DEFENSE NUCLEAR FACILITIES SAFETY BOARD

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January 10, 2007

The Honorable James A. Rispoli
Assistant Secretary for Environmental Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0113

Dear Mr. Rispoli:

As required by law, the Defense Nuclear Facilities Safety Board (Board) is continuing its review of the design of the Salt Waste Processing Facility (SWPF) prior to the start of construction at the Savannah River Site. The Board's review is currently focused on the safety documents completed during the preliminary design phase in support of the Department of Energy (DOE) Critical Decision-2 and -3A milestones pursuant to DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets*. Completion of the preliminary design is expected to provide a technically sound basis for establishing the project performance baseline and for initiation of the final design.

During the preliminary design phase of the project, the viability of the facility design is established, and all significant technical issues related to nuclear safety are expected to be satisfactorily resolved by DOE before starting the final design and the procurement of long-lead-time items. The Board believes there are significant structural analysis deficiencies remaining as the SWPF project approaches Critical Decision-2. In addition, the geotechnical engineering report for the SWPF has yet to be issued. Geotechnical engineering work would normally be done by the end of the conceptual design or by Critical Decision-1. Without a geotechnical engineering report, critical issues, such as an estimate of differential soil settlement as a result of the Design Basis Earthquake, are subject to uncertainty, speculation, and debate.

The majority of radioactive hazardous materials will be contained and processed in the SWPF's Central Processing Area (CPA) building. The Board has completed an initial review of the structural design documentation for the CPA facility when subjected to design loads, including natural phenomena hazards, and the effects of earthquake-induced differential soil settlement. As outlined in the enclosed report, several significant structural analysis deficiencies indicate that the current CPA building may not be adequately designed to resist these loads safely. The Board notes that these types of structural analysis deficiencies apparently have not been identified by the architect-engineer as part of its ongoing design review.

The Board is concerned that there may be adverse schedule and cost impacts when nuclear safety issues are not resolved early in the design process. Given the deficiencies in the analysis of the facility's preliminary structural design, and the lack of a geotechnical engineering report justifying the assumed soil properties used in that analysis, a significant redesign of the CPA building may be warranted. Such a redesign could impact the performance baseline being established.

Some of the nuclear safety issues raised in the enclosed report are consistent with comments raised by DOE and its Independent Review Team. However, the Board is not aware of any action being taken to resolve these issues. *Timely resolution of issues raised by DOE and by the Board is critical to reaching a technically supportable decision to proceed with the design of the SWPF.*

DOE has well-qualified peer reviewers but they have been allowed only a limited role thus far. In the Board's opinion, DOE needs to perform a thorough review of the architect-engineer's design as part of its project oversight.

The Board recognizes that the construction and startup of the SWPF is a key component of the Implementation Plan for Board Recommendation 2001-1, *High-Level Waste Management at the Savannah River Site.* Hence, the Board proposes that the Board and DOE senior management work closely to minimize impacts on the High-Level Waste program. The Board is committed to rapid evaluation of actions taken by DOE and its contractors to resolve geotechnical and structural engineering issues. Therefore, pursuant to 42 U.S.C. § 2286b(d), the Board requests a report within 30 days of receipt of this letter that (1) indicates what actions DOE has taken to address the issues and conclusions set forth in the enclosed report, and (2) summarizes DOE's geotechnical and structural engineering design reviews and the disposition of any findings. The Board also requests that a Summary Structural Engineering Report (SSR) be prepared upon completion of the final design for the CPA, comparable in scope and technical content to SSRs being prepared for the Hanford Waste Treatment Plant.

Sincerely,

A. J. Eggenberger
Chairman

c: Mr. Jeffrey M. Allison
Mr. Mark B. Whitaker, Jr.

Enclosure

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

December 14, 2006

MEMORANDUM FOR: J. K. Fortenberry, Technical Director

COPIES: Board Members

FROM: J. Blackman

SUBJECT: Review of the Preliminary Structural Design of the Salt Waste Processing Facility at the Savannah River Site

This report documents an on-site review of the preliminary structural design of the Salt Waste Processing Facility (SWPF) Central Processing Area (CPA) at Savannah River Site (SRS). The review was conducted on October 17–18, 2006, by members of the staff of the Defense Nuclear Facilities Safety Board (Board) D. Andersen and J. Blackman and outside experts J. Stevenson, P. Rizzo, and N. Vaidya. This review was followed by a series of discussions between the Department of Energy (DOE) and the Board's staff, as well as independent analyses conducted by the Board's staff.

Background. The preliminary structural design of the CPA was recently completed by the Parsons Infrastructure and Technology Group. The resulting building design information provides input for the development of the performance baseline in support of Critical Decision-2 and Critical Decision-3A, consistent with the requirements of DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets.* This information also serves as an indication of the acceptability of design approaches and analytical processes that, in turn, are part of determining the resources required during the final project design and construction.

Geotechnical Engineering Report for the SWPF. Geotechnical conditions at SRS are complex and difficult to interpret. As a result, the geotechnical engineering report typically involves significant field investigation, complex computations, and extensive peer reviews of technically controversial subjects, such as soft zone identification, liquefaction, and settlement assessment.

As discussed later in this report, allowable and ultimate bearing capacity, soil compressibility properties, and normal and post-earthquake settlement profiles control the design of the CPA foundation and parts of the building structure. Sound engineering practice dictates that foundation design parameters be finalized during conceptual design or at the very beginning of preliminary design to preclude impacts on building design adequacy. At SWPF, the preliminary design has been completed, however, this information has not been finalized; it is incomplete and uncertain. As a result, the Board's staff cannot assess whether the current building design is adequate. The Board's staff understands that DOE will accept the current

design with the expectation that the assumed geotechnical design parameters can be justified, but will add cost and schedule contingencies to the baseline cost estimate to account for the indeterminate uncertainties. Unfortunately, this approach unnecessarily distorts the proposed project performance baseline and it is not clear how these cost and schedule contingencies can be rationally developed given the indeterminate level of uncertainty.

Structural Design for the CPA. The staff's review of the preliminary design of the CPA structure focused on two calculations prepared by the architect-engineer. The first calculation, C-CLC-J-00015, *CPA Enhanced Design*, covered the analysis and design verification of the CPA building structure, while calculation C-CLC-J-00020, *CPA In-Structure Response Spectra,* addressed the development of in-structure response spectra (IRS) for the CPA building for use in seismic analyses of safety-related systems and components.

CPA Enhanced Design—This calculation utilized a large finite element model to represent the building structure. Static and dynamic analyses were performed using the Georgia Tech Structural Design Language (GTSTRUDL) computer program. The analysis considered 0.5-inch static settlement and 3-inch dynamic settlement uniformly distributed along the building centerlines. The building structural engineering analysis also incorporated a non-linear soil property relationship to model soil compressibility properties. The staff's review of this work disclosed several issues and apparently erroneous results:

- It is expected that the foundation displacements resulting from the 3-inch dynamic settlement will be nearly symmetrical with respect to the longitudinal building axis, but the reported results are not symmetrical and reflect anomalous behavior. This problem is indicative of errors in modeling and/or analysis. Until the source of this erroneous behavior is determined and corrected, the acceptability of the CPA building design cannot be verified. Furthermore, given the inherent variability of geotechnical conditions at the site, other non-uniform settlement profiles should be considered in the building analysis.

- The soil compressibility properties used in the analysis are not representative of values typically encountered at SRS. They are based on the premise that when the soil-bearing pressure reaches twice its allowable value (6 ksf [kips per square foot]), the soil reaches its maximum capacity and is no longer capable of resisting additional load. In fact, soil-bearing capacities at SRS are typically much higher than those used in the analysis. The use of more typical soil compressibility properties, including non-linear behavior at higher strain levels, would likely result in a significant load increase in the building structure.

- The finite element model was generated using four node quadrilateral shell elements. At least four elements are provided between floors and an average of eight elements between walls for modeling the basemat and floor slabs. While this mesh size may be reasonable for representing overall behavior in the preliminary analysis of a shear wall building, it is not clear that such a level of refinement will be appropriate when

the final analysis is performed. In general, four elements are capable of accurately modeling in-plane forces and moments, but may not be adequate for estimating out-of-plane forces and moments. During final analysis, detailed cut section analyses are typically performed around openings and at wall-to-slab junctions to develop detailed reinforcement requirements. The mesh refinement employed in the preliminary analysis does not appear to be adequate for this purpose. Lack of adequate substantiation of the mesh will necessitate preparing mesh refinement studies before completing the final analysis.

- Soil stiffness and impedance effects were represented using relationships for uniform soil sites as presented in American Society of Civil Engineers (ASCE) Standard 4-98, *Seismic Analysis of Safety-Related Nuclear Structures and Commentary.* However, the soil conditions beneath the CPA are not uniform and, as indicated in Section *C3.3.4.2.3 Layered soil sites* of ASCE Standard 4-98, "layering of soil deposits can have a significant effect on impedance functions." For this condition, ASCE 4-98 recommends that frequency-dependant impedance functions be developed. It is not clear that the approach used in the current analysis is conservative.

CPA In-Structure Response Spectra (IRS)—The purpose of this calculation is to provide the IRS for the CPA building for use in seismic analyses of safety-related systems and components. The building is modeled as a cantilever beam attached to an infinitely rigid foundation slab, which in turn is supported by vertical and horizontal soil springs whose properties are based on average soil conditions.

According to the analysis results, seismic floor acceleration levels are attenuated as compared with the input (free-field) acceleration levels. This is contrary to expected behavior, whereby floor and IRS acceleration levels should increase as a result of soil-structure interaction effects. Subsequently, DOE determined that the IRS in the calculation were incorrect since relative acceleration was erroneously output instead of absolute acceleration. It is not clear why the internal review process employed by the architect-engineer failed to identify and correct the erroneous IRS. Therefore the internal review process is also suspect.

Inherent in the IRS analysis is the assumption that the building's behavior can be characterized as a shear beam. However, examination of the mode shapes in the seismic analysis results from the *CPA Enhanced Design* indicates that this shear beam assumption is not correct and appears to be nonconservative. A more detailed analysis considering wall and floor slab flexibility and soil-structure interaction effects is required.

Quality Assurance Program. Three quality assurance issues arose during the staff's review. First, the architect-engineer reviewers failed to identify the erroneous IRS. Second, the architect-engineer did not follow proper quality assurance procedures (i.e., did not file a nonconformance report) when it was determined that the software being used, GTSTRUDL, was predicting unrealistically large membrane forces. As a result, the architect-engineer assumed,

but did not verify, that the problem was corrected by using a newer version of the GTSTRUDL software. Finally, the architect-engineer used prerelease (unverified) software capabilities in its analysis, which is inconsistent with software quality assurance requirements. The root cause and required corrective actions for these problems are still being developed by the architect-engineer and DOE.

Conclusions. The fundamental issues discussed above suggest that the analyses performed by the architect-engineer to confirm the adequacy of the design of the CPA need to be reverified under a functioning quality assurance program before the final design of the building proceeds or the basemat is constructed. In the staff's opinion, DOE needs to perform a thorough review of the architect-engineer's design as part of its project oversight. DOE has well-qualified peer reviewers but they have been allowed only a limited role thus far.

According to the seismic analysis, soil modes of behavior dominate in both horizontal directions. Given this predicted response, the Board's staff believes it is essential that the architect-engineer perform a fixed-based analysis (decouple the soil response) to ensure that the structural portion of the finite element model is adequate.

The development of IRS for seismic design evaluation of safety-related equipment needs to take into account the soil-structure interaction between the representative distributed mass model of the CPA and the multilayer soil stratum beneath the building.

The lack of a SWPF geotechnical engineering report at this stage of the design creates uncertainty, speculation, and debate as regards foundation design and building behavior. Proceeding without such a document is not consistent with good practice for designing Performance Category 3 facilities. The architect-engineer reports that dynamic settlement controls the design of the foundation basemat and many of the building walls. Variation in the soil stiffness properties, as well as the magnitude, distribution, and location of the dynamic settlement profile needs to be addressed in the geotechnical engineering report and considered in the design of the building before the building's structural design configuration is finalized. The Board's staff understands that the draft SWPF geotechnical engineering report is scheduled to be released for review and discussion during March 2007.

Further elaboration on the technical details summarized in this report will be communicated separately to DOE Savannah River Office.