REVIEW COMMENTS ON EXPLORATORY STUDIES FACILITY DESIGN PACKAGE 2C: TOPOPAH SPRING NORTH RAMP

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Contributors

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ABSTRACT

A technical review was conducted of the "Exploratory Studies Facility (ESF) Title II Design Package 2C: Topopah Spring (TS) North Ramp." Design Package 2C was prepared to provide comprehensive design, analysis, records, and quality assurance for construction of the TS North Ramp. This technical review concentrates on: (i) technical comprehensiveness of the TS North Ramp design, (ii) technical soundness of the approaches and methodology, (iii) conservatism of the design analyses, and (iv) accuracy of the applications of knowledge and design calculation. Listed below are some of the major concerns raised in this review.

- Assumptions and criteria used in the blast design may not be conservative
- The TS North Ramp Stability Analysis is incomplete and cannot be used to supplement the ground support design
- Required design air velocity data used in the ESF Ventilation Flexibility Analysis need to be updated
- Assumptions in TS North Ramp Rock Mass Classification may not be conservative
- Input parameters in seismic design are either not clearly discussed or not properly chosen, leading to confusion and nonconservative design
- Definitions and interpretations given in TS North Ramp Ground Scoping Analysis are ambiguous
- Methods, assumptions, and criteria in waste isolation evaluation are inconsistent, leading to arbitrary and unknown levels of conservatism

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1 INTRODUCTION

The Civilian Radioactive Waste Management System Management & Operating Contractor (M&O) completed the Exploratory Studies Facility (ESF) Title II Design Package 2C: Topopah Spring (TS) North Ramp on May 2, 1994. During May 16–20, 1994, the M&O performed the 90 percent management and technical design review of this design package; and the Nuclear Regulatory Commission (NRC) observed this M&O design review. Before observing the ESF design review, an NRC and Center for Nuclear Waste Regulatory Analyses (CNWRA) team reviewed and commented on selected sections of the ESF Title II Design Package 2C. The review comments were used by the NRC/CNWRA team during observation of the M&O review of ESF Design Package 2C. These comments, along with the additional comments generated by the NRC while observing the ESF design review, were transmitted by the NRC to the U.S. Department of Energy (DOE) as "U.S. Nuclear Regulatory Commission Design Review Observation Report 94-02"[1]. The ESF Design Package 2C was subsequently modified to take these comments into consideration as well as those comments generated by the M&O 90 percent review and internal Quality Assurance (QA) review. The updated version of Package 2C was then reviewed again by the CNWRA team to support the NRC in-field verification activity. Major review comments were used by the NRC/CNWRA team to conduct in-field verification related to ESF Design Package 2C. This report documents concerns that exist after the in-field verification of ESF Package 2C, in which CNWRA representatives took part in the discussions.

The ESF Title II Design Package 2C: TS North Ramp reviewed herein is the version that has been approved by the DOE for construction[2]. The scope of the review includes a review of: (i) TS North Ramp Geology Design Analysis; (ii) Material Dedication Analysis for Commercial Grade Items–Steel Sets; (iii) North Ramp Layout Calculation; (iv) TS North Ramp Blast Design Analysis; (v) TS North Ramp Stability Analysis; (vi) Requirements Allocation Analysis for North Ramp Excavation and Layout; (vii) ESF Ventilation Flexibility Analysis; (viii) TS North Ramp Rock Mass Classification Analysis; (ix) ESF Subsurface—Cable Tray Support Design; (x) Requirements Allocation Analysis for ESF Subsurface Ventilation; (xi) TS North Ramp Alcove Ground Support Analysis; (xii) ESF Subsurface Design–Ventilation Duct Supports–Design Calculations; (xiii) Requirements Allocation Analysis for Linings and Ground Support; (xiv) TS North Ramp Ground Support Scoping Analysis; (xv) Specifications for Construction Quality Control/QA, Subsurface General Construction, Rockbolts and Accessories, and Steel Sets Accessories; (xvi) Determination of Importance Evaluation for ESF Package 2C; (xvii) Waste Isolation Evaluation, Construction Water for Package 2C Excavation of the ESF North Ramp; (xviii) Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction; and (xix) Test Interference Evaluation for Tunnel Boring Machine (TBM) Operation, Utilities Installation, and Support for TBM Operation for Construction of North Ramp.

This report documents specific concerns. These concerns are presented in a standard format consistent with previous NRC submittal of concerns provided to the DOE (Nuclear Regulatory Commission, 1989). This standard format includes objections, comments, and questions, if any. The definitions of objections, comments, and questions are given in Section 2 of this report.

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[1] J.J. Holonich to R.A. Milner, letter dated August 10, 1994.

[2] A.V. Gill to W. Belke, December 1994.

Reference:

Nuclear Regulatory Commission. 1989. *NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada*. NUREG-1347. Washington, DC: Nuclear Regulatory Commission.

2 CATEGORIZATION OF CONCERNS

In this chapter, the major categories of concerns used for the review of the ESF Title II Design Package 2C report are summarized. These major categories consist of objections, comments, and questions and are defined and used consistent with other submittals of concerns from the NRC to DOE in the high-level waste (HLW) program.

2.1 OBJECTIONS

An "objection" is a concern with the DOE program related to either:

(i) Potentially adverse effects on repository performance

(ii) Potentially significant and irreversible/unmitigable effects on characterization that would physically preclude obtaining information necessary for licensing

(iii) Potentially significant disruption to characterization schedules or sequencing of studies that would substantially reduce the ability of the DOE to obtain information necessary for licensing

(iv) Inadequacies in the QA program that must be resolved before work begins

Objections are reserved primarily for concerns with activities, tests, and analyses which, if started, could cause significant and irreparable adverse effects on the site, the site characterization program, or the eventual utility of the data for licensing (programmatic fatal flaws). Due to the irreparable nature of activities associated with objections, the NRC would recommend that the DOE not start work until the objections are satisfactorily resolved.

2.2 COMMENTS

A comment is a concern with the DOE program that would result in a significant adverse effect on licensing if not resolved, but there would not be irreparable damage if site characterization started before resolution. The DOE program could be modified in the future, with some risk to not having the necessary information for licensing; the adverse effects would be primarily related to the program schedule. Therefore, for these concerns, the DOE would start work at its own risk before resolving such concerns with the NRC. The NRC would recommend timely resolution of comments. If resolution is not achieved in a timely manner, comments could be elevated to the higher category of objections described above (i.e., potential significant disruption of schedules that would reduce the ability to obtain information necessary for licensing).

2.3 QUESTIONS

A question is a concern with the presentation of the DOE program such as missing information, level of detail, contradictions, and ambiguities that preclude understanding part of the DOE program, thereby preventing the staff from being able to comment. The NRC would recommend a timely response by the DOE to such questions. If a question is related to a potential objection, satisfactory resolution should be accomplished before work begins. If the question is not related to an objection, then the DOE could choose to proceed with work at its own risk, and resolve the question in future reports.

3 SPECIFIC CONCERNS

3.1 OBJECTIONS

None.

3.2 COMMENTS

TS North Ramp Blast Design Analysis: Package 2C/Assumptions and Design Criteria

COMMENT 1

The assumptions, both inherent and explicit, and criteria taken in the TS North Ramp Blast Design may not be conservative.

Bases:

- The design methodology adopted to estimate the extent of the damaged zone uses empirical equations suitable for surface blasting with empirical constants relevant to Swedish blasting practices in granites. These equations and the empirical constants may not be suitable for the Yucca Mountain (YM) ESF site. As a result, there is a significant risk of underestimating the extent of the damaged zone.

- The methodology to estimate blast damage does not take into account the distribution of the explosive charge along the borehole, as suggested by Hustrulid and Holmberg (1991). As a result, there is a significant risk of underestimating the extent of the damaged zone.

- The recommended vibration limits for concrete damage from blast vibration, as given by Oriard (1982) in Table 4-6, use distance as one of the controlling factors. The values used in this design neglected the distance factor.

- The recommended critical peak particle velocity of 700 mm/s may not be conservative for tuff, although good agreement was found for gneiss, pegmatite, and granite.

Recommendations:

- The DOE should develop a ground vibration attenuation equation especially for close distances from the blast suitable for blasting conditions at the ESF unless the DOE shows documented evidence that the Swedish blasting practice can be adopted for YM without increasing the extent of the damaged zone.

- The methodology suggested by Hustrulid and Holmberg (1991) should be adopted to take into account the distribution of the explosive charge along the borehole.

- The DOE should either use the distance factor as recommended by Oriard (1982) or justify the reason(s) for omitting it.

- The DOE should conduct a systematic study to correlate peak particle velocity with rock damage (new fracture formation) to develop a criteria suitable for YM tuff.

<u>References</u>:

Hustrulid, W., and R. Holmberg. 1991. Drilling and Blasting. *Underground Structures Design and Construction*. R.S. Sinha, ed. Amsterdam: The Netherlands: Elsevier.

Oriard, L.L. 1982. Blasting effects and their control. *Underground Mining Methods Handbook*. W.A. Hustrulid ed. New York, NY: Society of Mining Engineers: 1,590–1,603.

TS North Ramp Stability Analysis/Modeling Assumptions

COMMENT 2

Some assumptions used in TS North Ramp Stability Analysis are not discussed sufficiently, which may lead to ambiguous modeling results or nonconservative design.

<u>Bases</u>:

- There is no discussion on the range of joint orientations, number of joint sets, or spacings assumed in the calculations. For example, the ubiquitous joint model analysis using the finite difference code FLAC presented in Section 10.5.3.2 gives no rationale as to the particular joint orientation(s) chosen. Similarly, for the distinct element analysis in Section 10.6, using the UDEC code, it is not clear whether the joint spacings and orientations were arbitrarily chosen or based on some site characterization field data.

- It is stated in Section 10.5 that two-dimensional (2D) plane strain analysis is sufficient as the radius of the tunnel is small compared to the length of the tunnel. However, this assumption implies that the tunnel axis is parallel to one of the principal horizontal stresses and that no shear stress is developed in the horizontal plane. It is unlikely that the ramp axis will always be parallel to one of the principal stress directions.

- Based on the site characterization studies to date, the joint orientations within the repository block are predominantly north-south at a near vertical inclination. The east-west trending TS North Ramp would intersect these joints at approximately 80°to 90° throughout its length. Even if the tunnel orientation makes the 2D analysis acceptable, the presence of the major joint sets in the rock mass makes the analysis with continuum media inappropriate, especially for an underground excavation of special importance, such as the TS North Ramp. It is unclear how these joints and their impact on stability have been considered in the analysis of a cross-section of the ramp. Also, no consideration is given to the affect of alcove intersections on the stability of the North Ramp. Moreover, these joints may play an important role in the stability analysis from seismic loads.

- In the dynamic analysis of the supported ramp in Section 10.7.2, the seismic input signal was introduced as a sinusoidal wave with a duration of 0.25 s and frequency of 10 Hz. The use of such a high-frequency, short-duration harmonic wave for seismic analysis does not seem to be conservative. The duration and frequency of a seismic event are important parameters that will affect the stability of an underground opening. An underground opening is likely to suffer more damage under a longer duration of shaking or if subjected to repetitive episodes of seismic shaking (Hsiung et al., 1992). It is recognized that the duration and frequency of the seismic events vary for different events. However, the duration of 0.25 s used in the analysis seems to be too short, the frequency of 10 Hz is too high and so may not be conservative. Furthermore, the calculated response based on an input consisting of an actual seismic motion will be different from that due to harmonic input.

Recommendations:

- A clear rationale should be given on the choice of joint orientations and spacings chosen in the analysis, as they have an important impact on the results of the stability analyses for both finite difference and distinct element calculations. The rationale should be given for not considering the range of joint orientations and spacings in the analysis. If they are not entirely known at this time, then it is recommended that the outcome of the analyses be reevaluated after better joint characterization data are obtained. It is essential that the TS North Ramp Stability Analysis makes use of data verified during initial testing in the ramp. It appears somewhat premature to conduct extensive numerical modeling until sufficient field data in the ramp has been collected. Once sufficient site characterization data has been collected, the decision can be made as to the necessity of 2D versus 3D analysis.

- It is recommended that some consideration be given to performing selective three-dimensional (3D) analyses considering both the 3D stress condition and 3D joint system as a verification of the conclusions regarding stability of the tunnel and on ground support, especially at locations of intersections of the ramp with alcoves and other underground structures.

- A realistic seismic signal with lower frequency and longer duration should be considered in the analysis. Consideration should also be given to making use of representative seismic motions for the particular region.

Reference:

Hsiung, S.M., A.H. Chowdhury, W. Blake, and T.J. Williams. 1992. Effects of mining-induced seismic events on a deep underground mine. *Pure and Applied Geophysics* 139: 741-762.

TS North Ramp Stability Analysis/Modeling Method

COMMENT 3

The North Ramp Stability Analysis is preliminary and incomplete. This analysis does not take into consideration all aspects of the design, nor does it consider all the potential mechanisms that may affect rock bolt performance.

Bases:

- Three types of rock bolts are recommended in the TS North Ramp Rockbolts and Accessories Details Drawing (BABEAB000-01717-2100-40157-01). The first two types (solid bar rockbolts with preinstalled thixotropic grout and super Swellex rockbolt) are fully grouted bolts with no mechanical anchor at the upper end. For these two types, the bonding strength between the grout and the borehole wall and the strength of the grout will essentially govern the performance of the rockbolts, rather than the yielding strength of the steel rod. The third type of rockbolt in the drawing is the hollow core rockbolt with mechanical anchors and thixotropic grout. This type is a combination of the fully grouted and mechanical rockbolts. In addition to the two mechanisms for the fully grouted rockbolts, other controlling mechanisms of this type of rockbolt include the anchorage capacity and the yielding strength of the hollow rod. Simulating the rockbolt using a cable element evaluates the performance of only one rockbolt type listed in the TS North Ramp Rockbolts and Accessories Details Drawing.

- The conditions of the rock mass that encompass the rock bolts often dictate the effectiveness of these rockbolts. These rock-mass conditions were not considered in the assessment of the effectiveness of the rockbolts.

- Rock support analysis was not performed using the ubiquitous joint model that was used to assess opening stability without rockbolts or steel sets.

Recommendation:

In evaluating the performance of rockbolts, the physical behavior and failure mechanisms of each of the three proposed rockbolt systems should be studied. In addition, the condition of the rock mass that encompasses the rock bolts should also be considered.

TS North Ramp Stability Analysis/Conclusions

COMMENT 4

On page 20, paragraph 2, Section 11.0, it is concluded that "The distribution of the stresses around the opening for all cases appears to be reasonably smooth. This indicates that the opening shape analyzed here is acceptable."

This conclusion may represent a misinterpretation.

Bases:

- The smoothness of the stress distribution around the opening does not necessarily imply the stability condition nor the suitability of the opening shape. Stability of the ramp and the suitability of its shape are more related to the magnitudes of the shear and mean stresses induced in the surrounding rock mass and the strength and orientation of the joint system.

- It should be recognized that the smoothness of the calculated stress distribution is due to the simplified constitutive model assumed for the rock mass, which in this case is assumed to be elasto-plastic and isotropic with ubiquitous joint model. If discrete joints are taken into account, the distribution of the stresses around the opening may not be smooth, and the conclusion could change.

Recommendation:

The DOE should define the acceptable criteria for evaluating opening stability and the suitability of the opening shape. The DOE should also discuss the representativeness of the stress analyses and discuss how this simplified constitutive model affects the assessment of the ramp stability with and without the support system.

ESF Ventilation Flexibility Analysis/Section 5.0 Design Inputs

COMMENT 5

Required design air velocity data used in the ESF Ventilation Flexibility Analysis are outdated. The DOE design may not be adequate based on the current Industrial Ventilation Manual.

Basis:

The design air velocity data used in the ESF Ventilation Flexibility Analysis have been taken from the 18th edition of the Industrial Ventilation Manual, instead of the current 20th edition (Committee on Industrial Ventilation, 1988).

Recommendation:

Update the values provided in Attachment X and determine whether the design air velocity is adequate based on the new manual.

Reference:

Committee on Industrial Ventilation. 1988. *A Manual of Recommended Practice*: Industrial Ventilation, 20th Edition. Cincinnati, OH: American Conference of Governmental Industrial Hygienists: 3–18.

TS North Ramp Rock Mass Classification Analysis/Section 10.5 and TS North Ramp Alcove Ground Support Analysis/Section 10.5.2

COMMENT 6

Section 10.5.2 assumes an Excavation Support Ratio (ESR) equal to 1.0. This value may not be conservative.

Bases:

- Table 7 of Barton et al. (1974) gives an ESR equal to 1.0 for "Power stations, major road and railway tunnels, civil defence chambers, portals, intersections, etc." They recommended an ESR equal to 0.8 for "Underground nuclear power stations, railway stations, sports and public facilities, factories, etc."

- The stability of the excavations is required for about 140 yr, which is beyond the documented engineering experience (Figure 6 of Hoek and Brown, 1980).

- Given the importance of the North Ramp in the proposed overall repository excavation, an ESR value that is more conservative than 1.0 is required.

Recommendation:

The DOE should provide justification for assuming the ESR to be equal to 1.0 instead of the more conservative 0.8.

References:

Barton, N., R. Lien, and J. Lunde. 1974. Engineering classification of rock masses for the design of tunnel support. *Rock Mechanics* 6(4): 189-236.

Hoek, E., and E.T. Brown. 1980. *Underground Excavations in Rock.* London, U.K: The Institution of Mining and Metallurgy.

ESF Subsurface-Cable Tray Support Design (Package 2C)/Design Input

COMMENT 7

Some of the input parameters with regard to seismic design are either not clearly discussed, leading to confusion, or are not properly chosen, resulting in a nonconservative design.

Bases:

- It is not clear whether the DOE is using a mean or median measure to determine the probability of design accelerations (Attachment I, ESF Seismic Design Basis, DOE Standard 1020-94, page 2-4, Table 2-1).

- There is discussion concerning whether the arithmetic average or the 50th constant percentile acceleration is the appropriate measure to use. Arithmetic average accelerations are considerably higher than the 50th constant percentile accelerations. It should be further noted that the use of neither the 50th constant percentile nor arithmetic average mean is likely to include the number of uncertainties originally sought by multiple expert opinion Probabilistic Seismic Hazard Analysis (PSHA) methods. They are simply the median or average values of experts. The Environmental Protection Agency (EPA) states in the *Federal Register* notice that promulgated

40 CFR Part 191 that "The Agency assumes that compliance can be determined based upon best estimates predictions, e.g., the mean or the median of the appropriate distribution, whichever is higher." The arithmetic mean or average is the higher of the two measures. However, the EPA regulation has been remanded. The opinion of Bernreuter et al. (1989) is that the 50th constant percentile is a stable measure and is recommended. Similar recommendations have been made by experts in statistical analysis to the DOE and to the NRC regarding a proposed revision to 10 CFR Part 100 to permit the use of probabilistic analyses in setting design criteria for nuclear power plants. The issue, however, is not yet determined.

- The Civilian Radioactive Waste Management System Management and Operating Contractor (1994) states that accelerations are mean values. However, on page A-1 of its report the "...mean number (or rate) of events in which Z exceeds z" in Eq A-1 is discussed. This mean number appears to be more closely related to the 50th constant percentile than to the arithmetic mean. Calculations are stated to be made with the computer programs XCEED and EXPOSE, but no descriptions of the programs are given.

- Proposed reductions in design acceleration with depth are not frequency dependent (Attachment III, Seismic Design Basis, page 2, Table 2). The proposed acceleration reductions with depth are based on high-frequency vibrations from underground nuclear tests. Observed and theoretical reductions of earthquake ground motion are frequency dependent. Empirical observations in boreholes of earthquake ground motions sometimes show amplification with depth near rock layers having velocity contrasts, for example, Douze (1966).

- Fault directivity and the reduced distance to earthquake fault rupture to underground facilities are not considered (Attachment VIII, ESF Seismic Design Basis, page 2, Tables 1 and 2, page 1 of Attachment I, Seismic Design deposits for the ESF at YM, April 29, 1994).

- The Civilian Radioactive Waste Management System Management and Operating Contractor (1994) states that background seismicity controls hazard. An independent analysis by the CNWRA concluded that background seismicity played a secondary role to the potential hazard from faults adjacent to the repository. Whether or not background seismicity is the most prominent contributor to hazard, adjacent faults are large contributors. Such faults are assumed to extend to depths of about 15 km. Large earthquakes on these faults would rupture the entire fault plane. Much of the energy radiating from such a rupture would be from a depth of several kilometers. Therefore, seismic wave paths would subtend an angle with the site-to-source line of less than 10 arc degrees, requiring that fault directivity be considered. Campbell (1987), for example, proposes an empirically derived attenuation curve, including fault directivity, that fits the near-field 1992 Little Skull Mountain strong motion data well [see Hofmann and Ibrahim (1994) for a figure showing the fit to data]. The repository, at a 300-m depth, would be closer to the source of these nearby potential earthquakes than would a site on the surface, thus requiring less attenuation.

- The 5×10^{-4} seismic hazard for underground design may not be conservative. No rationale is given for this choice of hazard to be used in the design. EPA regulations (U.S. Environmental Protection Agency, 1983), although currently remanded, state that effects observed once in 10,000 yr should be considered in the design. This value is a more conservative probabilistic seismic risk than that proposed by the DOE. The EPA regulations are included by reference in NRC and DOE regulations regarding HLW repositories.

Recommendations:

- The DOE should clarify the probabilistic measure of acceleration it is using and justify its use in view of the discussion accompanying the promulgation of the EPA regulation in the *Federal Register*.
- Pertinent literature should be reviewed and a frequency (and wavelength) dependent reduction of acceleration with depth should be used, if any reduction is deemed appropriate.
- Design accelerations should be increased to accommodate fault directivity and the shorter path length of seismic waves to the site below the surface from earthquake sources at depth. An alternative is to not take credit for diminution of acceleration with depth for nearby earthquake sources.
- Probabilistic seismic design criteria should be increased to ground motions expected at a 1 in 10^{-4} per year rate. The proposed 5×10^{-4} acceleration of 0.37 g is not adequately justified.

References:

Bernreuter, D.L., J.B. Savy, R.W. Mensing, and J.C. Chen. 1989. *Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains.* NUREG/CR-5250 (UCID-21517): Vols. 6 & 7. Washington, DC: Nuclear Regulatory Commission.

Campbell, K.W. 1987. Predicting strong ground motion in Utah. *Evaluation of Regional and Urban Earthquakes and Risk in Utah.* W.W. Hays and P.L. Gori, eds. U.S. Geological Survey Professional Paper 87-585II, L1-L90. Washington, DC: Department of Interior.

Civilian Radioactive Waste Management System Management and Operating Contractor. 1994. *Seismic Design Inputs for the Exploratory Studies Facility at Yucca Mountain Technical Report.* BAB000000-01717-5705-00001 Rev. 00.

Douze, E.J. 1966. Noise attenuation in shallow holes. *Bulletin of the Seismological Society of America.* 56: 0619–0632.

Hofmann, R.B., and A.K. Ibrahim. 1994. Published attenuation functions compared to 6/29/1992 Little Skull Mountain earthquake motion. *Proceedings of the Fifth Annual International High-Level Radioactive Waste Management Conference.* La Grange Park, IL: American Nuclear Society: 2,402–2,408.

U.S. Environmental Protection Agency. 1983. Environmental standards for the management and disposal of radioactive wastes: Final rule, SUMMARY. September 19, 1985. *Federal Register* 50: 38,066–38,084.

ESF Subsurface-Cable Tray Support Design (Package 2C)/Design Method)

COMMENT 8

The use of Uniform Building Code (UBC) procedures for a nuclear facility is questioned.

Bases:

- For underground structures, there is little or no experience to validate empirical aspects of the UBC in underground applications, particularly design ground motion reductions by means of the factors R_W and F_μ.

- Surface facilities built to the UBC showed poor performance in the M=6.7 Northridge, California, earthquake. Dr. Popov, Professor Emeritus of Civil Engineering at the University of California at Berkeley, pointed out in his 1993 address at the Earthquake Engineering Research Institute annual meeting in Seattle, Washington, that seismic resistance required by the UBC had remained virtually unchanged for many decades because the formula for seismic resistance in the code had changed with increasing design acceleration requirements. An abstract by Popov et al. (1993) summarizes UBC formulae from 1927. Improvements in performance would seem attributable to design detail changes in the code. The ESF is a nonstandard structure that may not fully benefit from design detail changes based on failures observed in ordinary construction.

- The $1 m of damage to the Field Operating Center at YM from the small, M=5.7 Little Skull Mountain Earthquake in 1992 is also evidence of poor performance of UBC-designed buildings. The 1992 earthquake was less than 20 km from YM, which emphasizes the need for more sophisticated designs than those provided by the UBC. Bounding faults are strong contributors to seismic hazard at YM and have potential maximum magnitudes of 6.8 or more, based on fault length.

- YM facilities, which may ultimately include portions of the ESF, will process and store all civilian and some other nuclear waste. Civilian waste comprises one to two orders of magnitude more radioactive material than in any nuclear reactor fuel load, although it is not in a state of active fission process except for decay. However, if damage is permitted by allowing reductions for ductile material behavior, secondary releases and additional hazard to cleanup and repair personnel may result. Use of the UBC importance factor was not mentioned by the DOE, but should it be imposed. However, its limit of 1.25 cannot compensate for the reduction factors proposed.

Recommendation:

Because of the potential for a secondary hazard, should failure occur, a more conservative design procedure is recommended that uses recorded strong motion information without reductions. If the UBC is used for design, R_W and F_μ should be unity. No judgmental reductions should be taken.

Reference:

Popov, E.P., T.-S. Yang, and C.E. Grigorian. 1993. New directions in seismic design. Abstract in the *45th Annual Meeting of the Earthquake Engineering Institute Program Summary*. Oakland, CA: Earthquake Engineering Research Institute.

TS North Ramp Ground Support Scoping Analysis/Design Analysis on Rock Mass Quality

COMMENT 9

It is not clear how the revised Q (rock mass quality) listed in Figure 7 on page 23 (Section 10.8) and the second paragraph on page 40 (Section 10.8) was obtained. The definition of modified Q is not clear. Also, there is a typographic error for the subscription of Q listed in the fourth paragraph on page 40.

Bases:

- The Q value of a particular rock unit was used as the primary parameter in the ESF North Ramp Design Package 2C for the selection of the ground support system. It is therefore important to establish a systematic approach for Q determination. As presented in the North Ramp Ground Support Scoping Analysis, the method used for the calculation of the revised Q value was not discussed. However, the document did mention that the "Revised SRF" was used to calculate the "Modified Q" (page 26, third paragraph of Section 10.8). If this statement is true, then the modified Q can be obtained by using the following relation

  $$Q_M = Q / SRF^*$$

  where Q_M is the modified Q and SRF^* is the ratio of the modified stress reduction factor and the original one. Based on this relation, the modified Q values for the PTn rock mass unit (Paintbrush Tuff nonwelded) should be 0.33, 0.571, 0.998, 2.7, and 5.029 for the five subcategories of the PTn unit instead of 0.45, 1.11, 2.99, 16.07, and 71.14 as listed in Figure 7.

- The definition of the modified Q on page 40 (Section 10.9.3) is different from that defined in Section 10.8. In Section 10.8, the modified Q is based on the revised SRF value, which takes into account the effects of weakness zone (original SRF) and stresses (stress-dependent SRF) expected to be encountered during excavation.

- On page 40, paragraph 4, the subscription of Q values for PTn rock unit should be "Q-original" instead of "Q-modified" (Section 10.9.3).

Recommendations:

- The DOE should revise the modified Q values for PTn unit in Figure 7.

- Quantitative criteria used for taking into account the drilling-induced fractures for the modified Q values should be provided. The definition of the modified Q discussed on page 40 and the modified Q given in Section 10.8 and Figure 7 should be clarified.

TS North Ramp Ground Support Scoping Analysis/Design Method

COMMENT 10

There are a few concerns with regard to the methodology of using the empirical design charts to determine the necessary ground support for the TS North Ramp. Use of these charts is either not currently defensible because of limited available data or not conservative due to neglect of important factors.

Bases:

- Estimation of support system requirements using the Hoek Chart in Section 10.9.1 of the TS North Ramp Ground Support Scoping Analysis is not conservative. It did not utilize the variation of the uniaxial compressive strength given in the Attachment of TS North Ramp Stability Analysis.

- In Section 10.9.1 of TS North Ramp Ground Support Scoping Analysis, the proposed support system using the Hoek Chart is based on the mean value of uniaxial compressive strength given in Figure 7. Attachment I of TS North Ramp Stability Analysis shows that the uniaxial compressive strength varies significantly within a particular unit. For example, the uniaxial compressive strength varies from 10.4 to 332.4 MPa in TCw unit, from 2.0 to 61.8 MPa in PTn unit, from 17.4 to 149.4 MPa in TSw1 unit, and from 38.4 to 288.9 MPa in TSw2 unit. The type of support in the Hoek Chart is directly dependent on the ratio of principal stress over the uniaxial compressive strength. As the uniaxial compressive strength decreases, the ratio increases indicating more support is necessary to keep an excavation stable. On taking the lower bound values of the uniaxial compressive strength of each thermomechanical rock unit in the analysis, the ratio will be significantly lower than that obtained using only the mean value. Consequently, the requirement of the support system is underestimated by taking only the average value of the uniaxial compressive strength, when strength varies by more than an order of magnitude.

- The assessment of the PTn rock mass unit using the Hoek (Section 10.9.1) Chart indicated a potential for instability. The following reasons are given in the North Ramp Ground Support Scoping Analysis to discount the negative finding for the PTn unit from the Hoek Chart:

  - Hoek Chart is developed for deep mines that are in hard and brittle rocks and are subjected to high state of stresses. The PTn unit is neither hard and brittle nor is it subject to high stresses.

  - The range of the modified Q for the PTn unit compares well with the other thermomechanical units (see Figure 7, page 23).

- Past tunneling experience at the Nevada Test Site (NTS) in the same unit indicates that the PTn unit can be effectively excavated and supported.

If the first point hold true for the PTn unit, it should be equally true for all other thermomechanical units since they are all subjected to low stresses as compared to the high stress conditions under which the Hoek Chart was developed. This raises a concern regarding the applicability of the Hoek Chart for the design of the ESF North Ramp. For the second point, the range of the modified Q for the PTn does not necessarily compare favorably with other rock units. A calculation error is found (documented in a separate comment) for the modified Q values of the PTn unit. The argument in the third point would be more convincing if the modified Q and relevant rock properties for the cited tunnels are discussed, and a direct comparison is made between these properties and those provided in the North Ramp Ground Support Scoping Analysis.

- It is not clear how the five ground support categories proposed in the TS North Ramp Ground Support Scoping Analysis were correlated with the Norwegian Geotechnical Institute (NGI) rock mass classification. In the TS North Ramp Ground Support Scoping Analysis, the discussion for correlating the site-specific ground support categories with the ranges of Q values is not provided.

Recommendations:

- The DOE should re-evaluate the support requirement analysis, taking into account the variation obtained in actual measurement of the parameters.

- The North Ramp Ground Support Scoping Analysis should re-evaluate the applicability of the Hoek Chart in the context of designing repository drifts and ramps. More defensible rationales should be provided for discrediting the assessment results using the Hoek Chart for the PTn unit.

- Technical discussion should be given regarding the relationship between the proposed five site-specific support categories and the NGI rock mass quality.

Waste Isolation Evaluation: Construction Water for Package 2C Excavation of the ESF North Ramp, Rev. 03

COMMENT 11

There is a serious inconsistency in the approach used to determine maximum potential change in percolation flux under the ramp. Also, the information on particle sizes for the muck produced by the TBM in Section 3.4 is now out of date.

Bases:

- In attachments, it is stated that "due to uncertainties in how the piezometric head gradient may vary, the gradient will be assumed constant." Subsequently the average percolation flux beneath the ramp is approximated by the weighted mean of the effective hydraulic conductivities. Moreover, the zone of the flow region extending between the ramp and the water table is arbitrarily split into two distinct migration zones with contrasting degrees of saturation characterized as affected (upper zone) and unaffected (lower zone) regions that are homogeneous and partially saturated with different saturation levels.

First, since this problem was treated as steady-state and, the migration zone was assumed to be homogeneous, it would be expected that: (i) for a pressure head type boundary condition (i.e., Dirichlet condition) considered both at the ramp level (i.e., upper boundary) and at the water table level (i.e., lower boundary), where the applied pressure head in the first case is less than atmospheric, and atmospheric in the second case, the resulting pressure profile and the Darcy flux will be solely functions of the imposed boundary condition at the upper boundary; (ii) if, on the other hand, the imposed pressure head at the ramp level exceeds the atmospheric conditions (i.e., for the case of water ponded at the surface), the migration zone will be completely under saturation, and the resulting Darcy flux will then correspond to the value of the saturated hydraulic conductivity of the assumed homogenous matrix. Given these facts, it is difficult to accept the concept of "affected and unaffected regions," when the investigators do not clarify the boundary condition prevailing at the ramp level, a critical element in the resolution of this bounding analysis.

It may also be pointed out that, given the parameters for the Topopah Spring welded (TSw) matrix listed on page 22 of the document, the computed value for the matrix water saturation in the invaded zone S_2, based on the reported equation for the latter, seems to be far in excess of unity, when values of V_1 (the quantity of water introduced per meter of ramp excavation) and D_2 (depth) corresponding to 9.7 m^3/m and 40 m, respectively, are selected. This calculation seems inconsistent with the theory.

Finally, the North Ramp excavation, which begins at an elevation of about 1,123 m and ends at an elevation of 1,067 m, exhibits a nonhorizontal profile. This profile suggests the possibility of a surface runoff problem. The discussion of this potential problem has been disregarded in the analysis.

- References are cited to establish the range of particle sizes anticipated to be produced by the TBM. The particle sizes are therefore expected to correspond to those of "coarse sand." This information is then used to estimate porosity and, finally, to limit the water volume that could potentially be carried by the muck. In fact, now that the TBM has been operating for some time, it is clear that the muck particles produced by the TBM have a much larger size range than "coarse sand." Observed particle size ranges up to at least 10 cm. This disparity will affect the water volume limits estimated in this document.

Recommendations:

- The bounding analysis to determine the maximum potential change in percolation flux under the ramp should explicitly address the issues raised above. In addition, DOE should develop and implement a modeling approach which is more consistent with the requirements of the problem at stake and systematically consider the hydrogeologic data provided by the Total System Performance Assessment (TSPA) analyses. In this context, the use of the Green and Ampt (1911) theory, which has been extended to apply to stratified porous materials (see also Childs, 1971), is strongly recommended. The investigators should then couple the infiltration and the surface runoff processes for completeness. Alternatively, the investigators should have recourse to a finite-difference or finite-element based mathematical model to address their current objective.

- Observation of actual TBM muck particle size ranges and shapes could be used to more accurately estimate porosity and water volume limits. Size distribution of TBM muck should be determined as a basis for its ability to retain water. The adequacy of the bounding estimates of the water carrying capacity of the muck should be evaluated in the context of observed particle size ranges.

References:

Childs, E.C. 1971. *The Physical Basis of Soil Water Phenomena*. London, England: John Wiley & Sons 493.

Green., W.H., and G.A. Ampt. 1911. Studies in soil physics. I. The flow of air and water through soils. *Journal of Agricultural Science* 4: 1-24.

Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction, Rev. 03/Section 2.1 Evaluation Approach

COMMENT 12

The surrogate performance criteria adopted in this document may not be adequately conservative.

Bases:

- The surrogate criteria adopted in this document are based on the premise that the only way a chemical species introduced during construction of the ESF can affect radionuclide release is by transport of a species of interest from the ESF to a waste package, where it then can interact with the waste. The surrogate criteria establish a recommended limit for geochemical perturbations as a 10 percent variation in the species of interest "at the *closest* waste package" [original emphasis]. Application of this criterion requires estimation of transport of the species of interest from the source (typically distributed along the ESF tunnel and alcoves) to the "*closest* waste package" [original emphasis]. This transport estimation necessarily predicts a lower concentration of the species of interest close to the waste compared to the concentrations of the species of interest in the tunnel and alcoves.

- Basing the surrogate criteria on the concentration of the species of interest "at the *closest* waste package" [original emphasis] may not be an adequately conservative assumption. The ESF tunnel and alcoves themselves may at some time in the future constitute preferential radionuclide transport paths. Contrary to the general approach in this document, retention of the bulk of a chemical species of interest within, near, or on the surfaces of the tunnel and alcoves may have a greater effect on radionuclide transport than movement of the species of interest from the tunnel and alcoves toward the waste packages. For example, some time in the future, radionuclides may move away from the original waste package location (by any of various transport mechanisms) and at some point encounter the large (compared to most fracture zones) and continuous transport pathway comprised of the former ESF tunnel. There may be chemical species of interest (such as organics) that accumulated in the tunnel during construction and that largely remained within the tunnel (perhaps adhered to rock surfaces) in concentrations much greater than those predicted by the surrogate criteria at a waste package. The greater concentration of a chemical species along the tunnel (than the concentration predicted to occur at a waste package) could enhance the transport of radionuclides along the tunnel and out of the repository.

- The assumption that unburned hydrocarbon vapor is completely removed by the ventilation system due to its low aqueous solubility does not appear to be conservative. Use of the surrogate criterion of change to the ambient dissolved organic carbon (DOC) may not be conservative. Unburned hydrocarbon vapor could adhere to rock surfaces (in the form of an oily film, perhaps) even though, or because, it has a low aqueous solubility. Such hydrocarbon-coated surfaces could in the future form the boundaries of radionuclide pathways upon transport of radionuclides to that location. Interactions between the hydrocarbon residue (which may have altered during intervening time) and such transported radionuclides could result in enhanced transport of the radionuclides from that point (e.g., as colloids). Without a functional understanding of the behavior of diesel particulate matter, it is difficult to evaluate the assertion that the surrogate criterion is conservative. For example, it is stated that complete dissolution of the diesel particulate matter is conservative. It is conservative in the sense that complete dissolution would appear to increase the likelihood of transport of the dissolved constituents to the waste. It may not be conservative if the insoluble portions of the diesel particulate matter form a large percentage of the total, and if they form strong radionuclide colloids. Upon radionuclide transport to diesel particulate matter-coated former tunnel walls of the ESF, such matter could enhance the transport of the radionuclides out of the repository. It is not necessary for the diesel particulate matter to be transported to the waste for it to enhance radionuclide transport.

Recommendations:

- The possibility that concentrations of any of the various chemical species of interest that could accumulate within the ESF as a result of construction could significantly affect radionuclide transport should be evaluated and discussed. If necessary, this scenario should be included in the performance evaluation.

- The DOE should take into account the possibility that unburned hydrocarbon vapor could adhere to rock surfaces and provide more definitive arguments to establish the conservatism of the surrogate criterion.

Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction, Rev. 03/Section 3.2 Geochemistry

COMMENT 13

There are apparently inconsistent and arbitrary levels of conservatism in estimates of DOC, NO_3, and PO_4. Also, there is inadequate discussion of the possible interactions of retained organic material and available water.

Bases:

- The estimated concentration of DOC in the unsaturated zone is arrived at after listing average concentrations for DOC in "freshwater" around the world (4 ppm), and for "seawater" (1 ppm), and ranges of DOC concentration for "many natural groundwaters" (1–10 ppm), and for YM "saturated-zone ground waters" (0.14–0.58 ppm). The value of 1 ppm is then chosen for DOC in YM unsaturated zone groundwater. No rationale for this choice is provided. For NO_3, a "representative" concentration of 10 ppm is offered for YM "saturated zone fluids." This value (10 ppm) is then "accepted" to "approximate" the unsaturated zone composition. The justification offered is that this value is conservative because "most" unsaturated zone concentrations are "2 to 3" times more concentrated than saturated zone concentrations. No explanation is provided for using a different approach for estimating DOC in the unsaturated zone than for estimating NO_3 in the unsaturated zone. Using the argument provided for the NO_3 estimate, the DOC estimation could be as low as 0.28 ppm rather than the 1 ppm chosen (0.28 derives from using the low end of the saturated DOC concentration, 0.14 ppm, and the low end of the concentration multiple cited for "most" species between saturated and unsaturated fluids). An unsaturated DOC concentration of 0.28 ppm would lead to a "negligible" "peak perturbation" of 0.028 ppm (10 percent of the "ambient value") about 3.6 times lower than the 0.1 ppm used.

- The DOE has not been able to find measured phosphate values for saturated or unsaturated zone fluids. Because of this inability, a third approach (in addition to those used for DOC and NO_3) to estimating the significance of a species in the unsaturated zone has been adopted. Measurement of phosphate concentration in J-13 water has been reported in a DOE report prepared for Office of Civilian Radioactive Waste Management (OCRWM), YM Project (Wilson, 1990). This report gives a value of 2.8 μg/mL for PO_4 concentration (Appendix B, Table B.1). The peak $H_2PO_4^-$ concentration 37 meters from the tunnel calculated due to fire suppressant contamination is 0.75 ppm, which is considerably larger than the 10 percent ambient criterion when compared to the J-13 value.

- It is assumed that retained organic material converts completely to DOC.

Recommendations:

- The DOE should apply internally consistent methods for estimating unsaturated zone concentrations of DOC and NO_3 or provide rationale for the difference. Such changes would need to be reflected as appropriate throughout this document.

- It should be noted that a DOE measurement of dissolved PO_4 concentration in the saturated zone at YM exists. It is possible, using this value for PO_4, to derive an estimate of unsaturated zone PO_4 concentration consistent with the approach used for NO_3 (and consistent with the approach recommended here for DOC) and then to estimate a "negligible" "peak perturbation" as was done for the other species. An internally consistent approach is desirable compared to introduction of arguments based on the composition of the waste itself. If the argument based on the composition of the waste is retained, similar information should be provided for other components as well, perhaps in the form of an analysis of waste composition. Changes to this section would require appropriate changes to other sections of this document.

- Other possible interactions of retained organic material and available water should be discussed.

Reference:

Wilson, C.N. 1990. *Results from NNWSI Series 2 Bare Fuel Dissolution Tests*. PNL-7169 UC-802. Richland, WA: Pacific Northwest Laboratory.

Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C, Exploratory Studies Facility Construction/Attachment III and Attachment IV

COMMENT 14

The approach adopted in determining the effects of diffusion versus advection on radionuclide is far too simplistic. Also, the initial and boundary conditions in the transient, nonlinear model for saturation estimation are not explicitly defined.

Bases:

- The determination of the effects of diffusion versus advection on radionuclide releases from potential waste packages in Attachment IV completely disregards the spatial and temporal variation of water saturation in the porous matrix surrounding it. The tortuosity effects associated with the matrix, which play a primary role in the orientation aspect of radionuclide migration through the diffusion process, have also been disregarded.

- Although thermal dry out effects seem to have been reported by the investigators, their expression for the maximum bulk advective flux does not seem to account for such effects. Except the reference to Andrews et al. (1994) for an expression relating molecular diffusion to saturation, there is no justifying evidence that along a distance L (i.e, distance traveled by a typical radionuclide), the effective diffusion velocity $V_D(S)$ as reported by the investigators is a constant. For a given problem, an average value for $V_D(S)$ could be established only through integration of the numerator D(S) between the appropriate limits of the dependent variable S.

- Moreover, there is no evidence to suggest that the potential directions of radionuclide migration inherent to the diffusion and advection processes in a fractured rock are necessarily identical under isothermal conditions, let alone when thermal effects are considered as the text seems to suggest. The investigators have failed to account for changes of the hydraulic conductivity due to thermal effects, which are commonly reflected in variations of fluid density as a function of temperature (Cheng, 1978) (e.g., Boussinesq's approximation for temperatures less than 100 °C).

- The investigators rely on the diffusion-free form of the mass conservation equation for transient fluid flow in a partially saturated porous medium proposed by Richards (1931), to estimate the saturation at a point close to a waste package for a given input of water at the North Ramp. For such a transient nonlinear problem, the initial and boundary conditions are not explicitly defined. Moreover, the investigators fail to present a rationale for using a one-dimensional (1D) equation to estimate the saturation at a distance of 37 m from the waste package. In the absence of the diffusive term, the hyperbolic form of the mass conservation equation still remains nonlinear. The investigators have made no attempt to linearize the latter before using the solution based on the method of characteristics presented by Whitham (1974), which is suited only for a linear system. It is difficult to speculate if the reported results are on the conservative side, since no discussion pertaining to the particular features of the adopted solution method is reported. A distance of 37 m cannot be considered negligible to be used as a point of reference for estimating the matrix saturation in the vicinity of the waste package, given all the hydrogeologic uncertainties. Such an estimate of the performance measure should normally be supported by a probabilistic analysis, which would then allow the investigators to estimate the level of confidence of their predictions.

Recommendations:

- Although the reported results indicating that the transport process becomes predominantly diffusion oriented at decreasing water saturation are somewhat convincing, the adopted approach is far too simplistic. The current bounding analysis strategy should be revised and replaced by one that would explicitly address the spatial distribution of pressure/saturation around the waste package under isothermal and nonisothermal conditions. Consideration must also be given to the waste package, borehole, emplacement mode, and geologic properties of the surrounding matrix in order to demonstrate consistency with the repository design description and NRC guidelines.

- The mathematical solution should be revised to cope adequately with the nonlinearity aspect of the fundamental equation. If the investigators insist on using a 1D approach as opposed to a 2D one, the need for a probabilistic analysis becomes mandatory.

References:

Andrews, R.W., T.F. Dale, and J.A. McNeish. 1994. *Total System Performance Assessment: An Evaluation of the Potential Yucca Mountain Repository*. M&O Report B00000000-01717-2200-00099 Rev. 01. March 1994.

Cheng, P. 1978. Heat transfer in geothermal systems. *Advances in Heat Transfer*. New York, NY: Academic Press, Inc. 14: 1–104.

Richards, L.A. 1931. Capillary conduction of liquids through porous mediums. *Physics* 1:

Whitham, G.B. 1974. *Linear and Nonlinear Waves*. New York, NY: John Wiley & Sons 636.

3.3 QUESTIONS

None.

4 SUMMARY

The ESF Title II Design Package 2C: TS North Ramp presents various aspects of design and analysis, as well as relevant records and QA for the construction of the TS North Ramp of the proposed repository site. Design Package 2C comprises over 20 document titles, categorized by different subjects related to design and supporting records.

Comments raised herein are on eight document titles, which include (i) TS North Ramp Blast Design Analysis; (ii) TS North Ramp Stability Analysis; (iii) ESF Ventilation Flexibility Analysis; (iv) TS North Ramp Rock Mass Classification Analysis; (v) ESF Subsurface-Cable Tray Support Design; (vi) TS North Ramp Ground Support Scoping Analysis; (vii) Waste Isolation Evaluation, Construction Water for Package 2C Excavation of the ESF North Ramp; and (viii) Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction.

Many critical bases and rationales used in supporting the design have not been provided. Inappropriate application of the current state-of-the-art knowledge and industrial practices was found. There is a concern regarding the conservatism of the assumptions and criteria/bases used in the blast design analysis. The TS North Ramp Stability Analysis is found to be preliminary, and its results cannot be used to directly supplement or verify the adequency of ground support design. This analysis neither takes into consideration all aspects of the design nor considers some phenomena that might have impact on the evaluation of the effectiveness of rockbolts. For example: (i) not all types of rockbolts listed in the design drawing have been numerically modeled; (ii) conditions of the rock mass surrounding the rockbolts to be evaluated are not factored into the assessment of the effectiveness of the rockbolts; (iii) rock support analysis does not use the ubiquitous joint model that has been used to assess opening stability without rockbolts; (iv) the duration of the seismic input signal used in the dynamic analysis is very short, and frequency of the signal is high, thus, the signal may not be representative or conservative to assess opening stability from typical earthquakes; and (v) potential 3D effects (e.g., due to the presence of joint sets) on opening stability are not factored into the 2D analyses performed.

Other major concerns include: (i) required design air velocity data in the ventilation flexibility analysis are outdated; (ii) the Excavation Support Ratio (ESR) of 1.0 is not conservative; (iii) input parameters and UBC procedures in seismic design are questionable; (iv) the interpretation of some of the analysis results (e.g., Hoek and Schmidt Charts) to assist the design of ground supports may not be defensible due to limited available data and may not be conservative because important factors have been neglected; and (v) "surrogate" performance criteria adopted in the report may not be conservative, and methods for estimating some species concentrations are inconsistent, leading to arbitrary levels of conservatism. All these concerns raise doubts regarding the quality of the ground support design.