Near-term Task Force Recommendation 2.1 Seismic Hazard Evaluation

Salem Nuclear Generating Station

June 12, 2014

References for Today's Meeting

- Licensee Presentation Slides – ML14162A432
- NRC Presentation Slides – ML14162A440
- Public Meeting Agenda – ML14160B154
- Meeting Feedback Form (request from njd2@nrc.gov)
- May 9, 2014, NRC letter regarding Seismic Screening and Prioritization Results for CEUS Licensees (ML14111A147)
- May 21, 2014, NRC memo providing preliminary staff ground motion response spectra for CEUS Licensees (ML14136A126)
- Meeting Summary to be issued within 30-day

Meeting Introduction

Purpose: support information exchange and begin dialog to have common understanding of the causes of the primary differences between the preliminary NRC and licensee seismic hazard results

Background: NRC and Licensee seismic hazard require resolution to support a final seismic screening decision and to support related follow-on submittals

Outcomes:

- Begin NRC and licensee resolution to support regulatory decisions and development of seismic risk evaluations, as appropriate
- Establish resolution path, including timelines and identification of potential information needs

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Look-ahead: Potential Next Steps

- NRC will consider the meeting information
- Potential paths:
  - Licensee submits supplemental information based on public meeting dialog
  - NRC staff issues a request for information
  - Licensee sends a revision or supplement to the seismic hazard report
- NRC completes screening review and issues the final screening determination letter

Salem Generating Station (SGS)

Stephanie Devlin

Office of New Reactors

June 12, 2014

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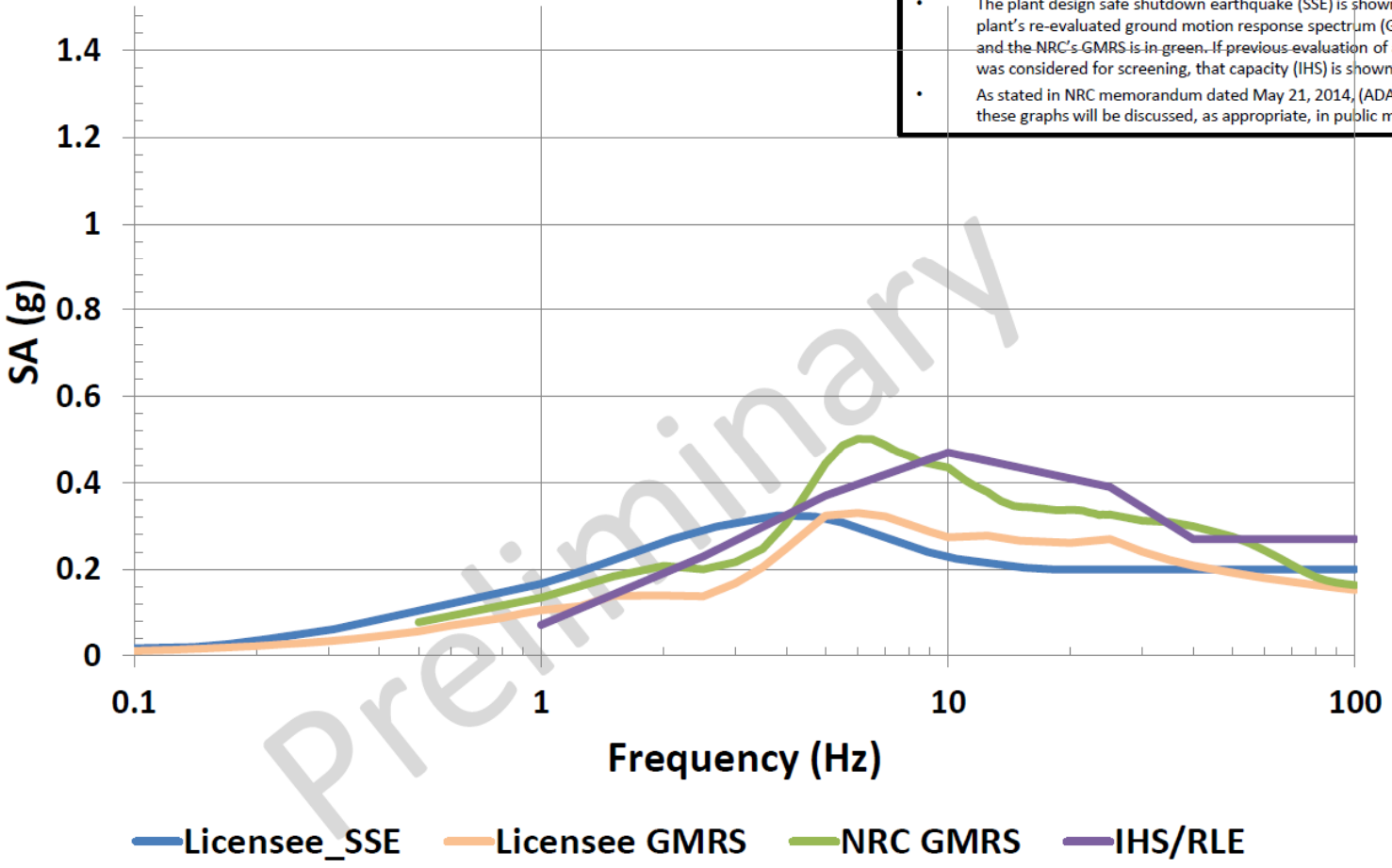
Salem

- As discussed in the May 9, 2014, letter (ADAMS ML14111A147), the NRC considered the re-evaluated hazard and previous estimates of plant capacity to conclude that this plant is safe to continue operating while additional evaluations are conducted.
- NRC staff used this preliminary graph, focusing on the 1-10 Hertz range, and other information to determine whether this plant requires a risk evaluation over the next few years.
- The plant design safe shutdown earthquake (SSE) is shown in blue; the plant's re-evaluated ground motion response spectrum (GMRS) is in orange and the NRC's GMRS is in green. If previous evaluation of a plant's capacity was considered for screening, that capacity (IHS) is shown in purple.
- As stated in NRC memorandum dated May 21, 2014, (ADAMS ML14136A126) these graphs will be discussed, as appropriate, in public meetings.



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NRC's Seismic Screening and Prioritization Results

Plant Name	Screening Result	Expedited Approach Evaluation	Seismic Risk Evaluation (Prioritization Group)	Limited-scope Evaluations		
				High Frequency Evaluation	Low Frequency Evaluation	Spent Fuel Pool Evaluation
Davis-Besse Nuclear Power Station, Unit 1	In	x	3	x		x
Duane Arnold Energy Center	Conditional In	x	3	x		x
James A. FitzPatrick Nuclear Power Plant	Conditional In	x	3	x		x
Fort Calhoun Station, Unit 1	Conditional In	x	3	x		x
Limerick Generating Station, Units 1 and 2	Conditional In	x	3	x		x
William B. McGuire Nuclear Station, Units 1 and 2	In	x	3	x		x
Millstone Power Station, Unit 2	Conditional In	x	3	x		x
Monticello Nuclear Generating Plant	Conditional In	x	3	x		x
Perry Nuclear Power Plant, Unit 1	In	x	3	x		x
Point Beach Nuclear Plant, Units 1 and 2	In	x	3	x		x
Quad Cities Nuclear Power Station, Units 1 and 2	Conditional In	x	3	x		x
Salem Nuclear Generating Station, Units 1 and 2	Conditional In	x	3	x		x
Seabrook, Unit 1	In	x	3	x		x
Surry Power Station, Unit Nos. 1 and 2	Conditional In	x	3	x		x
Three Mile Island Nuclear Station, Unit 1	In	x	3	x		x
Wolf Creek Generating Station, Unit 1	In	x	3	x		x

Modified from ML14111A147

References Reviewed by NRC

- Salem Generating Station Unit 1 and Unit 2, Updated Final Safety Analysis Report (UFSAR), Revision 23
- Hope Creek Generating Station UFSAR, Revision 0
- PSEG Nuclear Early Site Permit Application, Site Safety Analysis Report, Revision 3
- EPRI (2008) Assessment of Seismic Hazard at 34 U.S. Nuclear Plant Sites, Elec. Power Res. Inst., Report 1016736.
- EPRI (2013) Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic, Report 1025287
- Salem, Unit 1 & 2, "Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident - Base Case Velocity Profiles With Supporting Subsurface Materials and Properties," September 10, 2013 (ML13253A391)
- Salem, Units 1 & 2 - PSEG Nuclear LLC's Seismic Hazard and Screening Report (CEUS Sites) Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident - Salem Generating Station (ML14090A043)

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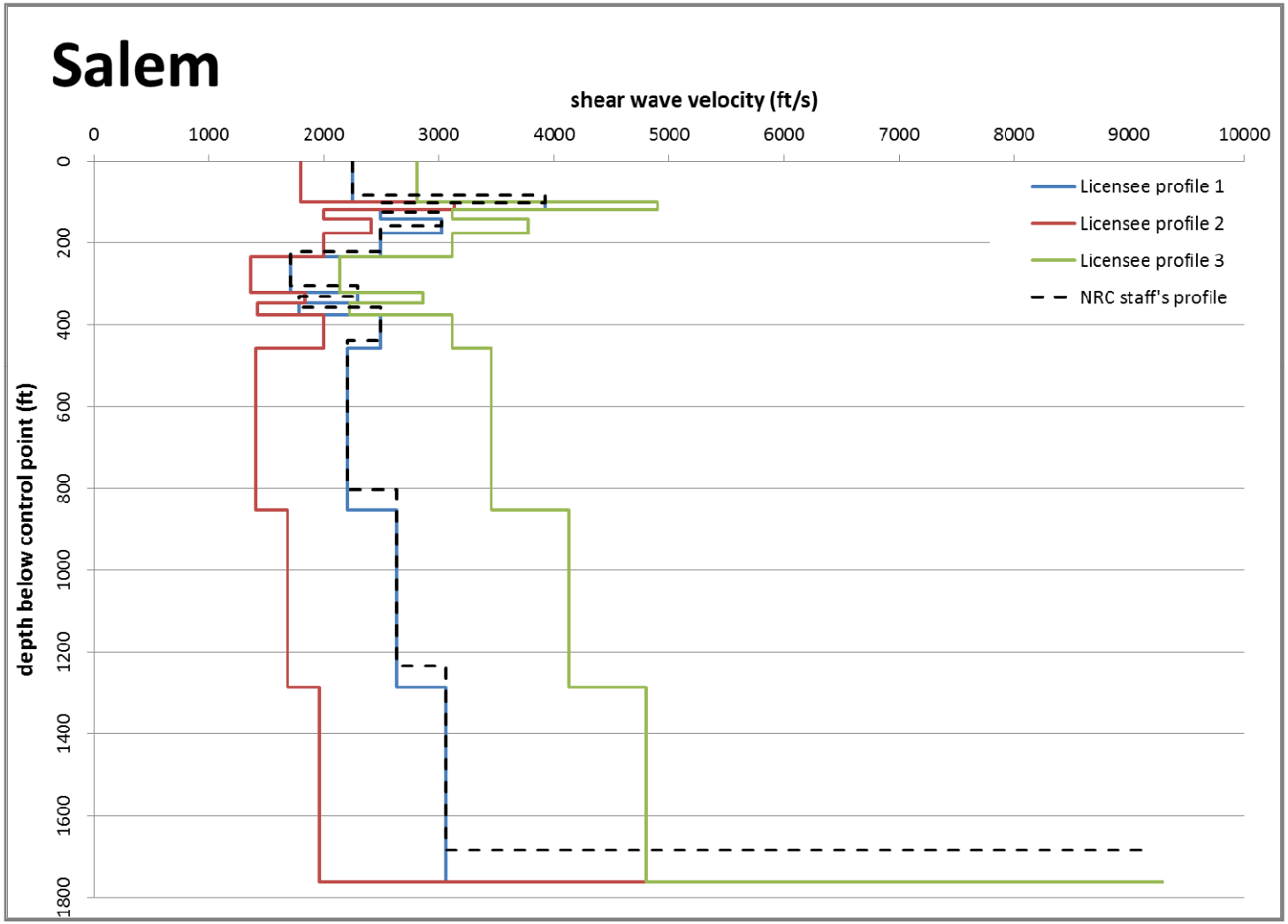
Stratigraphy

		Formation/Unit	Lithologies	Thickness
QUATERNARY	Holocene (recent)	Artificial fill	clays, silts, and sands of various proportions along with clayey and silty gravels	4.1 ± 5.1 feet
QUATERNARY	Holocene (recent)	Hydraulic fill	soft clayey silts, sandy silts and organic clays	33.5 ± 12.3 feet
QUATERNARY	Pleistocene	Alluvium	fine to coarse sand and gravel; peat and organic rich soils; silt and clay near base	12.7 ± 12.3 feet
		~~ unconformity ~~~~~~~~		
TERTIARY	Upper Tertiary (Neogene)	Kirkwood Formation	*Upper member:* greenish-gray, silty, fine sand, fine sand and greenish-gray to brown organic clay with organic material and shell fragments; *Lower member:* fine to coarse sand and gravel with variable amounts of silt and clay	*Upper member:* 14.5 ± 7.7 feet; *Lower member:* 7.2 ± 7.8 feet
		~~ unconformity ~~~~~~~~		
TERTIARY	Lower Tertiary (Paleogene)	Vincentown Formation	greenish-gray, fine to medium grained silty sand with some zones of clayey sand; variably glauconitic; cemented zones	52.0 ± 26.1 feet
TERTIARY	Lower Tertiary (Paleogene)	Hornerstown Formation	greenish-gray to dark green silty and clayey quartz and glauconitic sand with indurated zones	18.6 ± 3.2 feet
CRETACEOUS	Upper Cretaceous	Navesink Formation	fossiliferous, dark green to greenish-black glauconitic sand; pelecypod fragments	24.3 ± 2.3 feet
CRETACEOUS	Upper Cretaceous	Mount Laurel Formation	brownish gray to dark green, fine to coarse grained sand; variable amounts of silt and clay; coarsening upward sequence	10.3 ± 3.5 feet
CRETACEOUS	Upper Cretaceous	Wenonah Formation	sandy clay with clayey sand	15 feet
CRETACEOUS	Upper Cretaceous	Marshalltown Formation	glauconitic, silty and clayey fine sand	25 feet
CRETACEOUS	Upper Cretaceous	Englishtown Formation	dark gray to black sandy clay to clayey sand with shell fragments grades to black silt with trace amounts of mica and glauconite	44 feet
CRETACEOUS	Upper Cretaceous	Woodbury Formation	black, micaceous clay	36 feet
CRETACEOUS	Upper Cretaceous	Merchantville Formation	dark greenish-black glauconitic silts and clays with variable amounts of sand	30 feet
CRETACEOUS	Upper Cretaceous	Magothy Formation	interbeds of gray to dark gray, locally mottled silts and clays that are interbedded with sands; trace amounts of lignite and carbonaceous material	52 feet
		~~ unconformity ~~~~~~~~		
CRETACEOUS	Lower Cretaceous	Potomac Group (Formation)	red, gray, and white mottled clay	1300 feet (Reference 2.5.1-17) PSEG No. 6 Production Well
		~~ pre-Cretaceous unconformity ~~~~~~~~		
		Basement Complex		
PRECAMBRIAN TO PALEOZOIC	NeoProterozoic to Paleozoic	Philadelphia Terrane	Wissahickon Schist – reported as residual clay (PSEG No. 6 Production Well)	undetermined

control point → (at the unconformity between the Kirkwood Formation and the Vincentown Formation)

Source: ML14090A043 and PSEG ESP SSAR Rev3

NRC & Licensee's Velocity Profiles



The licensee used σ_{ln} to calculate its Profile 2 and 3. It used 0.25 to calculate shear-wave velocities above the Potomac Formation (~444 ft depth) and 0.35 for the Potomac formation and below.

Source: ML14090A043 and PSEG ESP SSAR Rev3

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Velocities & Uncertainties

NRC

	Thickness (ft)	Vs (ft/s)	Unit Weight (lb/ft^3)	Sigma (ln Vs)	Sigma (ln Bedrock Depth)
	84.5	1150	121	0.15	-
	18.5	3920	131	0.15	-
	11.5	2490	131	0.15	-
	84.5	3020	131	0.15	-
	61	2490	128	0.15	-
	84	1710	125	0.15	-
	16	2290	130	0.15	-
	25	1780	130	0.15	-
	81	2490	130	0.15	-
	365	2200	135	0.15	-
	430	2630	135	0.15	-
	450	3060	135	0.15	-
	Bedrock	9200	165	-	0.03
NRC's Source Material	PSEG ESP SSAR	PSEG ESP SSAR	PSEG ESP SSAR	NRC chose values to create a random field with velocity profiles close to that in the PSEG ESP SSAR	NRC chose 0.03, because it created ~±100 ft consistent with the PSEG ESP SSAR

Licensee

Thickness (ft)	Vs (ft/s)	Unit Weight (lb/ft^3)	Sigma (ln Vs)	Sigma (ln Bedrock Depth)
92	2250	121	0.25 (to 50 ft), 0.15 below	-
18	3920	131	0.15	-
22	2490	131	0.15	-
33.9	3020	131	0.15	-
61.8	2490	128	0.15	-
83.5	1710	125	0.15	-
26.1	2290	130	0.15	-
24.9	1780	130	0.15	-
81.9	2490	130	0.15	-
365	2200	135	0.15	-
430	2630	135	0.15	-
450	3060	135	0.15	-
Bedrock	9285	165	-	-

Source: ML14090A043 and PSEG ESP SSAR Rev3

Velocities & Non-Linear Properties

NRC

	Thickness (ft)	Vs (ft/s)	G/Gmax Curve	Damping Curve	Kappa
	84.5	2250	EPRI Soil (1993)	EPRI Soil (1993)	-
	18.5	3920	EPRI Soil (1993)	EPRI Soil (1993)	-
	21.5	2490	EPRI Soil (1993)	EPRI Soil (1993)	-
	34.5	3020	EPRI Soil (1993)	EPRI Soil (1993)	-
	62	2490	EPRI Soil (1993)	EPRI Soil (1993)	-
	84	1710	EPRI Soil (1993)	EPRI Soil (1993)	-
	26	2290	EPRI Soil (1993)	EPRI Soil (1993)	-
	25	1780	EPRI Soil (1993)	EPRI Soil (1993)	-
	82	2490	EPRI Soil (1993)	EPRI Soil (1993)	-
	365	2200	EPRI Soil (1993)	EPRI Soil (1993)	-
	430	2630	None - Linear	None - Linear	0.00197
	450	3060	None - Linear	None - Linear	0.001773
	Bedrock	9200	-	0.50%	0.006
NRC's Source Material	PSEG ESP SSAR	PSEG ESP SSAR	NRC's PSEG Confirmatory Analysis	NRC's PSEG Confirmatory Analysis	EPRI SPID (2013)

Licensee

Thickness (ft)	Vs (ft/s)	G/Gmax Curve	Damping Curve	Kappa
92	2250	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
18	3920	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
22	2490	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
33.9	3020	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
61.8	2490	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
83.5	1710	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	κ(ms) = 0.0605*H = 0.031
26.1	2290	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
24.9	1780	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
81.9	2490	EPRI Soil (1993) & Peninsular Range	EPRI Soil (1993) & Peninsular Range	
365	2200	None - Linear		
430	2630	None - Linear		
450	3060	None - Linear		
Bedrock	9285			0.006

Source: ML14090A043, ML13253A391, and PSEG ESP SSAR Rev3

Damping

NRC

- Represented layer damping using EPRI Soil (1993) curves for units from the control point down to ~800 ft depth.
- Kappa estimates represent low-strain damping for units below ~803 ft depth. Kappa was calculated utilizing the relationship between Vs, Q, and kappa.
- Total effective site kappa (damping curves + kappa below 803 ft) is 0.015.

Licensee

- Represented layer damping using two alternative curves EPRI Soil (1993) and Peninsular Range curves for units from the control point down to ~444 ft depth.
- In addition, kappa estimates, representing low-strain damping, was calculated using SPID equation:

$$\kappa(\text{ms}) = 0.0605^{*}\text{H (thickness in meters)}$$

- In ML14090A043, licensee stated total site kappa of 0.037 (near the SPID 0.040 limit) for each velocity profile.

Source: ML14090A043, ML13253A391, and PSEG ESP SSAR Rev3

Velocities & Damping

NRC

Thickness (ft)	Vs (ft/s)	Damping Curve		Estimated Kappa	
84.5	2250	EPRI Soil (1993)	=	0.000854	
18.5	3920	EPRI Soil (1993)	=	0.000094	
21.5	2490	EPRI Soil (1993)	=	0.000149	
34.5	3020	EPRI Soil (1993)	=	0.000197	
62	2490	EPRI Soil (1993)	=	0.000389	
84	1710	EPRI Soil (1993)	=	0.000768	
26	2290	EPRI Soil (1993)	=	0.000177	
25	1780	EPRI Soil (1993)	=	0.000219	
82	2490	EPRI Soil (1993)	=	0.000515	
365	2200	EPRI Soil (1993)	=	0.001627	
430	2630	None - Linear		0.001970	
450	3060	None - Linear		0.001772	
Bedrock	9200	0.50%		0.006000	
				0.014731	total effective site kappa

0.008731

Source: ML14090A043, ML13253A391, and PSEG ESP SSAR Rev3

Velocities & Damping

Licensee

Thickness (ft)	Vs (ft/s)	Damping Curve M1 (0.5 weight)		Kappa M1 (0.5 weight)	Damping Curve M2 (0.5 weight)		Kappa M2 (0.5 weight)	Kappa
92	2250	EPRI Soil (1993)	=	0.000818	Peninsular Range	=	0.000870	
18	3920	EPRI Soil (1993)	=	0.000092	Peninsular Range	=	0.000055	
22	2490	EPRI Soil (1993)	=	0.000152	Peninsular Range	=	0.000106	
33.9	3020	EPRI Soil (1993)	=	0.000194	Peninsular Range	=	0.000135	
61.8	2490	EPRI Soil (1993)	=	0.000428	Peninsular Range	=	0.000299	
83.5	1710	EPRI Soil (1993)	=	0.000763	Peninsular Range	=	0.000588	κ(ms) = 0.0605*H
26.1	2290	EPRI Soil (1993)	=	0.000178	Peninsular Range	=	0.000137	= 0.031
24.9	1780	EPRI Soil (1993)	=	0.000219	Peninsular Range	=	0.000169	
81.9	2490	EPRI Soil (1993)	=	0.000514	Peninsular Range	=	0.000396	
365	2200			total = 0.003357			total = 0.002756	
430	2630							
450	3060							
Bedrock	9285							0.006

Source: ML14090A043, ML13253A391, and PSEG ESP SSAR Rev3

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Velocities & Damping

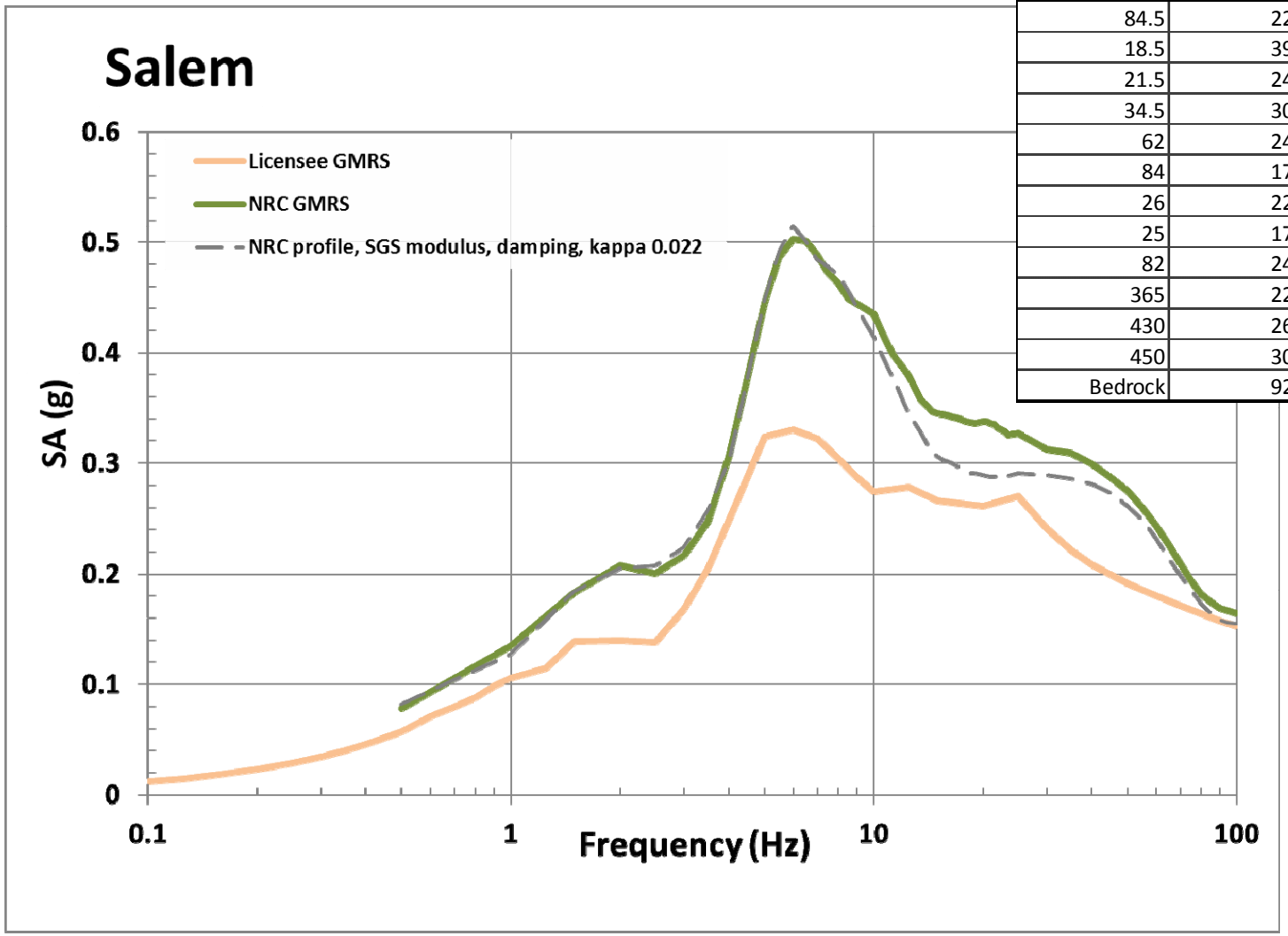
Licensee

Thickness (ft)	Vs (ft/s)	Damping Curve M1 (0.5 weight)		Kappa M1 (0.5 weight)	Damping Curve M2 (0.5 weight)		Kappa M2 (0.5 weight)	Kappa
92	2250	EPRI Soil (1993)	=	0.000818	Peninsular Range	=	0.000870	
18	3920	EPRI Soil (1993)	=	0.000092	Peninsular Range	=	0.000055	
22	2490	EPRI Soil (1993)	=	0.000152	Peninsular Range	=	0.000106	
33.9	3020	EPRI Soil (1993)	=	0.000194	Peninsular Range	=	0.000135	
61.8	2490	EPRI Soil (1993)	=	0.000428	Peninsular Range	=	0.000299	
83.5	1710	EPRI Soil (1993)	=	0.000763	Peninsular Range	=	0.000588	κ(ms) = 0.0605*H
26.1	2290	EPRI Soil (1993)	=	0.000178	Peninsular Range	=	0.000137	= 0.031
24.9	1780	EPRI Soil (1993)	=	0.000219	Peninsular Range	=	0.000169	
81.9	2490	EPRI Soil (1993)	=	0.000514	Peninsular Range	=	0.000396	
365	2200			total = 0.003357			total = 0.002756	
430	2630							
450	3060							
Bedrock	9285							0.006

TOTAL SITE KAPPA = (0.003357*0.5) + (0.002756*0.5) + 0.031 + 0.006 = 0.040

Source: ML14090A043, ML13253A391, and PSEG ESP SSAR Rev3

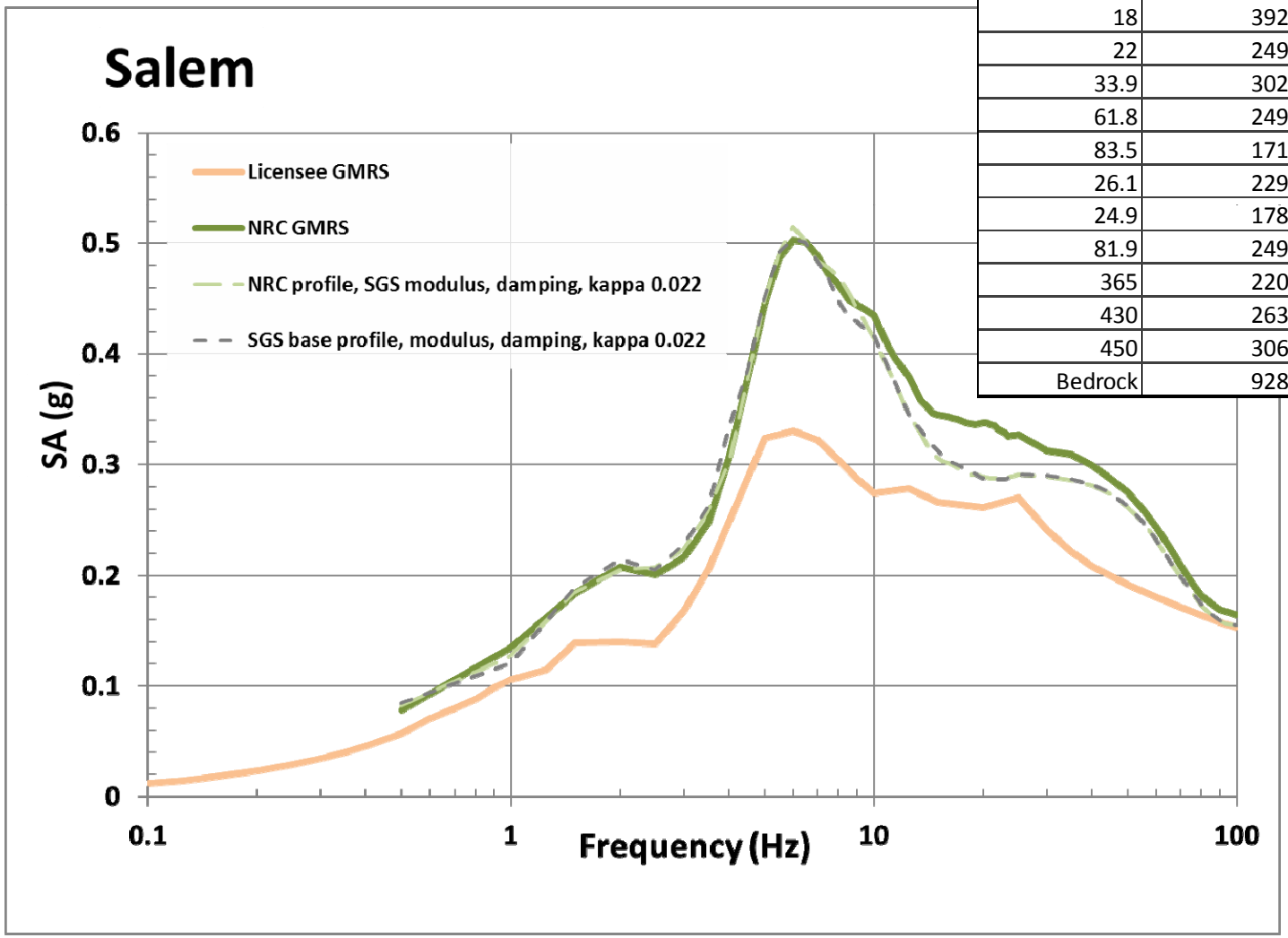
NRC's GMRS Sensitivity Studies



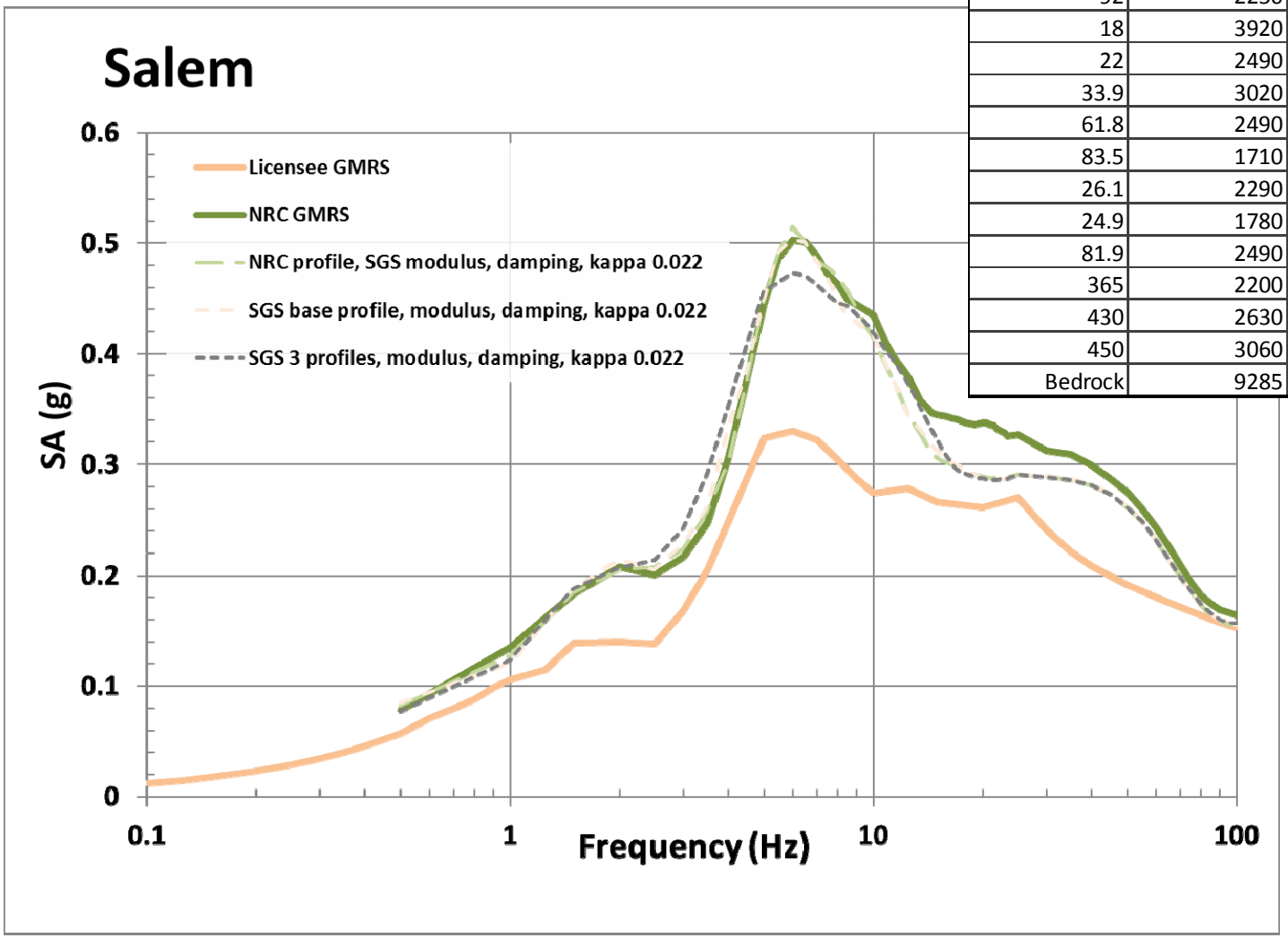
Thickness (ft)	Vs (ft/s)	Damping Curve
84.5	2250	EPRI Soil (1993) & Peninsular Range
18.5	3920	EPRI Soil (1993) & Peninsular Range
21.5	2490	EPRI Soil (1993) & Peninsular Range
34.5	3020	EPRI Soil (1993) & Peninsular Range
62	2490	EPRI Soil (1993) & Peninsular Range
84	1710	EPRI Soil (1993) & Peninsular Range
26	2290	EPRI Soil (1993) & Peninsular Range
25	1780	EPRI Soil (1993) & Peninsular Range
82	2490	EPRI Soil (1993) & Peninsular Range
365	2200	κ(ms) = 0.0605*H = 0.022
430	2630	
450	3060	
Bedrock	9200	

NRC's GMRS Sensitivity Studies

Thickness (ft)	Vs (ft/s)	Damping Curve
92	2250	EPRI Soil (1993) & Peninsular Range
18	3920	EPRI Soil (1993) & Peninsular Range
22	2490	EPRI Soil (1993) & Peninsular Range
33.9	3020	EPRI Soil (1993) & Peninsular Range
61.8	2490	EPRI Soil (1993) & Peninsular Range
83.5	1710	EPRI Soil (1993) & Peninsular Range
26.1	2290	EPRI Soil (1993) & Peninsular Range
24.9	1780	EPRI Soil (1993) & Peninsular Range
81.9	2490	EPRI Soil (1993) & Peninsular Range
365	2200	κ(ms) = 0.0605*H = 0.022
430	2630	
450	3060	
Bedrock	9285	



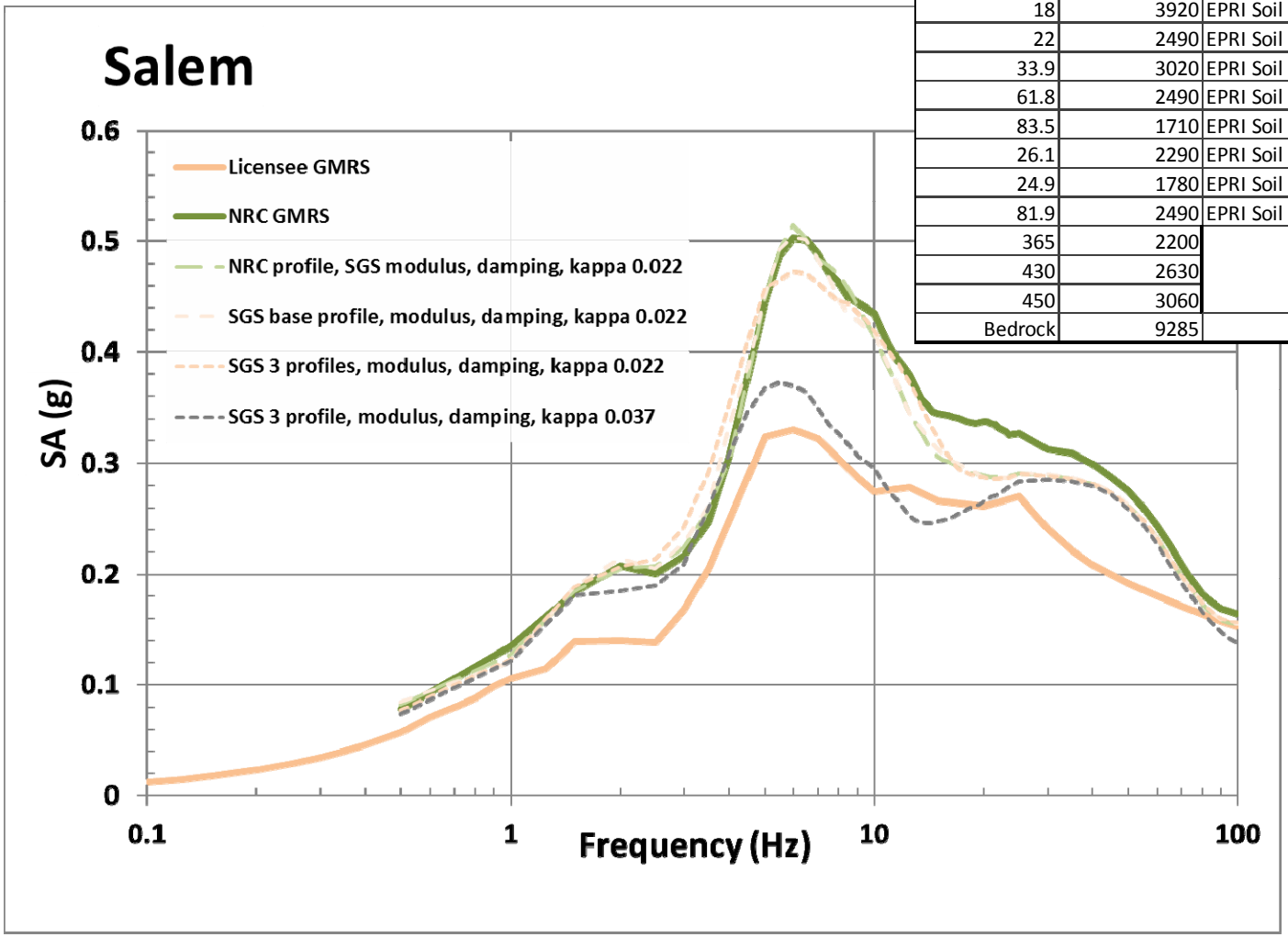
NRC's GMRS Sensitivity Studies



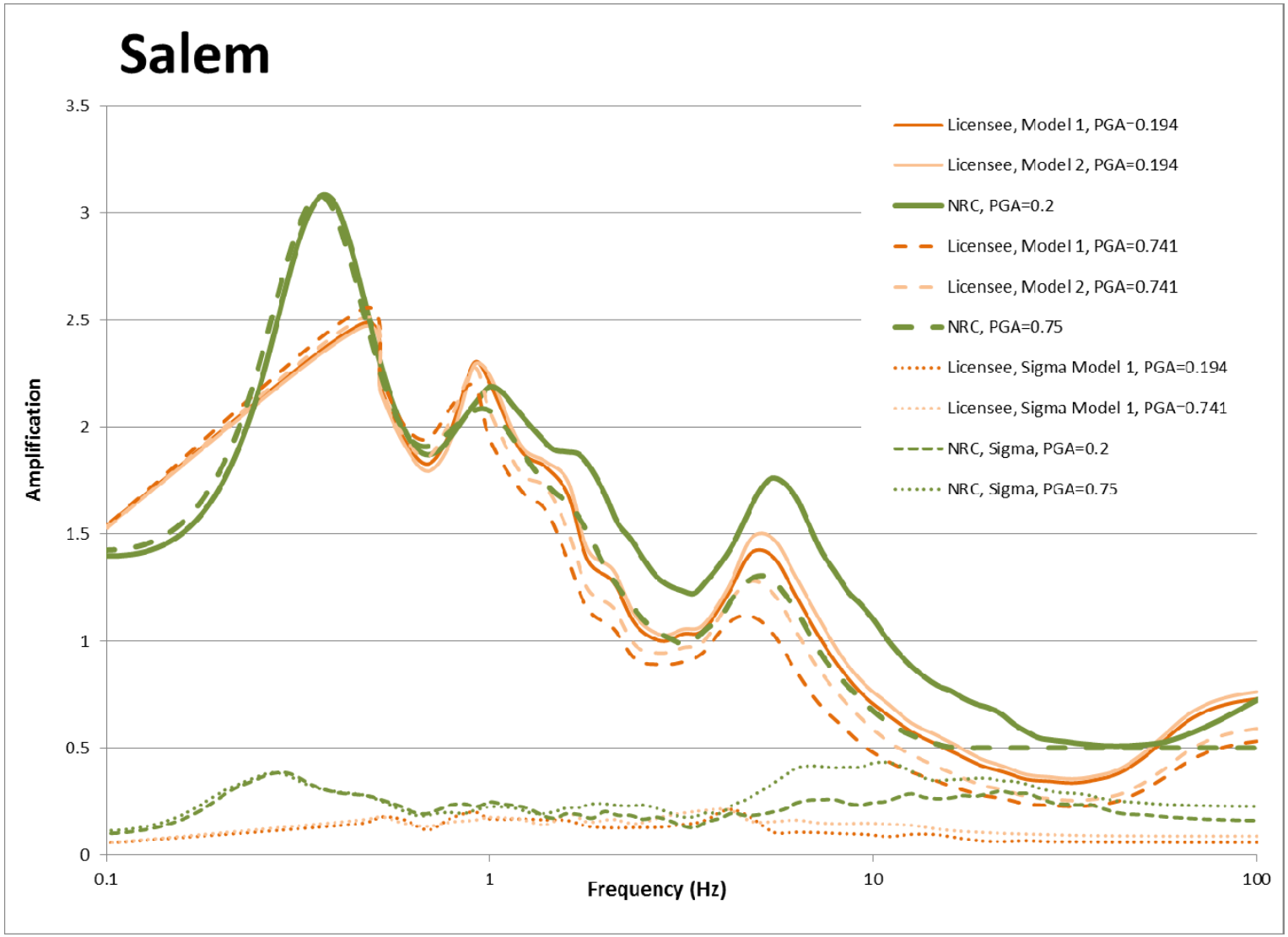
Thickness (ft)	Vs (ft/s)	Damping Curve
92	2250	EPRI Soil (1993) & Peninsular Range
18	3920	EPRI Soil (1993) & Peninsular Range
22	2490	EPRI Soil (1993) & Peninsular Range
33.9	3020	EPRI Soil (1993) & Peninsular Range
61.8	2490	EPRI Soil (1993) & Peninsular Range
83.5	1710	EPRI Soil (1993) & Peninsular Range
26.1	2290	EPRI Soil (1993) & Peninsular Range
24.9	1780	EPRI Soil (1993) & Peninsular Range
81.9	2490	EPRI Soil (1993) & Peninsular Range
365	2200	κ(ms) = 0.0605*H = 0.022
430	2630	
450	3060	
Bedrock	9285	

NRC's GMRS Sensitivity Studies

Thickness (ft)	Vs (ft/s)	Damping Curve	Kappa
92	2250	EPRI Soil (1993) & Peninsular Range	
18	3920	EPRI Soil (1993) & Peninsular Range	
22	2490	EPRI Soil (1993) & Peninsular Range	
33.9	3020	EPRI Soil (1993) & Peninsular Range	
61.8	2490	EPRI Soil (1993) & Peninsular Range	
83.5	1710	EPRI Soil (1993) & Peninsular Range	κ(ms) = 0.0605*H
26.1	2290	EPRI Soil (1993) & Peninsular Range	= 0.031
24.9	1780	EPRI Soil (1993) & Peninsular Range	
81.9	2490	EPRI Soil (1993) & Peninsular Range	
365	2200		
430	2630		
450	3060		
Bedrock	9285		0.006

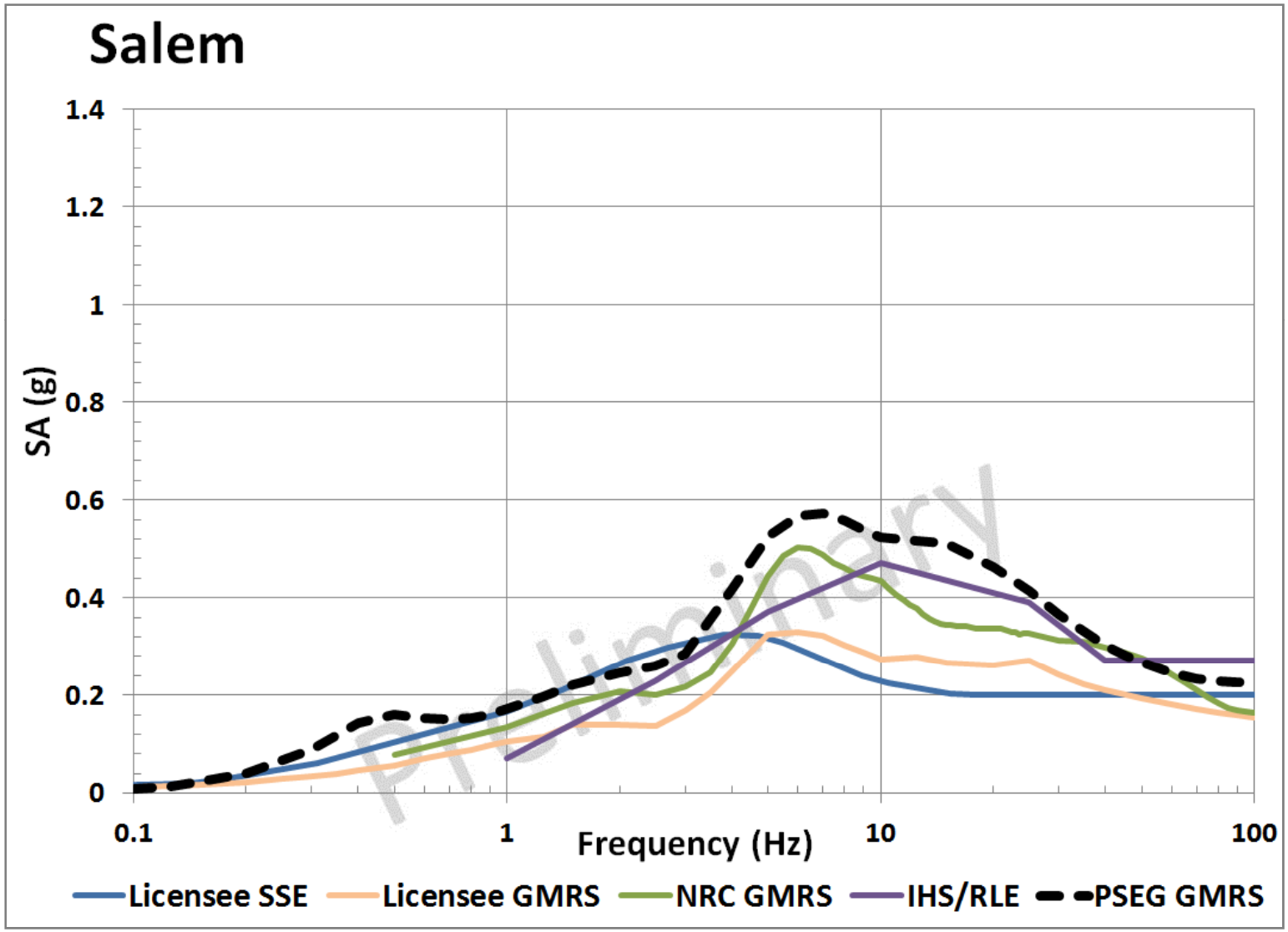


Amplification Functions



Source: ML14090A043 and NRC Calculations

NRC's Preliminary GMRS and PSEG ESP GMRS



Modified from ML14136A126 and PSEG ESP SSAR

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Primary Differences

- Different treatment of damping for Potomac Group Formation
- Licensee determined a total kappa value of 0.037
- NRC calculations produce a total kappa of 0.015
- Licensee used 3 base case profiles vs 1 for NRC