WNP-3 SEISMIC DESIGN BASIS MODEL VALIDATION
SOIL VARIATION STUDIES

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1.0 INTRODUCTION

This submittal presents the results of additional soil-structure interaction (SSI) analyses of the WNP-3 model to address variations in rock foundation material properties. Variations in rock material properties were identified as an open item in NRC 's letter dated February 28, 1991, regarding the Draft Safety Evaluation of the seismic SSI analyses of WNP-3 (Reference 1).

As part of the verification of the adequacy of the WNP-3 in-structure design response spectra, SSI analyses of the WNP-3 nuclear island model were performed using the methodology of the computer program SASSI (Reference 2). The WNP-3 nuclear island is a deeply embedded rock founded structure, and SASSI offers state-of-the-art capabilities to realistically model embedment, wave scattering, radiation damping and foundation flexibility SSI effects.

The SASSI analyses of the nuclear island demonstrated that the WNP-3 in-structure design response spectra have an adequate margin of conservatism when compared to the spectra generated using the state-of-the-art methodology of SASSI (Reference 2). The analyses performed in Reference 2 utilized the "Best Estimate" rock material properties, derived from the geotechnical investigations of WNP-3.

As stated in Reference 1, the NRC has concluded that "(WPPSS's) new methodology using state-of-the-art analytical technique (computer program SASSI) for resolving the deconvolution issue is acceptable" and "generally conforms to the requirements of the SRP Sections 3.7.1 and 3.7.2 of NUREG-0800, Revision 2". To satisfy the requirement of Section 3.7.2 of NUREG-0800, Revision 2 (Reference 3) on variation of soil properties, additional SSI analyses are performed using Lower Bound and Upper Bound variations of the rock material properties. The results of these analyses are documented in this report, which is organized in four sections. Section 2.0 presents the analyses and results of the variation study of the rock material properties and Section 3.0 presents the conclusions of this study regarding the adequacy of the WNP-3 in-structure design response spectra. Section 4.0 lists the references cited.

2.0 SOIL VARIATION ANALYSES AND RESULTS

For the soil variation study, analyses with the computer program SHAKE are initially performed in order to determine strain compatible rock properties. Subsequently, the strain-compatible properties are provided as input to SASSI, which generated the structural response and in-structure response spectra. Details of the analyses and the results are provided below.

2.1 Variation in Rock Properties

Per SRP Section 3.7.2, Revision 2 requirements on variation of rock material properties, Upper Bound and Lower Bound low-strain shear moduli for the rock material are computed as 200% and 50% of the Best Estimate low-strain shear modulus, respectively. Based on these values, the computer program SHAKE generated the strain-compatible shear moduli and material damping ratios of the Upper Bound and Lower Bound cases with the SSE ground motion. In the SHAKE analyses, the same shear modulus degradation and material damping curves as in the Best Estimate case are utilized. The results of the SHAKE analyses are tabulated in Table 2.1 below. Strain-compatible shear moduli, shear wave velocities and material damping ratios are listed for all the soil layers of the profile. For comparison purposes, the Best Estimate values are also included (from Reference 2).

Table 2.1 - Rock Material Properties: Lower Bound, Best Estimate and Upper Bound Cases

Layer No.	Thickness (ft.)	Shear Modulus (ksf)			Shear Wave Velocity (ft/sec)			Damping Ratio (%)		
		LB	BE	UB	LB	BE	UB	LB	BE	UB
1	27.5	27670	60912	111776	2618	3884	5262	1.3	1.0	0.8
2	31.0	24434	60283	99848	2460	3865	4973	2.0	1.5	1.3
3	25.0	29441	59742	120810	2700	3845	5470	2.1	1.8	1.4
H	-	33684	59000	138883	2889	3823	5865	2.4	2.0	1.7

H=Halfspace
LB=Lower Bound
BE=Best Estimate
UB=Upper Bound

2.2 SSI Analyses and Results

As in the Best Estimate case, two-dimensional SSI analyses are performed for the Upper Bound and Lower Bound soil cases using the computer program SASSI (Reference 4). Seismic motions are applied in two directions:

- Horizontal (E-W), and
- Vertical

The WNP-3 E-W horizontal building model is used in the horizontal analyses and the vertical building model is used in the vertical analysis. Both models (horizontal and vertical) are identical to the models used in the Best Estimate case. As in the case of the Best Estimate soil profile, the control motion was applied at the surface of the free field.

Response spectra with 2 percent damping ratio are generated at the following locations (refer to Figure 2.1 for location):

- Top of Shield Building (Node No. 1 in Figure 2.1)
- Top of Reactor Auxiliary Building (Node No. 23 in Figure 2.1)
- Top of Containment Vessel (Node No. 31 in Figure 2.1)
- Top of Internal Structures (Node No. 51 in Figure 2.1)
- Center of Basemat (Node No. 62 in Figure 2.1)

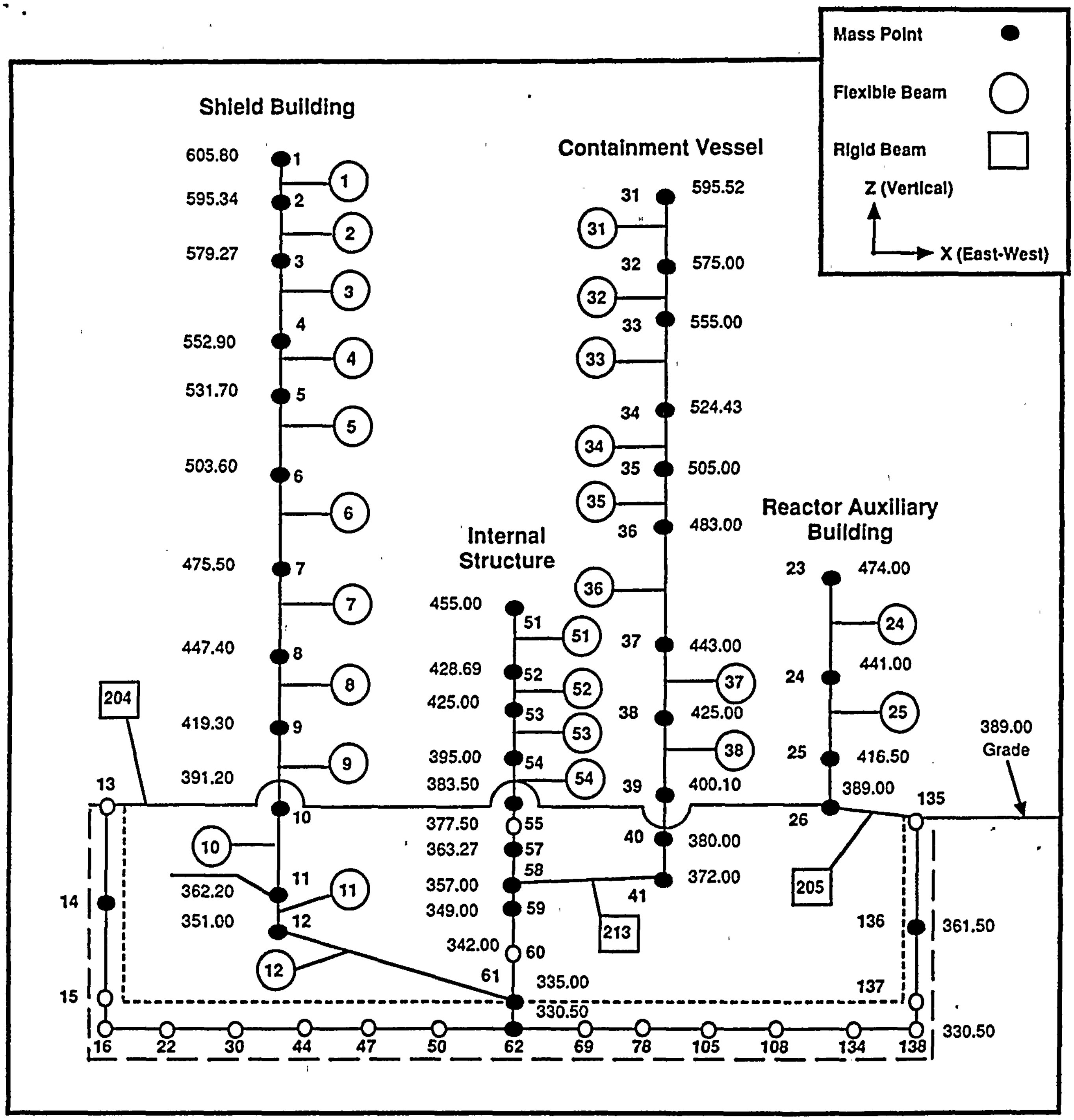
Figures 2.2 to 2.11 present the plots of the response spectra according to the numbering sequence that follows. Each figure contains the Upper Bound and Lower Bound spectra as well as the Best Estimate and the Design spectra, for comparison purposes.

Figure No.	Direction	Location
2.2	Horizontal	Top of Shield Building
2.3	Horizontal	Top of Reactor Auxiliary Building
2.4	Horizontal	Top of Containment Vessel
2.5	Horizontal	Top of Internal Structures
2.6	Horizontal	Center of Basemat
2.7	Vertical	Top of Shield Building
2.8	Vertical	Top of Reactor Auxiliary Building
2.9	Vertical	Top of Containment Vessel
2.10	Vertical	Top of Internal Structures
2.11	Vertical	Center of Basemat

In addition, the free-field motions at the foundation level corresponding to the Upper Bound and Lower Bound soil cases for the horizontal and vertical directions were generated and they are plotted in Figures 2.12 and 2.13, respectively. The free-field surface motion is superimposed in the same plot for comparison purposes.

The spectral plots demonstrate that the response of the WNP-3 model in the Upper Bound case is the highest, while that of the Lower Bound case is the lowest. The most important factor influencing the response pattern observed is the magnitude of the respective free-field motion at the foundation level (Figures 2.12 and 2.13). The Upper Bound case provides the highest ground motion at the foundation level, while the Lower Bound motion is the lowest at that level.

Due to the high stiffness of the rock material (even in the Lower Bound case), the fundamental SSI frequency at each location is approximately the same for all three cases (Upper Bound, Lower Bound and Best Estimate). Therefore, the Upper Bound case completely envelopes the response of the other two cases. Furthermore, it is observed that, in general, the design spectra envelop or are very close to the SASSI spectra for all the cases and at all frequencies. Minor exceedances occur in the vertical direction at three locations, Top of Containment, Top of Internal Structures and Center of Basemat, which are judged to be insignificant for design applications. At the Top of Internal Structures and Center of Basemat the exceedances occur in the 1-2 Hz frequency range, which is a low range for response of systems in the vertical direction. At the Top of the Containment, and only for the Upper Bound case, the SASSI spectra exceed the design spectra around 15 Hz. This is also judged to be of no significance to the design spectra, since the Upper Bound case is associated with rock shear wave velocities greater than 5000 ft/sec, which are well out of the range of the velocities recorded by the geotechnical investigations at WNP-3.



Primary Structures with Foundation
(All elevations in Feet)

Figure 2.1 - Structural Model of WNP-3

Top of Shield Building, 2% Damping, EW Component

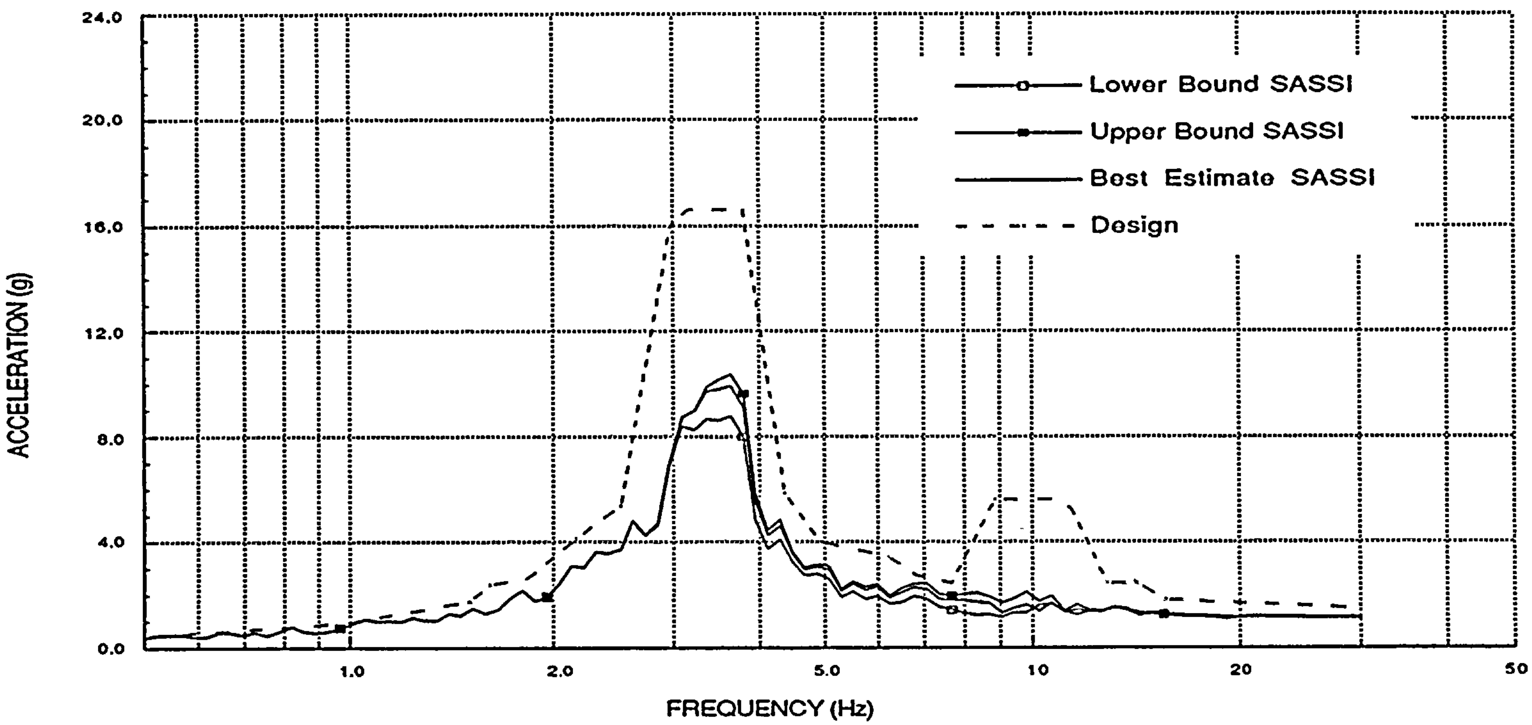


Figure 2.2 - Horizontal In-Structure Response Spectra WPPSS WNP-3 Top of Shield Building

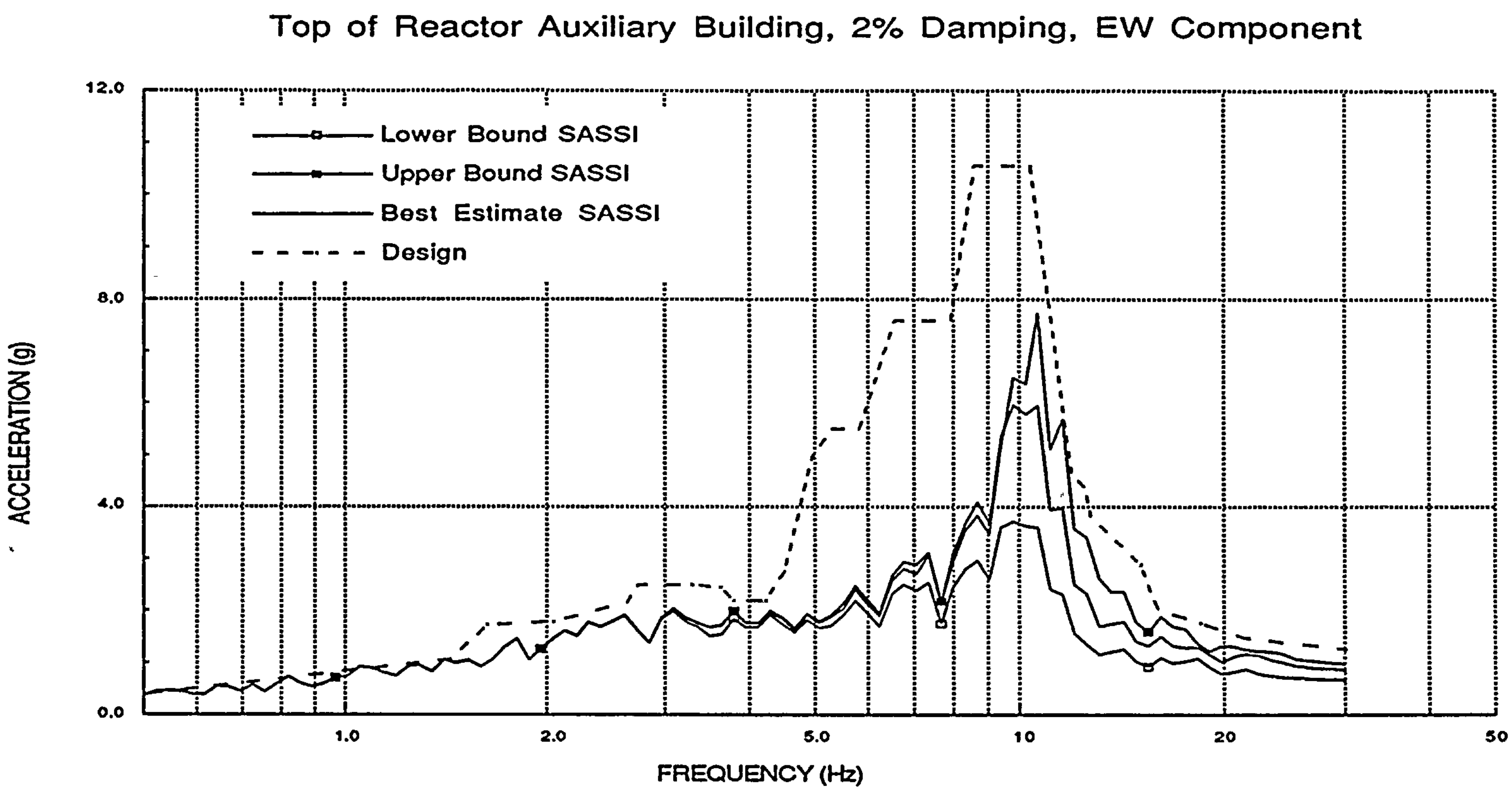


Figure 2.3 - Horizontal In-Structure Response Spectra
WPPSS WNP-3 Top of Reactor Auxiliary Building

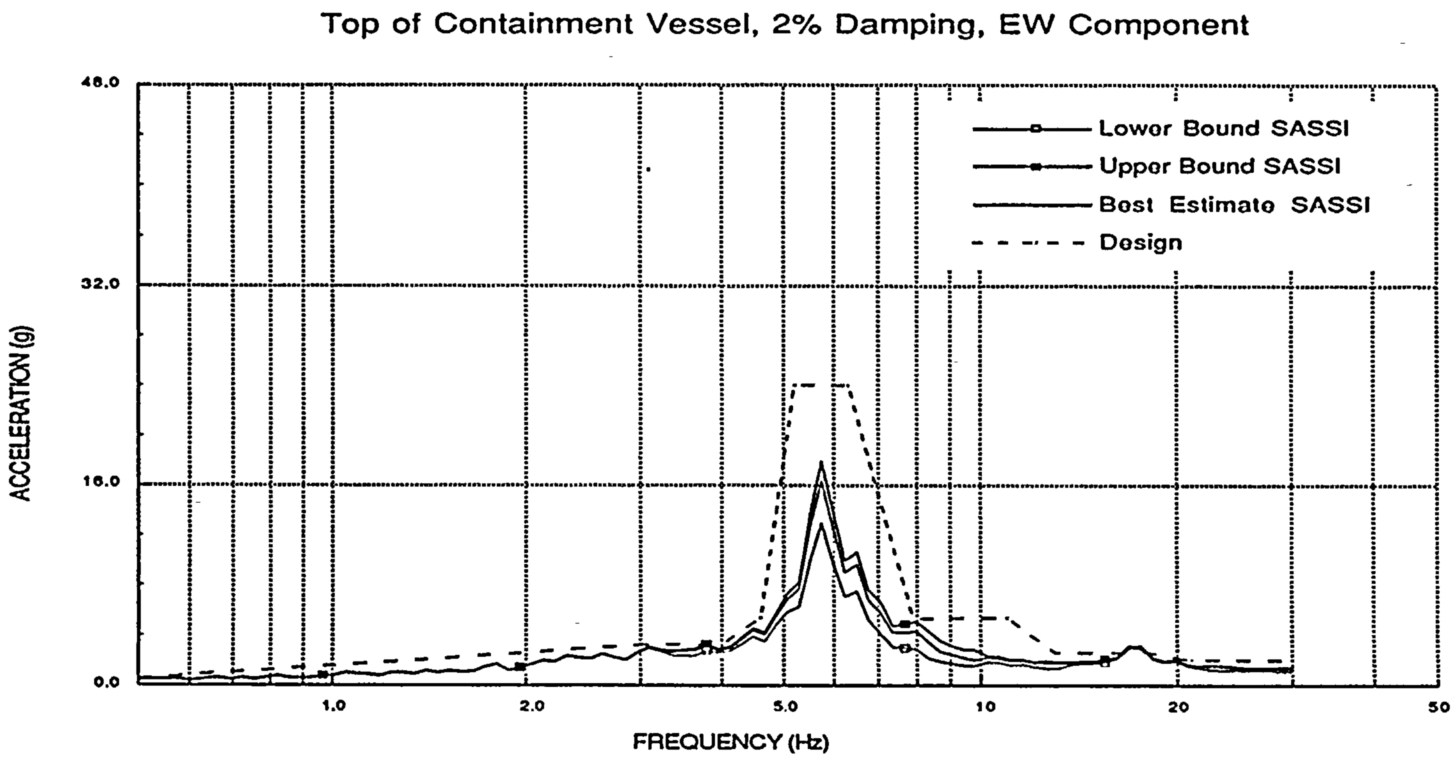


Figure 2.4 - Horizontal In-Structure Response Spectra
WPPSS WNP-3 Top of Containment Vessel

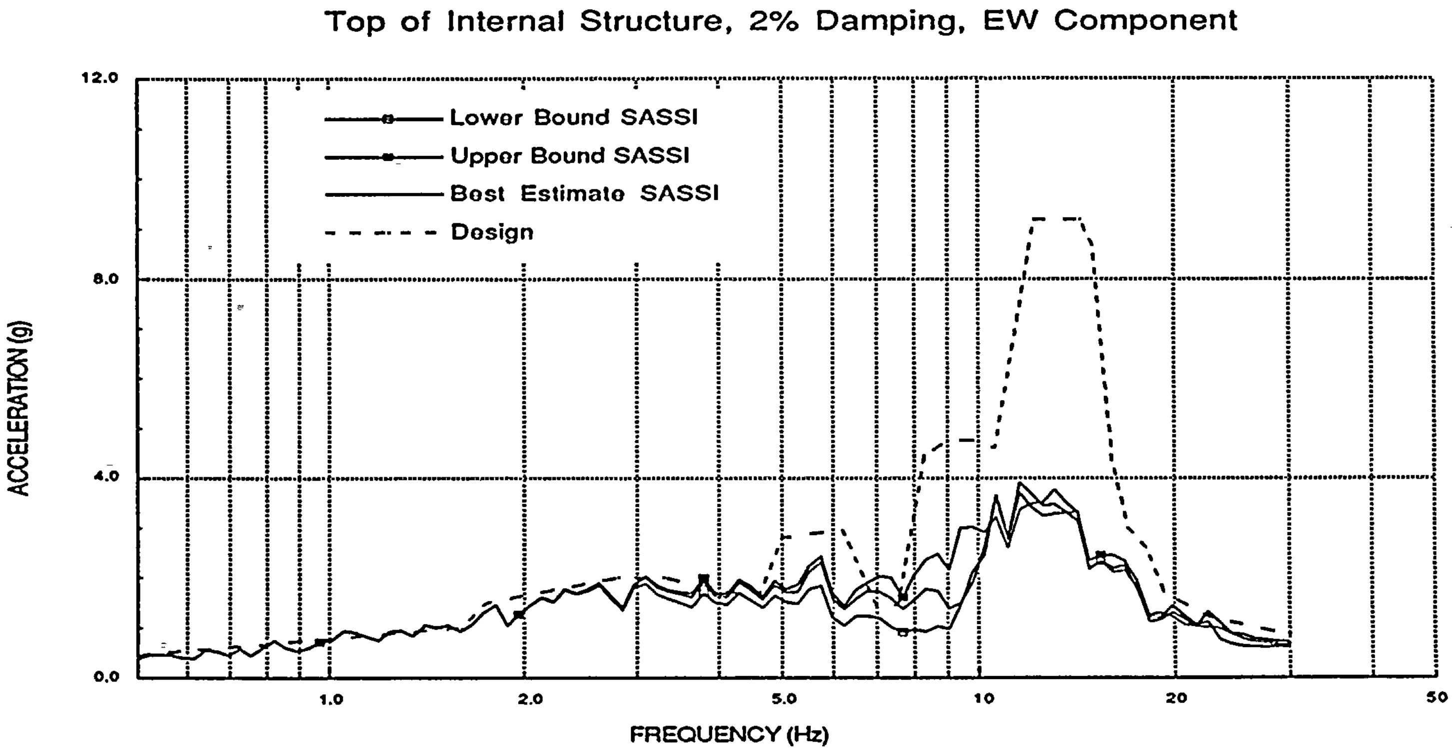


Figure 2.5 - Horizontal In-Structure Response Spectra
WPPSS WNP-3 Top of Internal Structures

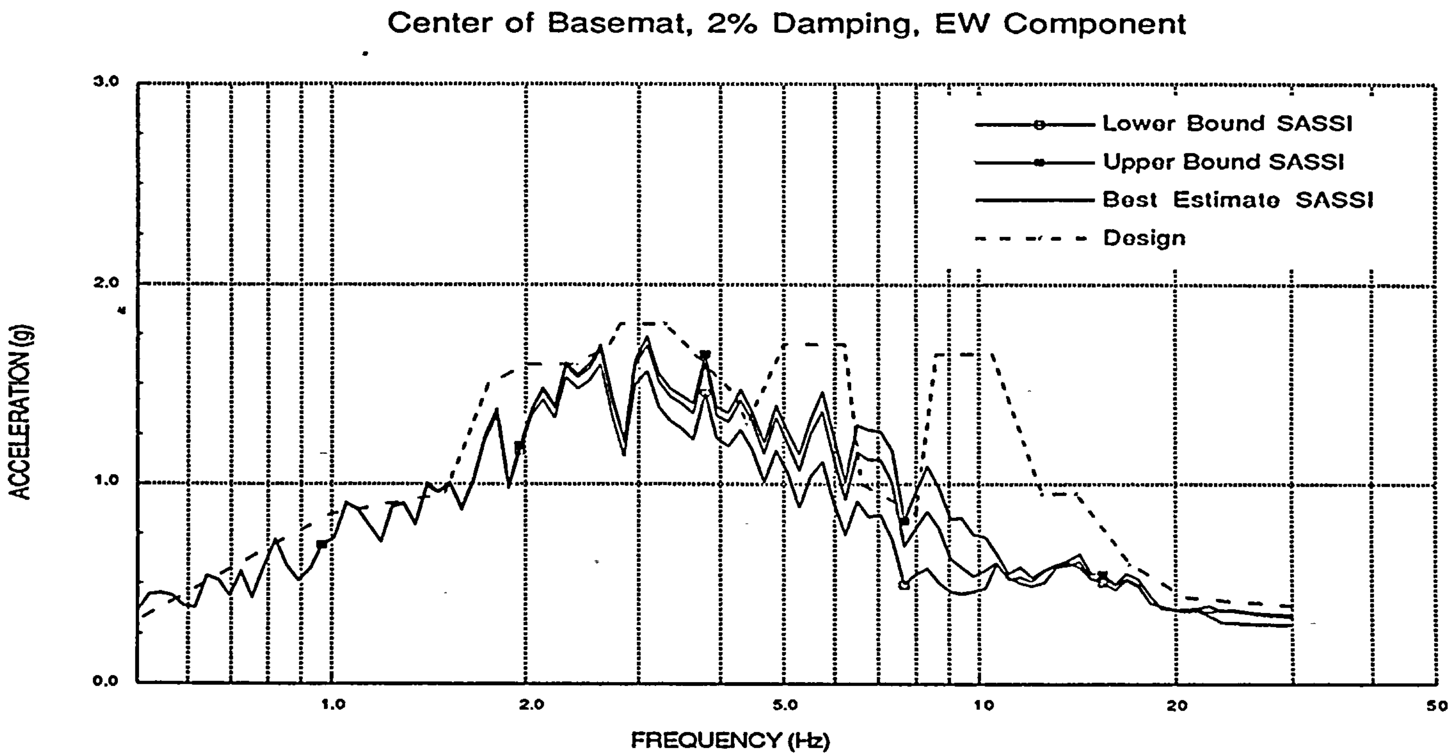


Figure 2.6 - Horizontal In-Structure Response Spectra
WPPSS WNP-3 Center of Basemat

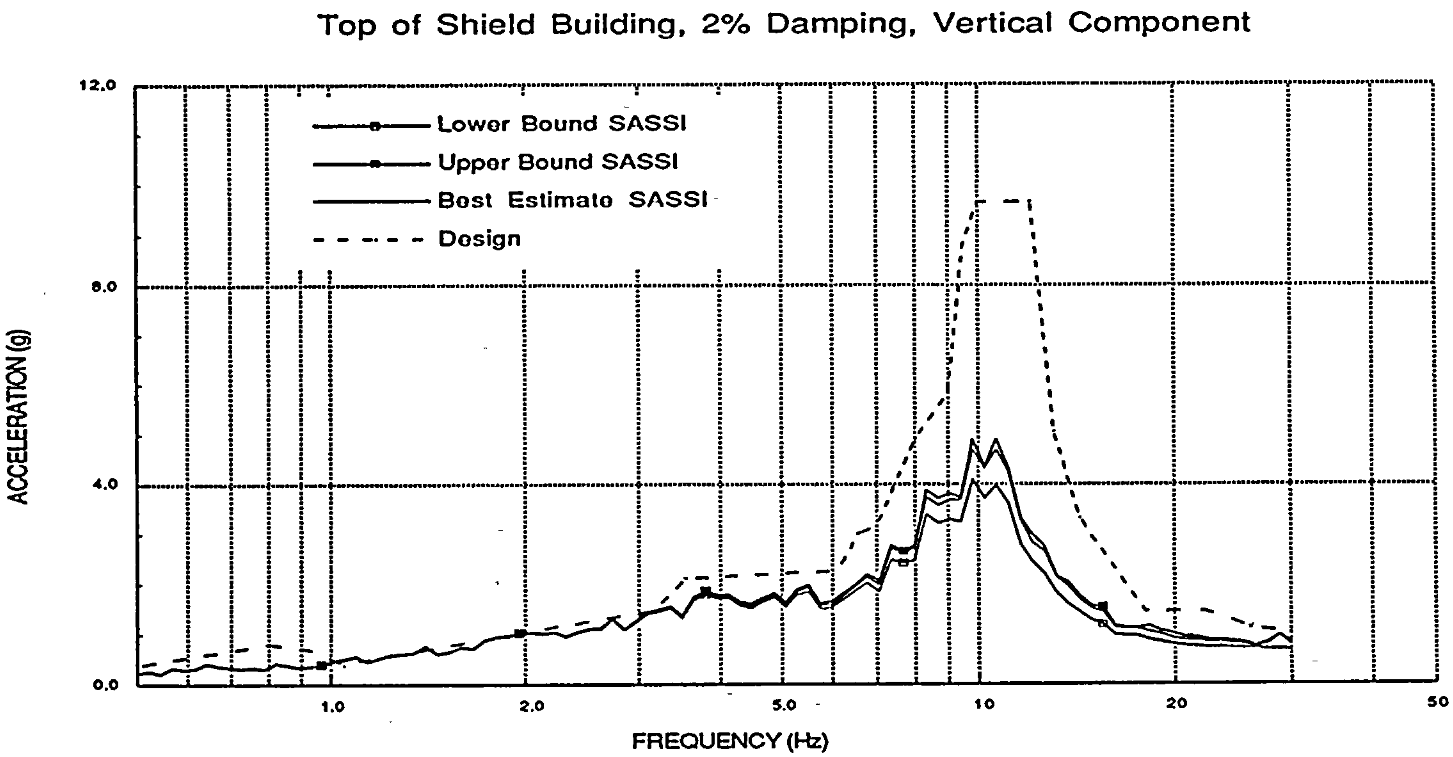


Figure 2.7 - Vertical In-Structure Response Spectra WPPSS WNP-3 Top of Shield Building

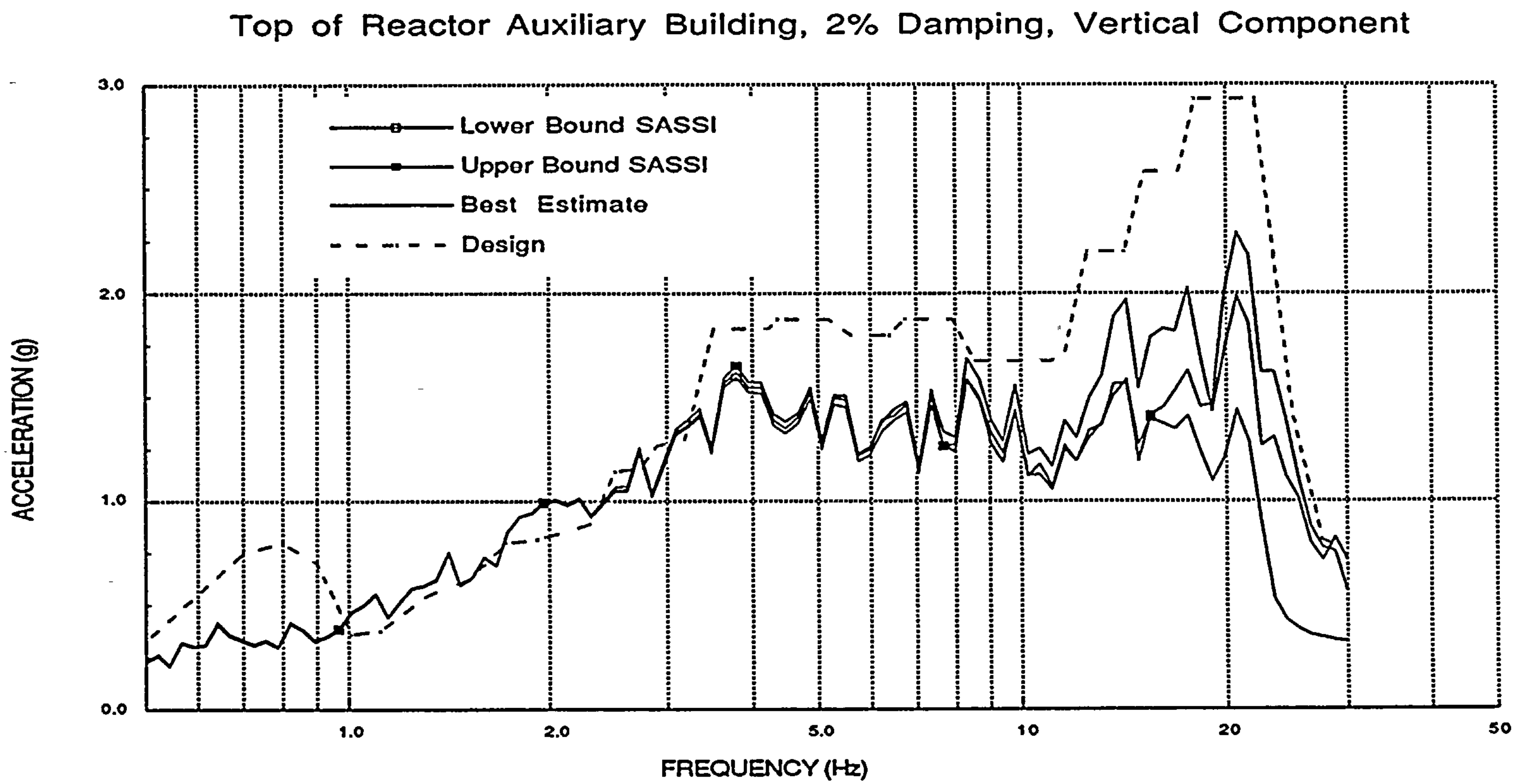


Figure 2.8 - Vertical In-Structure Response Spectra
WPPSS WNP-3 Top of Reactor Auxiliary Building

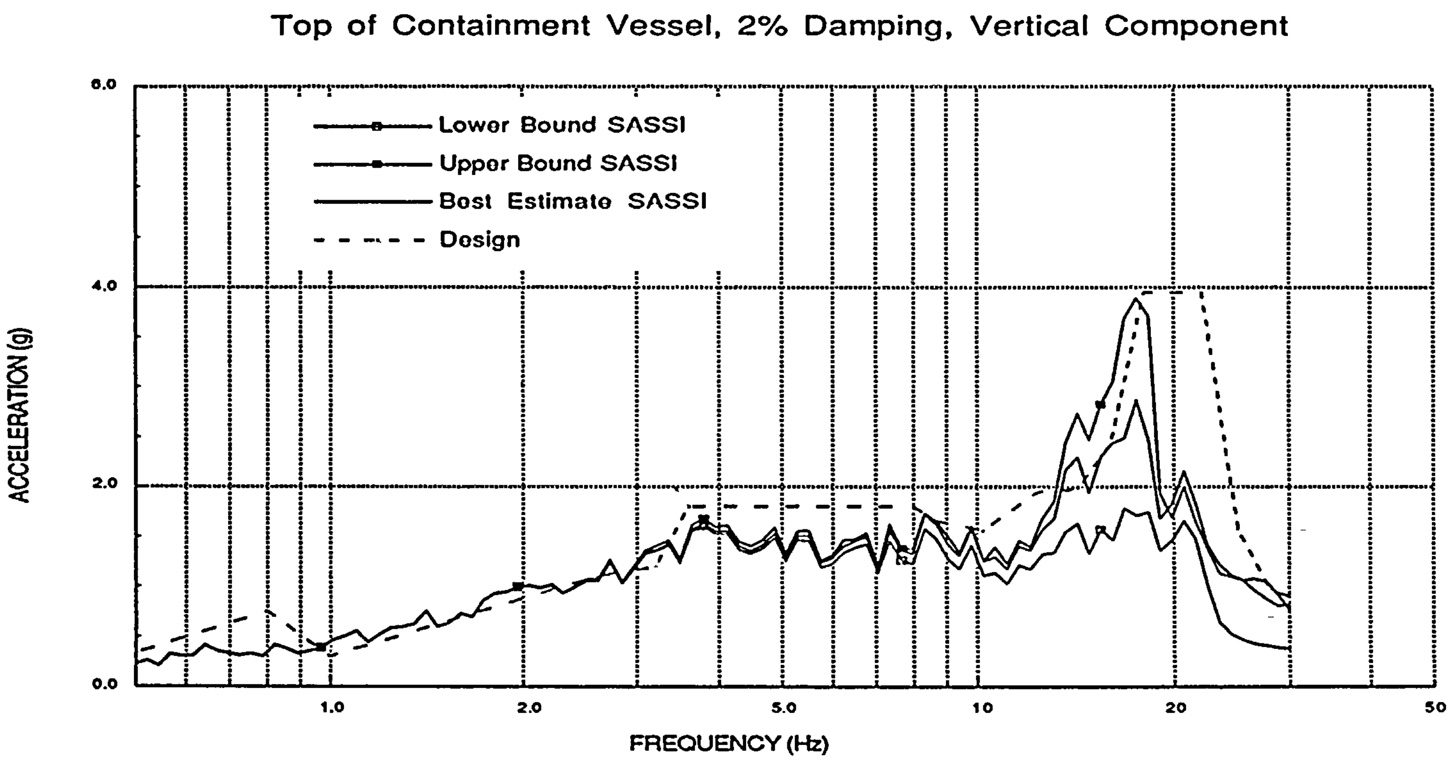


Figure 2.9 - Vertical In-Structure Response Spectra WPPSS WNP-3 Top of Containment Vessel

Top of Internal Structure, 2% Damping, Vertical Component

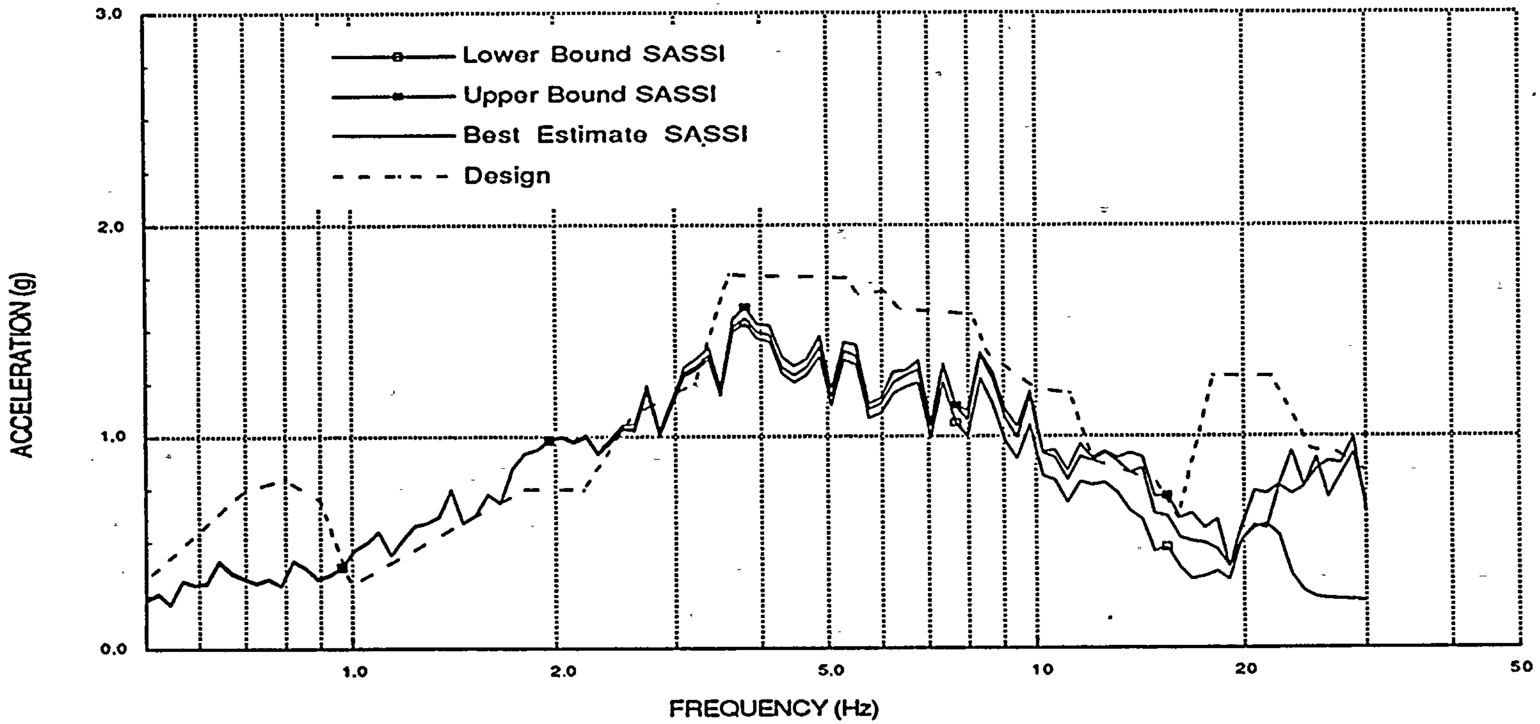


Figure 2.10- Vertical In-Structure Response Spectra
WPPSS WNP-3 Top of Internal Structures

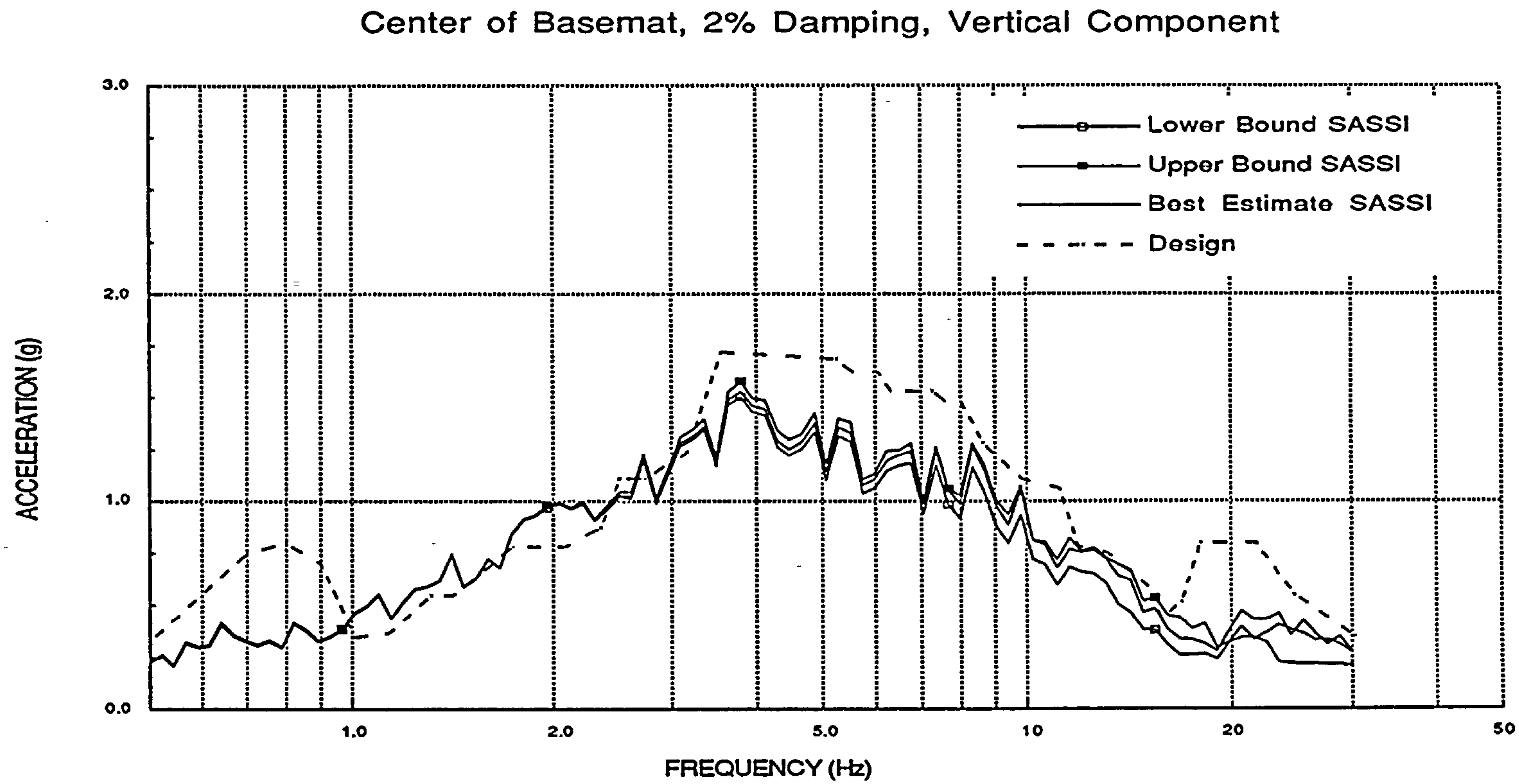


Figure 2.11 - Vertical In-Structure Response Spectra
WPPSS WNP-3 Center of Basemat

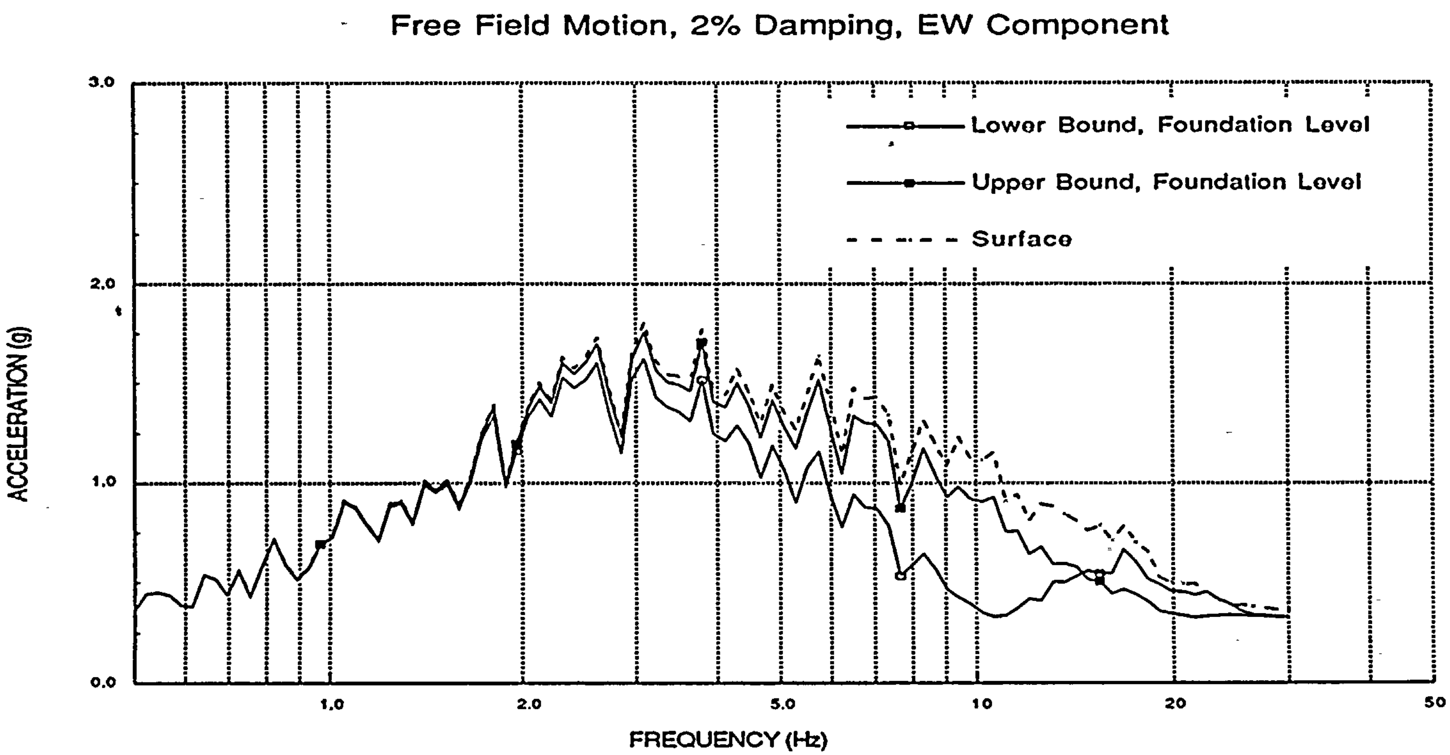


Figure 2.12 - Horizontal Free-Field Response Spectra
WPPSS WNP-3

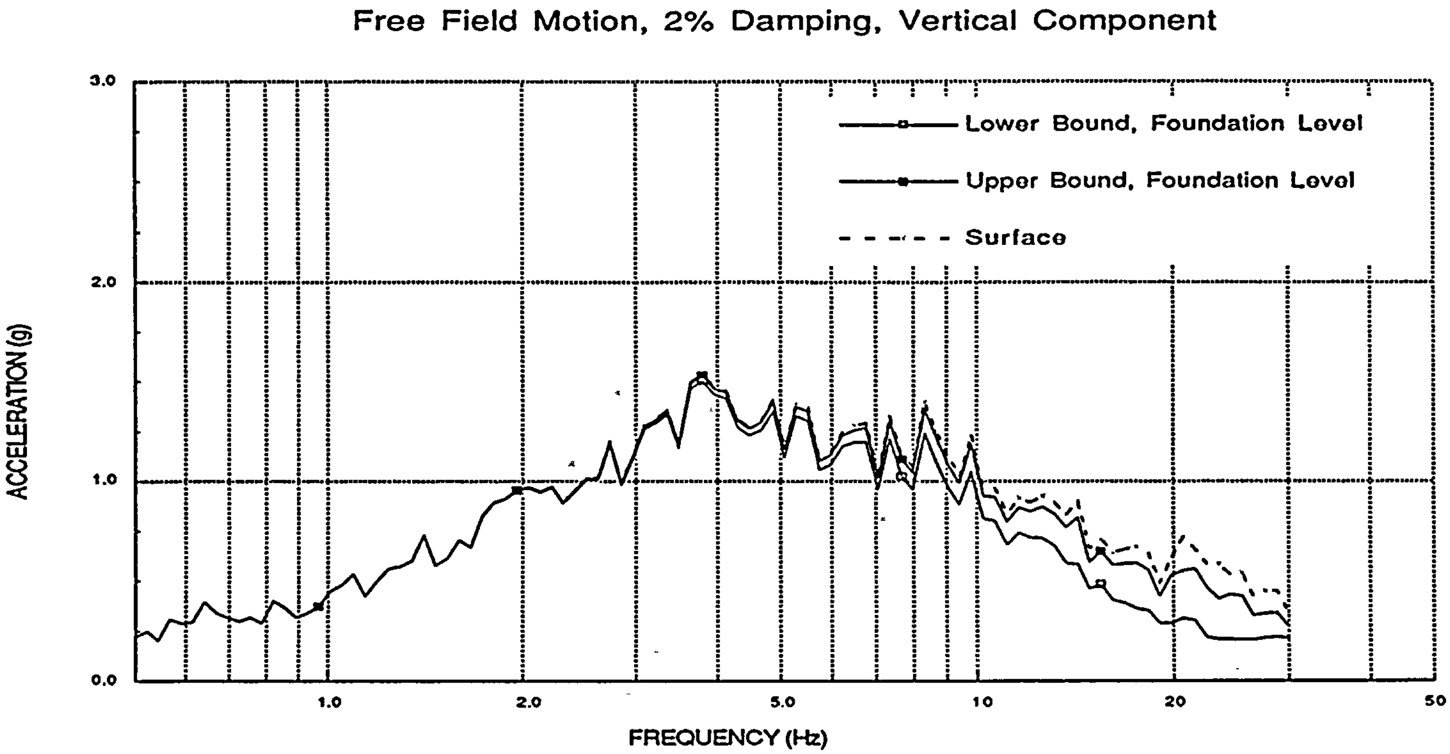


Figure 2.13 - Vertical Free-Field Response Spectra
WPPSS WNP-3

3.0 CONCLUSIONS

Soil variation studies are perofrmed for the WNP-3 model. The rock shear moduli were varied by 50% and 200%, according to the recommendations of the SRP Section 3.7.2, Revision 2, and additional SASSI analyses are performed with Upper Bound and Lower Bound rock properties. Using the results of these analyses, Upper Bound and Lower Bound response spectra are generated at selected locations. The resulting Upper Bound and Lower Bound response spectra as well as the Best Estimate spectra are, in general, enveloped by the design spectra by an adequate margin. Minor spectra exceedances are of no significance to design applications.

The state-of-the-art methodology of SASSI combined with the soil variation studies satisfy all SRP Section 3.7.1 and 3.7.2 requirements on SSI analyses and response spectra generation. Therefore, the SSI analyses performed for the WNP-3 structural model demonstrate that there is ample conservatism in the WNP-3 design spectra.

4.0 REFERENCES

1. Letter from Marvin Mendonca, USNRC, to D. W. Mazur, Washington Public Power Supply System, dated February 28, 1991, Subject: NRC Review of the Soil-Structure Interaction (SSI) Analysis/Deconvolution Issue for WNP-3.

2. Impell Corporation, Calculation WNP3-01, "WNP3 2D SASSI SSI Analysis", Revision 1, August, 1988.

3. U.S. Nuclear Regulatory Commission, Standard Review Plan, NUREG-0800, Revision 2, 1989.

4. ABB Impell Corporation, Standard Computer Program SASSI, Version 4.0 (Cyber 990), User's Manual Revision 1.