BSC	**Technical Report Administrative Change Notice** *Complete only applicable items.*	9. QA: QA Page 1 of 80

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5. Does this ACN supersede any other ACN? ☒ Yes ☐ No	**If Yes, ACN Number(s):** 01
6. Approvals:	
Originator: Marvin Stine Print name and sign	03/04/09 Date
Checker: Sushil Kothari Print name and sign	03/04/2009 Date
QER: Darrell Svalstad Print name and sign	3/4/09 Date
Lead or Supervisor: Thomas Misiak Print name and sign	03/04/09 Date
Responsible Manager: Raj Rajagopal Print name and sign T. Misiak for R.R.	03/11/09 Date

7. Affected Pages:	**8. Reason for, and Description of Change:**
	The following changes are made (changed wording in **bold** type, see revised pages as attached):
Page vii, List of Figures	Selected Figures are no longer needed as the horizontal and vertical design spectra information is contained in the referenced DTNs. Change the list of Figures to delete Figures 6-1 through 6-7 and Figure F-1.
Page ix, List of Tables	Selected Tables are no longer needed as the horizontal and vertical design spectra digitized information is contained in the referenced DTNs. Change the list of Tables to delete Tables 6-3 through 6-8 and Table F2.
Page xi, Acronyms	Editorial correction, six acronyms are missing from the list. Revise the list of acronyms to include the following acronyms: **A.O.** **Aging Overpack and Aging Cask** **FOSID** **First onset of significant inelastic deformation** **ICC** **International Code Council** **IED** **Information Exchange Document** **SFTM** **Spent Fuel Transfer Machine** **STC** **Shielded Transfer Cask**
Page xii	Editorial correction due to addition of acronyms. Selected abbreviations will move from page xi to page xii. Delete "INTENTIONALLY LEFT BLANK" from page xii.
Page 2, Section 2, 1st paragraph, 4th sentence.	Update reference to latest revision. Change from ". . .in *Supplemental Soils Report* (BSC 2007 [DIRS 182582])." to ". . . in **the** *Supplemental Soils Report* (BSC 2008 [DIRS 185630])." ACN01 comment (modified).

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7. Affected Pages:	**8. Reason for, and Description of Change:**
Page 2, Section 2, 2nd paragraph, 1st and 2nd sentences	Editorial clarification and update reference to latest revision. Change the word "...pre-closure..." to "...preclosure..." in the first sentence and in the second sentence, change from "The preclosure duration design period for subsurface facilities is 100 years (BSC 2007 [DIRS 182131], Section 2.2.2.8)." to "The **duration of the preclosure** period for subsurface facilities is 100 years (BSC 2008 [DIRS 185694], Section 2.2.2.7)." ACN01 comment (modified).
Page 2, Section 2, 5th paragraph, 1st sentence	Correct reference title. Change from "...ICC 2000..." to "...ICC 2003...".
Page 2, Section 2, 6th paragraph, 2nd sentence	Editorial correction. Change "...Section 5.0." to "...Section 5."
Page 7, Section 3.2.2, last sentence	Update reference to latest revision. Change from "...(BSC 2007 [DIRS 182131], Section 8.1)." to "...(BSC 2008 [DIRS 185694], Section 8.1)." ACN01 comment (modified).
Page 8, Section 4.3, 2nd sentence	Correct the reference title and update to latest revision. Change from "...the *Basis of Design for the Canister Based Design Concept* (BOD) (BSC 2007 [DIRS 182131])." to "...the *Basis of Design for the TAD Canister-Based **Repository** Design Concept* (BSC 2008 [DIRS 185694])." ACN01 comment (modified).
Page 11, Section 5.2, 1st paragraph, 1st sentence	Correct the reference title and update to latest revision. Change from "...*Basis of Design for the TAD Canister-Based Repository Design Concept* (BSC 2007 [DIRS 182131])." to "...**the** *Basis of Design for the TAD Canister-Based Repository Design Concept* (BSC 2008 [DIRS 185694])." ACN01 comment (modified).
Page 11, Section 5.2, Table 5-2, footnote a	Correct the reference title and update to latest revision. Change from "Basis of design for the transportation, aging, and disposal canister based repository design concept (BSC 2007 [DIRS 182131])." to "***Basis of Design for the TAD Canister-Based Repository Design Concept*** (BSC 2008 [DIRS 185694])." ACN01 comment (modified).
Page 11, Section 5.2, Table 5-2, footnote b	Correct the footnote to show EDGF is non-ITS, and change reference title and callout. Change from "Preliminary Preclosure Nuclear Safety Design Bases (BSC 2007 [DIRS 184154]) identifies EDGF as an ITS structure but is silent on the seismic requirements. It will be designed for DBGM-2 similar to other ITS structures but not evaluated for BDBGM." to "***Basis of Design for the TAD Canister-Based Repository Design Concept*** (BSC 2008 [DIRS 185694]) **Section 7.1.2 classifies the** EDGF as **a non-ITS** structure. **Conservatively, it** will be designed for DBGM-2 similar **to ITS** structures but not evaluated for BDBGM." ACN01 comment (modified).
Page 12, Section 5.4, 1st paragraph, 1st sentence	Correct reference title. Change from "...ICC 2000..." to "...ICC 2003...".
Page 12, Section 5.4, 1st paragraph, 3rd sentence	Editorial correction. Change the word "...Catagories." to "Categories".
Page 13, NOTE (a) of Table 5-4	Correct reference title. Change from "...ICC 2000..." to "...ICC 2003...".
Page 13, NOTE (b) of Table 5-4	Correct reference title. Change from "...ICC 2000..." to "...ICC 2003..." and delete the last sentence of this note beginning with the word "However...".

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7. Affected Pages:	8. Reason for, and Description of Change:
Page 14, Section 6.1, 1st paragraph, last sentence	Update DTN references. Change from "DTN: MO0706DSDR5E4A.001 [DIRS 181422], and DTN: MO0706DSDR1E4A.001 [DIRS 181421])." to "**DTN: MO0805DSDR1E3A.000 [DIRS 185929]**, DTN: MO08**05**DSDR5E4A.00**0** [DIRS 185**930**], DTN: MO08**05**DSDR1E4A.00**0** [DIRS 185**931**]) **and DTN: MO0805DSRB5E4A.000 [DIRS 185935]**." ACN01 comment (modified).
Page 14, Section 6.1, 2nd paragraph, 2nd sentence	Editorial correction to delete reference to design spectra in Section 6.3 which were deleted. Change "The design spectra. . ." to "The **source documents for** design spectra. . .".
Page 14, Section 6.1, 3rd paragraph, 1st sentence	Correct reference title. Change from ". . .ICC 2000. . ." to ". . .ICC 2003. . ." .
Page 14, Section 6.1, 3rd paragraph, 2nd sentence	Editorial correction. Delete this sentence in its entirety and replace with the following: "The design spectra for **the surface and subsurface** non-ITS SSCs **are** based on the site-specific seismicity considerations and **are** given in Sections **6.4.1 and 6.4.2**."
Page 14, Section 6.1, 4th paragraph (new)	Insert a new paragraph to provide a reference to the Seismic and Seismic Data IED as follows: **Sources for seismic data, ground motion inputs and site response model inputs are summarized in the *IED Seismic and Seismic Consequence Data*, BSC 2009 [DIRS 186141].**
Page 14, Section 6.2.1, 1st paragraph, next to last sentence	Update reference to latest revision. Change from ". . . is presented in *Supplemental Soils Report* (BSC 2007 [DIRS 182582])." to ". . . is presented in **the** *Supplemental Soils Report* (BSC 2008 [DIRS 185**630**])." ACN01 comment (modified).
Page 15, Section 6.2.1, Source note to Table 6-1	Update reference to latest revision. Change from "(BSC 2007 [DIRS 182582]), Tables 2-1 and 2-2." to "(BSC 2008 [DIRS 185**630**]), Tables 2-1 and 2-2." ACN01 comment (modified).
Page 15, Section 6.2.1, Source note to Table 6-2	Update reference to latest revision. Change from "(BSC 2007 [DIRS 182582]), Tables 2-1 and 2-2." to "(BSC 2008 [DIRS 185**630**]), Tables 2-1 and 2-2." ACN01 comment (modified).
Page 15, Section 6.2.1, 4th paragraph, 1st sentence	Update and revise the DTN references to the latest documents. Change ". . .DTN: MO0706SCSPS5E4.002 [DIRS 181616] for 5 × 10^{-4} annual exceedance probability, and in DTN: MO0706SCSPS1E4.002 [DIRS 181618] for 10^{-4} annual exceedance probability." to "MO08**01**SCSPS5E4.00**3** [DIRS 184**682**] for 5 × 10^{-4} annual exceedance probability, and in DTN: MO08**01**SCSPS1E4.00**3** [DIRS 184**683**] for 10^{-4} annual exceedance probability." ACN01 comment (modified).
Page 15, Section 6.2.1, 4th paragraph, last sentence	Update and revise the DTN references to the latest documents. Change ". . .DTNs: MO0706SCSPS5E4.002 [DIRS 181616] and MO0706SCSPS1E4.002 [DIRS 181618]. . ." to ". . .DTNs: MO08**01**SCSPS5E4.003 [DIRS 184**682**] and MO08**01**SCSPS1E4.003 [DIRS 184**683**]. . ." ACN01 comment (modified).
Page 16, Section 6.2.2, 2nd paragraph	Update reference to latest revision. Change from "(BSC 2007 [DIRS 182582])." to "(BSC 2008 [DIRS 185**630**])." ACN01 comment (modified).

Complete only applicable items.

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7. Affected Pages:	8. Reason for, and Description of Change:
Page 16, Section 6.2.3, 1st paragraph, 1st sentence	Update reference to latest revision. Change from "...more *Supplemental Soils Report* (Fig. B6-2) (BSC 2007 [DIRS 182582])." to ""...more **per the** *Supplemental Soils Report* (Fig. B6-2) (BSC 2008 [DIRS 185630])." ACN01 comment (modified).
Page 16, Section 6.3, 1st paragraph, last sentence	Editorial correction. Change the word "FOR" to "**for**".
Page 16, Section 6.3, 2nd paragraph	Update the referenced DTNs by deleting the existing paragraph and inserting a new paragraph as follows: **The design response spectra (DRS) and the compatible time histories for ITS SSCs are available in the DTNs identified below:** • **MO0805DSDR1E3A.000 [DIRS 185929], Seismic Design Spectra for the Surface Facilities Area at 1E-3 APE For Multiple Damping Levels.** • **MO0805DSDR5E4A.000 [DIRS 185930], Seismic Design Spectra for the Surface Facilities Area at 5E-4 APE For Multiple Damping Levels.** • **MO0805DSDR1E4A.000 [DIRS 185931], Seismic Design Spectra for the Surface Facilities Area at 1E-4 APE For Multiple Damping Levels.** • **MO0805DSRB5E4A.000 [DIRS 185935], 5% Damped Seismic Design Spectra for the Repository Block at 5E-4 APE.** • **MO0805TH1E3APE.000 [DIRS 185936], Time Histories for the Surface Facilities Area at 1E-3 APE.** • **MO0805TH5E4APE.000 [DIRS 185953], Time Histories for the Surface Facilities Area at 5E-4 APE.** • **MO0805TH1E4APE.000 [DIRS 185952]. Time Histories for the Surface Facilities Area at 1E-4 APE.**
Page 16, Section 6.3, 3rd paragraph	Reference to initial design is no longer relevant to this document. Delete this paragraph in its entirety.
Pages 16 & 17, Section 6.3.1, 1st paragraph	Editorial correction to delete reference to figures and tables which have been deleted and to update references for design spectra. Delete this paragraph in its entirety and replace with the following: "**The DTNs listed below are the source documents for** the surface DRS **in the** horizontal and vertical directions at multiple damping values for 1,000-year, 2,000-year, and 10,000-year return period earthquakes. Both spectral shapes and digitized spectra are **available in DTNs:** MO0805DSDR1E3A.000 [DIRS 185929], MO0805DSDR5E4A.000 [DIRS 185930], and MO0805DSDR1E4A.000 [DIRS 185931]." Note that Section 6.3.1 has moved from page 16 to page 17 on the attached pages.
Page 17, Section 6.3.2, 1st paragraph	Editorial corrections and update references. Delete this paragraph in its entirety including the cautionary note sentence added by ACN01 to the end of this paragraph, and replace with the following: "**The DTN listed below is the source document** for the subsurface DRS **in the** horizontal and vertical directions at the repository elevation (Point B), with 5% damping value for the 2,000-year return period earthquake. Digitized spectra are provided in DTN: MO0805DSRB5E4A.000 [DIRS 185935])."
Page 17, Section 6.3.2, 2nd paragraph	Reference to initial design is no longer relevant to this document. Delete this paragraph in its entirety.

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7. Affected Pages:	**8. Reason for, and Description of Change:**
Page 17, Section 6.3.3, 1st paragraph	Update references for time histories and editorial corrections. Delete the cautionary note sentence added by ACN01 to the end of this paragraph, and change ". . MO0706TH1E3APE.000 [DIRS 182460], MO0706TH5E4APE.001 [DIRS 181961], and MO0706TH1E4APE.001 [DIRS 181960]" to ". . . MO0**805**TH1E3APE.000 [DIRS 18**5936**], MO0**805**TH5E4APE.00**0** [DIRS 18**5953**]), and MO0**805**TH1E4APE.00**0** [DIRS 18**5952**]."
Page 17, Section 6.3.4, 1st paragraph	Editorial correction, caveat for high period accelerations no longer applicable. Delete the cautionary note sentence added by ACN01 to the end of this paragraph.
Page 17, Section 6.3.5 Pages 18 through 30, Figures and Tables	Editorial corrections. Delete this paragraph in its entirety (added by ACN01, no longer applicable). The Figures and Tables on pages 18 through 30 are being deleted as the information provided is available in the referenced DTNs. This will require one to refer to the source documents to obtain the latest seismic design information. See below for the affected Figures and Tables.
Page 18, Figure 6-1	Delete Figure 6-1 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 19, Table 6-3	Delete Table 6-3 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 20, Figure 6-2	Delete Figure 6-2 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 21, Table 6-4	Delete Table 6-4 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 22, Figure 6-3	Delete Figure 6-3 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 23, Table 6-5	Delete Table 6-5 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 24, Figure 6-4	Delete Figure 6-4 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 25, Table 6-6	Delete Table 6-6 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 26, Figure 6-5	Delete Figure 6-5 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 27, Table 6-7	Delete Table 6-7 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 28, Figure 6-6	Delete Figure 6-6 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 29, Table 6-8	Delete Table 6-8 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 30, Figure 6-7	Delete Figure 6-7 in its entirety. Cautionary note of ACN01 comment no longer applies.
Page 31, Section 6.4, 1st paragraph	Correct reference title. Change from ". . .ICC 2000. . ." to ". . .ICC 2003. . ." .
Page 31, Section 6.4.1, Title	Editorial correction in section title. Change the word "Spectra" to "Spect**rum**".
Page 31, Section 6.4.1, 1st paragraph, 1st sentence	Editorial correction and correct reference title. Change the word "spectra" to "spect**rum**", and change from ". . .ICC 2000. . ." to ". . .ICC 2003. . ." .

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7. Affected Pages:	**8. Reason for, and Description of Change:**
Page 31, Section 6.4.1, 1st paragraph, 1st bulleted item	Editorial correction and revision to clarify the approach to develop the design spectrum. Delete this item in its entirety and replace with the following: • **Determine the short-period and one second period spectral accelerations for a 2,500-year return period for 5% damping by interpolation between 5×10^{-4} and 1×10^{-4} probability earthquakes. These spectral accelerations will correspond to the "maximum considered earthquake" in IBC.**
Page 31, Section 6.4.1, 3rd bulleted item (new)	Addition of new bulleted item to clarify the approach to develop the design spectra. Insert the following item: • **Develop the site-specific design spectrum using the approximate 500-year return period accelerations following the procedure outlined in IBC 2000 (ICC 2003 [DIRS 173525]), Section 1615.1.4.**
Page 31, Section 6.4.1, last paragraph	Reference to initial design is no longer relevant to this document. Delete this paragraph in its entirety.
Page 32, Section 6.4.2, Title	Editorial correction in section title. Change the word "Spectra" to "Spectr**um**".
Page 32, Section 6.4.2, 1st paragraph, 1st sentence	Editorial correction and correct reference title. Change the word "spectra" to "spectr**um**", and change from ". . .ICC 2000. . ." to ". . .ICC 2003. . ." .
Page 32, Section 6.4.2, 1st paragraph, 1st bulleted item	Editorial correction and revision to clarify the approach to develop the design spectra. Delete this item in its entirety and replace with the following item: • **Determine the short-period and one second period spectral accelerations for a 2,500-year return period for 5% damping by interpolation between 5×10^{-4} and 1×10^{-4} probability earthquakes. These spectral accelerations will correspond to the "maximum considered earthquake" in IBC.**
Page 32, Section 6.4.2, 1st paragraph, 3rd bulleted item (new)	Addition of new bulleted item to clarify the approach to develop the design spectra. Insert the following item: • **Develop the site-specific design spectrum using the approximate 500-year return period accelerations following the procedure outlined in IBC 2000 (ICC 2003 [DIRS 173525]), Section 1615.1.4.**
Page 32, Section 6.4.2, last paragraph	Reference to initial design is no longer relevant to this document. Delete this paragraph in its entirety.
Page 33, Figure 6-9, Source note	Editorial correction. Change Source from "BSC 200 [DIRS 184192], Figure 3." to "BSC 2007 [DIRS 184192], Figure 3."
Page 34, Section 7.1.1, 1st paragraph, 4th sentence	Editorial correction to delete comparisons. Change from "The floor accelerations will be used to assess the model and the amplification throughout the structure, and later will be compared with the Tier # 2 results for confirmation of the models." to read "**The floor accelerations will be used to assess the model and the amplification throughout the structure.**"

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Page 35, Section 7.1.3, 1st paragraph, 3rd sentence	Editorial correction. Change the words "...Tier # 1 analyses results will result..." to "...Tier # 1 analyses will result...".
Page 35, Section 7.1.3, 2nd paragraph	Editorial correction to modify wording to reflect the objective of the Tier # 2 analyses. Delete this paragraph in its entirety and replace with the following: **The Tier # 2 analyses are performed to support the detailed design for the construction of the surface nuclear facilities. The design acceptance criteria are given in Section 8.4.**
Pages 35 & 36, Section 7.1.3, 3rd paragraph	Editorial revision to delete reference to OPTCON Program which is not being used. Delete this paragraph in its entirety.
Page 36, Section 7.2.1, 2nd paragraph	Editorial corrections. Add a comma after the words "In both models**,** ..." and add the following at the end of the paragraph "...**(see Section 8.3.1).**
Page 37, Section 7.2.1.2, last paragraph, 2nd sentence	Update the DTN references. Change the DTN references from "...DTN: MO0706SCSPS5E4.002 [DIRS 181616] and in DTN: MO0706SCSPS1E4.002 [DIRS 181618])." to "...DTN: MO**0801**SCSPS5E4.003 [DIRS 18**4682**] and in DTN: MO**0801**SCSPS1E4.003 [DIRS 18**4683**]." ACN01 comment (modified).
Page 37, Section 7.2.2.1, 1st paragraph, 2nd sentence	Editorial correction to clarify that DRS's are available in the referenced DTNs. Change the words "...are given in Section 6..." to "...are **available in the referenced DTNs** in Section 6...".
Page 38, Section 7.2.2.2, 1st sentence	Editorial correction to clarify that DRS's are available in the referenced DTNs. Change the words "...time histories defined in Section 6..." to "...time histories **available in the referenced DTNs** in Section 6...".
Page 38, Section 7.2.2.2, 2nd sentence	Editorial correction to clarify that DRS's are available in the referenced DTNs. Change the words "The DRS provided in Section 6..." to "The DRS **available in the referenced DTNs** in Section 6...".
Page 38, Section 7.2.3,	Editorial correction and update the DTN references. Delete this paragraph in its entirety and replace with the following [ACN01 comment (modified)]: **Poisson's ratio and total density will be obtained from the *Supplemental Soils Report* (BSC 2008 [DIRS 185630]). Dynamic soil properties in terms of shear and compression wave velocities and low-strain shear wave velocity will be as given in DTN: MO0801SCSPS5E4.003 [DIRS 184682] and DTN: MO0801SCSPS1E4.003 [DIRS 184683]. The strain compatible soil properties will be used in the SSI analyses.**
Page 43, Section 7.4, 1st paragraph, 1st bullet	Correct reference title. Change from "...ICC 2000..." to "...ICC 2003..." .
Page 43, Section 7.4.1, 1st paragraph, second sentence	Editorial correction. Change "...codes (ICC 2000[DIRS 173525])." to "...codes **(IBC 2000** (ICC 2003 [DIRS 173525]))."
Page 48, Section 7.7, 2nd paragraph, last line	Update reference. Change "...(BSC 2007 [DIRS 182131], Section 8.1)." to "...BSC 2008 [DIRS 18**5694**], Section 8.1)."

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7. Affected Pages:	8. Reason for, and Description of Change:
Page 49, Section 7.7.1, 1st paragraph, 2nd sentence	Update reference from Figure 6-7 (now deleted) to the applicable DTN. Change "...(see Figure 6-7 for. . ." to "...(see **DTN: MO0805DSRB5E4A.000 [DIRS 185935]** for. . .".
Page 50, Section 8.2, 2nd paragraph, 2nd sentence	Editorial correction. Change "...the these codes..." to "...these codes...".
Page 50, Section 8.2, 2nd paragraph, last reference	Update reference title. Change "IBC 2000 [DIRS 173525]" to "IBC 2000 (**ICC 2003** [DIRS 173525])".
Page 51, Section 8.3.1, 2nd paragraph, 2nd sentence, Notation L, last line	Editorial corrections and correct reference number. Change "...earthquake (where justified, a higher percentage may be used) (IBC 2000 (ICC 2000 [DIRS 173525], Section 1617.5.1))" to "...earthquake (where **necessary**, a higher percentage may be **considered**) (IBC 2000 (ICC 2003 [DIRS 173525], Section 1617.5.1))".
Page 54, Section 9.1, 1st, 2nd, 3rd and 4th paragraphs	Correct reference number (4 places). Change "ICC 2000" to "ICC 2003".
Page 54, Section 9.2, 1st bulleted item	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 54, Section 9.2, 2nd bulleted item, 1st sentence	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 54, Section 9.2, 2nd bulleted item, 2nd paragraph	Editorial correction and correct reference number. Change the words "...calculated (ICC2000 [DIRS 173525], . . ." to "...calculated **per IBC 2000** (ICC 2003 [DIRS 173525], . . .".
Page 55, Section 9.2, 2nd bulleted item, variables S_1 and R	Correct reference number (2 places). Change "ICC 2000" to "ICC 2003".
Page 55, Section 9.2.1, 1st paragraph, 2nd sentence	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 55, Section 9.2.2, 1st sentence	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 55, Section 9.3, 1st paragraph, 2nd sentence	Correct reference number. Change "ICC 2000" to "ICC 2003". Note: this paragraph now moved to page 56 on revised pages.
Page 56, Section 9.3, 1st paragraph, 2nd bulleted item	Correct reference number. Change "ICC 2000" to "ICC 2003".

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Page 56, Section 9.4.1, 1st sentence	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 56, Section 9.4.2, 1st paragraph, 1st sentence	Correct reference number and section reference. Change "ICC 2000 [DIRS 173525], Sections 1622 and 1517.4)." to "ICC 2003 [DIRS 173525], Section 1622)."
Page 57, Section 9.4.3, 4th bulleted item	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 58, Section 10.2, 5th referenced code	Correct reference number. Change "IBC 2000 (ICC 2000 [DIRS 182945])" to "IBC 2000 (ICC 2003 [DIRS **173525**])."
Page 58, Section 10.3.1, 1st paragraph, 2nd sentence under Notation L	Editorial corrections and correct reference number. Change ". . .earthquake (where necessary, a higher percentage may need to be considered) (IBC 2000 [DIRS 173525], Section 1617.5.1))" to ". . .earthquake (where necessary, a higher percentage **may be considered**) (IBC 2000 **(ICC 2003** [DIRS 173525], Section 1617.5.1))".
Page 59, Section 10.3.2, 3rd paragraph.	Editorial correction. Change the words ". . .10-4 are to used in. . ." to ". . .10-4 are used in. . .".
Page 59, Section 10.4, 1st paragraph, 2nd sentence	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 61, Section 11.2, 2nd paragraph, 1st sentence	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 61, Section 11.2, 3rd paragraph, 2nd sentence	Correct reference number. Change "ICC 2000" to "ICC 2003".
Page 63, Section 12, 1st bulleted item.	Editorial revision to delete reference to GT-STRUDL Program which is not being used. Delete this bulleted item in its entirety.
Pages 63 & 64, Section 12, 4th bulleted item.	Editorial revision to delete reference to OPTCON Program which is not being used. Delete this bulleted item in its entirety.
Page 64	Due to the above deleted item, this page is now blank. Insert the words "INTENTIONALLY LEFT BLANK" in the center of this page.
Page 65, Section 13.1, 2nd Reference	Editorial correction for [DIRS 179641] and delete ACC number for the CBCN. Change "BSC 2007" to BSC **(Bechtel SAIC Company**) 2007", and delete ". . .ENG.20071108.0001".
Page 65, Section 13.1, 3rd Reference	Update reference. Delete the 3rd reference [DIRS 182131] in its entirety and replace with the following [ACN01 comment (modified)]: **185694** **BSC (Bechtel SAIC Company) 2008.** ***Basis of Design for the TAD Canister-Based Repository Design Concept,*** **000-3DR-MGR0-00300-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20081006.0001.**

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7. Affected Pages:	8. Reason for, and Description of Change:
Page 65, Section 13.1, 4th and 6th References	These two references [DIRS 177170 and 178243] are no longer used. Delete these references in their entirety.
Page 65, Section 13.1, 5th and 7th References	Editorial correction to two references [DIRS 184022 and 184192]. Change "BSC 2007" to "BSC **(Bechtel SAIC Company)** 2007".
Page 65, Section 13.1, 8th Reference	This reference [DIRS 184154] is no longer used. Delete this reference in its entirety. ACN01 comment (modified).
Page 65, Section 13.1, 9th Reference	Update reference. Delete the 9th reference [DIRS 182582] in its entirety and replace with the following [ACN01 comment (modified): **185630 BSC (Bechtel SAIC Company) 2008.** ***Supplemental Soils Report.*** **100-S0C-CY00-00100-000-00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080828.0016.**
Page 67, Section 13.1, last (new) Reference	Add reference. Add the following new reference at the end of Section 13.1: **186141 BSC (Bechtel SAIC Company) 2009.** ***IED Seismic and Seismic Consequence Data.*** **800-IED-MGR0-00701-000-00D. Las Vegas, Nevada: Bechtel SAIC Company.**
Page 69, Section 13.3, 1st Reference	Update reference. Delete the 1st reference [DIRS 181618] in its entirety and replace with the following [ACN01 comment (modified)]: **184683 MO0801SCSPS1E4.003. Strain Compatible Material Properties for the Surface Facilities Area at 1E-4 Annual Probability of Exceedance. Submittal Date: 01/11/2008.**
Page 69, Section 13.3, 2nd Reference	Update reference. Delete the 2nd reference [DIRS 181616] in its entirety and replace with the following [ACN01 comment (modified)]: **184682 MO0801SCSPS5E4.003. Strain Compatible Material Properties for the Surface Facilities Area at 5E-4 Annual Probability of Exceedance. Submittal Date: 01/11/2008.**
Page 69, Section 13.3, 3rd through 6th References	These four references [DIRS 170683, 172425, 172426 and 172427] are no longer used. Delete these references in their entirety.
Page 69, Section 13.3, 7th Reference	Update references. Delete the 7th reference [DIRS 181423] in its entirety and replace with the following: **185929 MO0805DSDR1E3A.000. Seismic Design Spectra for the Surface Facilities Area at 1E-3 APE For Multiple Damping Levels. Submittal date: 05/16/2008.**
Page 70, Section 13.3, 8th through 14th references	Update a total of 7 references. Delete the 8th through 14th references for this Section {DIRS 181422, 181421, 182460, 181961, 181960, 182465 [ACN01 comment (modified)], and 183130} and replace with the following: **185930 MO0805DSDR5E4A.000. Seismic Design Spectra for the Surface Facilities Area at 5E-4 APE For Multiple Damping Levels. Submittal date: 07/01/2008.** **185931 MO0805DSDR1E4A.000. Seismic Design Spectra for the Surface Facilities Area at 1E-4 APE For Multiple Damping Levels. Submittal date: 07/01/2008.**

1. Document Number: 000-30R-MGR0-02000-000	2. Revision: 001	3. ACN Number: 02
4. Title: Seismic Analysis and Design Approach Document		

7. Affected Pages:	8. Reason for, and Description of Change:
	185936 MO0805TH1E3APE.000. Time Histories for the Surface Facilities Area at 1E-3 APE. Submittal date: 05/06/2008.
	185953 MO0805TH5E4APE.000. Time Histories for the Surface Facilities Area at 5E-4 APE. Submittal date: 06/30/2008.
	185952 MO0805TH1E4APE.000. Time Histories for the Surface Facilities Area at 1E-4 APE. Submittal date: 07/01/2008.
	186003 MO0901HCUHSSFA.002. Mean Ground Motion Hazard Curves and Mean Uniform Hazard Spectra for the Surface Facilities Area. Submittal date: 01/14/2009.
	185935 MO0805DSRB5E4A.000. 5%-Damped Seismic Design Spectra for the Repository Block at 5E-4 APE. Submittal date: 07/02/2008.
Page 70, Section 13.4, 1st & 2nd references	The two software programs, GT-STRUDL (166081) and OPTCON (178237) are not being used on the project. Delete these references in their entirety.
Page 75, Appendix B, 1st paragraph, 2nd sentence, item 2)	Editorial correction. Change the words "...the structuresfor a..." to "the structures for a ...".
Page 78, Section B3, 1st paragraph, 2nd sentence.	Editorial correction, outdated information. Delete the sentence starting with "This information..." in its entirety.
Page 81, Section B.3.2, 4th line	Editorial correction. Change "BDBGM = Spectral acceleration at 5 Hz for the beyond design basis ground motion for which the structure has been evaluated." to "BDBGM = **B**eyond design basis ground motion parameter for which the structure has been evaluated." [ACN01 comment (modified)].
Page 82, Section B3.4, 1st paragraph, 2nd sentence	Editorial correction. Change the words "...Section 4.4.4 0f DOE..." to "...Section 4.4.4 **of** DOE...".
Page 84, Section B.4.2, Step 8, last sentence	Editorial correction. Change the word "...should..." to "...**could**..." in the last line of this sentence.
Page 84, Section B.4.2, last paragraph	Clarification on method for fragility calculations. After the last paragraph in this Section, add the following Note [ACN01 comment]:
	NOTE: **In the above steps, instead of BDBGM, the DBGM-2, or any other level of ground motion for which the structures are analyzed, may be used.**
Page 86:	The following two changes are made to page 86 to address <u>CR 13226</u>:
Page 86, Section B.4.3, Step 3, 2nd paragraph	Revised paragraph to clarify the use of a 10% increase in minimum specified concrete strength for preliminary fragility calculations. Delete this paragraph in its entirety and replace with the following:
	Capacities for structures and components should be defined at about 98% exceedance probability. In the capacity calculations for concrete, **use of** the minimum specified concrete design strength and appropriate capacity reduction factor approximates the 98% probability of exceedance of shear wall or slab capacity. **If actual concrete compressive strength data are available, use of the 95%**

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	exceedance probability material strength in combination with the code capacity equations, including the appropriate capacity reduction factors, will also achieve an overall shear wall or slab capacity at about the 98% exceedance probability. Concrete compressive strength increases are likely to range from 10% to 45% over the minimum specified 28-day strength (EPRI 1991 [DIRS 161330], p. 2-52). Therefore, for preliminary fragility calculations, it is reasonable to use a 10% increase in the minimum specified concrete design strength to estimate the 95% exceedance probability material strength. During construction or prior to operations, the project will verify the actual 95% exceedance probability of concrete material strength. Future project concrete specifications will include a requirement that cylinders shall be tested at 28 days and additional cylinders shall be tested at 90 days and one year to verify the actual strength.
Page 86, Section B.4.3, Step 3, 4th paragraph	Editorial correction and revision to be consistent with the above change. Change the word "evaluation" to '**calculation**" in the first sentence, and delete the 2nd and 3rd sentences. Note: this paragraph now moved to page 87 on revised pages.
Page 87, Step 4, 1st paragraph, 1st sentence	Editorial correction. Change the words "...factor i.e. a..." to "...factor**,** **i.e.,** a...".
Page 88, Step 7, 1st paragraph, 1st sentence	Editorial correction. Change the word "...mediun..." to "...median..." NOTE: This section now moved to page 89.
Page 89, Section B4.3, Step 8, last paragraph	Editorial correction. Change the words "...Equation 3-18 for..." to "...Equation **B**-18 for...".
Page 95, Step 6, 3rd paragraph, 1st sentence	Editorial correction. Change the words "Item a is..." to "...Item **"a"** is...".
Page 97, Section B4.5, 1st and 2nd paragraphs	Editorial correction, combination of two paragraphs and update to reference. Delete 1st and 2nd paragraphs and replace with the following new (combined) paragraph [ACN01 comment (modified)]: **In Sections B4.3 and B4.4 of this Appendix, the reference limit states used were Limit State A (large permanent distortion, no confinement) and Limit State C (limited permanent distortion, HVAC-controlled confinement). The energy dissipation factors given in those sections are consistent with the limit states. In some cases Limit State D (elastic response, no damage) may need to be specified, with an energy dissipation factor, $F_\mu = 1.0$. For this limit state, the *Basis of Design for the TAD Canister-Based Repository Design Concept,* (BSC 2008 [DIRS 185694]) specifies the following requirements:**
Page 106, Section C3, 1st bulleted item under the additional caveats, 1st sentence	Update DTN References to current revisions. Change "DTN: MO0706SCSPS5E4.002 [DIRS 181616]." to **"**MO0**801**SCSPS5E4.00**3** [DIRS 18**4682**]." ACN01 comment (modified).
Page 106, Section C3, 1st bulleted item under the additional caveats, last sentence	Update and correct Reference. Change the words "...in the geotechnical report (BSC 2007 [DIRS 182582] for..." to "...in the ***Supplemental Soils Report*** (BSC 200**8** [DIRS 18**5630**] for..." ACN01 comment (modified).
Page 137, Section F2, 1st paragraph, 4th bulleted item	Editorial correction. Add a close parentheses after the word "...Horizontal)".

Complete only applicable items.

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7. Affected Pages:	8. Reason for, and Description of Change:
Page 137, Section F2, last paragraph	Editorial corrections and update to References. Delete this paragraph in its entirety and replace with the following revised paragraph [ACN01 comment (modified)]: **The horizontal and vertical response spectra for the extreme seismic event (APE 2E-6) are available in MO0901HCUHSSFA.002 [DIRS 186003]). The corresponding digitized response spectra for the extreme seismic event (APE 2E-6) are also available in MO0901HCUHSSFA.002 [DIRS 186003]). Table F1 lists the seismic requirements for selected mechanical equipment.**
Page 138, Figure F-1	Figure no longer needed, use referenced DTN as noted above. Delete Figure F-1 in its entirety. ACN01 comment (modified).
Page 140, Table F2	Table no longer needed, use referenced DTN as noted above. Delete Table F2 in its entirety. ACN01 comment (modified).

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ACRONYMS AND ABBREVIATIONS

Acronyms

ACI	American Concrete Institute
AISC	American Institute of Steel construction
ANSI	American National Standards Institute
A.O.	Aging Overpack and Aging Cask
ASCE	American Society of civil Engineers
BDBGM	Beyond Design Basis Ground Motion
BSC	Bechtel SAIC Company
CDFM	Conservative Deterministic Failure Margin
DBGM	Design Basis Ground Motion
D/C	Demand/Capacity (Ratio)
DIRS	Document Input Reference System
DOE	U.S. Department of Energy
DRS	Design Response Spectra
FOSID	First onset of significant inelastic deformation
HCLPF	High Confidence Of Low Probability of Failure
HVAC	Heating, Ventilation, and Air Conditioning
IBC 2000	*International Building Code 2000*
ICC	International Code Council
IED	Information Exchange Document
ISRS	In-Structure Response Spectra
ITS	Important To Safety
PDC	*Project Design Criteria Document*
PGA	Peak Ground Acceleration
RSA	Response Spectrum Analysis
SASSI	System for Analysis of Soil-Structure Interaction
SADA	Seismic Analysis and Design Approach
SEI	Structural Engineering Institute
SFTM	Spent Fuel Transfer Machine
SRSS	Square Root of the Sum of the Squares
SSCs	Structures, Systems, and Components
SSI	Soil-Structure Interaction
STC	Shielded Transfer Cask
YMP	Yucca Mountain Project

Abbreviations

C_c	Computed capacity
D/C	Demand/Capacity ratio
D/E	Point D and Point E on Figure 3-3
ft	foot/feet
kcf	Kips per cubic foot
kip	Kilo (one-thousand) pounds
ksf	Kips per square foot

ksi	Kips per square inch
m	meter
mi	mile
pcf	pounds per cubic foot

2. SCOPE

This document provides guidance for seismic analyses and design using the input data provided in the cited references. The guidelines provided herein are to be used for the preclosure seismic analysis and design of YMP SSCs. Studies regarding site geotechnical conditions and seismicity, and seismic design input based on those studies, have been completed by others. The geotechnical input is given in the *Supplemental Soils Report* (BSC 2008 [DIRS 185630]). The seismic design input is provided in the PDC (BSC 2007 [DIRS 179641], Section 6.1.10) and includes design spectra at both surface and subsurface levels for 1,000-year, 2,000-year, and 10,000-year return period earthquakes. Corresponding time-histories have also been developed.

Surface facilities for the repository shall be designed for a preclosure duration period of 50 years. The duration of the preclosure period for subsurface facilities is 100 years (BSC 2008 [DIRS 185694], Section 2.2.2.7).

The analysis guidelines include static as well as dynamic analyses. The static analysis procedures cover computation of seismic loads using static force methods. The dynamic analysis procedures cover soil-structure interaction modeling and analysis, and generation of seismic loads and in-structure response spectra (ISRS) for qualification of important to safety (ITS) SSCs.

The guidelines discuss a combination of seismic loads with other loads to be used for structural design, proportioning, and detailing of the structure to ensure ductile behavior, evaluation of foundation stability against sliding and overturning, story drift, building separation, and anchorage. Design and evaluation of slabs and other structural elements for heavy load drop effects, and tornado missile impact effects, are beyond the scope of this document.

These guidelines meet the seismic design requirements of NUREG-0800 (NRC 1987 [DIRS 138431]) for ITS SSCs and of *International Building Code 2000* (IBC 2000) (ICC 2003 [DIRS 173525]) for non-ITS SSCs. In addition, these guidelines also meet the U.S. Department of Energy (DOE) requirements of DOE-STD-1020-02 [DIRS 159258], which addresses the facility safety provisions of DOE O 420.1A [DIRS 159450].

The analysis methodology provides guidance on design of YMP facilities for vibrational ground motion and does not address approaches used for fault displacement from seismic events. Fault displacement hazards are addressed in DOE 2007, YMP/TR-003-NP, REV 5 [DIRS 181572] Section 5.

3.2.2 Subsurface Facility

The subsurface facility provides space for the emplacement, post-emplacement, and subsurface development activities. The subsurface facility includes the portals, ramps, access mains and rails, turnouts, emplacement drifts (including ground support, invert structures and ballast, waste package emplacement pallet, drip shield, and, if used, backfill), ventilation mains, shafts, shaft access drifts, alcoves, and performance confirmation areas. The facility includes the surface structures at the shafts, and closure seals and plugs. The facility isolates radioactive material from the environment and monitors the underground area (BSC 2008 [DIRS 185694], Section 8.1).

4. ASSUMPTIONS, DIRECT INPUTS, QUALITY ASSURANCE, SOFTWARE USAGE, AND PEER REVIEW

4.1 ASSUMPTIONS

This document presents methods to be used for the preclosure seismic analysis and design of SSCs at YMP. No analyses are performed in this report. As such, there are no assumptions or limitations to the methodologies hereinafter.

4.2 DIRECT INPUTS

4.2.1 Design Response Spectrum for Conventional Surface Facilities, Utilizing Updated Soils Data, Figure 6-8. BSC 2007 [DIRS 184022], Figure 3

4.2.2 Design Response Spectrum for Conventional Subsurface Facilities, Utilizing Updated Soils Data, Figure 6-9. BSC 2007 [DIRS 184192], Figure 3

4.3 QUALITY ASSURANCE

This report was prepared in accordance with PA-PRO-0313, *Technical Reports*. The methodology described in this report will be used for the design of facilities classified as ITS in the *Basis of Design for the TAD Canister-Based Repository Design Concept* (BSC 2008 [DIRS 185694]). The approved version is designated as QA:QA.

4.4 SOFTWARE USAGE

Excel® 2000 and Word® 2000, which are part of the Microsoft® Office® suite of programs were used in this report. Office® 2000, as used in this report, is classified as Level 2 software usage as defined in IT-PRO-0011, *Software Management*. Office® 2000 is listed on software report SW Tracking Number 607273, and in *Repository Project Management Automation Plan* (ORD 2007 [DIRS 182418]).

The software was executed on a personal computer system running Microsoft® Windows® 2000 operating system. The results can be confirmed by visual inspection and by performing hand calculations.

4.5 PEER REVIEW

An independent peer review panel (PA-PRO-0201, *Peer Review*) should review seismic analysis and design of SSCs designed for Design Basis Ground Motion–2 (DBGM-2). As a minimum, the review should include the following:

- Conformance to the Project Design Criteria
- Conformance to the Seismic Analysis and Design Approach (this document)
- Analysis and design philosophy
- Lateral force resisting systems
- Lateral load path

Table 5-1. Seismic Design Bases for ITS SSCs

SSCs	Seismic Event	Earthquake Annual Exceedance Probability	Earthquake Return Period	Design Consideration
Designed to meet event sequences of Category 1[a]	DBGM-1	10^{-3}	1,000 years	SSCs are qualified to design codes and standards for 1,000-year return period earthquake loads.
Designed to meet event sequences of Category 2[a]	DBGM -2	5×10^{-4}	2,000 years	SSCs are designed to codes and standards for 2,000-year return period earthquake loads.
	BDBGM	10^{-4}	10,000 years	Structures are qualified to remain within acceptable inelastic limits under the 10,000-year return period earthquake.

[a] See 10 CFR 63.2 [DIRS 176544] for a definition of event sequences, and corresponding criteria.

5.2 ITS SSCs

The seismic design basis for ITS SSCs shall be in accordance with the *Basis of Design for the TAD Canister-Based Repository Design Concept* (BSC 2008 [DIRS 185694]). Structures listed in Table 5-2 are important to safety (ITS) and are designed to meet Category 1 and Category 2 event sequences. Table 5-2 also identifies their seismic design and evaluation bases. The structures will be designed to meet the requirements of NUREG-0800 (NRC 1987 [DIRS 138431]) and appropriate design codes.

Table 5-2. Seismic Design Basis of ITS Structures

Location	SSCs	Seismic Basis[a] for Analysis/Design	Seismic Basis[a] for Evaluation
Surface	Aging Pads	DBGM-2	BDBGM
	Canister Receipt and Closure Facility	DBGM-2	BDBGM
	Emergency Diesel Generator Facility	DBGM-2[b]	N/A[b]
	Initial Handling Facility	DBGM-2	BDBGM
	Receipt Facility	DBGM-2	BDBGM
	Wet Handling Facility	DBGM-2	BDBGM

[a] *Basis of Design for the TAD Canister-Based Repository Design Concept* (BSC 2008 [DIRS 185694).

[b] *Basis of Design for the TAD Canister-Based Repository Design Concept* (BSC 2008 [DIRS 185694]) Section 7.1.2 classifies the EDGF as a non-ITS structure. Conservatively, it will be designed for DBGM-2 similar to ITS structures but not evaluated for BDBGM.

Overall Design Approach for ITS Structures

There are three considerations in the design of the ITS structures consistent with DOE 2007 [DIRS 181572] Sections 3 and 4. These are described below in the sequence to be followed in the design process:

1. Design the ITS structure for the seismic design basis indicated in Table 5-2. The design must be in conformance to project design criteria and the applicable codes.

2. For structures designed to DBGM-2, demonstrate that the HCLPF capacity is greater than the demand corresponding to BDBGM.

3. For structures designed to DBGM-2, develop a fragility curve. This fragility curve will be convolved with the seismic hazard curve to estimate the performance factor (probability of unacceptable behavior of the structure) which should be equal to 2xE-6 or less.

The design, calculation of the HCLPF value and the fragility curve will be performed by the CSA group. The convolution will be carried out by others.

5.3 SEISMIC INTERACTION OF NON-ITS SSCs WITH ITS SSCs

Some of the non-ITS SSCs, if they fail during a seismic event, may affect ITS SSCs. The non-ITS category SSCs in this group are classified as non-safety impacting safety (generally referred to as 2/1 consideration in the nuclear power industry) and are addressed in Section 11.3.

5.4 NON-ITS SSCs

Non-ITS structures will be designed in accordance with IBC 2000 (ICC 2003 [DIRS 173525]). Table 5-3 defines the various non-ITS SSC's and lists their seismic use groups (SUG) and importance factors (I). Table 5-4 lists the various surface and sub-surface non-ITS SSC's along with their SUG's and Seismic Design Categories. The design spectra for non-ITS SSC's are provided in Section 6.4.

Table 5-3. Seismic Use Group and Importance Factors of SSCs Designed to IBC 2000

Seismic Use Group	Importance Factor, I	SSCs (Non-ITS) Designed to IBC
I	1.0	Non-ITS SSCs for standard occupancy
II	1.25	SSCs that represent substantial hazard to human life (Example: Heavy Equipment Maintenance facility)
III	1.5	SSCs that are essential and hazardous (containing toxic and hazardous materials)

Table 5-4. Classifications of Non-ITS SSCs Designed to IBC 2000

Location	SSCs	Seismic Use Group	Seismic Design Category (a)
Surface	Administration Facility including the EOC	IBC SUG III	D
	Central Control Facility	IBC SUG III	D
	Low level Waste Facility	IBC SUG III	D
	Switchgear Building	IBC SUG III	D
	Waste Package and Non-nuclear Receipt Facility	IBC SUG III	D
	Heavy equipment Maintenance Facility/Warehouse	IBC SUG II	D
	Change House	IBC SUG I	D
	Remaining Balance of Plant Facilities	IBC SUG I	D
	Switchyard	IBC SUG I	D
	Utility Building	IBC SUG I	D
	Warehouse and Non-nuclear Receipt Facility	IBC SUG I	D
Subsurface (b)	Concrete Inverts in Main Drifts	IBC SUG I	C
	Steel Bulkheads	IBC SUG I	C
	Transfer Dock	IBC SUG I	C
	Shaft Collars	IBC SUG I	C
	Muck Handling Facilities	IBC SUG I	C
	Steel Platforms	IBC SUG I	C
	Portal Structures	IBC SUG I	C
	Steel Inverts in Emplacement Drifts	IBC SUG I	C
	Miscellaneous Structures	IBC SUG I	C

NOTES: (a) Seismic Design Categories C and D refer to IBC 2000 (ICC 2003 [DIRS 173525]) Section 1616.3 definitions.

(b) Subsurface facilities will be designed in accordance with IBC 2000 (ICC 2003 [DIRS 173525]) as Seismic Design Category C and with the importance factor of 1.0.

IBC = International Building Code; SUG = Seismic Use Group; EOC = Emergency Operations Center.

6. DESIGN MOTION

6.1 GENERAL

Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada (CRWMS M&O 1998 [DIRS 103731]) is a comprehensive report that was produced as a result of collaboration and review by a multitude of experts. The report provides a probabilistic seismic motion at a hypothetical rock outcrop at the YMP site for various return periods. This report was reviewed and concurred with by a peer review group consisting of experts in the areas of seismology and seismic design. Figure 3-3 shows the relations among the hypothetical point rock outcrop (Point A) and locations of the surface facilities (Points D and E) as well as the location of the repository drifts (Point B). Using the hypothetical rock outcrop motion, the motions at the ground surface level (Points D and E) for surface facilities and at a subsurface depth of 300 m below the surface (Point B) were developed for various return periods using the site-specific soils data (DTN: MO0805DSDR1E3A.000 [DIRS 185929], DTN: MO0805DSDR5E4A.000 [DIRS 185930], DTN: MO0805DSDR1E4A.000 [DIRS 185931], and DTN: MO0805DSRB5E4A.000 [DIRS 185935]).

Site-specific design spectra were developed by others for the ITS SSCs. In addition, compatible time histories were developed. The source documents for the design spectra for DBGM-1, DBGM-2, and BDBGM seismic categories, and their compatible time histories, are given in Section 6.3.

Non-ITS SSCs will be designed in accordance with IBC 2000 (ICC 2003 [DIRS 173525]). The design spectra for the surface and subsurface non-ITS SSCs are based on the site-specific seismicity considerations and are given in Sections 6.4.1 and 6.4.2.

Sources for seismic data, ground motion inputs and site response model inputs are summarized in the *IED Seismic and Seismic Consequence Data* (BSC 2009 [DIRS 186141]).

6.2 GEOTECHNICAL PARAMETERS

6.2.1 Static and Dynamic Soil properties

The soil bearing strata at the site consist of an alluvium layer with a varying thickness of a few feet to over 100 ft, depending on the location of the structures on North Portal Pad. The alluvium is underlain by a layer of tuff that extends to depths in excess of 1,000 ft. Both layers provide a very competent bearing stratum with adequate bearing capacity and very small compressibility. The soil properties at the site were developed based on the results of field and laboratory investigation, including the results from various field geophysical testing. Geotechnical testing was also used to develop the foundation design parameters. A summary of the geotechnical investigation is presented in the *Supplemental Soils Report* (BSC 2008 [DIRS 185630]). According to Section 6.1.4.4 of that report, the water table is below the emplacement drift levels, and thus needs not be considered in design.

Table 6-1 lists the estimated range of soil static and dynamic properties to be used in static analysis for preliminary design purposes for both long- and short-term loads. Table 6-2 lists the friction coefficient and the active, at-rest, and passive pressure coefficients (dynamic incremental pressures are addressed in Section 6.2.2).

Table 6-1. Static and Dynamic Soil Parameters

Material	Case	Elastic Modulus E (ksi)	Coefficient of Subgrade Reaction (kcf)
Alluvium	Static	30 to 75	155 to 520
	Dynamic[a]	100 to 500	310 to 1,040
Engineered Fill	Static	14 to 28	75 to 250
	Dynamic[a]	30 to 170	150 to 500

Source: *Supplemental Soils Report* (BSC 2008 [DIRS 185630]), Tables 2-1 and 2-2.

[a] Short term or low strain values

Table 6-2. Friction and Lateral Soil Pressure Coefficients

Material	Moist Density (pcf)	Friction Angle (Φ) (degrees)	Friction Coefficient $\delta = \tan \Phi$.	Cohesion c	Soil Pressures Active Pressure K_a	At-Rest Pressure K_o	Passive Pressure K_p
Alluvium	114 to 117	39	0.81	0	0.23	0.37	4.4
Engineered Fill	127	42	0.90	0	0.20	0.33	5.0

Source: *Supplemental Soils Report* (BSC 2008 [DIRS 185630]), Tables 2-1 and 2-2.

For static structural analysis and basemat design, the soil properties are typically characterized by "soil springs" that are determined based on: foundation size and depth, soil properties and layering geometry, and loading conditions with and without temporary loading such as earthquake loading. Therefore, equivalent soil springs used in design shall be determined based on the specific foundation geometry and design loading for the structures(s) of concern (see Appendix C for further discussion on this subject).

The dynamic soil properties for soil structure interaction (SSI) analyses are provided in DTN: MO0801SCSPS5E4.003 [DIRS 184682] for 5×10^{-4} annual exceedance probability, and in DTN: MO0801SCSPS1E4.003 [DIRS 184683] for 10^{-4} annual exceedance probability. These properties include the effect of soil nonlinearity by developing the strain-compatible soil properties obtained from free-field analysis using the design motions. In addition, the strain-compatible damping values (DTNs: MO0801SCSPS5E4.003 [DIRS 184682] and MO0801SCSPS1E4.003 [DIRS 184683] were developed for use in a system for analysis of soil-structure interaction (SASSI). (See also Appendix C.)

6.2.2 Lateral Dynamic Soil Pressures

When an SSI analysis is performed, the dynamic lateral soil pressures will be calculated in the SSI analysis and will be applied as a static load in the stress analysis of the structure. Dynamic soil pressure will include the effect of structure-to-structure interaction, if warranted.

When SSI analysis is not performed, lateral dynamic soil pressures will be calculated following the procedure given in Section 3.5.3 of the American Society of Civil Engineers (ASCE) code ASCE 4-98 [DIRS 159618], together with the recommendation of the *Supplemental Soils Report* (BSC 2008 [DIRS 185630]).

6.2.3 Foundation Settlement and Bearing Capacity

Due to the relatively dense granular nature of the alluvium at the site, the bearing capacity, particularly for the large foundation mats, is 50 ksf or more per the *Supplemental Soils Report* (Figure B6-2) (BSC 2008 [DIRS 185630]). This bearing capacity exceeds the anticipated foundation pressure imposed from the structures. Thus, the permissible foundation pressure is controlled by the amount of foundation settlement for which the mat and the structure can be reasonably designed. Since nearly all of the settlement is immediate elastic settlement, using soil springs at the base of the mat best represents the effect of foundation settlement on the mat and structure.

As discussed in Section 6.2.1, the soil springs attached to the base of the mat shall be determined based on the specific foundation geometry and design loading for the structure(s) of concern and will be used in conjunction with the detail stress analysis model of the structures to design the structural members. Foundation springs will be determined for both long-term (i.e., gravity) and short-term (i.e. seismic) loads as discussed in Appendix C.

6.3 DESIGN BASIS GROUND MOTION (DBGM) FOR ITS STRUCTURES

The surface facilities of the YMP are located on the North Portal site. To meet the performance objectives of 10 CFR Part 63 [DIRS 176544], surface facilities that are ITS must be designed for site-specific seismic ground motions. The facility location is schematically identified by Point D on Figure 3-3. As stated in Section 6.1, the seismic motions at Point A, which is a hypothetical rock outcrop, have been defined by a panel of seismic experts. The seismic design inputs at Point D are derived from seismic motions at Point A. Similarly, the input motion for subsurface SSCs is calculated for Point B.

The design response spectra (DRS) and the compatible time histories for ITS SSCs are available in the DTNs identified below:

- MO0805DSDR1E3A.000 [DIRS 185929], Seismic Design Spectra for the Surface Facilities Area at 1E-3 APE For Multiple Damping Levels.
- MO0805DSDR5E4A.000 [DIRS 185930], Seismic Design Spectra for the Surface Facilities Area at 5E-4 APE For Multiple Damping Levels.
- MO0805DSDR1E4A.000 [DIRS 185931], Seismic Design Spectra for the Surface Facilities Area at 1E-4 APE For Multiple Damping Levels.
- MO0805DSRB5E4A.000 [DIRS 185935], 5% Damped Seismic Design Spectra for the Repository Block at 5E-4 APE.
- MO0805TH1E3APE.000 [DIRS 185936], Time Histories for the Surface Facilities Area at 1E-3 APE.
- MO0805TH5E4APE.000 [DIRS 185953], Time Histories for the Surface Facilities Area at 5E-4 APE.

- MO0805TH1E4APE.000 [DIRS 185952]. Time Histories for the Surface Facilities Area at 1E-4 APE.

6.3.1 DRS for Surface Facilities

The DTNs listed below are the source documents for the surface DRS in the horizontal and vertical directions at multiple damping values for 1,000-year, 2,000-year, and 10,000-year return period earthquakes. Both spectral shapes and digitized spectra are available in DTNs: MO0805DSDR1E3A.000 [DIRS 185929], MO0805DSDR5E4A.000 [DIRS 185930], and MO0805DSDR1E4A.000 [DIRS 185931].

6.3.2 DRS for Subsurface Facilities

The DTN listed below is the source document for the subsurface DRS in the horizontal and vertical directions at the repository elevation (Point B), with 5% damping value for the 2,000-year return period earthquake. Digitized spectra are provided in DTN: MO0805DSRB5E4A.000 [DIRS 185935].

6.3.3 Design Time Histories for Surface Facilities

Time histories are used in soil-structure interaction analysis to determine the seismic responses of the structures in terms of seismic load, in-structure response spectra and dynamic soil pressure. Horizontal and vertical time-history motions compatible with the 1,000-year, 2,000-year, and 10,000-year return period earthquakes, showing the acceleration, velocity, and displacement time history for each earthquake component are available in MO0805TH1E3APE.000 [DIRS 185936], MO0805TH5E4APE.000 [DIRS 185953], and MO0805TH1E4APE.000 [DIRS 185952].

6.3.4 Design Time Histories for Subsurface Facilities

For subsurface SSCs, horizontal and vertical time-history motions compatible with the 2,000-year return period earthquake are given in the PDC (BSC 2007 [DIRS 179641], Table 6.1-1).

6.3.5 Deleted

Figure 6-1. NOT USED

Table 6-3. NOT USED

Figure 6-2. NOT USED

Table 6-4. NOT USED

Figure 6-3. NOT USED

Table 6-5. NOT USED

Figure 6-4. NOT USED

Table 6-6. NOT USED

Figure 6-5. NOT USED

Table 6-7. NOT USED

Figure 6-6. NOT USED

Table 6-8. NOT USED

Figure 6-7. NOT USED

6.4 DESIGN BASIS GROUND MOTION FOR NON-ITS STRUCTURES

Design for non-ITS facilities is based on IBC 2000 (ICC 2003 [DIRS 173525]). To be consistent with the ITS SSCs and to be able to use the database on site-specific geotechnical testing, design of non-ITS facilities will be based on site-specific seismic data as described in Sections 6.4.1 and 6.4.2.

6.4.1 Design Spectrum for Non-ITS Surface Facilities

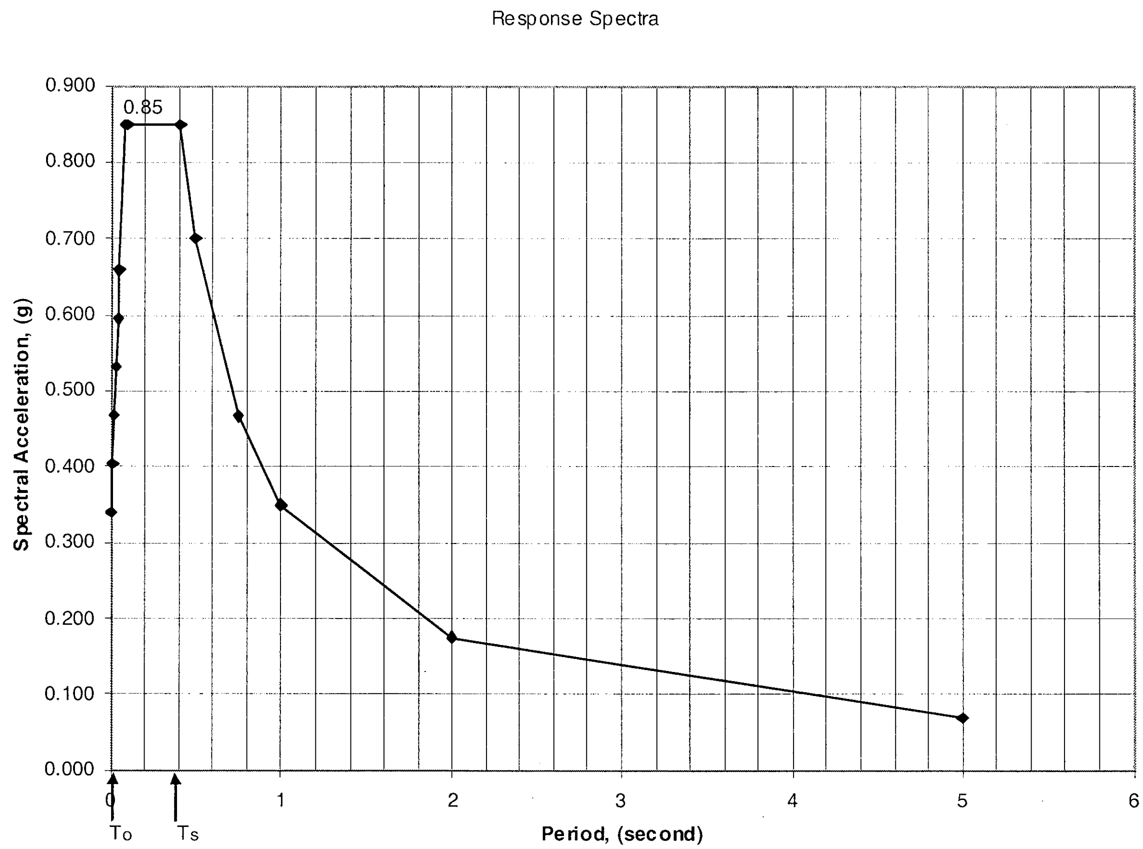
The site-specific design spectrum for the non-ITS surface facilities is developed using the approach given in IBC 2000 (ICC 2003 [DIRS 173525]), as follows:

- Determine the short-period and one second period spectral accelerations for a 2,500-year return period for 5% damping by interpolation between 5×10^{-4} and 1×10^{-4} probability earthquakes. These spectral accelerations will correspond to the "maximum considered earthquake" in IBC.

- Apply the 2/3rds factor to the 2,500-year return period accelerations to obtain the approximate 500-year return period earthquake design parameters.

- Develop the site-specific design spectrum using the approximate 500-year return period accelerations following the procedure outlined in IBC 2000 (ICC 2003 [DIRS 173525]), Section 1615.1.4.

The resulting design spectrum for non-ITS surface structures is calculated by BSC (2007 [DIRS 184022]) and is shown in Figure 6-8.



Source: BSC 2007 [DIRS 184022], Figure 3.

Figure 6-8. Horizontal Design Response Spectrum for Non-ITS Surface Facilities, Five-Percent Damping

6.4.2 Design Spectrum for Non-ITS Subsurface Facilities

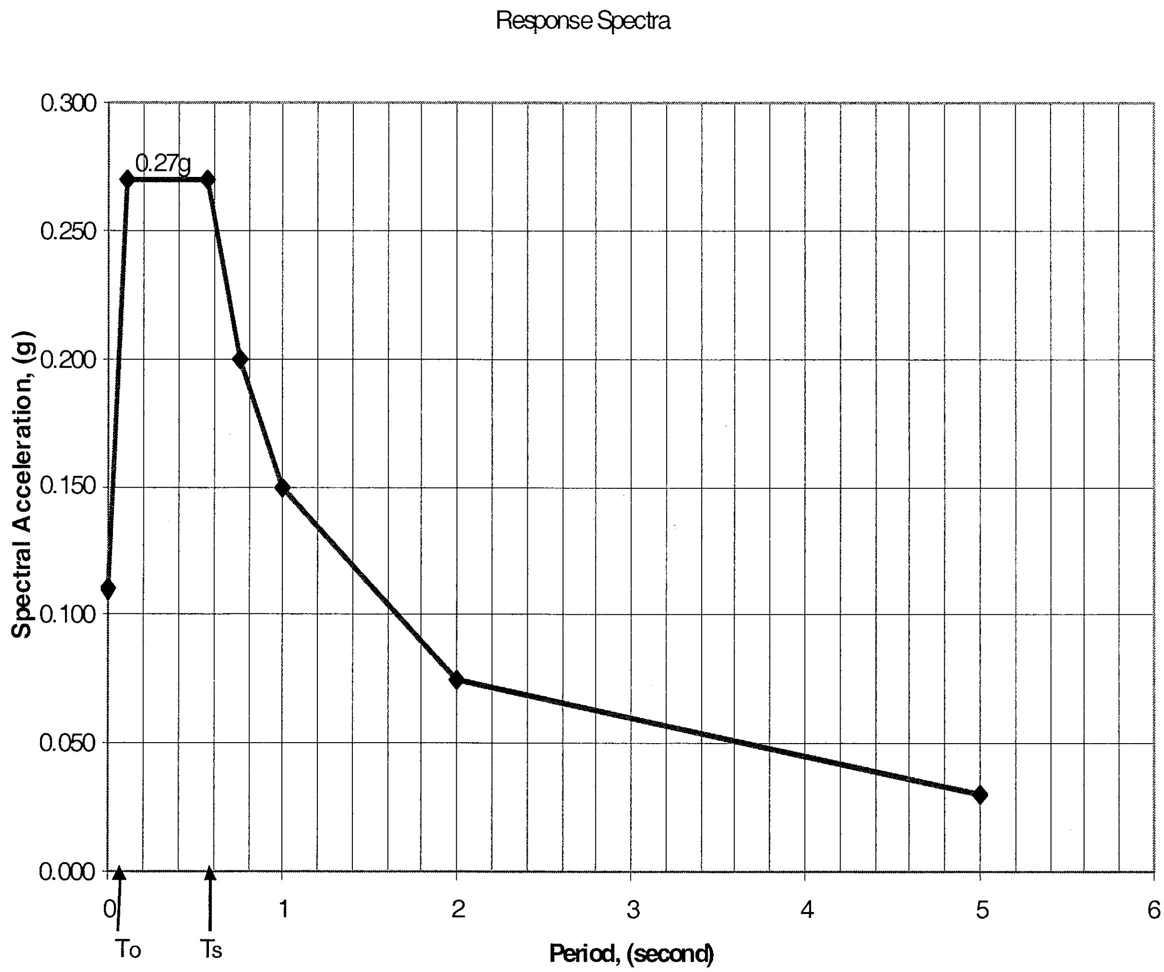
The site-specific design spectrum for the non-ITS subsurface facilities is also developed using the approach given in IBC 2000 (ICC 2003 [DIRS 173525]), as follows:

- Determine the short-period and one second period spectral accelerations for a 2,500-year return period for 5% damping by interpolation between 5×10^{-4} and 1×10^{-4} probability earthquakes. These spectral accelerations will correspond to the "maximum considered earthquake" in IBC.

- Apply the 2/3rds factor to the 2,500-year return period accelerations to obtain the approximate 500-year return period earthquake design parameters.

- Develop the site-specific design spectrum using the approximate 500-year return period accelerations following the procedure outlined in IBC 2000 (ICC 2003 [DIRS 173525]), Section 1615.1.4.

The resulting site-specific design spectrum for the non-ITS subsurface structures is calculated by BSC (2007 [DIRS 184192]) and is shown in Figure 6-9. All non-ITS structures will be designed for 5% damping.



Source: BSC 2007 [DIRS 184192], Figure 3.

Figure 6-9. Horizontal Design Response Spectrum for Non-ITS Subsurface Facilities, Five-Percent Damping

7. SEISMIC ANALYSIS OF ITS SSCs

7.1 METHODOLOGY

Various seismic analyses are needed to determine the seismic response of structures as well as to calculate the effects of seismic loads on SSCs. These analyses include: (1) seismic response analysis of structures–to determine seismic responses in terms of the nodal accelerations, and to determine in-structure response spectra, (2) seismic stress analysis of structures–to determine the internal forces and moments in the structures, and (3) seismic analysis of systems and components–to determine the design forces for the supports of systems and components, to qualify these systems and components, and to determine the loads on the supporting structure.

These analyses will be performed during the preliminary design stage (Tier # 1 Analyses) and also during the detail design stage (Tier # 2 Analyses) using different approaches. In general, an approximate method is adequate during the preliminary stages (Tier # 1) and a more refined approach is needed for detail design (Tier # 2). Attributes of Tier # 1 and Tier # 2 analyses are described in the Sections 7.1.1 and 7.1.2.

In addition to seismic, the structures must be analyzed for the non-seismic loads, such as gravity loads, lateral soil pressures, hydrodynamic loads and other applicable loads. The analyses for both seismic and non-seismic loads are discussed in Sections 7.1.1 and 7.1.2.

7.1.1 Tier # 1 Analyses

A response spectrum analysis (RSA) will be carried out using a lumped-mass multi-stick model with the surface design response spectrum. Results of this analysis will include gross overturning moments and sliding forces, floor accelerations, and individual element forces. The overall overturning moments and sliding forces will be used for stability evaluations. The floor accelerations will be used to assess the model and the amplification throughout the structure. Finally, the element forces will be used for preliminary design of selected critical walls. The Tier # 1 multi-stick model is for a simplified analysis and, therefore, the floors are considered rigid. Furthermore, the primary interest is the in-plane response of the structure and concrete cracking does not significantly affect the in-plane response. Therefore, cracking is not considered in Tier # 1 analysis.

The same multi-stick model will be used to perform a static analysis under the gravity loads. The results of this analysis will be combined with the seismic analysis results to determine the preliminary design forces. A shear wall design procedure has been developed and is provided in Appendix D.

The Tier # 1 analysis will be carried out using SAP2000 (V. 9.1.4. 2005. WINDOWS 2000. STN: 11198-9.1.4-00 [DIRS 178238]).

7.1.2 Tier # 2 Analyses

For Tier # 2 analyses, a detailed finite-element structural model will be developed after the building layout is sufficiently matured. This model will be used to perform the following analyses:

- A time history seismic analysis, including the soil-structure interaction (SSI) effects, is performed using the computer code SASSI2000 (V. 3.1 2007. WINDOWS XP STN: 10825-3.1-00 [DIRS 182945]). Maximum accelerations at each node in the model are calculated for each of the 9 directions (response in X, Y, and Z directions due to input seismic motion in the X, Y, and Z directions). These maximum nodal accelerations are used to develop the static equivalent seismic load. The acceleration time histories at selected nodes may be used to generate In-Structure-Response-Spectra. In addition, SASSI2000 may be used to obtain directly the element seismic design forces.

- The same model will be used to analyze the structure under applicable non-seismic loads using SAP2000 [DIRS 178238]. The analyses results will include element forces and nodal displacements.

7.1.3 Design of Structures

The preliminary structural design will be based on the forces and moments obtained from Tier # 1 analysis. For this purpose the shear wall design spreadsheets previously discussed and described in Appendix D will be utilized for the design. It is expected that the Tier # 1 analyses will result in a conservative design. Tier # 1 design will be documented with adequate data (i.e. load combinations, section forces, resulting reinforcement, and demand/capacity (D/C) ratios) to permit future comparison with the Tier # 2 design. It is expected that the Tier # 1 design D/C ratios will be significantly smaller than unity, as discussed subsequently in Section 8.4 (Equation 8-4). The resulting design is expected to meet the performance objectives of the limited seismic probabilistic risk assessment.

The Tier # 2 analyses are performed to support the detailed design for the construction of the surface nuclear facilities. The design acceptance criteria are given in Section 8.4.

7.1.4 Other Analyses

In addition to the previously described analyses, special analyses will be carried out to determine the structural sliding and overturning responses. Guidance on these issues is provided in ASCE/SEI 43-05 [DIRS 173805], Section 7.0.

Another special analysis is the determination of fragility for structures. In general, the fragilities for structures will be calculated using the "Conservative Deterministic Failure Margin" approach, which may also require special nonlinear analyses. Guidance for performing the Conservative Deterministic Failure Margin (CDFM) analysis is given in Appendix B.

7.2 ANALYSES PARAMETERS

7.2.1 Modeling

Different models will be used for the Tier # 1 (multi-stick model) and the Tier # 2 (finite element model) analyses as described in Sections 7.2.1.1 and 7.2.1.2, respectively, for both seismic response and stress analyses.

In both models, the dead load will include the weight of the structure, partitions, permanent equipment, piping, raceways, HVAC ductwork, and other permanent static loads. The seismic mass will consist of full dead load and 25% of design live load (see Section 8.3.1).

The other model properties (element types, boundary conditions, soils properties, input motions, coupling criteria, etc.) and parameters to be used in analyses (modal and spatial combinations, damping, etc.) are discussed in Sections 7.2.2 through 7.2.10.

7.2.1.1 Tier # 1 Model

Tier # 1 seismic analysis will be performed using a lumped-mass, multi-stick model in which all walls or segments of walls are modeled as beam elements using gross section properties. The beams span between the floors. Ends of the beams are constrained to a master node at each floor diaphragm level and, thus, the floors are considered to be rigid in all three directions. Soil springs will be calculated in accordance with Appendix C considering the layered media.

7.2.1.2 Tier # 2 Model

The finite element model used for Tier #2 stress analysis will include the entire structure, including the foundation mat, walls, roof and floor slabs, structural steel framing, and major penetrations and openings in the walls and slabs. In general, small openings may be represented by determining an equivalent thickness for the corresponding element. Since the structures are founded on soil, it is important to take into account the effects of foundation flexibility. For seismic stress analysis, this may be accomplished by calculating the soil impedances from the

SSI model or by other appropriate methods and converting them into soil springs (see Appendix C for soil spring calculation methodology). Since the soil impedances are frequency dependent, the values corresponding to the fundamental frequency of the soil-structure system will be used in calculating the soil springs. The distribution of soil springs should be based on the rocking impedance of the foundation.

The concrete slabs and walls will be modeled using an improved shell element (i.e., with out-of-plane shear calculation capability) that has recently been added to SASSI2000 [DIRS 182945]. Similar elements also exist in the SAP2000 [DIRS 178238] library. Concrete columns (if any) and selected steel members will be modeled by beam elements. In slabs, the effect of the supporting steel may be approximated by composite action. The resulting seismic forces will then be used for composite design of the system. Concrete cracking will also be taken into account where it is deemed significant.

The mesh size used in a finite element model should be adequate to obtain accurate design forces and moments. In-plane forces can be accurately determined using a coarse mesh. In general, only two elements would be sufficient for determination of the in-plane forces between two supports (i.e. between floors or walls). On the other hand, out-of-plane forces require a refined mesh; in general a minimum of six elements are needed between supports. Therefore, modeling should consider not only the geometry, but also the relative importance of the in-plane and out-of-plane forces and moments on design. This requires exercise of judgment to obtain sufficient accuracy and to avoid making the model so complicated that meaningful interpretation of the results may be compromised.

The detailed SAP2000 [DIRS 178238] analysis model will include mathematical representation of the soil layers around and beneath the structure. The procedure for calculating soil springs is given in Appendix C.

The embedment effects (if any) will be taken into account by considering the soil backfill. The soil nonlinearity will be considered using an equivalent linear method. The strain-compatible soil properties using the equivalent linear method are provided in DTN: MO0801SCSPS5E4.003 [DIRS 184682] and in DTN: MO0801SCSPS1E4.003 [DIRS 184683].

7.2.2 Input Motions

7.2.2.1 Tier # 1 Analysis

The DRS are used for the input motion in Tier # 1 analysis. The DRS for the YMP are available in the referenced DTNs in Section 6 for both surface and subsurface facilities.

The spectra for the ITS SSCs are given at different damping levels. These spectra should be applied at the foundation level. In RSA, the appropriate damping curve should be used for determining the modal damping for each mode.

7.2.2.2 Tier # 2 Analysis

In Tier # 2 dynamic analysis, the acceleration time histories available in the referenced DTNs in Section 6 will be used as input motion in the SSI analyses. The DRS available in the referenced DTNs in Section 6 include soil amplification effects and, therefore, the control point for the time histories will be set at the ground surface level in the free-field. The wave field will consist of vertically propagating shear and compression waves. Variation of amplitude and frequency content with depth in the free-field motion will be considered in the analysis as recommended in Section 3.3 of ASCE 4-98 [DIRS 159618]. ASCE 4-98 also considers the accidental eccentricity as discussed in Sections 7.2.8 and 7.2.9 to fully account for the possible effects of nonvertically propagating waves.

7.2.3 Dynamic Soil Properties

Poisson's ratio and total density will be obtained from the *Supplemental Soils Report* (BSC 2008 [DIRS 185630]). Dynamic soil properties in terms of shear and compression wave velocities and low-strain shear wave velocity will be as given in DTN: MO0801SCSPS5E4.003 [DIRS 184682] and DTN: MO0801SCSPS1E4.003 [DIRS 184683]. The strain-compatible soil properties will be used in the SSI analyses.

7.2.4 Damping

7.2.4.1 Soil Damping

Soil damping may be an important factor in the response of the structure in Tier # 1 RSA. Soil springs and associated damping coefficients (dashpots) can be calculated using the half-space approach (ASCE 4-98 [DIRS 159618], Section 3.3). Methods are available to determine the composite modal damping for structures supported on soil springs. The composite modal damping (ASCE 4-98 [DIRS 159618], Section 3.1.5) will be used in the response analysis to ensure more realistic response calculations.

In Tier # 2 SASSI analysis, the soil damping is accounted for by modeling the soil medium, including radiation-damping effects.

Appendix C provides additional information on soil damping.

7.2.4.2 Structural Damping

The structural damping values are given as a function of response level in members and are listed in Table 7-1 (ASCE/SEI 43-05 [DIRS 173805], Section 3.4.3). The response levels relate to the stress levels in terms of demand-capacity ratios; less than 0.5 for Response Level 1, between 0.5 and 1.0 for Response Level 2, and equal to or greater than 1.0 for Response Level 3. Response Level 2 damping values will be used for computing seismic loads. Response Level 1 values will be used for developing in-structure response spectra and input motions for subsystems. Level 3 values will be used in BDBGM evaluations.

- Soil pressures behind the embedded walls of the structure will be tracked in the SSI analysis. Parametric studies will be performed to include the effect of potential soil-wall separation.

- Consideration of structure-to-structure interaction analysis for local effects, such as lateral seismic soil pressures, if warranted, will be given per Section 3.3.1.5 of ASCE 4-98 [DIRS 159618]

The effect of uneven thickness of alluvium on the foundation response will be assessed and incorporated in design loads if warranted.

7.3.2.2 Generation of In-Structure Response Spectra

In-structure acceleration response spectra will be generated for 0.5%, 1%, 2%, 3%, 5%, 7%, and 10% damping at the locations of the subsystems. The SRSS method will be used to combine the spectral amplitudes of co-directional responses. The responses from the best-estimate lower-bound and upper-bound soil properties will be enveloped. ISRS are calculated between 0.2 Hz. and 34.0 Hz. at frequency steps equal to 100 frequencies per decade that are equally spaced in the log scale. A peak broadening of plus or minus 15% will be used in accordance with the recommendations of Section 3.4.2.3 of ASCE 4-98 unless a more rigorous analysis is performed to determine the peak broadening. The enveloping acceleration response spectra will be constructed in accordance with the requirements of Regulatory Guide 1.122 [DIRS 151404].

7.4 SEISMIC STRESS ANALYSIS OF STRUCTURES

Seismic stress analysis of the structures to determine the design forces and moments will be carried out using the Tier # 1 and Tier # 2 models described in Section 7.1.1 and 7.1.2, respectively, and any one of the following approaches:

- **Code Approach**–Using the IBC 2000 (ICC 2003 [DIRS 173525]) approach with the design spectra at the surface as input

- **Static Method**–Using a finite element model of the structure in a static analysis, with the floor accelerations obtained from the seismic response analysis of Section 7.2 as input

- **Response Spectrum Analysis**–Using finite element or lumped-mass models and performing an RSA with the design spectra at the surface as input.

- **Time-History Analysis**–Using time-histories to obtain realistic member design forces.

Application of these methods is discussed in Sections 7.4.1 through 7.4.5.

7.4.1 Code Approach

This method may be used for very simple structures following the equivalent static procedures with the design spectra given in Section 6.3 for ITS structures. This approach is not discussed in detail as the procedures are given in applicable codes (IBC 2000 (ICC 2003 [DIRS 173525])).

test response spectrum of the shake table should generally envelop the required response spectrum.

When combined analysis and testing method is used, the interface of scope of work for each method must be clearly established. When similarity or experience database methods are used, objective evidence of the applicability of similarity must be documented, including those related to the supports and attachments. For more information, see ASCE/SEI 43-05 [DIRS 173805], Section 8.3.

7.6 SEISMIC EVALUATION OF STRUCTURES FOR BDBGM

Structures designed for DBGM-2 will be evaluated to determine the seismic effects during the 10,000-year return period earthquake, BDBGM in accordance with Table 5-2. These evaluations will include the following:

- Structural analysis to determine the stresses
- Seismic response analysis to determine the ISRS
- Seismic margin assessment to demonstrate that the high confidence of low probability of failure (HCLPF) capacity values are at least 10% higher than the demand imposed by the BDBGM 10,000-year return period earthquake
- Development of the fragility curves for selected structures and components that are credited with preventing/mitigating unacceptable event sequences. These fragility curves will be used to carry out a limited seismic probabilistic risk assessment.

The approach to be used in these evaluations is given in Appendix B.

7.7 SEISMIC ANALYSIS OF UNDERGROUND ITS SSCs

Although most of the subsurface facilities are expected to be non-ITS, this section for ITS subsurface facilities is provided for possible use in the future.

Underground SSCs include main drifts, emplacement drifts, vertical shafts, collars, and all the systems and components supported by these structures. Emplacement drifts are about 1,000 ft below the ground surface and provide for the emplacement of waste packages. Shafts provide access for the ventilation of the repository as well as emergency egress from the repository horizon to the surface. Shaft collars penetrate the top layers of rock strata at a particular location. In addition to linking the shaft tube with the surface, the shaft collar often serves as the foundation for the surface structure (i.e., hoisting facility and the head frame) (BSC 2008 [DIRS 185694], Section 8.1).

Underground structures track the motions of the surrounding soil medium. Consequently, soil-structure interaction analysis is deemed unnecessary. However, variation of the ground motion with depth must be taken into account in the design of SSCs. In addition, the underground SSCs must also be evaluated for the deformations imposed by the surrounding soil medium.

7.7.1 Seismic Analysis of Force-Controlled Underground SSCs

Seismic inertia loads for the underground SSCs will, in general, be computed using the Equivalent Static Load Method (Section 7.4.2) in accordance with the requirements of NUREG-0800 (NRC 1987 [DIRS 138431], Section 3.7.2). To obtain an equivalent static load in the horizontal direction and in the vertical direction, the spectral acceleration at depth may be used (see DTN: MO0805DSRB5E4A.000 [DIRS 185935] for underground facilities). If the frequency is not calculated, then a factor of 1.5 shall be applied to the respective peak acceleration of the site-specific response spectra, corresponding to a 2,000-year return period. If the SSC frequency is determined using approximate methods, where a single degree of freedom is representative of the SSC response, then a factor of 1.0 is applied. An appropriate structural damping value for the structure or component, expressed in terms of the percent of critical damping, will be used for Response Level 2 as shown in Table 7-1. For components and systems, the damping values given in ASCE/SEI 43-05 [DIRS 173805], Table 3-2, Response Level 2, should be used.

Alternatively, a dynamic analysis, either response spectrum or time history methods, may be used when the use of the equivalent static load method cannot be justified. Where applicable, torsional effects must be included.

Combination of responses from the three orthogonal components of earthquake motions will be carried out using the processes given in Section 7.2.7.

7.7.2 Seismic Analysis of Deformation-Controlled Underground Structures

Invert steel structure and other SSCs connected to the subsurface emplacement and to the main drift walls will additionally undergo structural deformations that are imposed and controlled by the racking of the cross-section of the drift, caused by the seismic ground motion. Such actions are termed deformation-controlled. Seismically-induced racking deformations will be accounted for in the design of the steel invert structure and other structural components connected to the drift walls that may be affected by such racking.

7.7.3 Seismic Analysis of Vertical Shaft Liners and Collars

For the vertical shafts and collars, both acceleration and deformation responses will be considered. The analyses approach will be similar to those utilized for the drift structures. Design spectra to be used in these analyses may be obtained by a linear interpolation of the spectra at the drift and surface levels. Racking analysis of the shafts and collars will consider the maximum strains imposed by the ground motions and considering the motions in three orthogonal directions. The imposed deformations are important in the design process to ensure acceptable behavior of the shafts and collars.

8. SEISMIC DESIGN OF ITS SSCs

8.1 GENERAL

This section details the criteria to be used for the design of ITS SSCs for load combinations that include seismic loads. It lists the acceptable industry codes to be used in design. It identifies the loads that should be considered in conjunction with the seismic loads. It provides the load combination to which design must conform. Finally, it addresses the acceptance for the design of ITS SSCs. This section must be used together with Section 7, which provides the methodology for determination of seismic forces on ITS SSCs. For evaluation of ITS SSCs, for the loads resulting from BDBGM, see Appendix B.

8.2 DESIGN CODES

The design methods and the design codes for the ITS structures are listed as follows:

ACI 349-01 [DIRS 181670]	Reinforced concrete design	Strength Design
ANSI/AISC N690-1994 [DIRS 158835]	Structural steel	Allowable Stress Design

These codes are applicable to both surface and subsurface structures. In addition to these codes, the design of ITS structures will be based on the following standards:

ANSI/AISC 341-02 [DIRS 171789]	*Seismic Provisions for Structural Steel Buildings*
ASCE 4-98 [DIRS 159618]	*Seismic Analysis of Safety-Related Nuclear Structures and Commentary*
ASCE/SEI 43-05 [DIRS 173805]	*Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*
IBC 2000 (ICC 2003 [DIRS 173525])	*International Building Code 2000*

8.3 LOADS AND LOAD COMBINATIONS

This section provides guidance on the load combinations that include earthquake loads. A full set of load combinations is provided in the PDC (BSC 2007 [DIRS 179641], Section 4.2.11.4.4).

8.3.1 Notations and Load Definitions

D = Dead load, including all permanently attached loads as well as crane dead weights, and loads due to weight of fluids

L = Live loads present during an earthquake, including the roof snow load or portion of the roof live load considered to be present during earthquakes. Normally, 25% of the design live load should be considered as existing during an earthquake (where necessary, a higher percentage may be considered) (IBC 2000 (ICC 2003 [DIRS 173525], Section 1617.5.1))

E = Earthquake load (based on D + 0.25 L as total weight)

H = Lateral earth pressure

T_o = Thermal loads during normal operating conditions. This term includes significant creep, shrinkage, differential settlements and similar self-relieving loads.

T_a = Thermal loads during abnormal conditions

S = Allowable stress per Allowable Stress Design method

U = Required strength per Strength Design method

Special loads, such as ventilation pressure differential and fluid pressure, are added when applicable.

8.3.2 General Notes on Load Combinations

- Where the structural effects of differential settlement, creep, or shrinkage may be significant, they should be included with the dead load D in all the load combinations. Estimation of these effects should be based on a realistic assessment of such effects occurring in service.

- Other loads that could occur simultaneously with the earthquake loads (e.g., differential pressures) should be added to the load combinations.

- Where any load reduces the effect of other loads, the corresponding coefficient for that load should be taken as 0.9 if it can be demonstrated that the load is always present or occurs simultaneously with the other loads. Otherwise, the coefficient for that load should be taken as zero.

- All load combinations should be checked for zero live load condition.

9. SEISMIC ANALYSIS OF NON-ITS SSCs

9.1 GENERAL

Earthquake loads on non-ITS SSCs will be calculated per IBC 2000 (ICC 2003 [DIRS 173525], Section 1616), using the design spectra given in Section 6.4. Either equivalent static or dynamic analysis procedures may be used, depending on the complexity of the structure.

In Sections 9.2 through 9.4, analysis procedures using the equivalent lateral force are summarized. The quoted equations are from IBC 2000 (ICC 2003 [DIRS 173525]). These equations are to be used in conjunction with the design spectra given in Section 6.4.

The IBC 2000 (ICC 2003 [DIRS 173525], Section 1616) equations express the earthquake loads in terms of "strength level." Therefore, the calculated seismic forces are to be used in load combinations based on strength design. If allowable stress design methods are used, the seismic forces should be divided by the factor 1.4 to obtain the appropriate seismic loads. The resulting stresses should be compared with the allowable values without the one-third increase.

If dynamic analysis is used, Section 1618 of IBC 2000 (ICC 2003 [DIRS 173525]) should be followed, in conjunction with the design spectra for non-ITS structures.

9.2 SEISMIC ANALYSIS OF NON-ITS STRUCTURES

- The non-ITS structures at the YMP are in Seismic Design Categories C and D as defined in IBC 2000 (ICC 2003 [DIRS 173525], Section 1616.3) and as shown in Table 5-4.
- The minimum design seismic loads will be determined in accordance with Section 1617.1 of IBC 2000 (ICC 2003 [DIRS 173525]). The minimum load calculation takes into account the "redundancy" factor, which should be determined following Section 1617.2 of IBC 2000.

  The base shear will be calculated per IBC 2000 (ICC 2003 [DIRS 173525], Section 1617.4) as follows:

$$V = C_s W \quad \text{(Eq. 9-1)}$$

$$C_s=(S_{DS}/R)I_E \quad \text{(Eq. 9-2)}$$

  with limits on C_s as follows:

$$0.044S_{DS}I_E \leq C_s \leq (S_{D1}/RT)I_E \quad \text{(Eq. 9-3)}$$

  where

  C_s = seismic response coefficient
  W = total seismic dead load of the structure
  I_E = occupancy importance factor

S_{DS} = design spectral acceleration at short period

S_{D1} = design spectral acceleration at one-second period

S_1 = maximum considered earthquake spectral one-second-period response acceleration from IBC 2000 (ICC 2003 [DIRS 173525], Figure 1615(3), Section 1615)

R = response modification factor from IBC 2000 (ICC 2003 [DIRS 173525])

T = the fundamental period of structure.

In Equations 9-1 to 9-3, S_{DS} and S_{D1} account for the seismic hazard, which is discussed in Section 6.4. The importance factor corresponds to the seismic use groups and reflects the higher seismic design forces for the more important structures (Section 5). The C_s factor accounts for the amplification of the ground motion through the structure as a function of the fundamental period of the structure (T) and including the soil effects. Finally, the R factor reflects the energy dissipation characteristics of the structure; higher values being allowed for structures with greater demonstrated energy dissipation capacity while remaining within the acceptable limits of deformation.

9.2.1 Site-Specific Design Parameters

The design shall be based on the site location being at the North Portal, Latitude N 36.85°, Longitude W 116.43 (BSC 2007 [DIRS 179641], Section 6.1.10.2.1), and on site-specific design parameters. The site-specific design ground motion has been derived in accordance with IBC 2000 (ICC 2003 [DIRS 173525], Section 1615) from site investigations. The value of S_1 is from IBC 2000 and the values of S_{DS} and S_{D1} are from Figure 6-8 of this document:

- $S_{DS} = 0.85$
- $S_{D1} = 0.35$
- $S_1 = 0.22$.

9.2.2 Earthquake Loads Criteria Selection

The criteria selection for earthquake loads shall be based on IBC 2000 (ICC 2003 [DIRS 173525], Section 1616.1). The seismic design category shall be based on IBC 2000, Tables 1616.3 (1) and 1616.3 (2) for short period response acceleration, S_{DS}, and one-second-period response acceleration, S_{D1}, respectively, using the values of S_{DS} and S_{D1} defined in Section 9.2.1. The seismic use group shall be the category for the nature of occupancy based on IBC 2000, Table 1604.5. The importance factor, I_E, shall correspond to the nature of occupancy shown in IBC 2000, Table 1604.5. Non-ITS SSCs currently identified are listed in Table 5-4.

9.3 SEISMIC ANALYSIS OF NON-ITS, NON-BUILDING STRUCTURES

Non-building structures are structures that generally do not have the features of buildings, but carry gravity loads to the ground and resist earthquake loads. In accordance with IBC 2000 (ICC 2003 [DIRS 173525], Section 1622), the following considerations apply to these structures:

- Non-building structures may be analyzed using the equivalent lateral force procedure or dynamic analysis.
- The base shear for non-building structures will be determined as in Section 9.2, with the exception that the minimum seismic response coefficient must be at least equal to:

  $$C_s = 0.14 S_{DS} I \qquad \text{(Eq. 9-4)}$$

  where I is the importance factor for the non-building structure as given in Table 1622.2.5(2) of IBC 2000 (ICC 2003 [DIRS 173525]).

When dynamic analysis methods are used, lumped-mass models or finite element models will be utilized in conjunction with the design spectra for non-ITS structures.

9.4 SEISMIC ANALYSIS OF NON-ITS SYSTEMS AND COMPONENTS

Mechanical and electrical equipment not important to safety (non-ITS) shall be designed using the following criteria for seismic loads:

9.4.1 Mechanical and Electrical Components Supported by Non-ITS Buildings

Seismic loads for the mechanical and electrical equipment supported by the Non-ITS buildings shall be determined using IBC 2000 (ICC 2003 [DIRS 173525], Section 1621). The S_{DS} value in IBC 2000 equations 16-67, 16-68, and 16-69 shall be taken as 0.91.

9.4.2 Mechanical and Electrical Components Supported at Grade

Seismic loads for non-ITS components supported directly on the ground shall be determined using IBC 2000 (ICC 2003 [DIRS 173525], Section 1622). The S_{DS}, S_{D1}, and S_1 values in the equations shown in these sections of IBC 2000 are as follows:

- S_{DS} = 0.85
- S_{D1} = 0.35
- S1 = 0.22.

9.4.3 Mechanical and Electrical Components Supported Either by Non-ITS Buildings or at Grade

The following criteria shall be applied to both categories of components covered under Sections 9.4.1 and 9.4.2 above:

- Seismic loads obtained from the referenced equations are intended for use with the strength design methods. If the allowable stress design methods are being used, then the seismic forces determined from these equations shall be divided by the factor 1.4.
- The calculated lateral force FP shall be distributed in proportion to the mass distribution of the equipment.
- The anchorage for the component shall be designed for the total lateral loads, including the overturning effects.
- Where approved national standard or approved physical test data are available, such data would be acceptable if they comply with IBC 2000 (ICC 2003 [DIRS 173525]) requirements.

10. SEISMIC DESIGN OF NON-ITS SSCs

10.1 GENERAL

This section details the methodology to be used for the design of non-ITS SSCs for load combinations that include seismic loads. It lists the acceptable industry codes to be used in the design. It identifies the loads that should be considered in conjunction with the seismic loads. It provides the load combinations to which design must conform. Finally, it addresses the acceptance criteria for design of such SSCs.

This section must be used together with Section 9, which provides the methodology for determination of earthquake loads on non-ITS SSCs.

10.2 DESIGN CODES

The design codes and design methods to be used for the non-ITS structures are as follows:

ACI 318-02/318R-02 [DIRS 158832]	Reinforced concrete design	Strength Design
AISC 1997 [DIRS 107063] AISC 1995 [DIRS 146097]	Structural steel	Allowable Stress Design Load and Resistance Factor Design
ACI 530-02 [DIRS 158925]	Masonry design	Allowable Stress Design
IBC 2000 (ICC 2003 [DIRS 173525])	Design of non-ITS Structures	

These codes and design methods are applicable to both surface and subsurface non-ITS structures.

10.3 LOADS AND LOAD COMBINATIONS

10.3.1 Notations and Load Definitions

The load definitions are similar to those for ITS SSCs except that the non-ITS structures are not normally designed for thermal effects and pipe reactions. However, thermal and other loads that may have a significant effect on the behavior of the non-ITS structures should be included in the load combinations.

D = Dead load, including all permanently attached loads as well as crane dead weights, and loads due to weight of fluids.

L = Live loads present during an earthquake, including the roof snow load or portion of the roof live load is considered as present during earthquakes. Normally, 25% of the design live load should be considered as existing during an earthquake (where necessary, a higher percentage may be considered) (IBC 2000 (ICC 2003 [DIRS 173525], Section 1617.5.1)).

E = Earthquake load reduced by the appropriate response reduction factor (R)

H = Lateral earth pressure

S = Allowable stress per Allowable Stress Design method

U = Required strength per Strength Design method

10.3.2 Load Combinations for Non-ITS Structures

The load combinations involving seismic loads that will be used in the design of non-ITS structures are:

- Reinforced Concrete-Strength Design:

$$U = 1.2D + 0.25L + 1.6H + E \qquad \text{(Eq. 10-1)}$$

$$U = 0.9D + E \qquad \text{(Eq. 10-2)}$$

- Steel and Masonry-Allowable Stress Design:

$$S = D + 0.25L + E/1.4 \qquad \text{(Eq. 10-3)}$$

$$S = 0.9D + E/1.4 \qquad \text{(Eq. 10-4)}$$

These load combinations are anticipated to be governing, but this must be verified; the full set of load combinations is provided in the PDC (BSC 2007 [DIRS 179641], Section 4.2.11.5).

Equations 10-3 and 10-4 are used in the working stress design methods for the design of steel and masonry structures.

Alternatively, steel structures may be designed using the Load and Resistance Factor Design method and the masonry structure may be designed using the strength method. In such cases, Equations 10-1 and 10-2 must be used instead of Equations 10-3 and 10-4.

10.4 ACCEPTANCE CRITERIA

The analysis and design of non-ITS SSCs are based on elastic methods. However, the response modification factors are greater than unity (as given in IBC 2000 (ICC 2003 [DIRS 173525])) to account for inelastic response under the design ground motions. Nonetheless, the acceptance criterion for these SSCs is given by:

$$D/C \leq 1.0 \qquad \text{(Eq. 10-5)}$$

where D is the demand, as calculated by the right side of Equations 10-1 to 10-4, C is the capacity of the SSC as determined using the applicable codes.

The design intent for non-ITS SSCs is to ensure life safety. Therefore, inelastic behavior is expected under design basis seismic loads. These SSCs are expected not to collapse.

Overturning–In the case of overturning, the minimum factor of safety listed above should be provided for both ITS structures and non-ITS structures. Overturning stability may be demonstrated by static calculations or using the reserve energy approach given in ASCE/SEI 43-05 [DIRS 173805], Section 7.2.

11.1.2 Subsurface Structures and Components

Some underground SSCs are anchored to the main and emplacement drift walls. Therefore, the stability (sliding and overturning) is not a consideration in the design. However, in other cases an analysis may be necessary for calculating the restoring forces required for stability. Evaluation of both static sliding and overturning may be performed using the non-ITS methods. When sliding and overturning evaluations are performed, the following factors of safety should be used with the DBGM.

Load Combination	Sliding	Overturning	Reference
D + H + E	1.1	1.1	NRC 1987 [DIRS 138431], Section 3.8.5

11.2 STORY DRIFTS

Story drifts should be calculated using the deflections from elastic analysis of the structure. Story drift is the difference between the lateral displacements at the top and bottom of the story under consideration. In the calculation for story drifts, both translational and torsional deflections should be considered.

Story drifts for ITS structures and for non-ITS structures should not exceed the limits given in ASCE/SEI 43-05 [DIRS 173805], Section 5.2.3, and IBC 2000 (ICC 2003 [DIRS 173525]), respectively.

In calculating the story drifts for the non-ITS structures, the deflection under lateral loads should be determined without dividing the earthquake forces by the factor 1.4 (i.e., at the strength design level). Furthermore, the anticipated inelastic response should be taken into consideration through the application of the deflection amplification factor given in Section 1617.4.6 of IBC 2000 (ICC 2003 [DIRS 173525]).

11.3 INTERACTION OF NON-ITS WITH ITS SSCs (Seismic 2/1 Issue)

Based on the provisions of Section 3.7.2 of NUREG-0800 (NRC 1987 [DIRS 138431]) the design of a non-ITS structure adjacent to an ITS structure must meet one of the following requirements:

- The collapse of the non-ITS SSCs will not cause it to strike an ITS structure or component.

12. USE OF COMPUTER PROGRAMS

Several computer programs will be used in the course of the analysis and design of SSCs for the YMP. These computer programs have been verified and validated by the project. These programs include:

- SASSI2000 (V. 3.1. 2007. WINDOWS® XP/X64. STN: 10825-3.1-00 [DIRS 182945]) (A System for Analysis of Soil-Structure Interaction)—a linear elastic finite element substructuring program that can solve two- and three-dimensional SSI problems with embedded flexible foundations. The program is formulated in the frequency domain using the complex response method. Conversions between the time domain and the frequency domain are performed by the Fast Fourier Transform technique. SASSI2000 is a state-of-the-art industry program for dynamic SSI analysis of critical structures.

- SAP2000 (V. 9.1.4. 2005. WINDOWS® 2000. STN: 11198-9.1.4-00 [DIRS 178238]) and WINDOWS XP. STN: 11198-9.1.4-01—a structural engineering, finite element software program that allows model creation and modification, execution of static, dynamic, linear and non-linear analyses, design optimization, and results review. The program includes graphical three-dimensional model generation using plan, elevation, and developed views. Steel member design is done based on American Institute of Steel Construction design code. Animation of deformed shapes, mode shapes, stress contours, and time history results can be displayed.

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13. REFERENCES

13.1 DOCUMENTS CITED

181572 DOE (U.S. Department of Energy) 2007. *Preclosure Seismic Design and Performance Demonstration Methodology for a Geologic Repository at Yucca Mountain Topical Report.* YMP/TR-003-NP, REV 5. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management, ACC: DOC.20070625.0013.

179641 BSC (Bechtel SAIC Company) 2007. *Project Design Criteria Document.* 000-3DR-MGR0-00100-000-007, Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071016.0005.

185694 BSC (Bechtel SAIC Company) 2008. *Basis of Design for the TAD Canister-Based Repository Design Concept.* 000-3DR-MGR0-00300-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20081006.0001.

184022 BSC (Bechtel SAIC Company) 2007. *Design Response Spectrum for Conventional Surface Facilities Utilizing Updated Soil Data.* 100-S0C-CY00-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071113.0020.

184192 BSC (Bechtel SAIC Company) 2007. *Design Response Spectrum for Conventional Subsurface Facilities Utilizing Updated Soil Data.* 800-S0C-SS00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071204.0008.

185630 BSC (Bechtel SAIC Company) 2008. *Supplemental Soils Report.* 100-S0C-CY00-00100-000-00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG. 20080828.0016.

165660 Budnitz, R.J.; Amico, P.J.; Cornell, C.A.; Hall, W.J.; Kennedy, R.P.; Reed, J.W.; and Shinozuka, M. 1985. *An Approach to the Quantification of Seismic Margins in Nuclear Power Plants.* NUREG/CR-4334. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 254460.

177779 SEAOC (Structural Engineers Association of California) 1997. *Recommended Lateral Force Requirements & Commentary, with Errata.* 6th Edition. Sacramento, California: Structural Engineers Association of California. TIC: 258828.

165664 Taylor, J.M. 1993. "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs." Memorandum from J.M. Taylor (NRC) to the Commissioners, April 2, 1993, SECY-93-087, with enclosures. ACC: MOL.20031016.0008.

166056 Tsai, N.C.; Hadjian, A.H.; Kuo, P.T.; Adair, M.J.; Morrow, W.M.; Yeh, G.C.K.; and Sobkowski, S.L. 1974. *Seismic Analyses of Structures and Equipment for Nuclear Power Plants.* BC-TOP-4-A, Rev. 3. San Francisco, California: Bechtel Power. TIC: 255198.

184234 BSC (Bechtel SAIC Company) 2007. *Nuclear Facilities Buildings Location Plan.* 100-S00-MGR0-00101-000 REV 00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071015.0015.

184057 BSC (Bechtel SAIC Company) 2007. *Geologic Repository Operations Area Aging Pad Site Plan.* 170-C00-AP00-00101-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071116.0005.

184014 BSC (Bechtel SAIC Company) 2007. *Geologic Repository Operations Area North Portal Site Plan.* 100-C00-MGR0-00501-000 REV 00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071116.0004.

186141 BSC (Bechtel SAIC Company) 2009. *IED Seismic and Seismic Consequence Data.* 800-IED-MGR0-00701-000-00D. Las Vegas, Nevada: Bechtel SAIC Company.

13.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

176544 10 CFR 63. 2006. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Internet Accessible.

158832 ACI 318-02/318R-02. 2002. *Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (ACI 318R-02).* Farmington Hills, Michigan: American Concrete Institute. TIC: 252731.

167041 ACI 318-89/318R-89. 1990. *Building Code Requirements for Reinforced Concrete (ACI 318-89) and Commentary—ACI 318R-89.* Detroit, Michigan: American Concrete Institute. TIC: 237379.

118294 ACI 318-99. 1999. *Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99).* Farmington Hills, Michigan: American Concrete Institute. TIC: 245142.

173525 ICC (International Code Council) 2003. *International Building Code 2000, with Errata to the 2000 International Building Code.* Falls Church, Virginia: International Code Council. TIC: 251054; 257198.

176259 IEEE Std 344-2004. 2005. *IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.* New York, New York: Institute of Electrical and Electronics Engineers. TIC: 258050.

IT-PRO-0011, *Software Management*

PA-PRO-0201, *Peer Review*

PA-PRO-0313, *Technical Reports*

151404 Regulatory Guide 1.122, Rev. 1. 1978. *Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components.* Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 2787.

138431 NRC (U.S. Nuclear Regulatory commission) 1987. "Design of Structures Components, Equipment and Systems." Chapter 3 of *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants.* NUREG-0800. Washington D.C.: U.S. Nuclear Regulatory commission. TIC:203894.

13.3 SOURCE DATA

184683 MO0801SCSPS1E4.003. Strain Compatible Material Properties for the Surface Facilities Area at 1E-4 Annual Probability of Exceedance. Submittal Date: 01/11/2008.

184682 MO0801SCSPS5E4.003. Strain Compatible Material Properties for the Surface Facilities Area at 5E-4 Annual Probability of Exceedance. Submittal Date: 01/11/2008.

185929 MO0805DSDR1E3A.000. Seismic Design Spectra for the Surface Facilities Area at 1E-3 APE For Multiple Damping Levels. Submittal date: 05/16/2008

185930 MO0805DSDR5E4A.000. Seismic Design Spectra for the Surface Facilities Area at 5E-4 APE For Multiple Damping Levels. Submittal date: 07/01/2008

185931 MO0805DSDR1E4A.000. Seismic Design Spectra for the Surface Facilities Area at 1E-4 APE For Multiple Damping Levels. Submittal date: 07/01/2008

185936 MO0805TH1E3APE.000. Time Histories for the Surface Facilities Area at 1E-3 APE. Submittal date: 05/06/2008

185953 MO0805TH5E4APE.000. Time Histories for the Surface Facilities Area at 5E-4 APE. Submittal date: 06/30/2008

185952 MO0805TH1E4APE.000. Time Histories for the Surface Facilities Area at 1E-4 APE. Submittal date: 07/01/2008

186003 MO0901HCUHSSFA.002. Mean Ground Motion Hazard Curves and Mean Uniform Hazard Spectra for the Surface Facilities Area. Submittal date: 01/14/2009.

185935 MO0805DSRB5E4A.000. 5%-Damped Seismic Design Spectra for the Repository Block at 5E-4 APE. Submittal date: 07/02/2008.

13.4 SOFTWARE CODES

178238 SAP2000 V. 9.1.4. 2005. WINDOWS XP. STN: 11198-9.1.4-00.

182945 SASSI2000 V. 3.1. 2007. WINDOWS XP. STN: 10825-3.1-00.

APPENDIX B
EVALUATIONS FOR BDBGM

The ITS structures analyzed and designed in accordance with Sections 7 and 8 need to be evaluated for BDBGM. The goals of these evaluations are: (1) to demonstrate that there is margin beyond the rare earthquakes with a 10,000-year return period, and (2) to establish approximate fragility curves for the structures for a limited probabilistic risk assessment using Conservative Deterministic Failure Margin (CDFM) methodology described in Section B3.1 below. However, fragility for equipment and components will be based on the median-centered fragility analysis method as noted in Section B3.4.

The evaluations for BDBGM will be carried out using the mean-centered seismic hazard curves. A seismic hazard curve shows the annual probability of exceedance versus a defined ground motion parameter. A typical curve is shown in Figure B-1. The ground motion parameter in this figure is the peak ground acceleration. Seismic hazard curves at 5 and 10 Hz (or the average of 5 and 10 Hz) will result in more realistic evaluations and may be used on this project. The seismic analyses and the evaluations performed for BDBGMs are described in Sections B1 through B3.4.

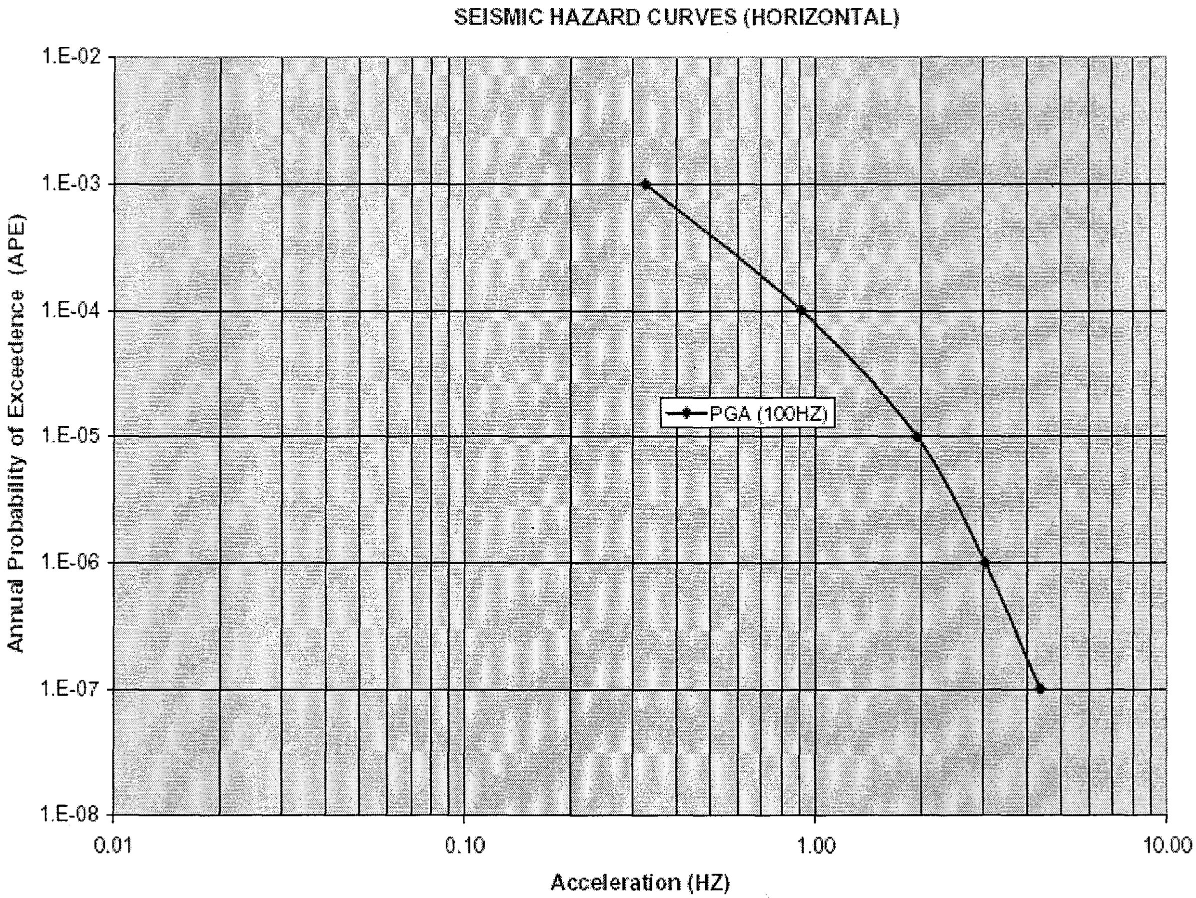

Figure B-1. Example Seismic Hazard Curve for YMP

Failure (HCLPF) capacity that exceeds the designated review level earthquake, termed BDBGM event for Yucca Mountain facilities (BSC 2007 [DIRS 181572])

Seismic margins assessment is based on a comparison of a conservative estimate of the *capacity* of the facility to maintain safety functions with the *demand* imposed by "review level earthquake" ground motions. HCLPF capacities (see Section B3) will be estimated for ITS structures using the Conservative Deterministic Failure Margin (CDFM) approach, following the guidance given in *A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1)* (EPRI 1991 [DIRS 161330]). The HCLPF capacity is defined as the ground motion level at which there is a mean conditional probability of unacceptable performance of 0.01 or less. ASCE 4-98 [DIRS 159618], Appendix A, provides a discussion of the applicability of the seismic margin analysis approach to demonstrate seismic safety of plants designed using NUREG-0800 (NRC 1987 [DIRS 138431]) codes and standards. As discussed in Section B3, the HCLPF capacity estimates will also be used to develop fragility curves for the probabilistic seismic analyses for the compliance demonstration.

The seismic margins evaluation will ensure that the HCLPF capacity of individual ITS structures is greater than the demand imposed on the structures by the BDBGM event. It is recommended that approximately 10% margin be provided as per Equation B-2 below:

$$(C_{HCLPF}/D_{BDBGM}) \geq 1.10 \qquad \text{(Eq. B-2)}$$

Satisfaction of the above equation will ensure that adequate seismic design margin will exist for ITS structures, such that they will maintain their defined functions credited in the preclosure safety analysis to prevent or mitigate dose consequences. Although the seismic margins assessment is not a demonstration of compliance with the preclosure performance objectives in 10 CFR 63.111 [DIRS 176544], its widespread precedent in seismic safety evaluation for nuclear power facilities will ensure the adequacy of the seismic design bases and the design codes and design procedures.

B3 FRAGILITIES FOR LIMITED PROBABILISTIC SEISMIC ANALYSES

For compliance with the requirements of 10 CFR 63.111(b)(2) [DIRS 176544], limited probabilistic seismic analyses will be performed, considering the seismic hazard and the behavior of ITS structures under seismic loads. These evaluations require definition of fragility curves for the individual components or event sequences.

This subsection defines the approach to be used in fragility calculations. Prior to the calculations, the permissible limit states will be defined per ASCE/SEI 43-05 [DIRS 173805], Table 1-4. A fragility curve shows the probability of unacceptable seismic performance as a function of a ground motion parameter such as peak ground acceleration or dominant spectral acceleration. Seismic fragilities will be developed as a function of the limit states and ground motions using the methods described in Sections B3.1 to B3.5.

B3.2 DETERMINATION OF CDFM CAPACITY

By definition, the CDFM capacity of any structure can be estimated from:

$$C_{CDFM} = F_S * F_\mu * BDBGM \qquad \text{(Eq. B-6)}$$

where

BDBGM = Beyond design basis ground motion parameter for which the structure has been evaluated

F_S = computed strength margin factor

F_μ = inelastic energy dissipation factor

B3.2.1 Strength Margin Factor

The strength margin factor is given by:

$$F_S = \frac{F_C C_C - D_{NS}}{D_{BDBGM}} \qquad \text{(Eq. B-7)}$$

where

C_C = capacity computed using code capacity acceptance criteria (including code specified strength reduction factors ϕ)

D_{NS} = expected concurrent non-seismic demand

D_{BDBGM} = seismic demand computed for the BDBGM input in accordance with the requirements of ASCE 4-98 [DIRS 159618], Section 3.1.1.2

F_C = capacity increase factor based on information from EPRI (1991 [DIRS 161330], Equation 2-6) and from Kennedy (2001 [DIRS 155940], Appendix A)

$$F_C = \frac{C_{98\%}}{C_C} \qquad \text{(Eq. B-8)}$$

where $C_{98\%}$ is the estimated 98% exceedance probability capacity.

The estimate of $C_{98\%}$ capacity for the shear strength of low-rise concrete shear walls will be based on ASCE/SEI 43-05 [DIRS 173805], Section 4.2.3. A number of examples for estimating $C_{98\%}$ for other structures are given by EPRI (1991 [DIRS 161330], e.g., Appendices L and M), and this guidance will be followed. When data are inadequate to estimate $C_{98\%}$ or for the sake of simplicity, F_C can be taken as 1.0.

B3.2.2 Non-Linear Margin Factor

In the CDFM method (Kennedy 2001 [DIRS 155940], Section A.2.4; EPRI 1991 [DIRS 161330], Table 2-5), the inelastic energy dissipation factor, F_μ, is estimated at the 95% exceedance probability. Generic estimates of the 95% exceedance probability F_μ for structures are given in ASCE/SEI 43-05 [DIRS 173805], Tables 5-1 and 8-1 for Limit States A, B, and C (F_μ values are unity for Limit State D). The corresponding drift and rotation limits are given in Tables 5-2 and 5-3, respectively, of ASCE/SEI 43-05 [DIRS 173805]. The basis for the low-rise concrete shear wall drift limits is presented in ASCE/SEI 43-05 [DIRS 173805].

As an example, the lateral drift per story of a low-rise concrete shear wall (height to length ratio less than 2.0) is limited to less than 0.4% of the story height for Limit State C per Table 5-2 of ASCE/SEI 43-05 [DIRS 173805]. Thus, for a 10 ft story height, the lateral drift is limited to 0.48 in. This limit provides high confidence that shear cracks in the wall will be small and that the ultimate strength of the wall will not be reduced by a few cycles of plus and minus distortion carried to this drift limit. The wall retains its full strength and serviceability. This 0.4% of the story height drift limit is identical to the drift limit specified in DOE-STD-1020-94 [DIRS 161324], Section 2.3, for low-rise concrete shear walls.

B3.3 REFINEMENT OF FRAGILITY ESTIMATES

For some unique systems and components, estimates of the CDFM capacity and β values may be difficult due to lack of data in the literature. In such cases, confirmatory nonlinear analyses may be carried out to establish the fragility curve for the system or component. Although not anticipated, a similar approach may also be used for structures.

Such analyses will be performed for a BDBGM established at the 10^{-4} per year exceedance frequency. After completion of the BDBGM non-linear evaluation, the same non-linear model of the system or component can be used to refine the CDFM capacity estimate. The refined CDFM capacity estimate is then incorporated into the probabilistic calculations.

B3.4 FRAGILITY ESTIMATES FOR COMPONENTS

Development of the fragility curve for structural type components will follow similar analytical methodology as for the structures described in the preceding sections. However, for equipment and components the development of fragility curves will be based on median-centered fragility analysis method described in Section 4.4.4 of DOE 2007 [DIRS 181572].

In cases where the fragility curve is difficult to establish by analytical methods or if no information is available from the literature, testing may be performed to determine the fragility of a component. By performing testing with increasingly higher input motion, a fragility curve

Once the preliminary design of the structure for DBGM-2 is completed, the fragility calculations are performed using the following steps:

Step 1. Statically analyze the structure under both the non-seismic and seismic loads using an appropriate model. For the seismic loads, use the beyond design basis ground motion (BDBGM) as input.

Step 2. Determine the seismic demand under BDBGM for sections (concrete) or members (steel).

Step 3. Determine the capacities based on strength (concrete) or allowable stresses (steel).

Step 4. Determine the available strength margin (F_S) for both concrete and steel.

Step 5. Determine the allowable energy dissipation factor (F_μ).

Step 6. Calculate the HCLPF capacity using the Conservative Deterministic Failure Margin (CDFM) method.

Step 7. Determine the composite logarithmic standard deviation, β.

Step 8. Develop the mean seismic fragility curve in terms of conditional probability of failure as a function of seismic ground motion parameter such as peak ground acceleration (PGA) or 5% damped spectral acceleration at a specified natural frequency. Considering the soil-structure interaction frequency of structures ITS at high ground motion levels, spectral accelerations at 5 Hz could be used.

Once the mean seismic fragility curve is known, the probability of unacceptable behavior of the structure can be estimated by convolving the seismic hazard curves with the fragility curves.

NOTE: In the above steps, instead of BDBGM, the DBGM-2, or any other level of ground motion for which the structures are analyzed, may be used.

B4.3 HCLPF CALCULATIONS FOR CONCRETE STRUCTURES

By definition, HCLPF is the ground motion level at which there is less than 1% probability of unacceptable behavior under seismic loads. Expressed differently, it is the ground motion level corresponding to 99% non-exceedance probability. HCLPF may be expressed in terms of a ground motion parameter such as PGA or 5% spectral acceleration at a specified natural frequency.

HCLPF calculations must consider the mode of failure that will control the behavior of the structure, i.e., the "weakest link." Based on experience with seismic probabilistic risk assessments for nuclear plants, the HCLPF capacity is based on in-plane shear demand-capacity calculations for walls and out-of-plane bending requirements for the slabs. However, other modes of failure will be considered to establish confidence in the process as discussed in Section 5. Furthermore, the HCLPF capacity for the entire structure will be conservatively set equal to the lowest HCLPF capacity of a major wall or a slab.

Although the fragility calculations will be carried out for in-plane shear (walls) and out-of-plane moment (slabs), the other section forces will also be determined to demonstrate that any other failure mode will have a higher capacity than the HCLPF capacity obtained in the evaluations (See Section 5). The additional evaluations will be performed at any section with the highest demand/capacity ratios.

Step 3 Capacity Calculations

At this stage it is necessary to determine a preliminary reinforcement pattern (sizes and spacing) for the walls and slabs. The capacity calculations will be carried out using the preliminary design. As noted above, the fragility calculations for walls will be based on the in-plane shear demand and for slabs, out-of-plane bending moment demand.

Capacities for structures and components should be defined at about 98% exceedance probability. In the capacity calculations for concrete, use of the minimum specified concrete design strength and appropriate capacity reduction factor approximates the 98% probability of exceedance of shear wall or slab capacity. If actual concrete compressive strength data are available, use of the 95% exceedance probability material strength in combination with the code capacity equations, including the appropriate capacity reduction factors, will also achieve an overall shear wall or slab capacity at about the 98% exceedance probability. Concrete compressive strength increases are likely to range from 10% to 45% over the minimum specified 28-day strength (EPRI 1991 [DIRS 161330], p. 2-52). Therefore, for preliminary fragility calculations, it is reasonable to use a 10% increase in the minimum specified concrete design strength to estimate the 95% exceedance probability material strength. During construction or prior to operations, the project will verify the actual 95% exceedance probability of concrete material strength. Future project concrete specifications will include a requirement that cylinders shall be tested at 28 days and additional cylinders shall be tested at 90 days and one year to verify the actual strength.

For shear, the in-plane shear capacity will be calculated using the following equation (ASCE/SEI 43-05 [DIRS 173805]):

$$v_u = \phi\left[8.3\sqrt{f_c'} - 3.4\sqrt{f_c'}\left(\frac{h_w}{l_w} - 0.5\right) + \frac{N_A}{4l_w t_w} + \rho_{se} f_y\right] \qquad \text{(Eq. B-9)}$$

where

ϕ = capacity reduction factor,

f_c' = concrete compressive strength,

h_w = wall height,

l_w = wall length,

N_A = axial force (compression is positive),

t_w = thickness of the wall,

ρ_{se} = horizontal reinforcement ratio,

f_y = yield strength of reinforcing steel.

In this calculation, use a ϕ-factor of 0.8, consistent with ASCE/SEI 43-05 [DIRS 173805]. Equation B-9 implies that the in-plane bending moment does not significantly affect the in-plane shear capacity of a wall.

The total in-plane shear capacity, V_U, is then calculated from:

$$V_U = v_u d t_w \qquad \text{(Eq. B-10)}$$

Where d = the distance (in-plane) from extreme compression to the centroid of the tension reinforcement which can be determined from a strain-compatible section analysis. If such an analysis is not available, conservatively use $d = 0.6l_w$.

For out-of-plane bending, determine the capacity using the classical equation:

$$M_U = \phi(A_s f_y(d-a/2)) \qquad \text{(Eq. B-11)}$$

where

ϕ = 0.9, capacity reduction factor in bending,

A_s = the area of total reinforcement on one face of the slab,

f_y = the specified minimum yield strength of the reinforcement,

d = distance from the compression fiber to the centroid of the bending reinforcement, (note that d = length of the wall in shear calculations but it is the distance to the centroid of tension reinforcement perpendicular to the plane of the slab in bending calculation)

a = depth of the equivalent stress block.

In the case of flexure, combination of the use of a ϕ-factor of 0.9 and the minimum specified yield strength of reinforcing steel will result in approximately 98% exceedance level.

For slabs supported by beams and girders, a more detailed capacity calculation that will consider the contributions of the beams and girders, and the effect of composite action (if applicable) may be carried out.

Step 4 Strength Margin Factor, F_s

F_s is defined as the strength margin factor, i.e., a factor by which the calculated seismic demand at any cut section can be increased to reach a total demand / capacity ratio of unity. In equation form:

$$F_s = \frac{C_{98\%} - D_{NS}}{D_{BDBGM}} \qquad \text{(Eq. B-12)}$$

where $C_{98\%}$ is the section capacity at 98% probability of exceedance, D_{NS} is the non-seismic demand and D_{BDBGM} is the seismic demand under BDBGM.

Step 7 Estimation of Composite Variability, β

In general, fragility curves are defined by the median capacity and two lognormally distributed random variables β_R and β_U which define the uncertainty and randomness (Kennedy 2001 [DIRS 155940]). It is sufficient to define the fragility curve by a single mean (composite) fragility curve defined by a median capacity and composite logarithmic standard deviation β_c given by:

$$\beta_c = (\beta_R^2 + \beta_U^2)^{1/2} \qquad \text{(Eq. B-16)}$$

Studies show that the composite logarithmic standard deviation value ranges between 0.3 and 0.5 for structures (Kennedy 2001 [DIRS 155940], ASCE 2005 [DIRS 173805]). The lower value of β_c will result in higher probability of unacceptable behavior (see Figure B-2). Therefore, only $\beta_c = 0.3$ need to be used in the calculations and explicit calculation of the β_c value is not necessary. Higher values of β_c may be used to perform additional calculations to develop insight on the resulting probabilities.

Step 8 Mean Fragility Curves

With the HCLPF capacity known, the median capacity is determined from the following equation

$$C_{50\%} = C_{1\%}\ e^{2.326\beta} \qquad \text{(Eq. B-17)}$$

where β is the logarithmic standard deviation. .

Once the median capacity is established, the mean fragility curve is given by the following equation:

$$C_{X\%} = C_{50\%} e^{z\beta} \qquad \text{(Eq. B-18}$$

where

C_x = Capacity at 'x' exceedance probability (non-exceedance)

z = Value of normal variant (standard deviation) corresponding to "x"

The capacities obtained from Equation B-18 for each probability of exceedance are convolved with the seismic hazard curves to estimate the probability of unacceptable behavior.

B4.4 HCLPF CALCULATIONS FOR STEEL STRUCTURES

Steel Frames at YMP

At YMP, steel structures will be mostly braced frames. In general, concentric bracing (between two beam-column joints) but occasionally chevron bracing (inverted v connected to a beam, with the other ends connected to beam-column joints) will be used to accommodate access requirements. In rare cases there may be a need to use special moment frames. In the braced then, FS can be approximated as

$$F_S = \frac{1-\alpha_{NS}}{\alpha_S} \quad \text{(Eq. B-27)}$$

Step 6 Allowable Energy Dissipation Factors

Allowable energy dissipation factors (i.e., ductility of members) are given in ASCE/SEI 43-05 [DIRS 173805]. The approach described above is consistent with ASCE/SEI 43-05 [DIRS 173805] which provides the following criteria for braced frames (Section 6.1.2):

1. Energy Dissipation is permitted for bracing members only.
2. All other members are required to remain elastic under the design loads. (see ASCE/SEI 43-05 [DIRS 173805] 6.1.2).

For fragility calculation, the following energy dissipation factors will be utilized:

Table B-1. Allowable Energy Dissipation Factors for Steel Structures

Item	Member Type	F_μ
a	Braced frames: braces	2.50
b	Braced frames: beams connected to chevron braces	2.50
c	Moment frames: beams	2.50

Item "a" is consistent with ASCE/SEI 43-05 [DIRS 173805] Table 5.1 for Limit State "A". Item "b" is not explicitly addressed in ASCE/SEI 43-05 [DIRS 173805]. However, energy dissipation factor of greater than unity is reasonable for beams connected to chevron braces since most of the seismic load will be applied to the beam as bending moment with small axial load relative to the capacity of the member. Therefore, similar to columns with small axial load in moment frames, it is reasonable to assume "F_μ" > 1.0. The value of $F_\mu = 2.5$ is consistent with the value for the bracing member and is judged to be appropriate for beams connected to chevron bracing for Limit State "A".

For the moment frames, the allowable energy dissipation factor of 2.50 corresponds to Limit State C. This value was chosen for consistency and is conservative.

B4.5 ENERGY DISSIPATION FACTOR AND CONFINEMENT

In Sections B4.3 and B4.4 of this Appendix, the reference limit states used were Limit State A (large permanent distortion, no confinement) and Limit State C (limited permanent distortion, HVAC-controlled confinement). The energy dissipation factors given in those sections are consistent with the limit states. In some cases Limit State D (elastic response, no damage) may need to be specified, with an energy dissipation factor, $F_\mu = 1.0$. For this limit state, the *Basis of Design for the TAD Canister-Based Repository Design Concept,* (BSC 2008 [DIRS 185694]) specifies the following requirements:

> Performance Goal for Building collapse $\leq 2 \times 10^{-6}$ [mean frequency of 10^{-4} over a preclosure period of 50 years].

The HCLPF capacities are computed for establishing the fragility curves that will be convolved with the seismic hazard curves for determination of the performance factors to meet the performance goals. The HCLPF capacity is computed by combining Equations B-3 and B-6, as follows.

$$C_{HCLPF} = (F_S)\,(F_\mu)\,(PGA) \qquad \text{(Eq. B-34)}$$

The performance goal is accomplished as follows:

1. By having an appropriate HCLPF capacity determined by Equation B-34 with the F_μ factor associated with Limit State A defined in ASCE/SEI 43-05 [DIRS 173805]

2. By having the HCLPF capacity determined by the Equation B-34 with the energy dissipation factor F_μ associated with limit state D defined in ASCE/SEI 43-05 [DIRS 173805]

B5 SPECIAL EVALUATIONS

The HCLPF calculations discussed in the previous sections imply that the behavior of the structure is controlled by the section (concrete) or member (steel) with the lowest HCLPF value. It also implies that, any of the other failure modes will not occur in the lateral load path prematurely in any other member. In order to demonstrate the validity of this implicit assumption, additional evaluations must be carried out. This section provides the minimum additional evaluations for concrete and steel buildings as part of estimation of probability of unacceptable behavior.

Special Provisions for Concrete Structures

For concrete structures, the first onset of significant inelastic deformation (FOSID) value was based on in-plane shear for walls and out-of-plane bending for slabs. In order to demonstrate the adequacy of the entire structure, the additional evaluations shown in the following table must be carried out:

Step 7. Alternatively, foundation springs and damping coefficients can be used in SAP2000 [DIRS 178238] analysis. To use damping coefficients in SAP2000, a time history analysis should be performed using a direction-time integration method. Structural damping can be specified by mass and stiffness proportional damping as described in ASCE 4-98 [DIRS 159618], Section 3.1.5.2. Care must be taken in applying mass and stiffness proportional damping so as to not apply additional damping to the soil springs.

The additional caveats for the bounding calculations are:

- The soil and rock properties down to 500 ft have been provided in DTN: MO0801SCSPS5E4.003 [DIRS 184682]. These properties are given for both 35 and 110 ft depths of alluvium layers as required in Step 1. In equivalent shear modulus calculations, use either the entire depth or the depth to a point where the normal stress is less than 0.2 times the stress at the surface. Use Poisson's ratio of 0.3 as recommended in the *Supplemental Soils Report* (BSC 2008 [DIRS 185630]) for both alluvium and the tuff in these calculations.

- If there is any structural fill, the fill properties will be taken as equivalent to those of the alluvium. If the fill characteristics are determined to be different than those of the alluvium, additional parametric studies may need to be carried out.

APPENDIX F
SEISMIC REQUIREMENTS FOR MECHANICAL EQUIPMENT

F1 SCOPE

Section 7.5 of this document covers seismic analysis of systems and components which includes mechanical equipment. Section 8 covers the seismic design of ITS SSCs.

This appendix is provided to document design requirements for specific mechanical equipment currently being specified. It is expected that the list of equipment will grow over time and this appendix will be updated, as required.

F2 EQUIPMENT REQUIREMENTS

Table F1 shows the seismic requirements for the following equipment:

- Aging Overpack and Aging Cask (A.O.)
- Shielded Transfer Cask-Vertical (STC)
- Shielded Transfer Cask-Horizontal (STC)
- Tractor and Trailer (included with STC Horizontal)
- Transporter for Vertical A.O.
- Spent Fuel Transfer Machine (SFTM)

The seismic requirements were established as a result of discussions between engineering and the PCSA group personnel. The requirements are intended to maintain the functionality of each equipment after the design basis earthquake (DBGM-2). In addition, some of the equipment must be evaluated for BDBGM in order to demonstrate that their annual probability of exceedance (APE) for the failure modes listed in the table are less than or equal to 2E-6.

The horizontal and vertical response spectra for the extreme seismic event (APE 2E-6) are available in MO0901HCUHSSFA.002 [DIRS 186003]). The corresponding digitized response spectra for the extreme seismic event (APE 2E-6) are also available in MO0901HCUHSSFA.002 [DIRS 186003]). Table F1 lists the seismic requirements for selected mechanical equipment.

Figure F-1. NOT USED

Table F2. NOT USED