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GENERAL COUNSEL

January 11, 2002

Michael C. Farrar, Chairman
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dr. Peter S. Lam
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dr. Jerry R. Kline
Administrative Judge
Atomic Safety and Licensing Board
Washington, DC 20555

In the Matter of
PRIVATE FUEL STORAGE L.L.C.
(Independent Spent Fuel Storage Installation)
Docket No. 72-22-ISFSI

Dear Administrative Judges:

Enclosed please find Supplement No. 2 to the "Safety Evaluation Report Concerning the Private Fuel Storage Facility" ("SER"), which the NRC Staff ("Staff") issued on December 21, 2001. The enclosed Supplement contains revisions to Chapters 2, 4, 5, 6, 7, 11, and 15 of the Staff's SER issued on September 29, 2000, related to recent geotechnical information and design changes to the proposed Private Fuel Storage ("PFS") facility. Supplement No. 1 to the SER, concerning aircraft crash hazards, was issued on November 13, 2001.

Copies of the enclosed document were previously transmitted to Counsel for PFS and the State of Utah ("State") on December 21, 2001, based on their status as lead parties on geotechnical issues and their agreement to limit the distribution of this document pending a Staff determination as to whether the document should be redacted to remove any sensitive information. The Staff has now determined that this document may be released to the public without redaction.

Copies of the enclosed document have been provided to all persons on the Staff's service list, other than NRC addressees, by separate letter this date. Copies of the enclosed document are being provided to NRC addressees on the service list, and electronic copies are being provided to all persons on the service list, herewith.

Sincerely,

Sherwin E. Turk

Sherwin E. Turk
Counsel for NRC Staff

Enclosures: As Stated
cc: Service List

Template = SECY-028

SECY-02

REVISION 2

SAFETY EVALUATION REPORT

CONCERNING

THE PRIVATE FUEL STORAGE FACILITY

DECEMBER 21, 2001

these secondary faults and their contributions to the surface faulting hazard at the proposed site are discussed in detail in Section 2.1.6.3 of this SER.

Engineering Evaluation of Geologic Features

The static and dynamic engineering soil and rock properties of the various materials underlying the site are evaluated in Section 2.1.6.4 of this SER. The properties evaluated include grain size classification, Atterberg limits, water content, unit weight, shear strength, relative density, shear modulus, Poisson's ratio, bulk modulus, damping, consolidation characteristics, seismic wave velocities, density, porosity, strength characteristics, and strength under cyclic loading.

Staff Review

The staff reviewed the information in Section 2.6.1 of the SAR and found it acceptable because the basic geologic and seismic characteristics of the site and vicinity have been adequately described in detail to allow investigation of seismic characteristics of the Facility. The staff has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Facility, perform additional safety analysis, and demonstrate compliance with regulatory requirements in 10 CFR 72.92(a), 72.92(b), 72.102(e), and 72.122(b) with respect to this issue.

2.1.6.2 Ground Vibration and Exemption Request

Earthquake ground motion is discussed in Section 2.6.2 of the SAR, Vibratory Ground Motion. In the SAR, vibratory ground motion is addressed through discussions of historical seismicity and procedures to determine the design earthquake, including identification of potential seismic sources and their characteristics, correlation of earthquake activity with geologic structures, maximum earthquake potential, and seismic wave transmission characteristics.

According to 10 CFR 72.122(b)(2), structures, systems, and components important to safety must be designed to withstand the effects of natural phenomena, including earthquakes, without impairing their capability to perform safety functions. For sites west of the Rocky Mountains, such as Skull Valley, 10 CFR Part 72 requires that seismicity be evaluated by techniques set forth in Appendix A of 10 CFR Part 100 for nuclear power plants. This appendix defines the safe shutdown earthquake as the earthquake that produces the maximum vibratory ground motion at the site, and requires that the structures, systems, and components be designed to withstand the ground motion produced by the safe shutdown earthquake. This seismic design method implies use of a DSHA approach because it considers only the most significant event, and the method is a time-independent statement (i.e., it does not take into consideration the planned operating period of the Facility or how frequent or rare the seismic events are that control the deterministic ground motion). Also, 10 CFR 72.102(f)(1) requires that analyses using the

Appendix A methodology use a design peak horizontal acceleration equivalent to that of the safe shutdown earthquake for a nuclear power reactor.

A detailed geological survey conducted by Geomatrix Consultants, Inc.(1999a) identified additional faults in the vicinity of the site. Taking into account these newly discovered faults with the DSHA methodology, in revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000), the applicant estimated the peak horizontal and vertical acceleration values from the seismic event to be 0.72 and 0.80g, respectively (Geomatrix Consultants, Inc., 1999b). In Revision 22 of the SAR (Private Fuel Storage Limited Liability Company, 2001), using the DSHA methodology, the applicant estimated the peak horizontal and vertical acceleration values from a seismic event to be 1.15g and 1.17g respectively (Geomatrix Consultants Inc., 2001d). These values exceed the SAR proposed design values.

To resolve the issue of seismic design, the applicant submitted to the NRC, a request for an exemption to the seismic design requirement of 10 CFR 72.102(f)(1) to use PSHA along with considerations of risk to establish the design earthquake ground motion levels at the Facility (Parkyn, 1999b). The exemption request also proposed to design the Facility to the ground motions produced by 1,000-year return period earthquakes. Based on information supporting Revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000), these design-ground motions were calculated to have a peak horizontal acceleration of 0.40g and a peak vertical acceleration of 0.39g, resulting from a recent site-specific PSHA conducted by the Geomatrix Consultants, Inc. (1999a). These values were subsequently updated in Revision 22 of the SAR (Private Fuel Storage Limited Liability Company, 2001), as discussed below.

As part of the evaluation of PFS's exemption request, the staff conducted an independent technical review of seismic hazard investigations at the proposed site (Stamatakos et al. 1999). The objectives of this seismic investigation were to (i) conduct an independent review of existing seismic hazard studies at Skull Valley, in particular, to identify seismic and faulting issues important to siting the Facility; (ii) evaluate the adequacy and acceptability of PFS's seismic design approach; and (iii) determine an appropriate design basis return period for the PFS-proposed seismic design approach. The staff conducted its evaluation by reviewing information provided by the applicant, surveying other state-of-the-art literature, analyzing the bases of current NRC regulations, and performing independent analyses of geophysical data and sensitivity studies of model alternatives and consideration of uncertainties. This section of the SER summarizes information presented in the Revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000), the result of the staff's independent investigation, and staff's review of new information presented in Revision 22 of the SAR (Private Fuel Storage Limited Liability Company, 2001). A summary is included at the end of this section pertaining to the staff's evaluation of the adequacy of the PFS-proposed seismic design for the Facility.

Geological and Seismotectonic Setting

Seismicity in the Basin and Range is generally concentrated along the Wasatch Front, Sierra Nevada and a medial zone called the Central Nevada Seismic Belt (dePolo et al., 1991). Within the region surrounding the proposed site are four seismotectonic provinces: (i) the Basin and Range, (ii) Wasatch Front as part of the Intermountain Seismic Belt, (iii) the Snake River Plain, and (iv) the Colorado Plateau. Of these four seismotectonic provinces, the Wasatch Front is the only one with levels of seismic activity that could affect the proposed site (see Stamatakos et al. (1999) for a more thorough discussion of the seismotectonic provinces).

The Skull Valley site is approximately 50 miles west of the Wasatch Front. The seismotectonic setting of the proposed site was discussed (Private Fuel Storage Limited Liability Company, 2000, Appendix 2D) within the larger context of the tectonic evolution and historic seismicity of the western Cordillera. This discussion included a brief discourse of regional crustal stresses and the driving forces of the Basin and Range extension. The SAR concluded that gravitationally derived buoyancy forces drive extension (Jones et al., 1996; England and Jackson, 1989), although recent global positioning system data used to assess present strain rates across the Basin and Range seem to suggest that external forces from motion of the Pacific and Sierra Nevada tectonic plates also play a role in driving deformation (Thatcher et al., 1999). As concluded in the Revision 2 of the SAR (Private Fuel Storage Limited Liability Company, 2000, Appendix 2D), the site in Skull Valley is presently affected by active tectonic extensional strain and, therefore, will be subjected to future seismicity and deformation.

Historical Seismicity

Geomatrix Consultants, Inc. (1999a) used the earthquake catalog compiled by the University of Utah, which includes historical earthquakes from about 1850 to 1962 and instrument recorded earthquakes from the University of Utah network of 26 statewide stations from 1962 to 1996. The compiled catalog was filtered by Arabasz et al. (1989) to remove duplicates and manmade events such as quarry and mining blasts. All magnitudes were also converted by Arabasz et al. (1989) to a common magnitude scale. Foreshocks and aftershocks were removed following the methodology of Youngs et al., (1987). The largest earthquake in the catalog is the 1909 M 6.0 event. Seismicity is generally concentrated along the Wasatch Front east of the site and in the Central Nevada Belt west of the site.

Because the reporting techniques improved through time, the catalog was incomplete; small magnitude events below about M 5.0 are absent from the record until primitive instruments became available in the early 1930s. As instrumentation improved, the record of smaller and smaller earthquakes became more complete. Completeness of the catalog for different magnitude scales was assessed using the methodology recommended by Stepp (1972) and reported in Youngs et al. (1987). The maximum likelihood technique (Weichert, 1980) was used by Geomatrix Consultants, Inc. (1999a) to derive recurrence parameters.

The staff reviewed the information provided by the applicant and evaluated the applicant's analyses of historical seismicity. The staff found no evidence of historic seismicity in the vicinity of the site. The staff believes that the analyses and information in the SAR provide reasonable assurance that an adequate set of data was used in developing seismic recurrence relationships and determining the maximum earthquake potential in the hazard analyses.

Potential Seismic Sources and Their Characteristics

The seismic source characterization of the Facility was developed from examination of the available literature integrated with detailed site geological studies, including site stratigraphy, geologic mapping, cross-sectional construction, and geophysical investigations (Geomatrix Consultants, Inc.,1999a; Bay Geophysical Associates, Inc., 1999). The most important aspects for the evaluations of seismic hazards were identification and characterization of active faults derived from paleoseismic and geophysical investigations. Identification of a detailed Quaternary stratigraphy was also essential because it provided critical constraints on faulting activity. Based on detailed site investigations and review of the seismotectonic setting, Geomatrix Consultants, Inc. (1999a) identified 29 fault sources and 4 areal sources. A logic tree approach was used to combine alternative models of source geometry, activity, and seismicity to formulate the PSHA.

The staff reviewed the seismic source characterization and found it acceptable because it is thorough, complete, and conservative. Models used by the applicant for the hazard assessment were appropriate. For example, Geomatrix Consultants, Inc. (1999a) conservatively considered all faults to be planar and to extend through the thickness of the brittle crust rather than considering the possibility that the primary faults could be listric and sole into a seismic detachment above the base of the seismogenic crust. Uncertainties in other aspects of fault geometry and seismic activity were incorporated into the probabilistic assessment. Upper ranges of those parameters that describe fault geometry or seismic activity were constructed to adequately bound geologic and geophysical observations. The historic seismic record was appropriately used to develop b-values for recurrence relationships and to develop the background areal source zone.

One aspect of the staff review included the interpretations of fault geometries for newly discovered East and West faults in Skull Valley based on reflection seismic data and forward modeling of gravity data in Geomatrix Consultants, Inc. (1999a). Staff review of the alternative models shows that the Geomatrix Consultants, Inc. assessment may have led to an overly conservative hazard result. Reanalysis (Stamatakos et al., 1999) of the proprietary industry gravity data does not support the interpretation that the West fault is an independent seismic source. Rather, the staff interprets the West fault as a splay of the East fault, incapable of independently generating large magnitude earthquakes. Therefore, the staff found the probabilistic assessment provided by Geomatrix Consultants, Inc. (1999a) to be acceptable, albeit conservative because the Geomatrix Consultants, Inc. (1999a) model considers the West fault as an active seismic source.

The conservative nature of the applicant's source characterization and PSHA results presented in the SAR is evident when the results are compared to PSHA results for other sites in Utah, especially those in and around Salt Lake City. Such a comparison shows that the seismic hazard in Skull Valley was calculated by the applicant to be higher than seismic hazard assessments that have been performed for sites at, or near, Salt Lake City, despite the fact that fault sources near Salt Lake City are larger and more active than fault sources near the PFS site. For example, the results of the applicant's PSHA for Skull Valley (Geomatrix Consultants, Inc., 2001a) suggest that it is 1.5 times more likely that a ground motion of 0.5g horizontal peak ground acceleration or greater will be exceeded at the PFS site (assuming hard rock site conditions), than at Salt Lake City, based on the USGS National Earthquake Hazard Reduction Program (Frankel et al., 1997). Similarly, the 2000-yr horizontal peak ground acceleration for Skull Valley (soil hazard) as estimated by the applicant, is higher than the 2500-yr ground motions for the nine sites along the Wasatch Front that were evaluated as part of the Utah Department of Transportation I-15 Reconstruction Project (Dames & Moore, Inc., 1996). The ground motions estimated by the applicant in Skull Valley are higher than those for the I-15 corridor, despite the close proximity of Salt Lake City to the Wasatch fault, which has a slip rate nearly ten times larger than the Stansbury or East Faults (cf., Martinez et al., 1998; Geomatrix Consultants, Inc., 1999a) and is capable of producing significantly larger magnitude earthquakes than the faults near the PFS Facility site in Skull Valley (cf., Machette et al., 1991; Geomatrix Consultants, Inc., 1999a).

Slip Tendency

Another aspect of the seismic source characterization that appears to be conservative, is the site-to-source models used in the ground motion attenuation relationships and the development of distributions of maximum earthquake magnitude based on the dimensions of fault rupture. This conclusion of additional conservatism is derived from a slip tendency analysis of the Skull Valley fault systems performed by the staff.

A slip tendency analysis (Morris et al., 1996) was completed using an interactive stress analysis program (3DStress™) that assesses potential fault activity relative to crustal stress. For Skull Valley, the stress tensor is defined with a vertical maximum principal stress (σ_1), a horizontal intermediate principal stress (σ_2) with azimuth of 355°, and a horizontal minimum principal stress (σ_3) with an azimuth of 085°. The stress magnitude ratios are $\sigma_1/\sigma_3 = 3.50$ and $\sigma_1/\sigma_2 = 1.56$. This orientation for the principal stresses was based on recent global positioning satellite information (Martinez, et al., 1998a). The slip tendency analysis assumed a normal-faulting regime, with rock density equal to 2.7 g/cc, fault dip equal to 60°, water table at a depth of 40 m, and a hydrostatic fluid pressure gradient.

In slip tendency analysis, the underlying assumption is that the regional stress state controls slip tendency and that there are no significant deviations due to local perturbations of the stress conditions. This assumption is supported by a similar slip tendency analysis of the Wasatch fault, which shows highest slip tendency values for the segments of the fault considered to be most active (Machette et al., 1991).

The slip tendency analysis shows that segments of the East fault and the East Cedar Mountain fault nearest the PFS site have relatively low slip tendency values compared to segments farther north in Skull Valley. As discussed in the following sections on site-to-source distances and maximum magnitudes, these results indicate that the seismic source characterization of the PSHA study conducted by Geomatrix Consultants, Inc. (1999a, and 2001a) is conservative. Three areas of conservatism are the distribution of site-to-source distance, maximum magnitude earthquakes, and potential of the West fault as a seismogenic source (discussed in Stamatakos et al., 1999).

Distributions of Site-to-Source Distances

Results of the slip tendency analysis indicate that fault segments with approximately North-South strikes (azimuth = 175°) are optimally oriented for future fault slip. Faults with north northeast-south southwest strikes have high slip tendency values. In contrast, fault segments with northwest-southeast strikes, such as the East fault near the PFS Facility site and the southern segments of the East Cedar Mountain fault also near the PFS Facility site, have relatively low slip tendency values. Therefore, these fault segments are less likely to slip in the future than fault segments further from the site. Fault rupture close to the site greatly influence the seismic hazard. The closer the earthquake is to the site, the larger the resulting ground motions compared to an equal magnitude earthquake on a fault segment farther away from the site.

In the site-to-source distributions used in the ground motion attenuation equations, Geomatrix Consultants, Inc. (1999a) assumed uniform distributions of earthquake ruptures along active fault segments. Given the slip tendency analysis described above, this assumption by Geomatrix Consultants, Inc. (1999a) is conservative. The staff concludes that seismic source models that incorporate slip tendency would result in a lower ground motion hazard than the one developed by the applicant.

Maximum Magnitude

The slip tendency results suggest that Geomatrix Consultants, Inc. (1999a) may have overestimated the maximum magnitude of the East and East Cedar Mountain faults near the PSFS site. In the SAR, the applicant first developed conceptual models of the physical dimensions of fault rupture—either rupture area or trace length of surface fault rupture—based on the geologic record (Geomatrix Consultants, Inc.,1999a). Second, the applicant developed distributions of maximum magnitudes for each active fault using empirical scaling relationships developed from the magnitudes and associated rupture dimensions of historical earthquakes (e.g., Wells and Coppersmith,1994). In developing the fault segment models, the applicant conservatively assumed that the entire mapped length of the surface trace length represents active fault segments. Thus, these maximum fault dimensions produce conservative estimates of maximum magnitude.

The slip tendency analysis indicates that parts of the East and East Cedar Mountain faults near the PFS Facility site have relatively low slip tendency values. Thus, these faults may be smaller than in the fault models used by the applicant to estimate maximum magnitude. Fault rupture models developed using slip tendency analysis would therefore lead to fault segment models with smaller rupture dimensions (length or area) than those used by Geomatrix Consultants, Inc. (1999a). Because distributions of maximum magnitude for each active fault are derived from empirical scaling relationships of rupture area or rupture length (e.g., Wells and Coppersmith,1994), application of the slip tendency analysis would thereby result in smaller predicted maximum magnitudes than those developed by the applicant. Smaller maximum magnitudes would reduce the overall ground motion hazard.

In summary, the staff found that the applicant's considerations of seismic source characteristics and associated uncertainties provide reasonable assurance that all significant sources of future seismic activity have been identified and their characteristics and associated uncertainties are adequately or conservatively described and appropriately included in the evaluation of the seismic ground motion hazard. Stamatakos et al. (1999) provides more details of PFS's seismic source characterization and the staff's independent sensitivity analyses.

Further, the staff concludes that the seismic source characterization performed by the applicant is conservative (perhaps by as much 50% or more based on a comparison to Salt Lake City PSHA results). The staff does not attempt here to explicitly quantify the degree of conservatism in the seismic source characterization. Quantitative estimates of the degree of conservatism would require the staff to essentially recalculate the PFS PSHA, which is not necessary under the NRC Standard Review Plan (1997a). Nevertheless, this qualitative assessment of potential conservatism provides additional confidence that the applicant's seismic source characterization is acceptable. Because the applicant's seismic source characterization is conservative, it provides reasonable assurance that the seismic hazard has been adequately determined and is sufficient to assess safety of the PFS Facility. Therefore, the staff concludes that the information presented in Section 2.6.1.1 of the SAR is acceptable because the basic geologic and seismic characteristics of the site and vicinity have been adequately (albeit conservatively) described in detail to allow investigation of seismic characteristics of the proposed Facility site. The staff has determined that this information is acceptable for use in other sections of the SAR to develop the design bases of the Facility, perform additional safety analysis, and demonstrate compliance with regulatory requirements in 10 CFR 72.92(a), 72.92(b), 72.102(e), and 72.122(b) with respect to this subject.

Estimate of Ground Motion Attenuation

Yucca Mountain Approach

For purposes of estimating earthquake ground motions that may occur at the proposed site, the applicant utilized results of the PSHA conducted for the proposed high-level waste repository site at Yucca Mountain (Civilian Radioactive Waste Management System Management and Operating Contractor, 1998). The Yucca Mountain study developed and implemented a methodology for evaluating earthquake ground motions in the Basin and Range that includes the results of scientific evaluations and expert elicitations from seven ground motion experts. The staff found that the use of the Yucca Mountain methodology for the Facility PSHA ground motion analysis is appropriate, in general, because (i) it represents the state-of-the-art knowledge and (ii) both the PFS Facility site and site of the proposed geologic repository at Yucca Mountain have seismotectonic characteristics of the Basin and Range.

Geomatrix Consultants, Inc. (1999a) selected the published median ground motion attenuation models and weighted them according to the Yucca Mountain Seismic Hazard Study (Civilian Radioactive Waste Management System Management and Operating Contractor, 1998).

The Yucca Mountain PSHA used a sophisticated methodology for modeling and quantifying the epistemic uncertainty in ground motions. The Yucca Mountain analysis attempted to quantify all of the sources of uncertainty involved in the estimation of strong ground motion. As part of the Facility PSHA, Geomatrix Consultants, Inc. (1999a) elected to consider only that part of the epistemic uncertainty associated with the choice of different median ground motion models and not the uncertainty in the models themselves. As a consequence, sources of epistemic uncertainty that were quantified in the Yucca Mountain PSHA were not considered in the PFS Facility analysis. This leads to an underestimate of the total epistemic uncertainty and, therefore, an underestimate of the mean seismic hazard at the site. The staff performed sensitivity calculations and determined that the mean frequency of exceedance of ground motions changes by less than a factor of two. Therefore, the staff concludes this effect to be insignificant.

Revisions to the Ground Motion Modeling in 2001

In March 2001, Geomatrix Consultants, Inc. (2001a) published the revised probabilistic seismic hazard analysis result for the PFS Facility. The revision was motivated by the analysis of site-specific soils and velocity data obtained subsequent to the submittal of the initial PSHA results (Geomatrix Consultants, Inc., 1999a). In particular, the applicant provided additional shear wave velocity measurements of the upper 106.5 ft of strata in the soil column at the PFS Facility site in the SAR. The additional data were acquired from downhole geophysical measurements in two borings (Northland Geophysical Limited Liability Company, 2001) and 16 test pits excavated at the site. The applicant used the results to derive alternative interpretations of the shear wave velocity profiles that were used to develop site response models Calculation G(PO18)-2 of Parkyn, 2001.

The applicant provided revised dynamic properties of the soil strata above 106.5 feet in the SAR (Private Fuel Storage Limited Liability Company, 2001). Parkyn (2001) documents several changes in dynamic soil properties compared to those reported in the former revision of the SAR (Private Fuel Storage Limited Liability Company, 2000). These changes include:

(1) Small adjustment of the depths of the boundaries of several layers including the two prominent soil horizons.

(2) Incorporation of the downhole shear-wave velocity measurements from two boreholes, CTB-5(OW) and CTB-5A (Northland Geophysical. L.L.C., 2001).

(3) Alternative multi-step methodology to develop statistical models of shear wave velocity profiles from the 16 cone penetrometer tests and the CTB-5(OW) and CTB-5A borehole data.

(4) Direct measurement of shear wave velocities in the upper layers of the Tertiary Salt Lake Group strata, which lies just below the Quaternary-Tertiary unconformity.

(5) Revision of site response to include lower damping and lower levels of modulus reduction based on results of the resonant column tests leading to a more linear modulus reduction and damping relationship.

These revisions led to development of a nine-layer shear-wave soil profile used to calculate the site response. This change in the shear-wave profile and site response model led to a significant increase in estimated ground motions at the PFS site. As shown in Table 2-2, these changes significantly affect higher frequencies, but have much less effect on lower frequencies of ground motion (Appendix F of Geomatrix Consultants, Inc., 2001a).

Based on the new site velocity data, Geomatrix Consultants, Inc. (2001a) made several revisions to its assessment of the ground motions at the PFS site. These revisions included modifications to the site velocity model, the ground motion attenuation relationships adopted from the Yucca Mountain study, and the approach used in the site response analysis. In the aggregate, these changes resulted in an increase in the ground motion hazards estimated at the PFS site. Table 2-2 compares the estimated 2000-year PSHA accelerations as estimated in Revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000) and the updated 2000-year PSHA accelerations in Revision 22 of the SAR, for horizontal and vertical ground motions at selected periods.

Table 2-2. Comparison of PSHA for 2,000-Year Return Period Spectral Acceleration (with 5% Damping)

Period (sec)	Horizontal Ground Motion (g)		Vertical Ground Motion (g)	
	SAR Revision 22	SAR Revision 18 (former design)	SAR Revision 22	SAR Revision 18 (former design)
PGA	0.711	0.528	0.695	0.533
0.1	1.541	1.046	1.752	1.369
0.5	1.045	1.166	0.509	0.476
2.0	0.164	0.272	0.088	0.088

The process used to estimate the ground motion at the PFS site in the original PSHA (SAR Revision 18, Private Fuel Storage Limited Liability Company, 2000), as well as in the revised analysis, consisted of the following elements.

- Median Ground Motion Attenuation Models – the ground motion models used in the Yucca Mountain study (Civilian Radioactive Waste Management System Management and Operating Contractor, 1998) were adopted in the PFS analysis to define the median ground motion and the epistemic uncertainty in the median, as a function of earthquake magnitude and distance. These are empirical models derived from ground motions recorded principally in California.

- Faulting Type – an adjustment factor was used to account for differences in the type of faulting between faults in California and Skull Valley. This adjustment factor was used to scale the California median ground motion attenuation models.

- Regional Attenuation – an anelastic attenuation model was used to remove the effects of regional attenuation of seismic waves in the crust in California and to account for the regional attenuation as it would be expected to occur in Utah.

- Site-Specific Response – the effects of California surficial materials were removed and the response of the PFS soils were computed and incorporated in the analysis to model the response of the near surface geologic deposits on ground motion at the PFS site.

- Near-Source Effects – adjustment factors were used to account for the near-source effects of faulting kinematics on ground motions at the PFS site. While the elements of the process of developing site-specific ground motion estimates for the PFS site were the same in the original PSHA and in the revised analysis, there are differences in the implementation of two of the four elements. Table 2-3 tabulates the elements of the ground motion model and how they were implemented in Revisions 18 and 22 of the SAR.

The revised PSHA used the same adjustment factors for the effects of faulting type, regional attenuation, and near-source effects. However, the median ground motion attenuation models and the evaluation of site response changed in the revision of the PSHA.

In the original PSHA, Geomatrix Consultants, Inc. (1999a) used a set of California empirical ground motion models applicable to soil sites. These models were the companion empirical models to the rock attenuation models selected by the Yucca Mountain study experts. The choice to use soil ground motion attenuation models as a starting point was based on the original observation that the PFS velocity profile compared favorably with California soil sites (Geomatrix Consultants, Inc., Appendix F, 1999a). Following revision of the soil profile data, Geomatrix Consultants, Inc. (2001a) concluded that the PFS velocity profiles now compared more favorably with California rock sites rather than California soil sites. On this basis, the California empirical rock ground motion attenuation models selected by the Yucca Mountain study experts were chosen. A total of 20 rock horizontal attenuation models with associated probability weights were used in the PFS analysis. For the vertical motions, 11 models were used. The model weights were derived from the weights assigned by the ground motion experts that participated in the Yucca Mountain study. Based on a review of the current site data, the staff agrees that the PFS site conditions compare more favorably with the California rock site conditions. Further, the staff notes that the process used in the Yucca Mountain study and in the PFS analysis is designed to remove the California regional and site-specific effects that are inherent in empirical ground motion attenuation models and to incorporate appropriate regional and site-specific effects for the site in question (in this case, Utah and Skull Valley).

By virtue of this modeling approach, the issue as to whether rock or soil median ground motion attenuation models should be used is not significant. The staff agrees, however, based on the current PFS site-specific information, that the use of the empirical rock attenuation models for the PFS site is reasonable.

Table 2-3. Comparison of Ground Motion Modeling and Soil Velocity Profiles

<table>
<tr><th colspan="3"></th><th>SAR Revision 22</th><th>SAR Revision 18 (former design)</th></tr>
<tr><td colspan="3">Median Ground Motion Attenuation Model</td><td>California rock models</td><td>California soil models</td></tr>
<tr><td colspan="3">Faulting-Type Effect
(Strike-slip to normal faulting)</td><td>Yucca Mountain scaling factors (re-normalized weights for rock models)</td><td>Yucca Mountain scaling factors (re-normalized weights for rock models)</td></tr>
<tr><td colspan="3">Regional Attenuation (Crustal Path Effect)
(California motion to Utah motion)</td><td>Yucca Mountain technique</td><td>Yucca Mountain technique</td></tr>
<tr><td colspan="3">Near-Source Effects</td><td>Conservative application of Sommerville et al. (1997) factors</td><td>Conservative application of Sommerville et al. (1997) factors</td></tr>
<tr><td rowspan="5">Site Effect</td><td colspan="2">Empirical Approach</td><td>New</td><td>-</td></tr>
<tr><td rowspan="4">Modeling Approach</td><td>Input Motion</td><td>Rock recordings</td><td>Rock recordings</td></tr>
<tr><td>Soil Velocity Profile</td><td>New 9-layer model</td><td>3-layer average velocity model
1-layer average velocity model</td></tr>
<tr><td>Deconvolution</td><td>To a depth of 5 km</td><td>To a depth of 3 km</td></tr>
<tr><td>Response Analyses</td><td>PFS multilayer profiles
Western US generic rock profiles</td><td>PFS average profiles
Westurn US generic soil profiles</td></tr>
</table>

Site Response Effects

A final step in the assessment of site-specific ground motions for the PFS site requires that the response of near-surface geologic deposits be considered. The effects of site response are included in the estimates of ground motion by means of frequency (or period) dependent site-response factors. In the revision of the PFS PSHA, two approaches were used to derive the site-adjustment factors. The first approach is empirical and the second is based on site-response calculations for the PFS site soils. Geomatrix Consultants, Inc. (2001a, b) assigned probability weights to each approach, based on their interpretation of the credibility in each method.

The empirical approach, used by Geomatrix Consultants, Inc. (2001a, b), was assigned 1/3 weight in PSHA calculation. The empirical approach is based on two assumptions: (i) the PFS site can be classified as a shallow soil site, and (ii) PFS soil velocity characteristics are similar to those of western United States shallow soil sites. In the empirical approach, a set of strong motion recordings obtained at shallow soil sites were selected. The selected ground motion recordings were scaled to the desired ground motion levels at the PFS site. A set of empirical site response factors was determined from the distribution of spectral ratios that were determined from the set of shallow site recordings and the selected empirical hard-rock ground-motion models.

The second approach used by Geomatrix Consultants, Inc. (2001a) in the revision to the PSHA involved the calculation of site response factors using the SHAKE model and the PFS site data. The same approach was used in the original analysis. Based on the results of the site soils and velocity data obtained subsequent to the original submission of the PSHA, significant modifications were made to the site model. Geomatrix Consultants, Inc. (2001a, b, c) abandoned the 3-layer average velocity model used in the original study (Geomatrix Consultants, Inc., 1999a) and developed a new 9-layer soil velocity model above the Tertiary strata. The Tertiary strata in Skull Valley are part of the Salt Lake group, which is a ~500-700 ft thick sequence of semi-consolidated siltstones, claystones, and sandstones of Middle to Late Miocene Age (5.3 to 16.6 Ma). In the 2001 revisions, Geomatrix Consultants, Inc, (2001a) used both a constant velocity model and an increasing velocity model for these Tertiary strata, whereas a 1-layer average velocity model was used in the Geomatrix Consultants, Inc. (1999a) study.

The differences between the results of the empirical and site response analyses are considerable for periods less than about 0.3 s (see Fig. F-17 in Appendix F, Geomatrix Consultants, Inc., 2001a). At these periods, the site response analysis predicts higher scaling factors. However, at periods greater than about 1.0 s, the empirical factors are higher. In its revised PSHA report (Appendix F, Geomatrix Consultants, Inc., 2001a) Geomatrix Consultants, Inc. also concludes that the use of the empirical site response scaling factors is appropriate because they are based on actual strong motion recordings at shallow soil sites. At the same time, they recognize these factors are not site-specific and thus assign a lower weight to this approach.

Staff Review of Ground Motion Attenuation Models

The staff reviewed the characterization of strong ground motion in the Facility seismic hazard analysis and the approach taken to model the epistemic uncertainty, and found them acceptable. The approach to modeling strong ground motion provides reasonable assurance that the site hazard is adequately (albeit conservatively) estimated.

The staff agrees with the applicant that revision of the dynamic soil properties presented in the SAR was necessary because of the acquisition of new velocity data (Northland Geophysical, L.L.C, 2001), which was collected by the applicant after publication of the original SER. The revision of the original 3-layer shear-wave velocity profile to the current 9-layer model led to a large increase in the peak ground accelerations. However, the revised data are well within the uncertainty bands provided in the original 3-layer model. The staff considers the overall shear wave profile results, as revised, to be acceptable and conservative. In this regard, the staff notes that incorporation of the new shear-wave velocity data from the boreholes (Northland Geophysical Limited Liability Company, 2001) into the existing shear wave velocity profiles (Private Fuel Storage Limited Liability Company, 2000) or equal weighting of the original and new statistical methodologies would lead to a site response model with lower ground motions than the model presented in Revision 22 of the SAR.

The staff also agrees with the applicant's approach to estimate regional and site-specific ground motions based on the site response calculations for PFS Soils. There are sufficient technical bases for ground motion modeling based on this approach for use in development of the site specific PSHA and ultimately in development of the design basis earthquake. In contrast, the staff finds that PFS did not provide sufficient technical basis for use of empirical site response factors. These factors are based on strong-motion recordings obtained at California sites for which no information is provided that supports a comparison to the PFS site, other than a general shallow soil site characterization. However, sensitivity results provided by PFS (Parkyn, 2001) show that inclusion of the empirical site response factors approach has a small effect on the PGA values (~12%), and an even smaller effect on the predicted ground motions at lower frequencies. The small increase in ground motions that would occur if the applicant did not use the empirical site response approach is more than compensated for by other conservatisms in the PSHA results, including the noted conservatism in the seismic source characterization.

In summary, the staff concludes that there is sufficient information on shear wave velocity profiles in the soil strata and ground motion attenuation modeling for use in other sections of the SAR to develop the design bases of the proposed Facility, perform additional safety analysis, and demonstrate compliance with the regulatory requirements of 10 CFR 72.90(b-d), 72.92(a-c), 72.98(b), 72.98(c)(3), and 72.122(b) with respect to this issue.

Probabilistic Seismic Ground Motion Hazard

The Geomatrix Consultants, Inc. (1999a) PSHA uses a well-established methodology and basic equations (e.g., Cornell, 1968, 1971; McGuire, 1976, 1978; Civilian Radioactive Waste Management System Management and Operating Contractor, 1998). Calculation of probabilistic seismic ground motion hazard requires specification of three basic inputs: (i) geometric characteristics of potential sources, (ii) earthquake recurrence characteristics for each potential source, and (iii) ground motion attenuation estimates. Details of these inputs to the PSHA at Skull Valley have been evaluated in Stamatakos et al. (1999) and summarized in previous sections of this SER. PSHA calculations include the seismic hazard from each individual source and the total hazard from all potential sources. Such calculations establish hazard curves that depict the relationship between levels of ground motion and probabilities (frequencies) at which the levels of ground motion are exceeded. In Geomatrix Consultants, Inc. (1999a) computations, fault sources were modeled as segmented planar surfaces. Areal sources were modeled as a set of closely spaced parallel fault planes occupying the source regions. The distance density functions were computed assuming that a rectangular rupture area for a given size earthquake is uniformly distributed along the length of the fault plane and located at a random point on the fault plane. Depth distribution for earthquakes was based on depth distribution of recorded historical earthquakes along the Wasatch Front. The rupture size (mean rupture area) of an event was estimated based on the empirical relation of Wells and Coppersmith (1994). The basis for using the mean rupture area is the study of Bender (1984) that shows nearly equal hazard results using the mean estimates of rupture size and considering statistical uncertainty in rupture size. The minimum earthquake magnitude considered in the Geomatrix PSHA was M 5 (Geomatrix Consultants, Inc., 1999a).

Mean and percentile (95, 85, 50, 15, and 5^{th}) peak ground motion and 1-Hz spectral (5-percent damped) acceleration hazard curves were calculated and presented in Geomatrix Consultants, Inc. (1999a) for horizontal and vertical motions. In Revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000), the mean peak horizontal accelerations were 0.40g and 0.53g and the mean peak vertical accelerations were 0.39g and 0.53g for 1,000- and 2,000-year return periods, respectively. Equal-hazard response spectra for return periods of 1,000 and 2,000 year (mean annual probabilities of exceedance of 1×10^{-3} and 5×10^{-4}, respectively) were calculated and presented in Geomatrix Consultants, Inc. (1999c). In Revision 22 of the SAR (Private Fuel Storage Limited Liability Company, 2001), mean peak horizontal and vertical accelerations for the 2000-yr return period were calculated to be 0.711g and 0.695g, respectively.

Contributions of individual seismic sources were calculated and the results show that the dominating sources are the Stansbury, East-Springline, and East Cedar Mountain faults for peak ground acceleration for return periods greater than 1,000 years and for 1-Hz spectral acceleration for a return period greater than 2,000 years. Deaggregation results show that the total hazard is dominated by ground motions from nearby M 6 to 7 events. Sensitivity results indicate that the choice of attenuation relationship is a major contributor to uncertainty in the hazard calculation. Geomatrix Consultants, Inc. (1999a) sensitivity results also indicate (i) alternative models for the geometry and extent of the West fault have little effect on the total hazard because the East fault dominates the hazard from the Skull Valley faults as a result of its higher estimated slip rate, and the alternative models for the West fault have only minor effects on the parameters of the East fault, (ii) the West fault, considered as an independent source or as a secondary feature, has a minimal influence on the hazard, and (iii) the East and Springline faults, combined as a single source, produces slightly higher hazard at low probabilities of exceedance and for longer period motions than separating them as individual fault sources. The Geomatrix Consultants, Inc. (1999a) summary of contributions to the uncertainty in the total hazard at the proposed Skull Valley site for a return period of 2,000 years shows that the major contributors to the total uncertainty in the hazard are the selection of attenuation relationships, assessment of maximum magnitude, recurrence rate, and magnitude distribution.

Deterministic Seismic Ground Motion Hazard

Site-specific deterministic ground motion hazard for the Facility was assessed by Geomatrix Consultants, Inc. (1997), in which two potentially capable fault sources were identified to be within 7 miles of the site—the East Cedar Mountain and Stansbury faults. Their closest distances to the site were estimated to be about 6 miles to the Stansbury fault and 5.5 miles to the East Cedar Mountain fault. The potential for a random nearby earthquake was considered by including an areal source within 16 miles of the site. Maximum earthquake magnitudes for the two fault sources were estimated using empirical relationships of Wells and Coppersmith (1994) and Anderson et al. (1996) based on estimated maximum rupture dimensions (rupture length and rupture area). The resulting mean estimates of maximum magnitudes are M 7.0 for the Stansbury fault and M 6.8 for the East Cedar Mountain fault. The maximum magnitude for the areal source was estimated to range from M 5.5 to 6.5, with a mean value of 6, based on the Wells and Coppersmith (1993) study on the relationship between earthquake magnitude and the occurrence of associated surface faulting and the assumption that these random earthquakes do not produce significant surface faulting. A mixture of attenuation relationships for strike-slip faults in California and for extensional stress regimes were used to account for uncertainties. These include Abrahamson and Silva (1997), Campbell (1997), Sadigh et al. (1993, 1997), Idriss (1991), and Spudich et al. (1997). In the Geomatrix DSHA, uncertainties were included for maximum magnitude, minimum source-to-site distance, and the selection of attenuation relationships. The recommended 84th-percentile peak ground accelerations were calculated to be 0.67g in the horizontal direction and 0.69g in the vertical direction. These accelerations envelop the calculated accelerations for a rock site and a deep soil site.

The Geomatrix Consultants, Inc. (1999b) DSHA considers the two new faults (i.e., the East and West faults) near the proposed site and in-depth characterization of other capable faults. The detailed characteristics of the two new faults as well as other fault sources are reviewed in Stamatakos et al. (1999). In its updated DSHA, Geomatrix Consultants, Inc. (1999b) considered four nearby fault sources—the Stansbury, East, West, and East Cedar Mountains faults. The mean maximum magnitudes of these fault sources were estimated to be M 7.0, 6.5, 6.4, and 6.5, respectively, based on distributions for maximum magnitude of each source developed in Geomatrix Consultants, Inc. (1999a). The closest distances to the Canister Transfer Building from the surface traces of these faults were estimated to be 9, 0.9, 2.0, and 9 km, respectively. The ground motion models used in the updated DSHA were the set of 17 horizontal and 7 vertical attenuation relationships used in the PSHA (Geomatrix Consultants, Inc., 1999a). These relationships were reviewed and discussed in Stamatakos et al. (1999). The ground motion attenuation relationships were adjusted for near-source effects using the empirical model developed by Somerville et al. (1997). The updated DSHA results in 2000 showed that the ground motion from the East fault generally envelops those from the other sources. In Revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000), the 84th-percentile peak ground accelerations for the East fault were calculated to be 0.72g in the horizontal direction and 0.80g in the vertical direction. When compared with the PSHA results in Revision 18 of the SAR, the controlling deterministic spectra generally were between the 5,000- and 10,000-year return period equal-hazard response spectra. In revision 22 of the SAR (Private Fuel Storage

Limited Liability Company, 2001), the 84th percentile peak ground accelerations for the East fault were calculated to be 1.15g in the horizontal direction and 1.17g in the vertical direction (Geomatrix Consultants Inc., 2001d). As in revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000), the revised controlling deterministic spectra (Geomatrix Consultants Inc., 2001d) in revision 22 of the SAR generally fall between the 5,000-yr and 10,000-yr return period equal-hazard response spectra.

Design-Basis Ground Motion

The design ground motion response spectra for the proposed Skull Valley site were developed by Geomatrix Consultants, Inc. (2001b) based on its site-specific PSHA results as reviewed in this SER and Stamatakos et al. (1999) and documented in detail in Geomatrix Consultants, Inc. (1999a, 2001a). The Geomatrix Consultants, Inc. development of design spectra is based on the procedures outlined in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997c) and incorporates near-source effects.

The assessment of design ground motions for the Facility is described in Geomatrix Consultants, Inc. (2001b). The design ground motions were determined using the procedure described in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997c). However, prior to implementing the Regulatory Guide 1.165 procedure, the site seismic hazard results were modified to account for the near-source effects of rupture directivity and the polarization of ground motions. Adjustments to the PSHA results that account for these effects were made using empirical models developed by Somerville et al. (1997). Based on its review, the staff determined that the deterministic approach of shifting the seismic hazard results to account for rupture directivity and ground motion directional effects is conservative for the frequencies to which these adjustments were applied. Based on the results of Somerville et al. (1997), adjustments were not made for the peak ground acceleration seismic hazard results or for spectral accelerations greater than 1.0 Hz. There is empirical evidence that suggests peak ground accelerations and high frequency ground motions may also be influenced by rupture directivity and source radiation. In addition, there is limited empirical evidence to verify the Somerville et al. (1997) model and to predict, in an absolute sense, the systematic effect of rupture directivity on strong ground motion. However, as discussed in Stamatakos et al. (1999) and Geomatrix Consultants, Inc. (1999c), the random effects of rupture directivity are accounted for as part of the aleatory variability in ground motion. Therefore, it is an effect that is accounted for in the PSHA. In fact, for frequencies less than 1.0 Hz, these effects are double counted in the Facility estimate of design motions.

The Regulatory Guide 1.165 process for determining design basis ground motion spectra involves computing the contributions to the total hazard at the specified design return period (or reference probability) from events in discrete magnitude and distance bins. In the Geomatrix Consultants, Inc. (1999c) calculation, a magnitude bin size of 0.25 was selected. The distance bin size increases gradually from 3 to 32 miles as the source-to-site distance increases from 0 to 150 km. From these contributions and the average magnitude and distance for each bin, a weighted average magnitude, $\overline{M}$, and log average distance, $\overline{D}$, of the events contributing to the design level hazard were determined for spectral frequency ranges of 5–10 Hz and 1–2.5 Hz. Free-field ground surface response spectral shapes were developed using the 84th-percentile peak acceleration and the 84th-percentile response spectra for each of the $\overline{M}$ and $\overline{D}$ pairs using a weighted combination of the same ground motion attenuation relationships used for the PSHA (Geomatrix Consultants, Inc., 1999a). These response spectral shapes were scaled to the appropriate equal hazard spectra. Design ground motion response spectra were defined to be the envelope of the scaled spectra and equal hazard spectra. This envelope was further scaled by the adjustment factors for near-fault effect as described in Stamatakos et al. (1999). The final response spectra can be found in Geomatrix Consultants, Inc. (2001b). In Revision 18 of the SAR (Private Fuel Storage Limited Liability Company, 2000),these studies resulted in the following design ground motion accelerations: (1) for a 1,000-year return period earthquake, a peak horizontal acceleration of 0.40 g and a peak vertical acceleration of 0.39 g; and (2) for a 2,000-year return period earthquake, a peak horizontal acceleration of 0.53 g and a peak vertical acceleration of 0.53 g for a 2,000-year return period. In Revision 22 of the SAR (Private Fuel Storage Limited Liability Company, 2001), mean peak horizontal and vertical accelerations for the 2000-yr return period were calculated to be 0.711 g and 0.695 g respectively.

The applicant's exemption request specified a 1,000-year return period to calculate design basis ground motions with the PSHA methodology. The applicant (Parkyn, 1999b) stated (i) a 1,000-year return period is the same as that selected by the U.S. Department of Energy (1997) for preclosure seismic design of important to safety structures, systems, and components for NRC Frequency Category 1 design basis events at the proposed Yucca Mountain high-level waste geologic repository, and (ii) the consequences of a major seismic event at the Facility can be bounded using the HI-STORM 100 system technology and are limited to a storage cask-tipover event, which would result in a dose below regulatory limits. A Frequency Category 1 design basis ground motion refers to a mean recurrence interval of 1,000 years and a Frequency Category 2 design basis ground motion refers to a mean recurrence interval of 10,000 years. As discussed below, the staff has determined that a 2000-year return period is the appropriate value for the PFS Facility site.

Staff Review of Ground Vibration and Request for Exemption to 10 CFR 72.102(f)(1)

The staff found the applicant's seismic hazard results to be conservative, based on the review of geological and seismotectonic setting, historical seismicity, potential seismic sources and its characteristics, estimate of ground attenuation, estimates of probabilistic and deterministic ground motion hazards, development of design basis ground motion, and independent staff analyses. The staff also found that in the application:

- Seismic events that could potentially affect the site were identified and the potential effects on safety and design were adequately assessed.

- Records of the occurrence and severity of historical and paleoseismic earthquakes were collected for the region and evaluated for reliability, accuracy, and completeness.

- Appropriate methods were adopted for evaluations of the design basis vibratory ground motion from earthquakes based on site characteristics and current state of knowledge.

- Seismicity was evaluated by techniques of 10 CFR Part 100, Appendix A. Seismic hazard, however, was evaluated using a probabilistic approach as stated in the Request for an Exemption to 10 CFR 72.102(f)(1).

- Liquefaction potential or other soil instability from vibratory ground motions was appropriately evaluated.

- The design earthquake has a value for the horizontal ground motion greater than 0.10g with the appropriate response spectrum.

- The applicant's considerations with respect to the approach taken to model the epistemic uncertainty in ground motions and near-source effects are adequate.

- As discussed in Stamatakos et al. (1999), the applicant adequately applied adjustment factors for the near-fault effect using the state-of-the-art techniques and applied procedures described in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997c) for developing design-basis ground motion. The associated response spectra and design basis motion levels are adequate.

The staff reviewed the applicant's exemption request to use the PSHA methodology with a 1,000-year return period value by evaluating the technical basis of the PSHA methodology and its use in other Title 10 regulations regarding nuclear facilities and materials. Although 10 CFR Part 72 requires a deterministic approach for the seismic design of an ISFSI site west of the Rocky Mountain Front, a probabilistic approach for seismic design is acceptable by the 1997 amendments to 10 CFR Parts 50 and 100 that apply to new nuclear power plants, and 10 CFR Part 60 that applies to the disposal of high-level waste in geologic repositories. Also, the NRC issued Regulatory Guide 1.165 to provide guidance on PSHA methodology (Nuclear Regulatory Commission, 1997c). In addition, NRC has reviewed and approved the Request for Exemption to 10 CFR 72.102(f)(1) seismic design requirements to allow seismic design using PSHA results of 2,000-year return period earthquakes for the Three Mile Island Unit-2 (TMI-2) ISFSI (Nuclear Regulatory Commission, 1998b; Chen and Chowdhury, 1998). DSHA considers only the most significant earthquake sources and events with a fixed site-to-source distance. PSHA, on the other hand, considers contributions from all potential seismic sources and integrates across a range of source-to-site distances and magnitudes. Furthermore, DSHA is a time-independent statement, whereas PSHA estimates the likelihood of earthquake ground motion occurring at the location of interest within the time frame of interest. The staff concludes that there are sufficient regulatory and technical bases to accept the PSHA methodology for seismic design of the Facility.

The design basis ground motion for a particular structure, system, and component depends on the importance of that particular structure, system, and component to safety. As described in the NRC rulemaking plan for 10 CFR Part 72 (Nuclear Regulatory Commission, 1998a), an individual structure, system, and component may be designed to withstand only Frequency Category 1 events (1,000-year return period) if the applicant's analysis provides reasonable assurance that the failure of the structure, system, and component will not cause the Facility to exceed the radiological requirements of 10 CFR 72.104(a). If the applicant's analysis cannot support this conclusion, then the designated structures, systems, and component should have a higher importance to safety, and the structures, systems, and component should be designed such that the Facility can withstand Frequency Category 2 events (10,000-year return period).

The staff reviewed the applicant's request and supporting analysis to use the 1,000-year return period value and does not find this value acceptable because of the following reasons: (i) the DOE classification of Yucca Mountain proposed high-level waste geologic repository structures, systems, and components to design for Frequency Category 1 and Frequency Category 2 events as it applies to the proposed Yucca Mountain repository has not been reviewed or accepted by the NRC staff; (ii) the applicant has provided no technical basis for classifying all the important to safety structures, systems, and components for the Facility as those that could be designed for NRC Frequency Category 1 design basis events; and (iii) the consequence analysis using the HI-STORM 100 systems technologies includes only a single accident scenario (i.e., cask tipover) that is independent of ground motion level. The applicant did not demonstrate that the cask-tipover event envelops other unanalyzed conditions such as the effect of collapse of the Canister Transfer Building on canisters or the effects of sliding and bearing failures of the foundation and concrete pad on storage casks.

However, the staff has determined that a 2,000-year return value with the PSHA methodology can be acceptable for the following reasons:

- The radiological hazard posed by a dry cask storage facility is inherently lower and the Facility is less vulnerable to earthquake-induced accidents than operating commercial nuclear power plants (Hossain et al., 1997). In its Statement of Consideration accompanying the rulemaking for 10 CFR Part 72, the NRC recognized the reduced radiological hazard associated with dry cask storage facilities and stated that the seismic design basis ground motions for these facilities need not be as high as for commercial nuclear power plants (45 FR 74697, 11/12/80; SECY-98-071; SECY-98-126).

- Seismic design for commercial nuclear power plants is based on a determination of the Safe Shutdown Earthquake ground motion. This ground motion is determined with respect to a reference probability level of 10^{-5} (median annual probability of exceedance) as estimated in a probabilistic seismic hazard analysis (Reference Reg Guide 1.165). The reference probability, which is defined in terms of the median probability of exceedance, corresponds to a mean annual probability of exceedance of 10^{-4} (Murphy et al., 1997). That is, the same design ground motion (which has a median reference probability of 10^{-5}) has a mean annual probability of exceedance of 10^{-4} . Further, analyses of nuclear power plants in the western United States show that the estimated average mean annual probability of exceeding the safe shutdown earthquake is 2.0×10^{-4} (U.S. Department of Energy, 1997).

- On the basis of the foregoing, the mean annual probability of exceedance for the PFS Facility may be defined as greater than 10^{-4} per year.

- The DOE standard, DOE-TD-1020-94 (U.S. Department of Energy, 1996), defines four performance categories for structures, systems, and components important to safety. The DOE standard requires that performance Category-3 facilities be designed for the ground motion that has a mean recurrence interval of 2000 yrs (equal to a mean annual probability of exceedance of 5×10^{-4}). Category-3 facilities in the DOE standard have a potential accident consequence similar to a dry spent fuel storage facility.

- The NRC has accepted a design seismic value that envelopes the 2000-yr return period probabilistic ground motion value for the TMI-2 ISFSI license (Nuclear Regulatory Commission, 1998b; Chen and Chowdhury, 1998). The TMI-2 ISFSI was designed to store spent nuclear fuel in dry storage casks similar to the PFS Facility.

In summary, the staff agrees that the use of the PSHA methodology is acceptable. A 2,000-year return period is acceptable for the seismic design of the PFS Facility. As discussed in the subsequent chapters of this SER, the design analyses use a spectrum that envelops the 2,000-year return period uniform hazard spectra.

Additional Information on the East Great Salt Lake Fault

The staff reviewed additional information and analyses provided in Appendix 2G of the SAR (Private Fuel Storage Limited Liability Company, 2000) regarding reported fault characterization data for the East Great Salt Lake fault. Recent high-resolution seismic data collected from the Great Salt Lake and reported in Dinter and Pechmann (1999a,b) indicate a Holocene vertical slip rate for the East Great Salt Lake fault of 1 mm/yr (average recurrence period of 3000–6000 years). The applicant assessed the possibility of the East Great Salt Lake fault being linked with the Oquirrh fault and also with the Topliff-Hill and Mercur faults, which collectively could form a Wasatch-scale fault zone.

The applicant showed in Appendix 2G, that the information about slip in the East Great Salt Lake fault does not significantly change the existing PSHA given in Geomatrix Consultants, Inc. (1999a). The applicant reiterated that the possibility of a linked East Great Salt Lake-Oquirrh fault was already accounted for in the existing PSHA analyses. In the existing PSHA model, the mean slip rate for the East Great Salt Lake fault was 0.38 mm/yr. The data of Dinter and

Pechmann (1999a,b) indicate a higher slip rate of 1 mm/yr. The applicant stated that this increase will have little effect on the PSHA because the East Great Salt Lake and the Oquirrh faults are located too far from the site to generate significant ground motion. The applicant concluded that compared to all seismic sources, the East Great Salt Lake fault contributes only a small fraction to the total hazard, including an assumption of a 1 mm/yr slip rate.

The staff agrees the applicant's analyses are acceptable. The contribution of the East Great Salt Lake fault to the PFS seismic hazard is not significant, including the possible connection with the Oquirrh fault.

Co-Seismic Rupture of Stansbury and East Faults

The staff reviewed information and analyses provided in the SAR (Appendix 2G) regarding possible co-seismic rupture of the Stansbury and East faults or East/West fault and the potential impact of co-seismic rupture on ground motion hazard at the proposed PFS Facility. The staff agrees that co-seismic rupture of the East/West faults with the Stansbury fault is not supported by historic earthquakes, nor is it supported by recent geomorphic or geologic observations. Consequently, co-seismic rupture of these faults during the license period are unlikely. Thus, co-seismic rupture scenario would likely be given a very low weight in fault tree analysis and its contribution to the total hazard would be negligible.

The applicant estimated the potential effect of co-seismic rupture of the Stansbury and East faults on ground motion hazard at the proposed Facility based on scaling factors similar to those proposed for co-seismic rupture at Yucca Mountain, Nevada [developed by the expert elicitation for the Yucca Mountain PSHA (Civilian Radioactive Waste Management System Management and Operating Contractor, 1998)]. In its assessment, the applicant stated that because both Yucca Mountain and the proposed Facility are within the same tectonic setting (extension in the basin and range), the effects of coseismic rupturing on the characteristics of ground motion attenuation is similar. The staff agreed and found using Yucca Mountain scaling factors for the Facility to be acceptable. This finding, however, is specific to the proposed Facility because it is based on specific site conditions and regulatory requirements for the proposed Facility. It is not necessarily applicable to evaluations of co-seismic rupture at other spent nuclear fuel-related facilities.

The effects of simultaneous multiple-fault ruptures on ground motions at Yucca Mountain were estimated as an increase in the median ground motion and an increase in the standard error (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). The increase in the median ground motion is expressed as a multiple of the median. The increase in the standard error is expressed as either a multiple of the standard error or as an additional error incorporated using the square root of the sum of the squares. These scaling and additional factors for peak ground acceleration obtained by seven ground motion teams are summarized in tabular format in Appendix 2G. From this table, PFS computed the geometric means of the scale factors from all seven ground motion teams (Civilian Radioactive Waste Management System Management and Operating Contractor, 1998) for both the median ground motion and standard error and used these mean factors to estimate changes in the contributions of maximum magnitude earthquakes on Stansbury and East faults to the total hazard at the proposed PFS Facility. The calculations show that, without co-seismic rupture, a M 6.5 earthquake on East fault and a M 7.0 earthquake on Stansbury fault (the maximum expected magnitudes on these faults, respectively, Geomatrix Consultants, Inc., 1999a) have probabilities of approximately 0.35 and 0.32, respectively, of producing a peak ground acceleration in excess of 0.53g. The 0.53g is the 2000-year return period peak ground motion (Geometrix Consultants, Inc., 1999a). Considering that events of M 6.5 and larger on each fault have expected frequencies of occurrence of approximately 3×10^{-4} per year (Geomatrix Consultants, Inc., 1999a), these two earthquakes would contribute $0.35 \times (3 \times 10^{-4}) + 0.32 \times (3 \times 10^{-4}) = 2.0 \times 10^{-4}$ events per year to the annual frequency of exceeding 0.53 g. With co-seismic rupture of the East and Stansbury faults (i.e., assuming instead that the maximum earthquakes on the two faults occur as a single M 7.05 co-seismic rupture, M 7.05 was obtained using the combined moment for a M 6.5 and a M 7.0 earthquake), scaling the median ground motion level and the standard error produced by this earthquake by the mean factors results in a probability of approximately 0.62 of exceeding a peak ground acceleration of 0.53 g. Considering the frequency of the combined event remains to be 3×10^{-4}, the event would contribute $0.62 \times (3 \times 10^{-4}) = 1.8 \times 10^{-4}$ event per year to the annual frequency of exceeding 0.53g. This contribution does not exceed the contribution by two independent earthquakes.

The staff concludes that a co-seismic rupture for the Stansbury and the East faults is unlikely and will not impact the existing PSHA results. Therefore, a design earthquake analyses based on the 2000-year return period ground motion is acceptable.

2.1.6.3 Surface Faulting

Geomatrix Consultants, Inc. (1999a) documented several small faults in and around the site. These faults are all considered secondary faults related to deformation of the hanging wall above the larger East and West faults. These faults are too small to be independent seismic sources but large enough to be considered in the fault displacement analysis.

Similar to the seismic hazard evaluation, Geomatrix Consultants, Inc. (1999a) developed a probabilistic fault displacement hazard. The fault displacement hazard analysis was built on two methodologies developed for the Yucca Mountain PSHA (Civilian Radioactive Waste Management System Management and Operating Contractor, 1998). These methodologies, termed the earthquake approach and displacement approach, use Basin and Range empirical relationships with site-specific data to generate fault displacement hazard curves similar to seismic hazard curves.

Probabilistic fault displacement hazard results were calculated for three potential secondary faults that are under or near the site. These faults—informally named the C, D, and F faults—were identified from detailed seismic reflection profiles and confirmed by boreholes. The seismic profiles document offset of the unconformity between Promontory soil, deposited between 130–28 Ka, and Bonneville lacustrian deposits, deposited between 28–12 Ka. Vertical

NUCLEAR REGULATORY COMMISSION

Docket No. 72-22 Official Exh. No. 00

In the matter of PFS

Staff ✓ IDENTIFIED ✓

Applicant RECEIVED ✓

Intervenor REJECTED

Other WITHDRAWN

DATE 6/5/02 Witness ARABASZ

Clerk L. Shinderling