspect that this potential mechanism of vertical contaminant migration and dispersion above the water table, which is not recognized in the DEIS, may be important. We find it remarkable that the DEIS says nothing about the presence or absence of contaminants in the vadose zone and in soils above the plume, which have apparently never been sampled.

8. **Need for state-of-the-art modeling approaches:** The above deficiencies of the PA transport model could be remedied by adopting a more realistic transport model coupled to a three-dimensional groundwater flow model, the latter properly calibrated to available site data and subsequently augmented to include in a realistic manner all significant engineered components and waste forms planned under each alternative. We urge the authors to do so based on our opinion, stated earlier, that most previous computer- or software-related obstacles to the use of such models for purposes similar to those we deem advisable for PA at the WVDP site have by now been largely eliminated. We therefore question the continued reliance on flow tube models at the virtual exclusion of more realistic models in PA, considering their limited power and validity.

9. **Choice of modeling approach:** The authors expressed to us orally their opinion that the groundwater flow and contaminant transport modeling approach they had adopted in the DEIS is adequate for a comparative PA of the various site

decommissioning alternatives. We respectfully disagree for the following two reasons:

c. The PA is intended to provide a credible analysis of actual rather than just relative long-term environmental impacts that may be expected upon selecting any of the planned alternatives. Considering our opinion that the PA models used in the DEIS are not reliable, we do not have confidence in their ability to provide a credible prediction of actual long-term impacts.
d. We likewise see no reason to have confidence that PA models, which we consider to be unreliable, would provide a credible basis for a comparative analysis of such impacts among the various alternatives.

10. **Choice of longitudinal dispersion coefficient:** We were unable to find any stated rationale for particular choices of the longitudinal dispersion coefficient *D* used in PA, yet these choices may have an impact on the outcome. In particular, values of *D* that are too small would delay the first arrival of contaminants at receptor locations, and values that are too large would lower concentrations. In each case, the outcome would be non-conservative.

11. **Role of numerical dispersion:** The DEIS does not address explicitly the potential impact of numerical dispersion on contaminant concentrations computed using a finite difference model, as on page G-26 and G-33. Yet numerical dispersion may bias concentrations toward low (non-conservative) values. We are told that this issue has been addressed in verification calculations but were not able to find any details in the DEIS.

12. **Potential role of future pumping on the South Plateau:** We are not clear why a well is said to be feasible on the North Plateau but not on the South Plateau (lines106-107); what justifies excluding the possibility that someone might want to derive potentially contaminated water from the WLT on the South Plateau or, more likely, the KRS on either plateau?

Deterministic Versus Stochastic PA

The PA in the DEIS is largely deterministic, though some parameters were also varied randomly to produce a few hundred random outcomes. The PRG’s understanding of the uncertainty analysis is:

1. For the erosion analysis, a deterministic sensitivity analysis was conducted under which three sets of nominal (expected), favorable (conservative) and unfavorable (non-conservative) parameters were assigned deterministically to each component of the PA model. These parameters were selected to correspond to the 10th, 50th, and 90th percentiles of published frequencies of their occurrence in soils of similar texture. The PA model was executed for each of the three parameter sets producing three corresponding sets of deterministic outcomes. Most of the environmental consequences summarized in Chapter 4, and detailed in Appendix H, represent these deterministic outcomes.

2. For the groundwater flow and contaminant transport analyses, selected parameters were designated as random variables; deterministic parameters were set equal to their nominal values; each random parameter was assigned a univariate probability distribution, either assumed (in the case of most parameters) or based on actual data (the latter being the case for hydraulic conductivities in the various hydrogeologic units); several hundred sets of parameters were drawn randomly from the corresponding univariate probability distributions using the Latin Hypercube method; for each random set of parameters (and nominal set of deterministic parameters) the PA model was executed to produce several hundred random outcomes; and the random outcomes were summarized statistically. This Monte Carlo sampling process is referred to in the DEIS as stochastic PA or a parametric uncertainty analysis.

3. Contaminant doses from a few nominal deterministic runs were compared to those from Monte Carlo runs and found to be higher than the predicted mean, corresponding to high percentiles of the computed cumulative dose distributions (e.g. 70^{th} percentile for the Process Building and 99^{th} percentile for the SDA on page H-87). The authors have interpreted this as *a posteriori* support for their position that the nominal deterministic PA calculations provide conservative estimates of dose.

Finding: We find the emphasis on deterministic PA in the DEIS to be misplaced and the follow-up uncertainty analysis to be inadequate. Our reasons are as follows:

1. **Role of uncertainty:** Environmental systems are open and complex, rendering the interpretation of environmental data prone to multiple interpretations and the description of the environment or processes occurring within it inherently uncertain. It follows that neither conceptual-mathematical models of environmental processes nor their parameters or forcing terms (initial and boundary conditions, source terms) can be specified with certainty. Deterministic models of the kind employed for purposes of PA in the DEIS do not consider uncertainty and are therefore incapable of resolving this dilemma. These models are based on a single conceptualization of flow and transport at the site and on fixed parameters as well as forcing terms despite a general lack of knowledge about the system's real makeup and behavior. This conveys to the reader a false sense of confidence in the outcome of the PA which we believe is unjustified. In our opinion, the proper approach is to account formally for uncertainties that affect all aspects of the PA analysis, which would eliminate any need for a deterministic PA.

2. **Role of conceptual model uncertainty:** Though there is no known way to quantify environmental model uncertainty in an absolute sense (for reasons clearly articulated by Bredehoeft (2005), there is a way to do so in a relative sense for a given set of alternative models (NUREG/CR-6805, Neuman and Wierenga, 2003; Neuman, 2003; Ye et al., 2004, 2005). Ways to account for

parameter and forcing term uncertainty are well established and corresponding general purpose software is accessible. We urge the authors of the DEIS to consider applying this or a similar methodology in the context of PA at the WVDP in conjunction with three-dimensional flow and transport models of the kind we have advocated earlier.

3. **Stochastic analysis of flow and transport:** The stochastic analysis in the DEIS does not take into account uncertainty in the underlying PA models and forcing terms; treats the least certain parameters, which lack support in data, as deterministic (perfectly known) quantities; ascribes subjective probabilities to some parameters without an ability to update these probabilities on the basis of measurable data; does not insure that the models are compatible with key measurements such as hydraulic heads in the system interior; treats locally measured hydraulic conductivities, that vary by orders of magnitude across each hydrogeologic unit, as if they could represent uniform equivalent values across the entire unit; and does not consider auto- and cross-correlations between these and other parameters. The analysis is based on only a few hundred random Monte Carlo runs of the PA model without verifying that the statistics of the outcome have stabilized; it appears that many more runs would have been required to yield a stable probability distribution for the computed dose.

4. **Rationale for deterministic modeling:** We do not understand the rationale for first conducting a nominal deterministic PA and the verifying, *a posteriori* based on a stochastic analysis, that the deterministic outcome is conservative. Why would one run a deterministic PA given the results of a stochastic analysis, which yields not only a mean outcome representing a best estimate of dose, but an entire range of outcomes some of which are more and some less conservative? The only answer we can think of is that the stochastic PA has been added as an afterthought rather than having been planned from the start. We urge the authors to conduct a valid, comprehensive and thorough stochastic PA for the WVDP without resorting to a superfluous and uninformative (from the view point of uncertainties) deterministic analysis.

Estimation of Worker Collective Radiation Doses for Closure Alternative Number 1

In addition to conducting a review of the DEIS, one member of the Review Group was asked to review the estimation of worker collective radiation doses associated with Decommissioning EIS Alternative 1. As described above, this particular alternative would involve the removal of all contaminated facilities, buried waste and soil/groundwater contamination so that the entire site meets the unrestricted use/clean closure criteria. These estimates were provided as part of Alternative 1 and the results could influence the decision-making process. Thus, it is necessary to understand the basis for these estimates and their validity.

The closure engineering report on Alternative 1 (WSMS-WV-05-0001) provides little information useful in this evaluation. The report has a few, very succinct statements regarding the estimated doses. For example:

> Radiation exposure to operations workers was estimated on a task-by-task basis. The estimates were made based on historical records at WVDP and DOE published occupational radiation exposure report (DOE, 2002B). They take into account the nature of the work, the radiation fields where the work was performed, and the total amount of radiation exposure recorded by all workers involved. This approach was used (1) to reflect local work practices, (2) to assure that the exposures received by all people involved in a task, such as maintenance workers, were taken into account, and (3) to assure that exposures received when responding to unanticipated 'contingency' events were taken into account. (WSMS-WV-05-0001, page 77)

Later in the closure report a table is presented, which summarizes the collective doses (in units of person-rem) estimated to be received from all activities associated with Alternative 1. The total collective dose was estimated to be 1,170 person-rem, with more than 80% of the total collective dose being due to activities associated with waste management areas 3, 7, and 8. However, a more detailed description of the approach taken and the data sources is not provided in the closure report. In addition, no information is provided on the approach taken or the collective doses due to unanticipated events. To complete the review, additional information was requested and reviewed.

Estimates were made of the total effective dose equivalent (TEDE) for workers in a number of different labor categories. These estimates were based on commercial construction cost estimating information and exposure data available through Department of Energy reports. These latter data were actual exposures received during activities at DOE sites across the country in the years 2001 through 2003. The information above was used to establish two general labor categories to be used in the evaluation of Alternative 1. These were (1) the "estimated measurable dose rate;" and (2) the "estimated labor category dose rate."

The estimated measurable dose rate is the average hourly dose rate received for individuals in particular labor category. It includes only those individuals that received a measurable dose while performing work activities at a DOE facility. This dose rate was applied to workers involved in Alternative 1 that were expected to receive significant radiation exposure due to their work, e.g., removing contaminated equipment.

The estimated labor category dose rate is the average hourly dose rate received for all individuals in particular labor category. It includes all individuals whether or not they received a measurable dose while performing work activities in a DOE facility. This dose rate was applied to workers involved in Alternative 1 that were not expected to receive significant radiation exposure due to their work, e.g., demolishing decontaminated structures.

For each specific task, estimated doses were obtained by multiplying the estimated number of work hours for a particular labor category by either the estimated measurable dose rate or the estimated labor category dose rate (see for example, BUF-2005-111, Rev 0, 2005). The supplemental information also indicates that when contamination or exposure rate data obtained directly at WVDP were available, the actual contamination and/or dose rates were used in the evaluations.

This is a very difficult, non-trivial task and the approach taken attempts to use the available data to provide estimates of the collective dose for all of these activities. The calculations are contained in an extensive set of spread sheets and only the summary results are presented in the DEIS. There is not sufficient information provided in the DEIS to understand the logic of the approach and the significance of the results. It appears that these dose estimates are really “best case” estimates and are likely to be lower than the actual doses received. This statement is supported by the recognition that these estimates used data which, in effect, were “averaged” over the entire DOE complex and were not completely representative of the specific activities likely to be conducted at the WVDP. However, the magnitude of the differences between these “best case” estimates and more realistic estimates is also very difficult to determine.

In addition, it is not clear that there was an effort to seek other data that may be available and might be more representative of the exposures associated with Alternative 1. For example, for a number of years similar activities have been conducted at other DOE sites and it was not clear that there was an attempt to obtain more useful exposure data. Other sites could provide information on the size of the crews, time to complete tasks, etc. For example, the work at Rocky Flats could serve as a guide to efforts to completely level the site. In addition, since the WVDP buildings, etc. contain a large number of fission products (as opposed to alpha-emitting radionuclides encountered at Rocky Flats), buildings at sites such as the Idaho National Laboratory may provide useful information that could be factored into the analysis.

Since the information was contained mostly in spreadsheets with little additional information, it was not possible to determine how on-site measurements were used in the estimation of occupational exposures for specific cases. However, there are statements in the “notes” section of the spreadsheets that indicate some of the actual data was used. Since these latter estimates are likely to be more reliable that those obtained using other approaches, these results should be clearly delineated in the summaries and a description of the methods used to obtain these estimates should be prepared and included in the record.

Finally, the review showed no direct indication that there was an effort to “assure that exposures received when responding to unanticipated ‘contingency’ events were taken into account.” While this may have been done, the review did not find any information to explain the approach taken to address such contingencies.

Brief Recapitulation of Key Findings

- A significant effort was made to estimate the residual radionuclide inventories of the waste tanks. A combination of analyses, measurements and calculations were used for what the PRG views as a difficult and challenging task. It is important to recognize that the range between the “best” and “worst” case estimates is relatively large – ranging from a factor of 1.6 up to 6 for all 18 radionuclides, and that this range was not included in the uncertainty analyses of the DEIS.

- For Alternative 1, the total effective dose equivalents (TEDE) for workers in different labor categories were based on commercial construction cost estimating information and exposure data available through Department of Energy reports. Site-specific data were used when available; however such data were quite limited. The generic data for exposures to workers across the DOE complex was not filtered based on the similarity of facilities or operations to those proposed for Alternative 1.

- The assumptions made under “conditions expected to occur” are highly unlikely to be fulfilled. The DEIS expects institutional controls to be successfully maintained into the indefinite future. While predicted doses under these conditions are low, this is due in part to receptors being located at least several miles from the site and engineered barrier systems being assumed to remain unaffected by erosion or other disrupting processes. Dose predictions are based in part on calculations of contaminant transport by groundwater that are neither reliable nor conservative.

- Conditions under which institutional control of the site would be lost are “not expected to occur” in the DEIS. The PRG considers it to be highly likely that institutional control of the site would be lost sometime during the first few hundred years of the initial 1,000 year regulatory period.

- Dose calculations for a well driller and home constructor and for a resident farmer using contaminated groundwater while gardening on contaminated soil assume that engineered barriers continue to offer protection against some types of direct contact. However, the dose rates from the use of groundwater at the SDA or NDA exceed the license termination limits for Alternatives 2 through 5. The dose rate from the remainder of the Process Building exceeds the limits for Alternatives 3 through 5.

- The DEIS ignores the possibility that, in the case where erosion exposes waste, a farmer might reside on the site prior to erosion. In addition, the assumption that steep slopes are unsuitable for home construction and farming is not consistent with the fact that some houses are currently quite close to gullies.

- Analyses related to performance assessment are not described fully and clearly in the DEIS and are sometimes contradictory; assumptions, modeling procedures and parameters are not presented in sufficient detail to allow independent assessment of the results.

- The DEIS performance assessment is largely deterministic. The PRG is of the opinion that uncertainties must play a primary role in PA, urging the authors to account in a comprehensive manner for uncertainties related to (1) conceptualization and mathematical representations of erosional processes, groundwater flow and contaminant transport; (2) uncertainties in model parameters and forcing terms (initial and boundary conditions, source terms); (3) uncertainties arising from measurements and data processing; and (4) scenario uncertainties.

- The science behind landscape evolution models such as SIBERIA is not mature enough to justify relying on these models to provide long-term predictions of erosional processes and rates in glaciated terrains of the northeastern United States. A less sophisticated but more credible alternative would be to judiciously extrapolate observed short and long-term patterns and rates of erosion at the site and the surrounding region into the future, considering similar such patterns and rates recorded in similar terrains elsewhere, and quantifying in a conservative manner the associated predictive uncertainty bounds. However, the PRG expects the uncertainty associated with such extrapolation to be large.

- As presented in the DEIS, SIBERIA does not consider commonly accepted erosion processes such as knickpoint migration. SIBERIA has predicted future landscapes for the site that the PRG considers unrealistic and hence not credible. Whereas it might be possible to produce more realistic future landscapes with SIBERIA, its reliability as a predictor would still remain highly uncertain. No attempt has been made to quantify the uncertainty in SIBERIA predictions.

- Deterministic dose predictions associated with erosion scenarios are categorized in the DEIS as representing “favorable,” “best estimate” or “unfavorable” cases. A more apt description of these cases would be conservative, nominal and non-conservative. The PRG views the presentation of this range of cases as a deterministic sensitivity analysis, not as a comprehensive uncertainty analysis.

- If and when institutional controls eventually fail, then erosion would start gradually impacting groundwater flow and contaminant transport, a case the PRG considers important and highly likely which however is not included among any of the scenarios presently analyzed.

- The analysis of existing groundwater flow conditions at the site in Appendix E is unreliable, being neither realistic nor conservative.

- The flow tube network model used for groundwater flow in the PA does not capture adequately the full three-dimensional nature of subsurface flow conditions at the site. Flow through the ULT is ignored unjustifiably at the North Plateau and most likely underestimated at the South Plateau in the PA.

- The flow tube network model of groundwater flow in Appendix G is by its very nature difficult to reconcile with actual or expected groundwater flow conditions at the site, leading to an inherent inconsistency between the PA in Appendix G and groundwater flow analyses in Appendix E.

- Groundwater flow analyses in the EIS should be conducted using state-of-the-art numerical models that conserve water balance and allow representing key spatial and temporal aspects of current and anticipated groundwater flow conditions realistically, consistent with all relevant site data. The argument that one-dimensional flow tube network models have been traditionally employed by the US DOE and that they have been accepted as valid by some regulatory agencies is in our view not relevant to the unique and complex conditions of the VWDP.

- As flow is not represented accurately in the DEIS, the PRG sees no basis for confidence in long-term DEIS predictions of contaminant concentrations and doses presented under “conditions expected to occur.” This is especially true considering that the DEIS does not recognize the likelihood of vertical migration and dispersion of contaminants from the shallow saturated zone to the unsaturated zone and the soil surface.

- The PRG does not accept the opinion that the PA-related modeling approach adopted in the DEIS is adequate for a comparative assessment or ranking of the various site decommissioning alternatives.

- The PRG questions the suitability of the DEIS to serve as a basis for an informed selection of a preferred site closure or decommissioning alternative.

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