

Project 17 – Development of Next-Generation Seismic Design Values Maps

Multi-Period Spectral Parameters (of the 2020 NEHRP Provisions and ASCE 7-22)

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Project 17 Meeting July 18 , 2016
PUC Meeting – July 19, 2016)



Project 17 Planning Committee Report Recommendations – Scope - Multi-Period Spectral Values

- During the closing months of the 2015 PUC cycle, study was undertaken of compatibility of current Site Class coefficients, F_a and F_v with the NGA ground motion prediction equations (GMPEs) used by USGS to produce the design maps. In the course of this study, it was discovered that the standard spectral shape derived from the S_{DS} , S_{D1} , and T_L parameters is not appropriate for soft soil sites (Site Class D or softer) where hazard is dominated by large magnitude events. Specifically, on such sites, the standard spectral shape overstates the spectral demands for short period structures, and substantially understates spectral demand for moderately long period structures. The PUC initiated a proposal to move to specification of spectral acceleration values over a range of periods, abandoning the present three parameter format, as this would provide better definition of likely ground motion demands. However, this proposal was ultimately not adopted due to both the complexity of implementing such a revision in the design procedure and time constraints. Instead, the PUC adopted a proposal prohibiting the use of the general three-parameter spectrum, and instead requiring site-specific hazard determination for longer period structures on soft soil sites.
- Project 17 is charged with re-evaluating the use of multi-period spectra as a replacement or supplement to the present three-parameter spectral definition. If the multi-period spectral definition is indeed adopted, then Project 17 should also evaluate whether basin effects, near field effects and other effects typically included in site-specific studies should be considered in development of the maps. It will also be necessary for the Project 17 Committee to consider how the basic design procedures embedded in ASCE 7 should be modified for compatibility with the multi-period spectra.



Project 17 Planning Committee Report Recommendations – Level of Effort

- **Task Committee Multi-Period Spectral Values:**

This committee should include approximately 7 persons including practicing structural and geotechnical engineers; and, USGS representatives. It is envisioned that this task committee will meet once per quarter for a period of 18 months, then twice per year for the remaining project duration.

- **Task Committee Members:**

Charlie Kircher – CKA (Chair)

Nico Luco - USGS

Sanaz Razaeian – USGS

C.B. Crouse - AECOM

Jonathan Stewart - UCLA

John Hooper – MKA

David Bonneville - Degendkolb



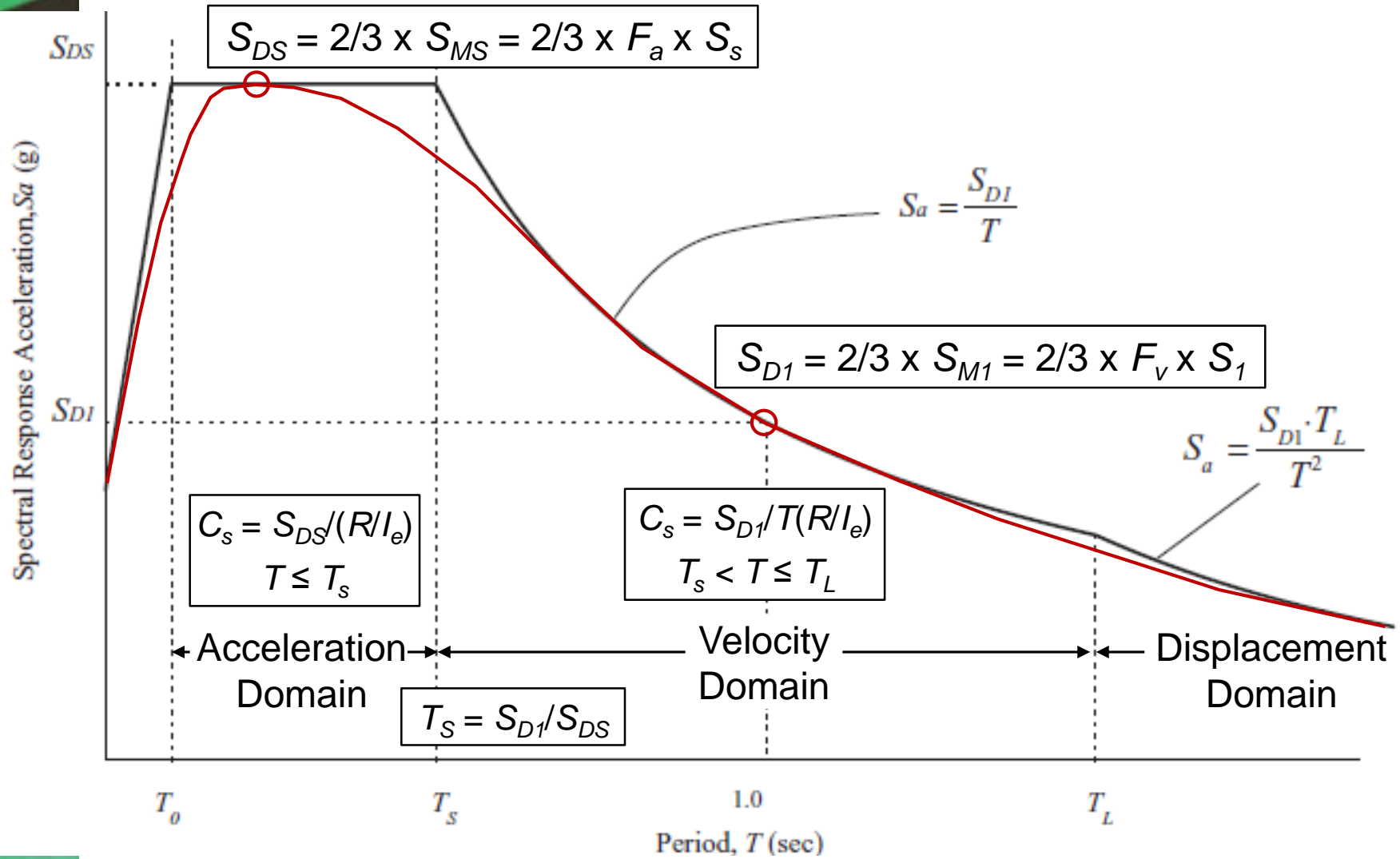
Topics

- Background Material
 - Design Response Spectrum (Figure 11.4-1 of ASCE 7-16)
- The Problem – Root Cause
- Short-Term Solution (ASCE 7-16)
 - Option 1 – Reformulate Design Parameters
 - Option 2 - Revise Site-Specific Requirements
- Long-Term Solution (ASCE 7-22)
 - *Project 17* – multi-period design spectra and parameters
- May 17, 2016 Task Committee Meeting
 - Discussed pertinent topics
 - Developed conceptual Code improvements



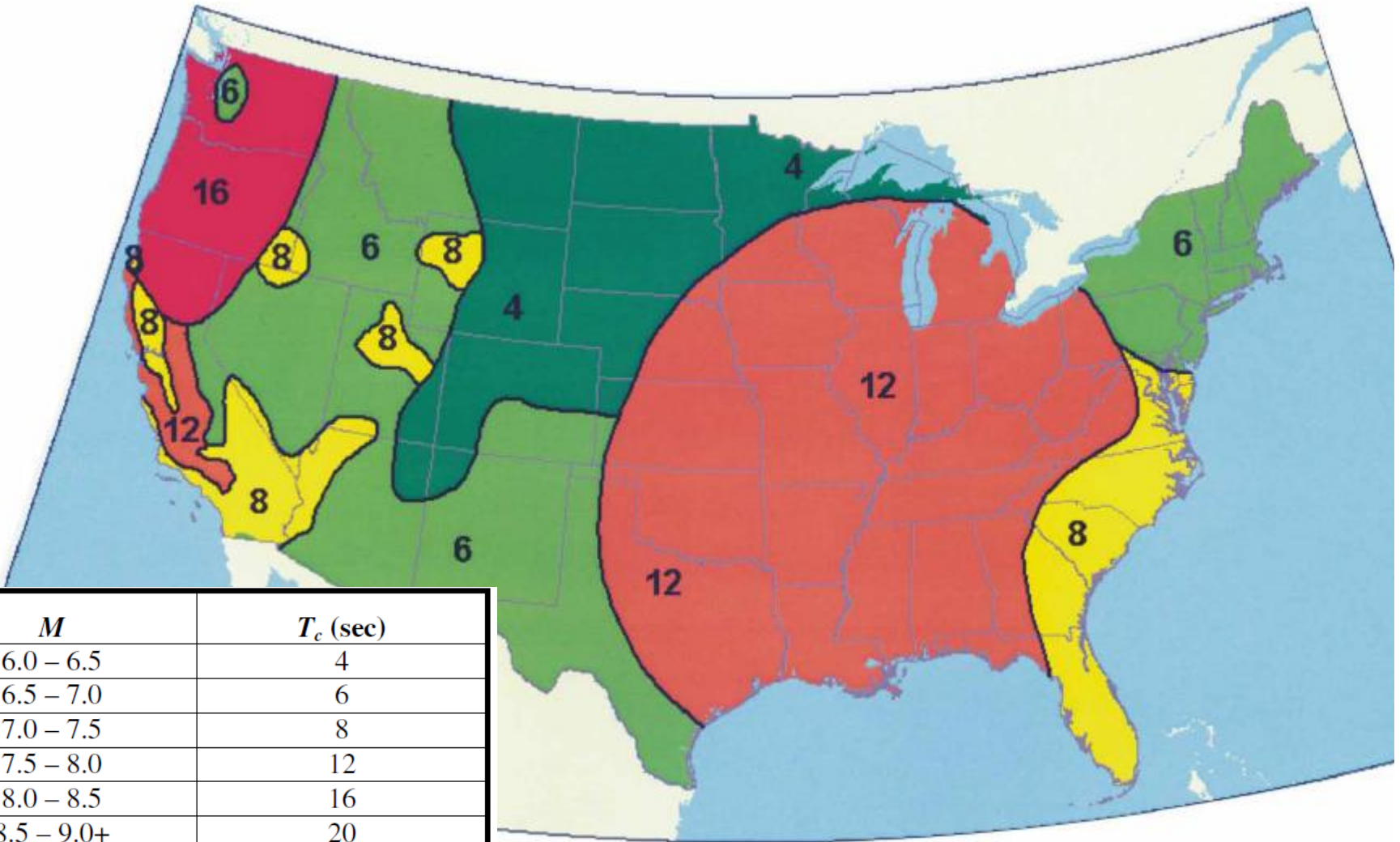
Design Response Spectrum

(Figure 11.4-1, ASCE 7-16 with annotation)



Background - Map of T_L Regions (and Relationship to Earthquake Magnitude)

(Chapter 22, ASCE 7-05, ASCE 7-10 and ASCE 7-16)



M	T_c (sec)
6.0 – 6.5	4
6.5 – 7.0	6
7.0 – 7.5	8
7.5 – 8.0	12
8.0 – 8.5	16
8.5 – 9.0+	20



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New Values of the Site Coefficient, F_a (Table 11.4-1 of ASCE7-16) (shown as proposed changes to ASCE 7-10)

Table 11.4-1 Site Coefficient, F_a

Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at Short Period					
	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.7$	$S_S = 1.0$	$S_S = 1.25$	$S_S \geq 1.5$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	1.0 0.9	1.0 0.9	1.0 0.9	1.0 0.9	1.0 0.9	0.9
C	1.2 1.3	1.2 1.3	1.1 1.2	1.0 1.2	1.0 1.2	1.2
D	1.6	1.4	1.2	1.1	1.0	1.0
E	2.5 2.4	1.7	1.2 1.3	See Section 11.4.7		
F	See Section 11.4.7					

Note: Use straight-line interpolation for intermediate values of S_S . At the Site Class B-C boundary, $F_a = 1.0$ for all S_S levels. If site classes A or B is established without the use of on-site geophysical measurements of shear wave velocity, use $F_a = 1.0$.

Note – Site Class B is no longer the “reference” site class of MCE_R ground motion parameters S_S and S_1 (i.e., new coefficients reflect Site Class BC boundary of 2,500 f/s) and Site Class D is no longer the “default” site class (since Site Class C amplification is greater in some cases)

Note – Site-Specific analysis is required for Site Class E sites where $S_S \geq 1.0$



New Values of the Site Coefficient, F_v (Table 11.4-2 of ASCE7-16) (shown as proposed changes to ASCE 7-10)

Table 11.4-2 Site Coefficient, F_v

Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameter at 1-s Period					
	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 = 0.5$	$S_1 \geq 0.6$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	1.0 0.8	1.0 0.8	1.0 0.8	1.0 0.8	1.0 0.8	0.8
C	1.7 1.5	1.6 1.5	1.5	1.4 1.5	1.3 1.5	1.4
D	2.4	2.0 2.2	1.8 2.0	1.6 1.9	1.5 1.8	1.7
E	3.5 4.2	3.2 3.3	2.8	2.4	2.4 2.2	2.0
F	See Section 11.4.7					

Note: Use straight-line interpolation for intermediate values of S_1 . At the Site Class B-C boundary, $F_v = 1.0$ for all S_1 levels. If site classes A or B are established without the use of on-site geophysical measurements of shear wave velocity, use $F_v = 1.0$.

Note – Site Class B is no longer the “reference” site class of MCE_R ground motion parameters S_s and S_1 (i.e., new coefficients reflect Site Class BC boundary of 2,500 f/s).

Note – Site-Specific analysis required for Site Class D sites where $S_1 \geq 0.2$ w/Exceptions

Site-Specific analysis required for Site Class E sites where $S_1 \geq 0.2$ w/o Exception



New Site-Specific Requirements of Section 11.4.7 of ASCE 7-16

- Site-specific ground motion procedures required for:
 - structures on Site Class E sites with S_S greater than or equal to 1.0.
 - structures on Site Class D and E sites with S_1 greater than or equal to 0.2.
- Exceptions permit ELF (and MRSA) design using conservative values of seismic coefficients:
 - Structures on Site Class E sites with S_S greater than or equal to 1.0, provided the site coefficient F_a is taken as equal to that of Site Class C.
 - Structures on Site Class D sites with S_1 greater than or equal to 0.2, provided the value of the seismic response coefficient C_s is increased by up to 50 percent at periods greater than T_s (by effectively extending the acceleration domain to $1.5T_s$).
 - Structures on Site Class E sites with S_1 greater than or equal to 0.2, provided that T is less than or equal to T_s and the equivalent static force procedure is used for design.



New Site-Specific Requirements of Section 21.4 of ASCE 7-16

- Section 21.4 – Improved derivation of design acceleration parameters S_{DS} and S_{D1} from a site-specific design spectrum:
- Base S_{DS} on 90 percent of the peak acceleration of the site-specific design spectrum (periods of 0.2s to 1s) – ignore 100 percent of the value at 0.2s

Consistently define domain of constant acceleration in terms of 90 percent of peak acceleration response regardless of the period of peak response (within the range 0.2s to 1s).

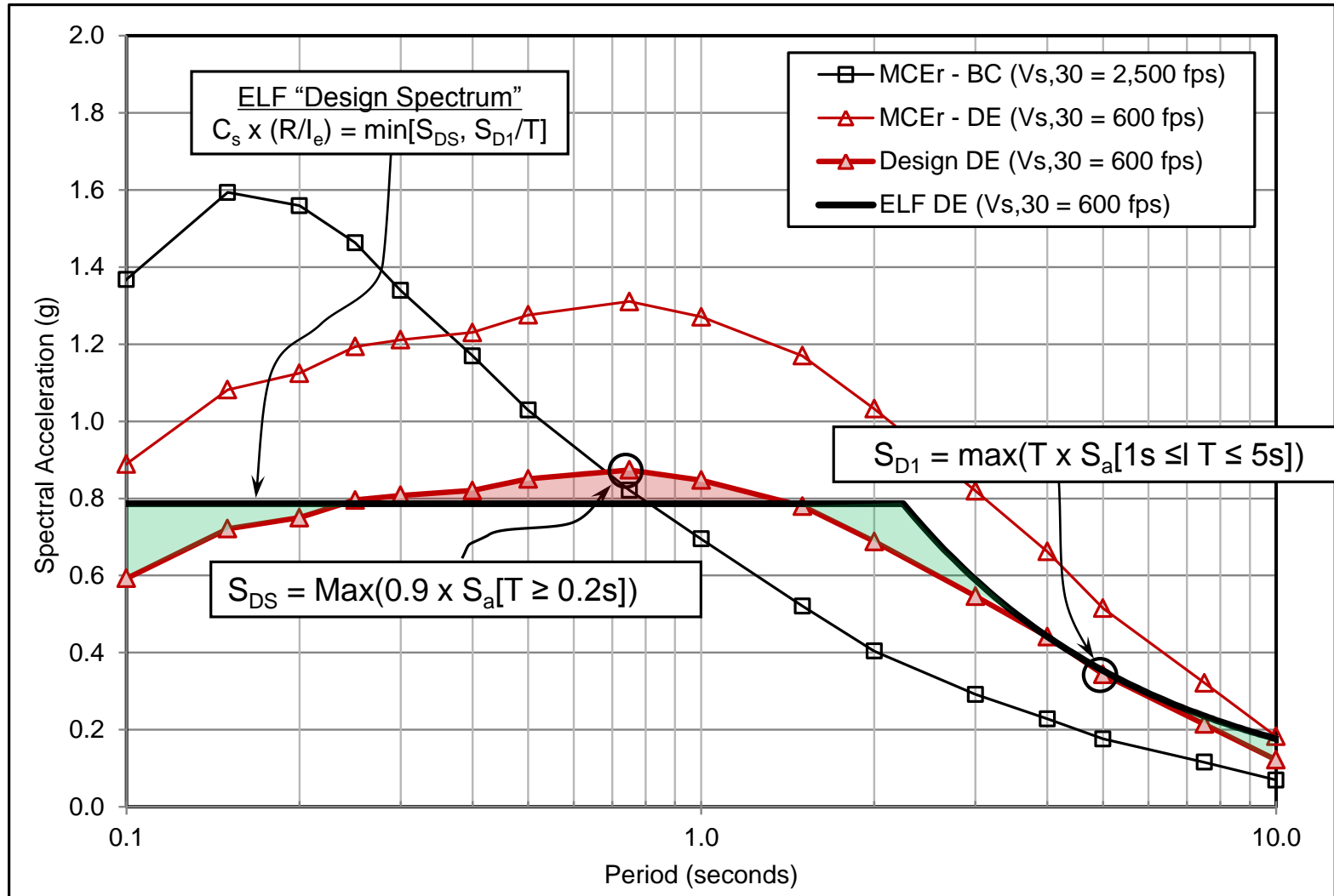
- Base S_{D1} on 100 percent of $T \times$ site-specific design spectrum at the period of peak velocity response (periods 1s to 5s)

Extend period range from 1s to 5s for Site Class D and E sites to avoid underestimating response in the domain of constant velocity for soil sites

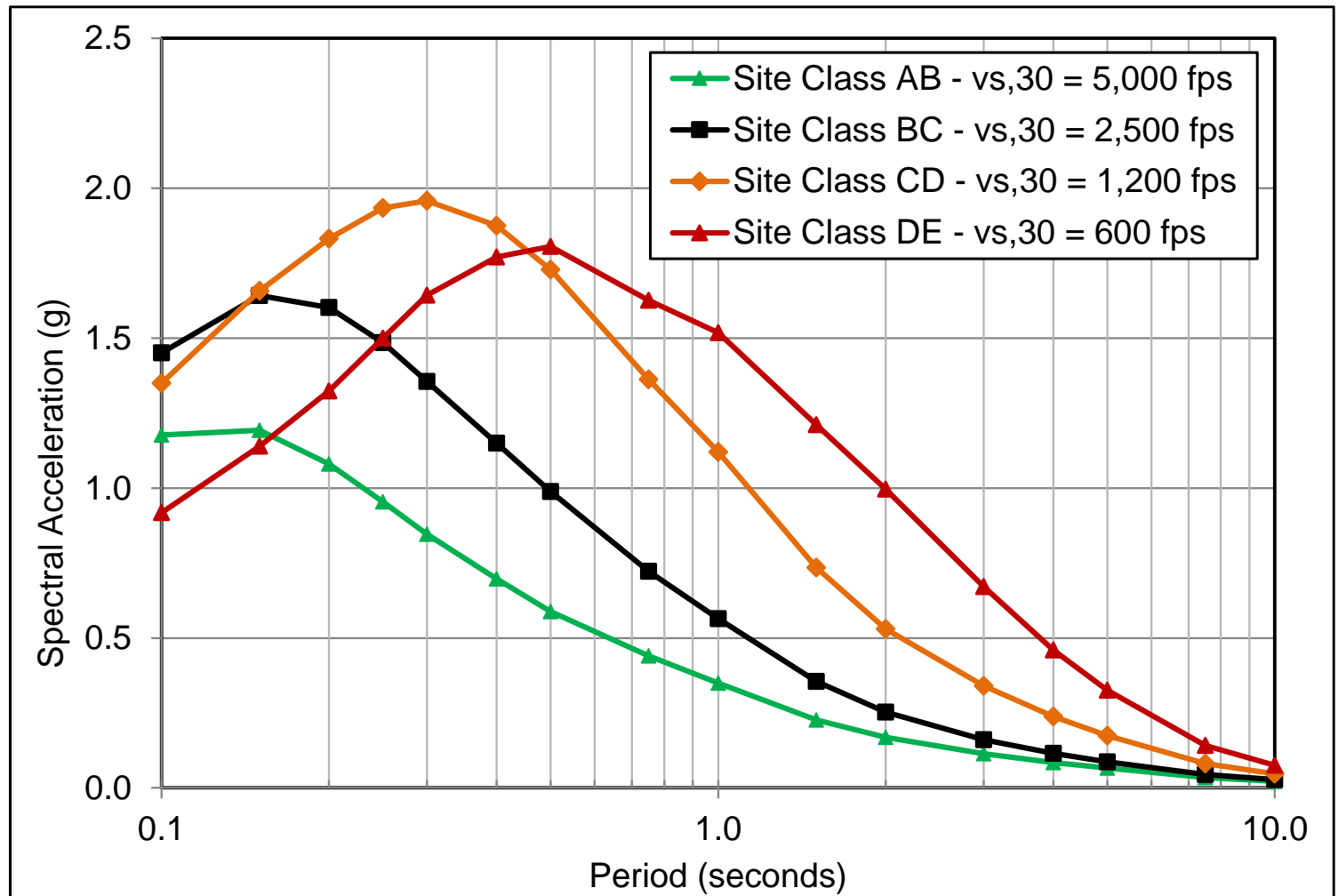


Illustration of the New Requirements of Section 21.4 of ASCE 7-16

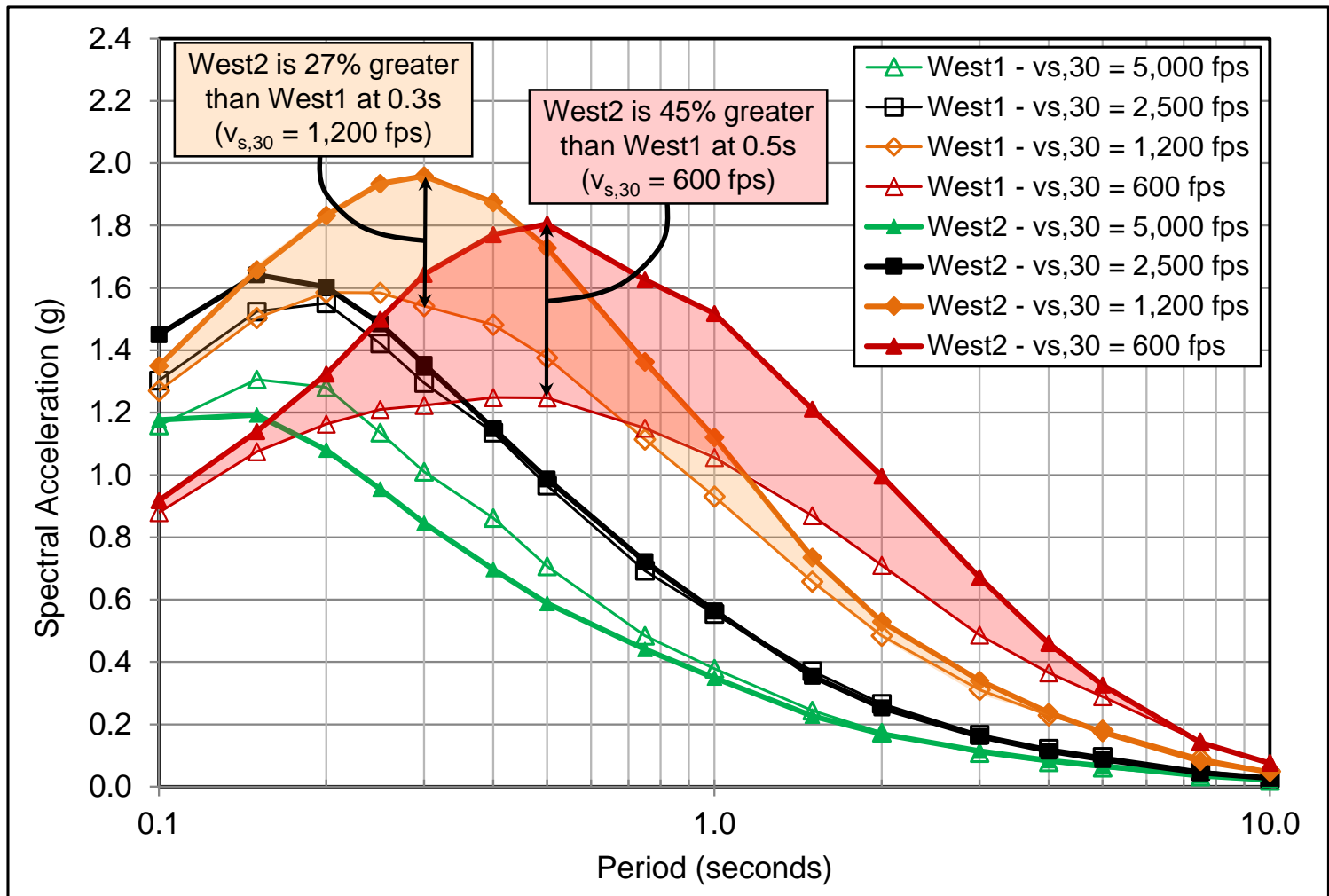
Site Class DE, M8 at R = 8.5 km (PEER NGA-West1 Relations)



Example Design Spectra - Deterministic MCE_R Ground Motions (ASCE 7-16) PEER NGA West2 GMPEs (M7.0 at $R_x = 6$ km, Site Class boundaries)



Example Comparison of Deterministic MCE_R Ground Motions NGA-West1 and NGA-West2 GMPEs (M7.0 at $R_x = 6$ km, Site Class boundaries)



PEER NGA GMPE spreadsheet calc's: West1 based on Al Atik, 2009, West2 based on Seyhan, 2014)



Root Cause of the “Problem”

(discovered by the late in the 2015 NEHRP Provisions update cycle)

- Section 11.4 of ASCE 7-10 (and ASCE 7-16) - Use of only two response periods (0.2s and 1.0s) to define ELF (and MRSA) design forces is not sufficient, in general, to accurately represent response spectral acceleration for all design periods
 - Reasonably Accurate (or Conservative) – When peak MCE_R response spectral acceleration occurs at or near 0.2s and peak MCE_R response spectral velocity occurs at or near 1.0s for the site of interest (i.e., frequency content matches the shape of the design response spectrum, Figure 11.4-1)
 - Potentially Non-conservative – When peak MCE_R response spectral velocity occurs at periods greater than 1.0s for the site of interest (e.g., soil sites whose seismic hazard is dominated by large magnitude events)

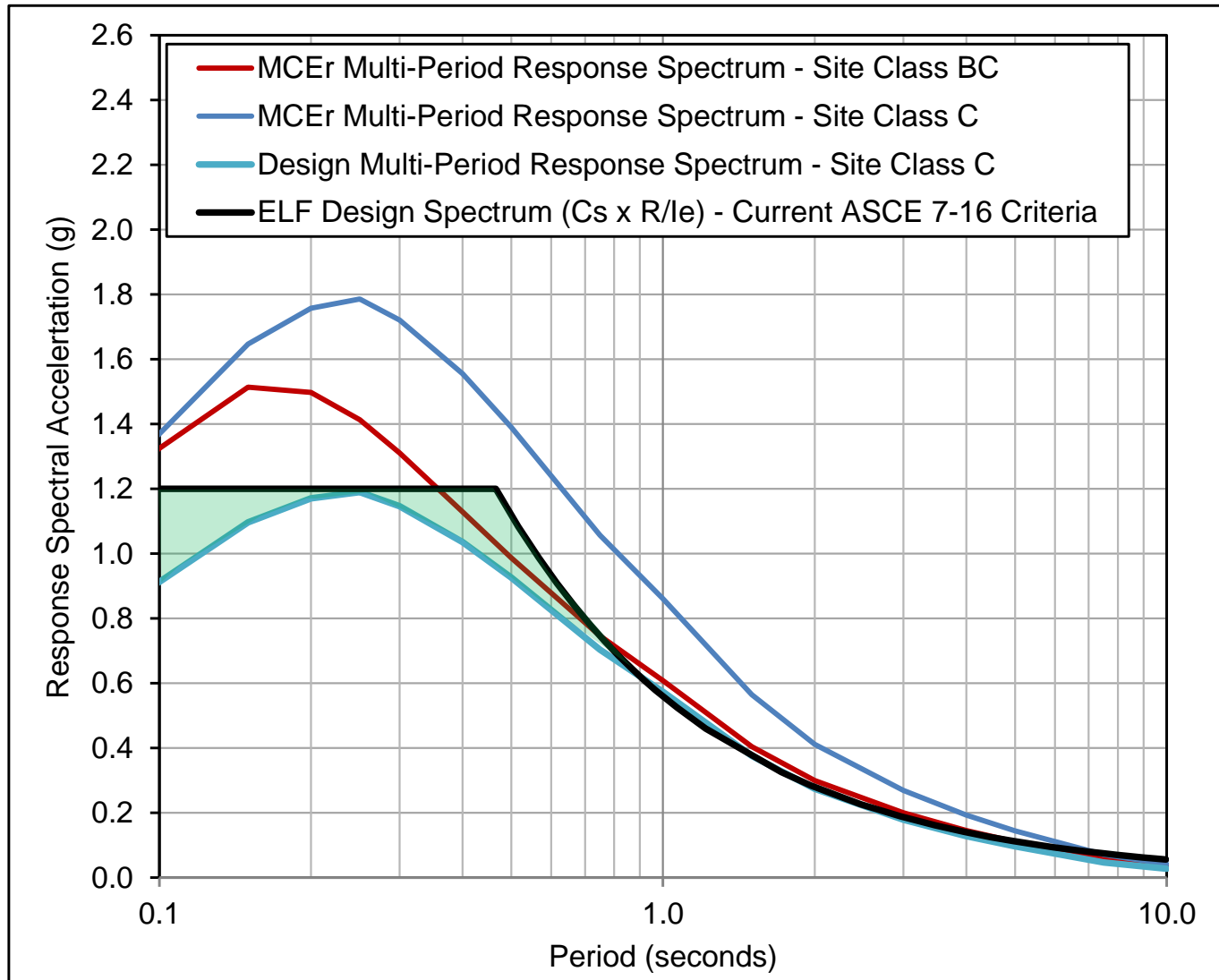


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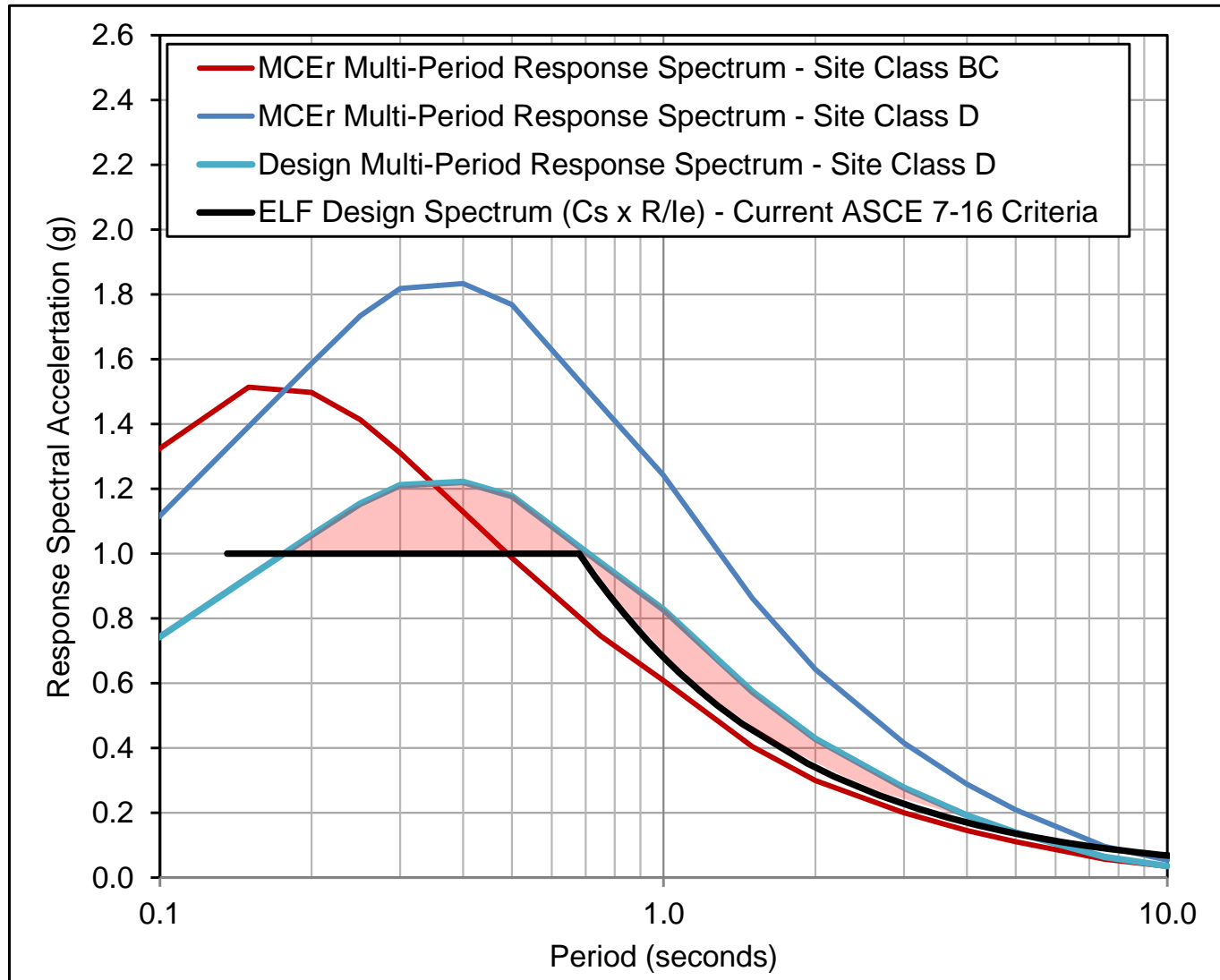


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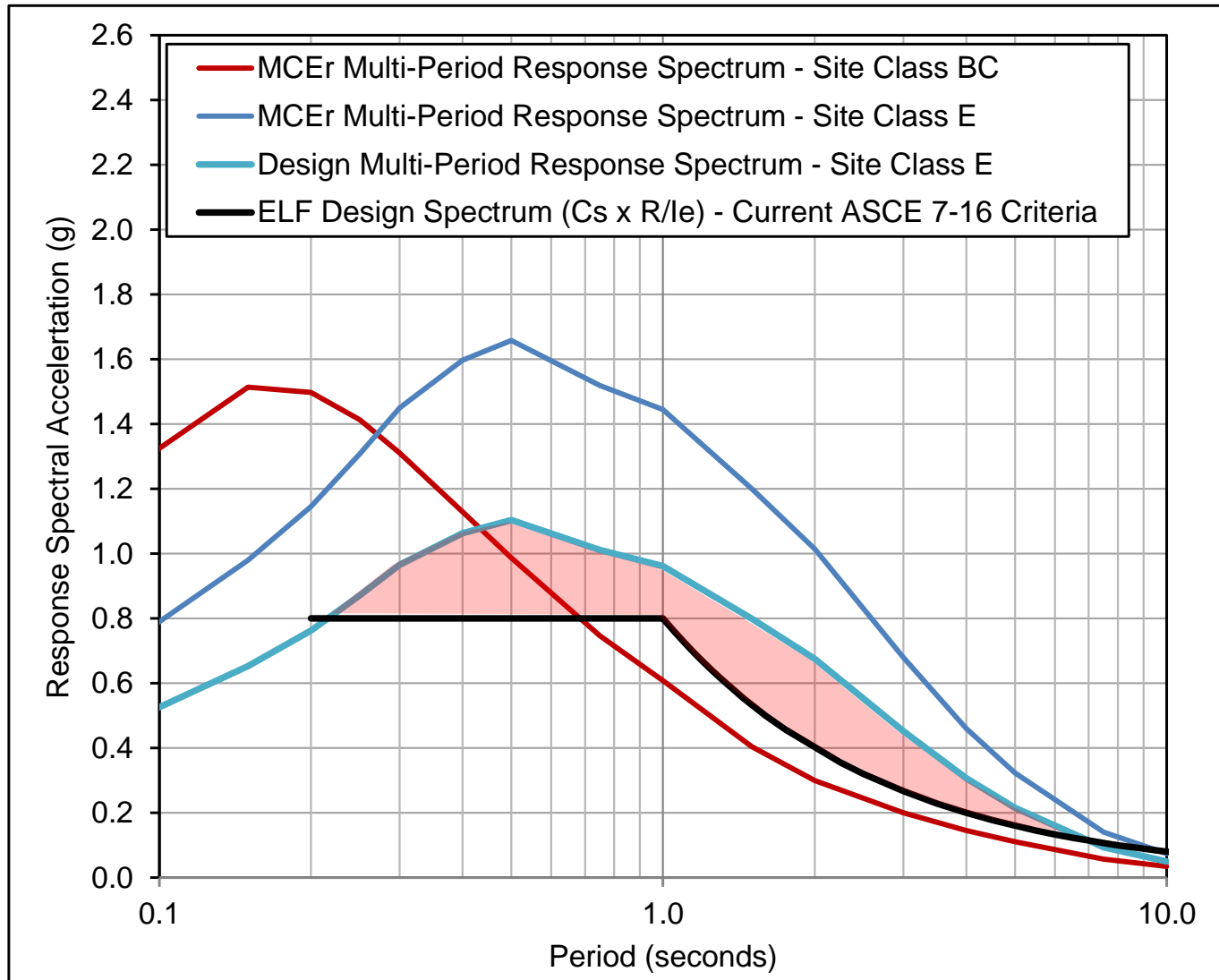
Example ELF "Design Spectrum" based on ASCE 7-16 Criteria M7.0 earthquake ground motions at $R_x = 6.5$ km, Site Class C



Example ELF "Design Spectrum" based on ASCE 7-16 Criteria M7.0 earthquake ground motions at $R_x = 6.5$ km, Site Class D

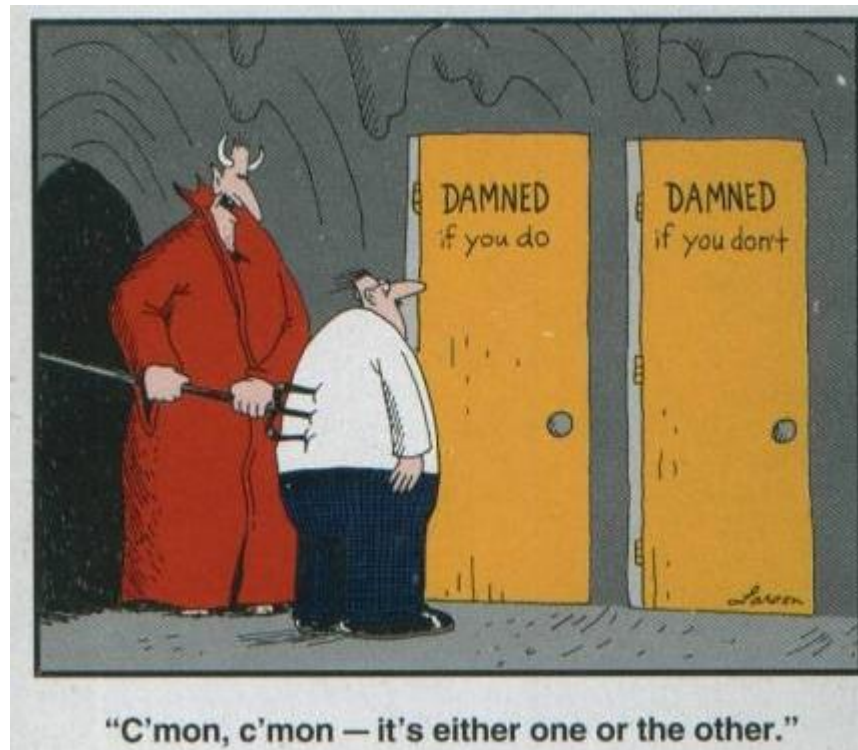


Example ELF "Design Spectrum" based on ASCE 7-16 Criteria M7.0 earthquake ground motions at $R_x = 6.5$ km, Site Class E



Short-Term Solution Options (considered by the 2010 PUC)

- Option 1 - Re-formulate seismic parameters to eliminate potential non-conservatism in ELF (and MRSA) seismic forces
- Option 2 - Require site-specific analysis when ELF (and MSRA) seismic forces could be potentially non-conservative



Short-Term Solution of ASCE 7-16

(to an identified short-coming in the seismic design procedures of ASCE 7-10)

- BSSC PUC Considered Two Options:
 - Re-formulate seismic parameters to eliminate potential non-conservatism in ELF (and MRSA) seismic forces (not adopted)
 - Require site-specific analysis when ELF (and MRSA) seismic forces could be potentially non-conservative (adopted)
- FEMA-funded BSSC study performed by Kircher & Associates that developed the technical approach and basis for proposing changes to current seismic criteria
 - Developed new values of re-formulated parameters (Option 1)
 - Developed criteria for requiring site-specific analysis (Option 2)
 - Developed conservative values of current seismic parameters for design using ELF (and MRSA) methods in lieu of site-specific analysis

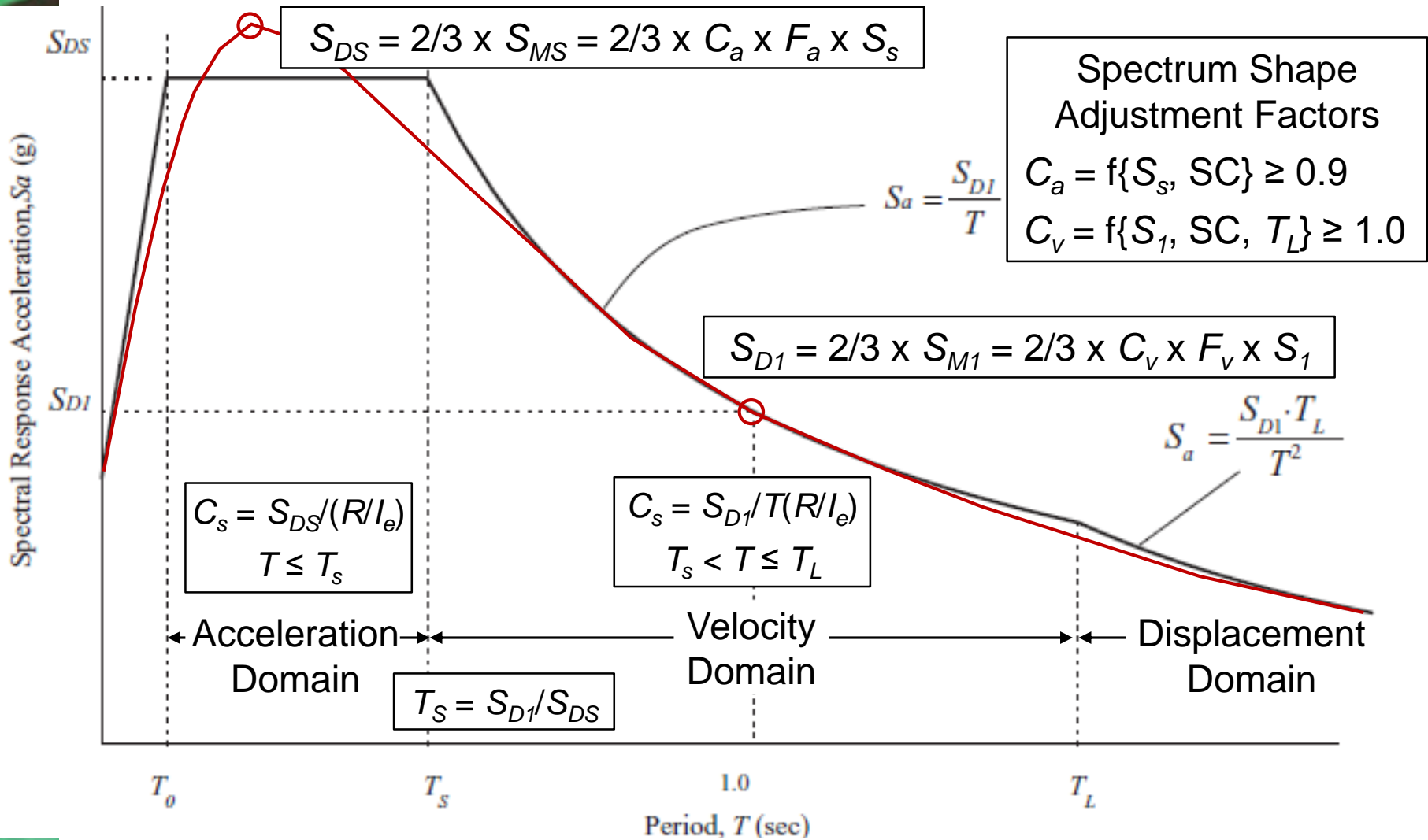


FEMA-Funded BSSC Study

- FEMA-funded BSSC study (Kircher & Associates):
“Investigation of an Identified Short-coming in the Seismic Design Procedures of ASCE 7-10 and Development of Recommended Improvements For ASCE 7-16”
https://www.nibs.org/resource/resmgr/BSSC2/Seismic_Factor_Study.pdf
- Study Advisors and Contributors:
 - Nico Luco (USGS)
 - Sanaz Rezaeian (USGS)
 - C. B. Crouse (URS)
 - Jonathan Stewart (UCLA)
 - Kevin Milner (SCEC)
 - David Bonneville (Degenkolb) – BSSC PUC Chair
 - John Hooper (MKA) – ASCE 7-16 SSC Chair
- PEER Center - Next Generation Attenuation Relations
 - Linda Al Atik (PEER NGA West1 GMPEs spreadsheet)
 - Emil Seyhan (PEER NGA West2 GMPEs spreadsheet)



Option 1 - Spectrum Shape Adjustment Reformulation of Design Parameters (Figure 11.4-1 annotated to show proposed C_a and C_v factors of PUC Proposal IT11-006)



Long-Term Solution (*Project 17/ASCE 7-22*)

- Develop and adopt multi-period design spectrum approach
 - Not feasible in the last code update cycle (ASCE 7-16)
- Multi-period spectrum approach will require:
 - Reworking of seismic design requirements and criteria now based on two response periods
 - Development of new ground motion design parameters (by the USGS) for each new response period of interest
 - Development of new site factors for each new response period of interest (or site effects embedded directly in ground motion design values maps)
- Challenges:
 - Non-WUS sites? – Multi-period GMPEs with built-in site amplification are not available for all U.S. regions
 - Too Many Maps (Too Many Tables)? – Can ground motion design parameters be provided electronically (e.g., via the web) without direct inclusion in ASCE 7 or the IBC?



May 17, 2016 Meeting of the Multi-Period Spectrum Parameters Working Group (MPSP WG)

- MPSP WG Attendance:
 - Charlie Kircher (Chair) - present
 - Nico Luco - present
 - Sanaz Rezaeian – by phone
 - C. B. Crouse - present
 - Jonathan Stewart – absent (but discussed topics on May 16)
 - David Bonneville – absent
 - John Hooper – present
- Topics Discussed (by ASCE 7-16 chapter/section):
 - Shape of the Design Response Spectrum (Figure 11.4-1)
 - Site Coefficients (Tables 11.4-1 and 11.4-2)
 - Site-Specific Requirements (Section 11.4.7)
 - Site Class Definitions (Chapter 20)
 - Site-Specific Requirements (Sections 21.2.2 and 21.3)
 - Mapped Values of Design Parameters (Chapter 22)



Tentative Design Response Spectrum Shape

(Figure 11.4-1, ASCE 7-22)

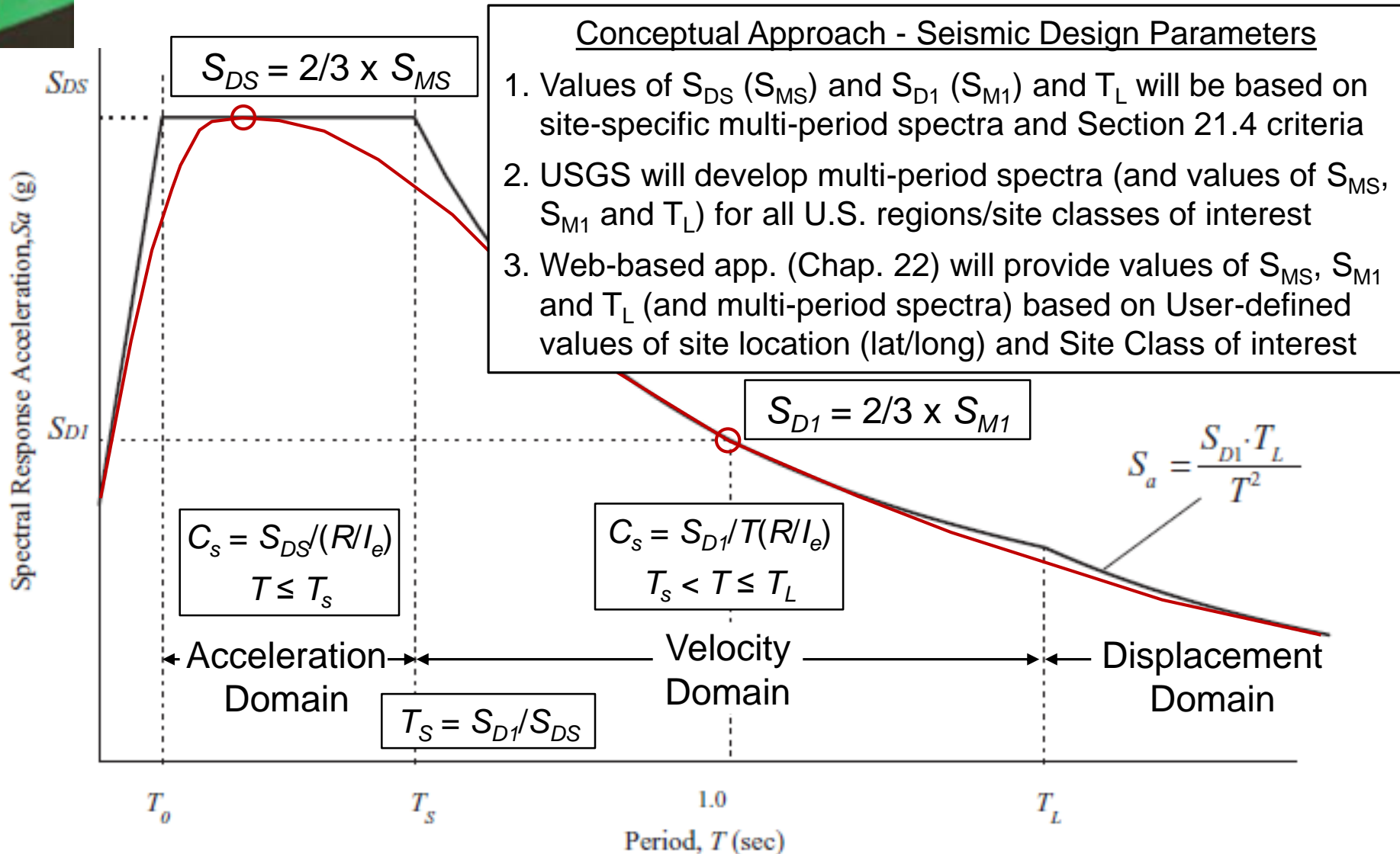
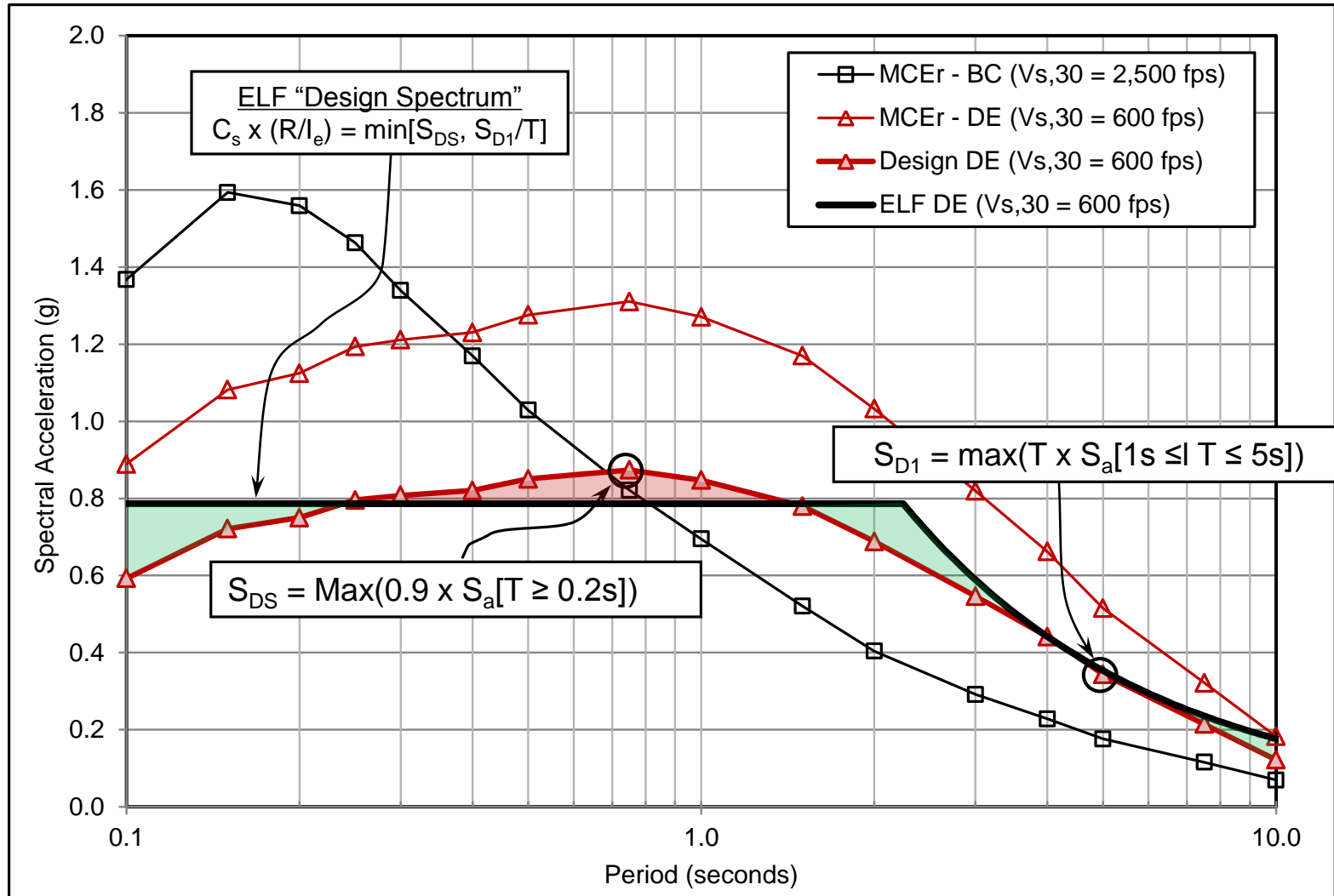


Illustration of the New Requirements of Section 21.4 of ASCE 7-16

Site Class DE, M8 at R = 8.5 km (PEER NGA-West1 Relations)



Summary of Issues Discussed by the MPSP WG

(WG positions/recommendations shown in bold)

- Site-Specific Information Provided by User:
 - Latitude/Longitude
 - Site Conditions (or use default values, if unknown):
 - Issue - Define site class by $v_{s,30}$ or Site Class? **Site Class**
 - Issue - Include site class boundaries as well as center of each site class (e.g., A, AB, B, BC, C, CD, D, DE, E)? **Yes**
- Site-Specific Design Parameters Provided by Web-Site:
 - Values of Design Parameters (w/site and spectrum shape effects):
 - S_{DS} (S_{MS}) and S_{D1} (S_{M1}) and T_L
 - Issue – How to include site and spectrum shape effects when GMPEs to not have such effects (fully) built-in? **Not an Issue**
 - **USGS will be able to provide multi-period spectra for all U.S. site locations and possible site conditions**
 - Issue – Provide site-specific values of T_L based on site-specific values of M that govern the deterministic MCE_R ? **Yes (USGS will be able to provide site-specific values of M and T_L)**
 - Multi-period design (and MCE_R) spectra (where possible) **Yes**



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Summary of Issues Discussed by the MPSP WG

(WG positions/recommendations shown in bold)

- Site Factor Tables
 - Issue - Remove or revise (i.e., make consistent with GMPE site amplification/site-specific spectra provided by web site)? **Remove**
 - Issue – Develop/provide site factor tables for sites not governed by shallow crustal events (e.g., CSZ, CEUS, etc.)? **Not an Issue – USGS will incorporate site effects in values of S_{MS} and S_{M1} for all sites of interest**
 - Issue – How to adjust for spectrum shape effects? **Not an Issue – multi-period spectra will include spectrum shape effects**
- Site-Specific Analysis Requirements (i.e., fixes to ASCE 7-16):
 - Issue – Revise Deterministic MCE_R floor criteria (Section 21.2.2) to be based on new parameters that incorporate both site and spectrum shape effects (if Deterministic MCE_R floor is required)? **Yes**
 - Issue – Revise 80% lower-bound limits (Section 21.3) to incorporate both site and spectrum shape effects (e.g., base directly on values of S_{DS} and S_{D1} provided by web site)? **Yes**
- Other? **None**



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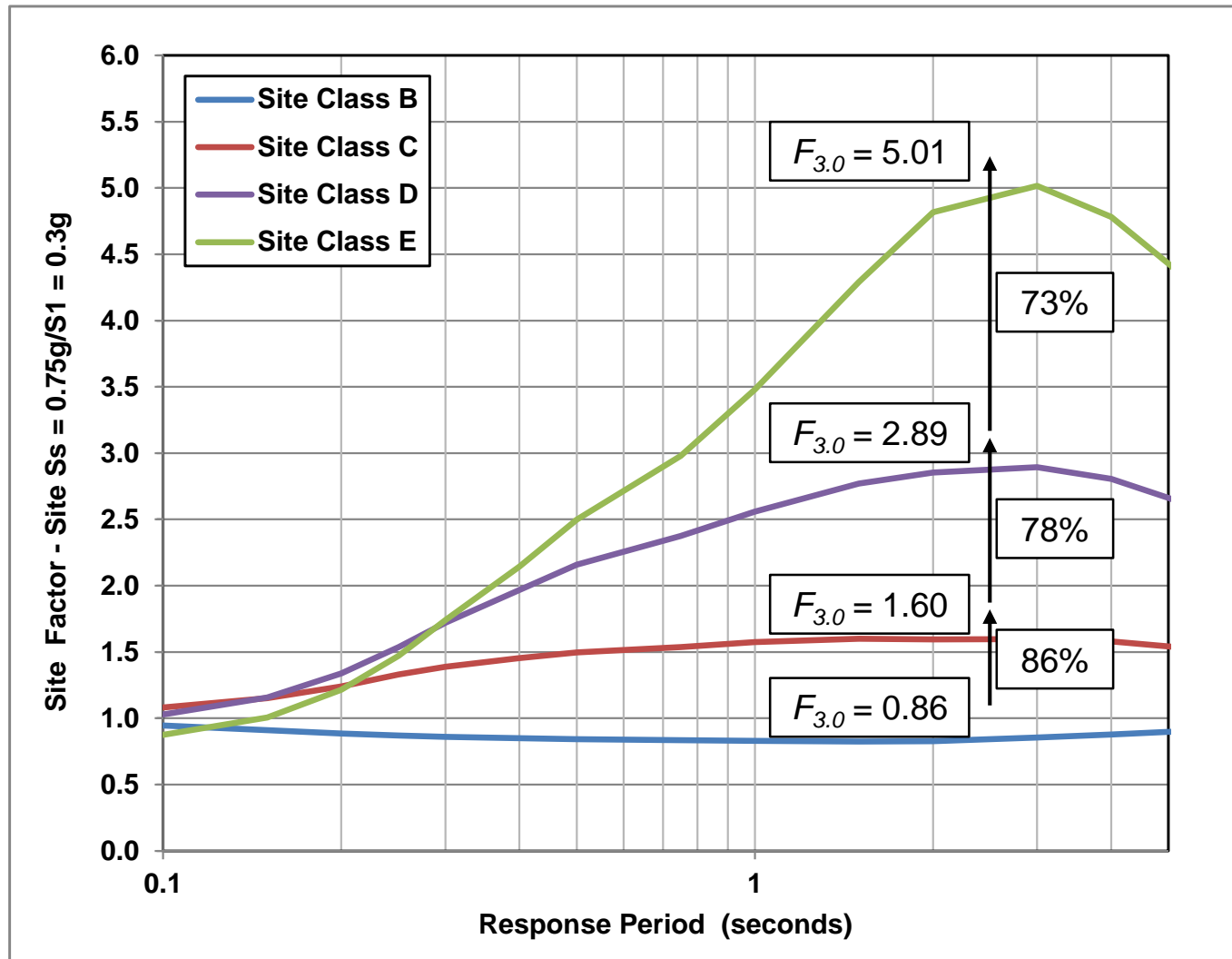


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Example Site Amplification Curves of Different Site Classes

Showing Large Differences in Amplification at Longer Periods
(PEER NGA West 2 GMPEs, $S_s = 0.75g$ and $S_1 = 0.3g$, default basin depth parameters)



Notional Revision of Table 20.3-1 to Include Three New Site Classes (BC, CD and DE) at Current Site Class Boundaries

Site Class		Geotechnical Criteria (average upper 100 ft)		
Name	Description	v_s (fps)	N or N_{ch}	s_u (psf)
A	Hard Rock	> 5,000	NA	NA
B	Rock	3,000 - 5,000	NA	NA
BC	Reference Rock	2,100 - 3,000	NA	NA
C	Very dense soil and soft rock	1,450 - 2,100	> 50	> 2,000
CD	Very Stiff soil	1,000 - 1,450		
D	Stiff soil	700 - 1,000	15 to 50	1,000 - 2,000
DE	Soft soil	500 - 700		
E	Soft clay soil	< 500	< 15	< 1,000
F	Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

Summary of MPSP WG Recommendations

(to the Project 17 committee)

- Chapter 11 (Section 11.4)
 - Retain 3-domain definition of the Design Response Spectrum (Figure 11.4-1) defined by site-specific values of S_{DS} , S_{D1} and T_L (developed by USGS and provided via a web-based app)
 - Delete site coefficient tables assuming values of S_{MS} (S_{DS}) and S_{M1} (S_{D1}) developed by the USGS include site (and spectrum shape) effects
 - Revise site-specific ground motion procedures (Section 11.4.7) to be the same as those of ASCE 7-10 (i.e., remove “band-aide”)
- Chapter 20 (Table 20.3-1)
 - Revise definitions/criteria to include new site classes at boundaries
- Chapter 21 (Sections 21.2.2, Figure 21.2-1 and Section 21.3)
 - Revise Deterministic MCE_R floor (Section 21.2.2 and Figure 21.2-1), if still required, to be based on S_{MS}/S_{M1}
 - Revise 80% lower-bound limit (Section 21.3) to be based on S_{DS}/S_{D1} (or multi-period design spectrum)
- Chapter 22
 - Provide mapped values of S_{DS} and S_{D1} for “default site” conditions only (provide all mapped parameters/site conditions via a web-based app.)



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Questions?

