RAIO-0918-61804

Docket No. 52-048

September 17, 2018

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 151 (eRAI No. 8974) on the NuScale Design Certification Application

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 151 (eRAI No. 8974)," dated August 05, 2017
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 151 (eRAI No.8974)," dated October 03, 2017
3. NuScale Power, LLC Supplemental Response to NRC "Request for Additional Information No. 151 (eRAI No.8974)," dated April 09, 2018

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) supplemental response to the referenced NRC Request for Additional Information (RAI).

The Enclosure to this letter contains NuScale's supplemental response to the following RAI Question from NRC eRAI No. 8974:

- 03.08.04-23

This letter and the enclosed response make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Marty Bryan at 541-452-7172 or at mbryan@nuscalepower.com.

Sincerely,

Zackary W. Rad
Director, Regulatory Affairs
NuScale Power, LLC

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Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 8974

Enclosure 1:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 8974

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 8974
Date of RAI Issue: 08/05/2017

NRC Question No.: 03.08.04-23

10 CFR 50, Appendix A, GDC 1, 2, and 4, provide requirements to be met by SSC important to safety. In accordance with these requirements, DSRS Sections 3.7.1 and 3.8.4 provide review guidance pertaining to seismic parameters and design of seismic Category I structures. Consistent with the guidance in DSRS 3.7.1.II.4.A.viii, the staff reviews comparison criteria for the acceptability of a standard design for a potential site.

COL item 3.8-2 in Section 3.8.4.8 directs the COL applicant to confirm that the site independent RXB and CRB are acceptable for use at the designated site. Further, Section 3.8.4.8 identifies locations within the building and respective ISRS which are to be used by the COL applicant to compare with their respective site-specific ISRS for purposes of confirming the acceptability of the site independent structures for the designated site. The applicant is requested to correct inconsistencies between the ISRS Figures referred to in FSAR Section 3.8.4.8 and the respective Figures in FSAR Section 3.7. Further, clarify whether the ISRS in these figures are based on the envelope of all or a partial envelope of the SSI and SSSI analysis cases.

Further, the staff request the applicant to address the following in the FSAR.

1. propose locations for the comparison of building member forces and deformations, with the identification of the respective FSAR Tables and Figures
2. clarify whether the current locations for ISRS comparison include responses at peripheral locations to detect rocking and torsion or propose additional locations as necessary
3. augment the list of locations for ISRS comparison in the RXB to address the fuel racks
4. include responses to check overturning, torsional, and sliding stability of the structures

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NuScale Response:

As discussed in an NRC Public meeting on June 12, 2018, the NRC provided supplemental questions to eRAI 8974 Question 03.08.04-23 as follows:

1. The staff requests the applicant to also indicate in COL Items 3.7-5 ISRS as part of the seismic demands to be investigated by the COL applicant.

   Response: COL Item 3.7-5 has been revised to state the following:

   "A COL applicant that references the NuScale Power Plant design certification will perform a soil-structure interaction analysis of the Reactor Building and the Control Building using the NuScale SASSI2010 models for those structures. The COL applicant will confirm that the site-specific seismic demands of the standard design for critical structures, systems, and components in Appendix 3B are bounded by the corresponding design certified seismic demands and, if not, the standard design for critical structures, systems, and components will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands. Seismic demands investigated shall include forces, moments, deformations, in-structure response spectra, and seismic stability of the structures."

2. The staff requests the applicant to provide FSAR markups identifying the specific FSAR Figures and/or Tables and/or Sections containing the standard design forces, moments, deformations, and seismic stability of the structures to be used in the comparison, also including identification of the corresponding locations throughout the structures and identification of the node(s) and or element(s) comprising the individual and/or envelop responses of ISRS, forces and moments, deformations, and seismic stability results, as applicable, consistent with RAI 8935, Q25.

   Response: This staff request will be responded to in RAI 8935 Question 03.07.02-25.

   For ISRS, Table 3.7.2-53 is added to the FSAR to list the nodes enveloped at each floor to produce the floor ISRS. Figures 3.7.2-142 through 3.7.2-148 are added to the FSAR to show the locations of the nodes.

3. The staff request for ISRS at wall locations is for ISRS that include results from nodes at or near the center of the wall so as to capture the amplified out-of-plane response of the wall. Therefore, the staff requests the applicant to provide ISRS at wall locations that include the results from nodes at or near the center of the wall and address such ISRS also under COL Item 3.8-2.

Response: There is no safety-related equipment attached to the exterior walls in the NuScale design, and, thus, no center-of-wall ISRS will be presented. If equipment moves to the exterior wall, this will be re-evaluated, and appropriate spectra will be developed and used to analyze that equipment.

4. Further, the staff requests the applicant to explain how the floor ISRS are developed; whether they account for contributions from all or selected nodes on that floor (if selected, criteria and justification for such selection) and a method of incorporation (averaging or enveloping).

Response: The horizontal and vertical ISRS at selected locations of the RXB are calculated at 2, 3, 4, 5, 7, and 10% damping ratios. In the SASSI analysis, the analysis model is subjected to only one component of seismic excitation at a time for each soil type and one of the two concrete conditions (i.e., cracked or uncracked).

The procedure for generating the ISRS follows the guidance of RG 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components", Rev. 1 (also see FSAR Section 3.7.2.5):

Step 1. Obtain the three acceleration response time histories at each selected nodal location due to the EW, NS, and vertical components of a seismic input.

Step 2. Calculate the ISRS of each response time history at 196 discrete frequencies provided in Table 1. These 196 frequencies include all frequencies given in the NRC Standard Review Plan (SRP) Section 3.7.1, Table 3.7.1-1 and an intermediate frequency between any two consecutive frequencies specified in Table 3.7.1-1 and some additional frequencies below 0.2 Hz.

Table 1 - The 196 Frequencies for ISRS Generation.

Row No.	196 Frequencies (Hz) for ISRS Generation Listed Row-wise in Increasing Frequencies.									
1	0.1	0.1125	0.125	0.1375	0.15	0.1625	0.175	0.1875	0.2	0.225
2	0.25	0.275	0.3	0.325	0.35	0.375	0.4	0.425	0.45	0.475
3	0.5	0.525	0.55	0.575	0.6	0.65	0.7	0.75	0.8	0.85
4	0.9	0.95	1	1.05	1.1	1.15	1.2	1.25	1.3	1.35
5	1.4	1.45	1.5	1.55	1.6	1.65	1.7	1.75	1.8	1.85
6	1.9	1.95	2	2.05	2.1	2.15	2.2	2.25	2.3	2.35
7	2.4	2.45	2.5	2.55	2.6	2.65	2.7	2.75	2.8	2.85
8	2.9	2.95	3	3.075	3.15	3.225	3.3	3.375	3.45	3.525
9	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5
10	4.6	4.7	4.8	4.9	5	5.125	5.25	5.375	5.5	5.625
11	5.75	5.875	6	6.125	6.25	6.375	6.5	6.625	6.75	6.875
12	7	7.125	7.25	7.375	7.5	7.625	7.75	7.875	8	8.25
13	8.5	8.75	9	9.25	9.5	9.75	10	10.25	10.5	10.75
14	11	11.25	11.5	11.75	12	12.25	12.5	12.75	13	13.25
15	13.5	13.75	14	14.25	14.5	14.75	15	15.5	16	16.5
16	17	17.5	18	19	20	21	22	23.5	25	26.5
17	28	29.5	31	32.5	34	35.5	37	38.5	40	41.5
18	43	44.5	46	47.5	49	50.5	52	53.5	55	56.5
19	58	59.5	61	64	67	70	73	76	79	82
20	85	88	91	94	97	100	-	-	-	-

Step 3. At each selected location, combine the three co-directional ISRS due to the three components of the seismic input by the SRSS method.

Step 4. Repeat Steps 1 through 3 for each seismic input.

Step 5. Average the ISRS that are obtained in Step 4 due to five CSDRS-compatible inputs. Note that, for CSDRS-HF-compatible input, no average is necessary because there is only one CSDRS-HF-compatible input.

Step 6. Repeat Steps 1 through 5 for different soil types.

Step 7. Repeat Steps 1 through 6 for the cracked and uncracked concrete conditions.

Step 8. The ISRS are enveloped over soil types and concrete conditions considered.

Step 9. Broaden each enveloped ISRS by ±15% to account for structural model uncertainties in accordance with ASCE 4-98 requirements. The broadening is identical to that specified in NRC Regulatory Guide 1.122. The enveloped ISRS is broadened 15% on the frequency scale; i.e., a frequency band of $0.85 \times f_i$ to $1.15 x f_i$ is used to widen the spectral acceleration of the i^{th} spectral frequency f_i.

Step 10. Envelope single and triple building ISRS for each selected node. The nodes selected for ISRS generation were chosen because they would provide maximum or representative responses. For example, at EL 24' (top of foundation in gallery), the northwest and northeast corner nodes of the RXB outer wall experience the highest displacements and, therefore, ISRS. Another approximate mid-point on the outer wall (gridline 4) was selected to provide an intermediate ISRS. At EL 25', (top of pool floor), the 6 nodes selected were at the center base node of NPM1 through NPM6. These 6 nodes lie on the north side of the RXB. Because the RXB is symmetric about the east-west axis, the ISRS beneath the NPMs on the south side will be nearly identical.

Step 11: Floor ISRS

The ISRS at select locations on the same floor are enveloped to obtain the floor ISRS.

Table 3.7.2-53 is added to the FSAR to list the nodes enveloped at each floor to produce the floor ISRS. Figures 3.7.2-142 through 3.7.2-148 have been added to the FSAR to show the locations of the nodes.

5. The staff requests the applicant to provide an ISRS at the NPM support skirt location that is consistent with the input used for the NPM analysis documented in TR-0916-51502 and identify the node(s) for such ISRS.

Response: Please see FSAR markup.

At the CNV skirts of NPM1 and NPM6, response spectra are generated for the time histories at the eight spider nodes, corresponding to the eight spider elements. The SASSI node numbers are listed in Table 2 of this response.

The resulting spider node spectra are then averaged for each module. This results in nine averaged skirt response spectra for each module, based on the three seismic cases provided (Soil Type 7, Capitola time history, cracked concrete nominal stiffness, cracked concrete reduced stiffness, uncracked concrete nominal stiffness), each with three components (X,Y, and Z). The ISRS of the nine averaged skirt response spectra is then enveloped for NPM1 and NPM6 in the X, Y, and Z directions. The six resulting enveloping ISRS (two modules x one skirt support x three directions) for the NPM1 and NPM6 CNV skirts are shown in Figures 1 and 2.

Table 2. SASSI CNV skirt nodes

NPM1	NPM6
6027	6287
6028	6288
6029	6289
6039	6299
6042	6302
6053	6307
6054	6308
6055	6309

At the CNV lugs of NPM1 and NPM6, response spectra are generated for the time histories at the nodes listed in Table 3. The spectra are then enveloped at each of the lugs on NPM1 and NPM6, resulting in 18 total enveloping spectra (two modules x three lugs x three directions). These spectra are shown in Figures 3 through 8.

Table 3. SASSI CNV lug nodes

	NPM1	NPM6
West Lug	6477	31081
North Lug	6483	31087
East Lug	6486	31090

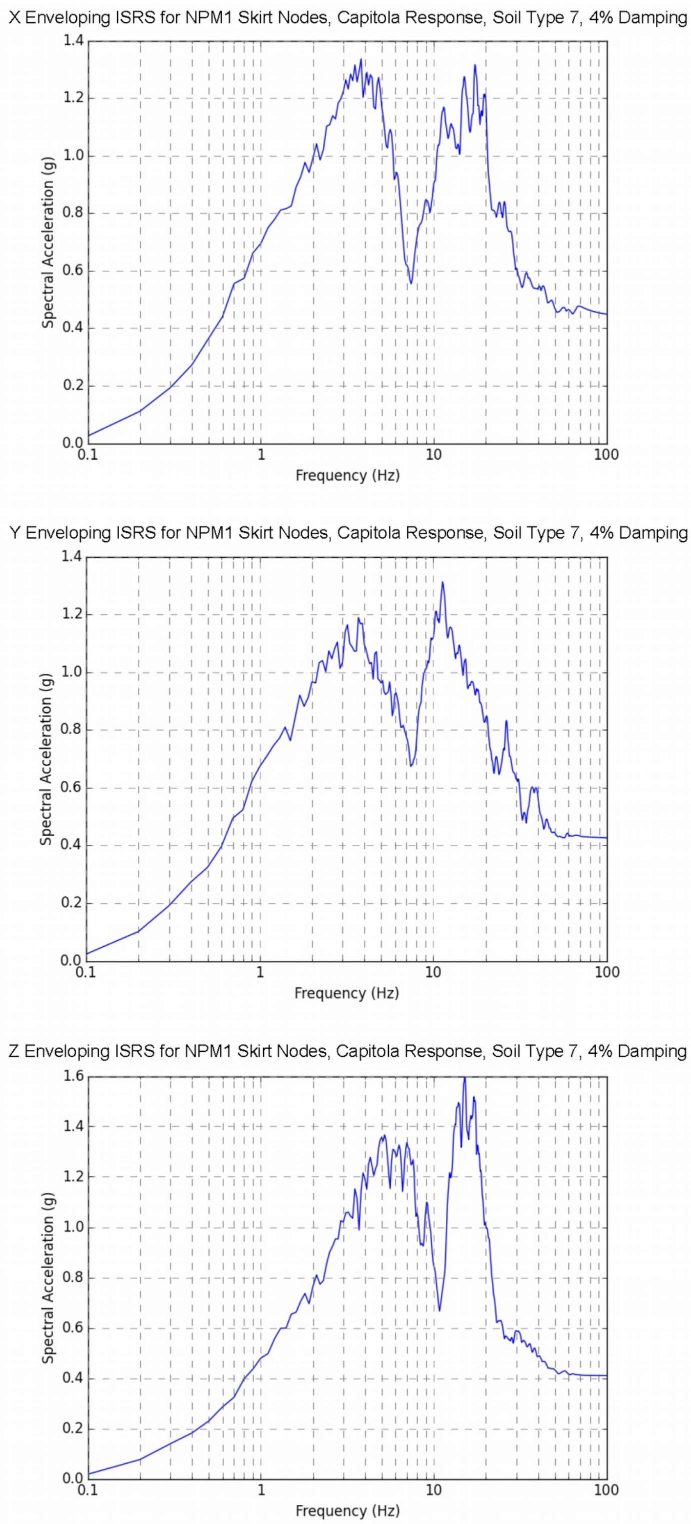


Figure 1 - Enveloping ISRS of cases 1, 2 and 3 at the CNV skirt of NPM1

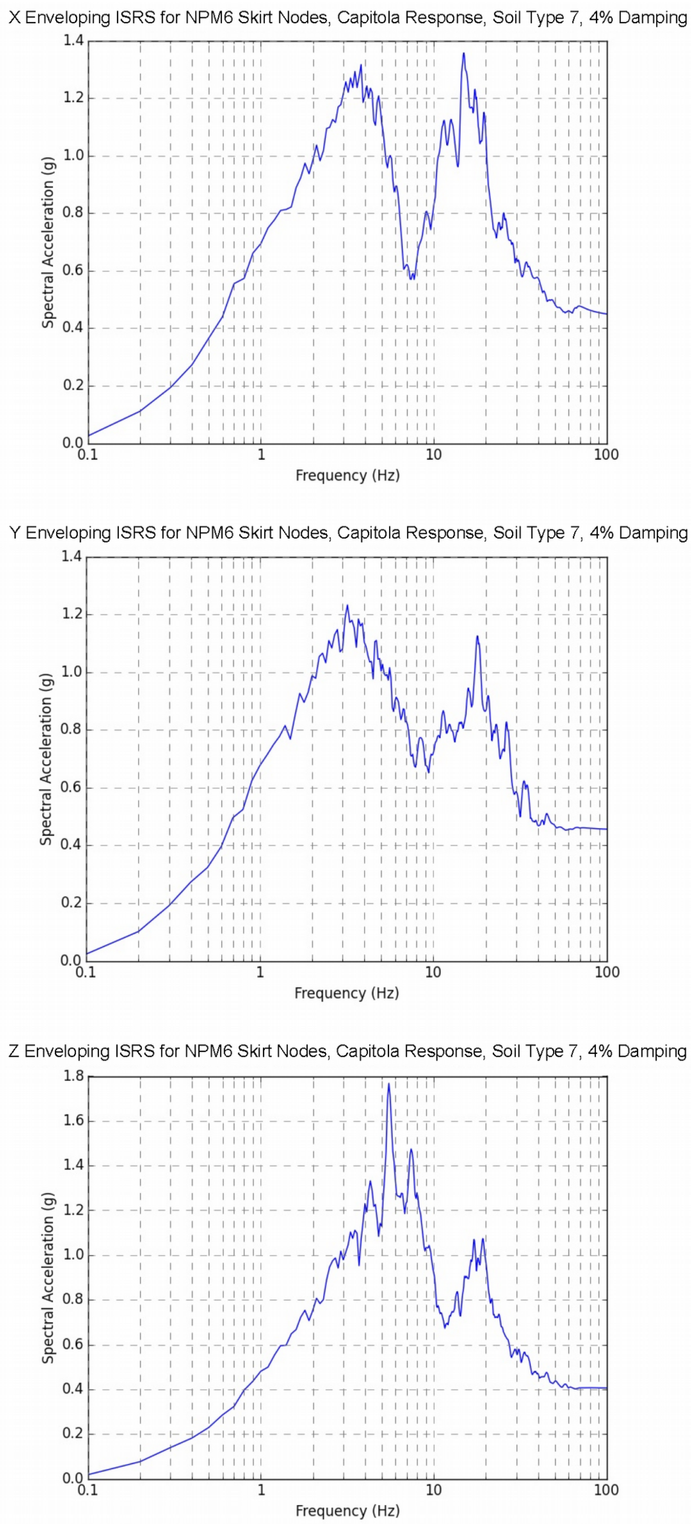


Figure 2 - Enveloping ISRS of cases 1,2 and 3 at the CNV skirt of NPM6

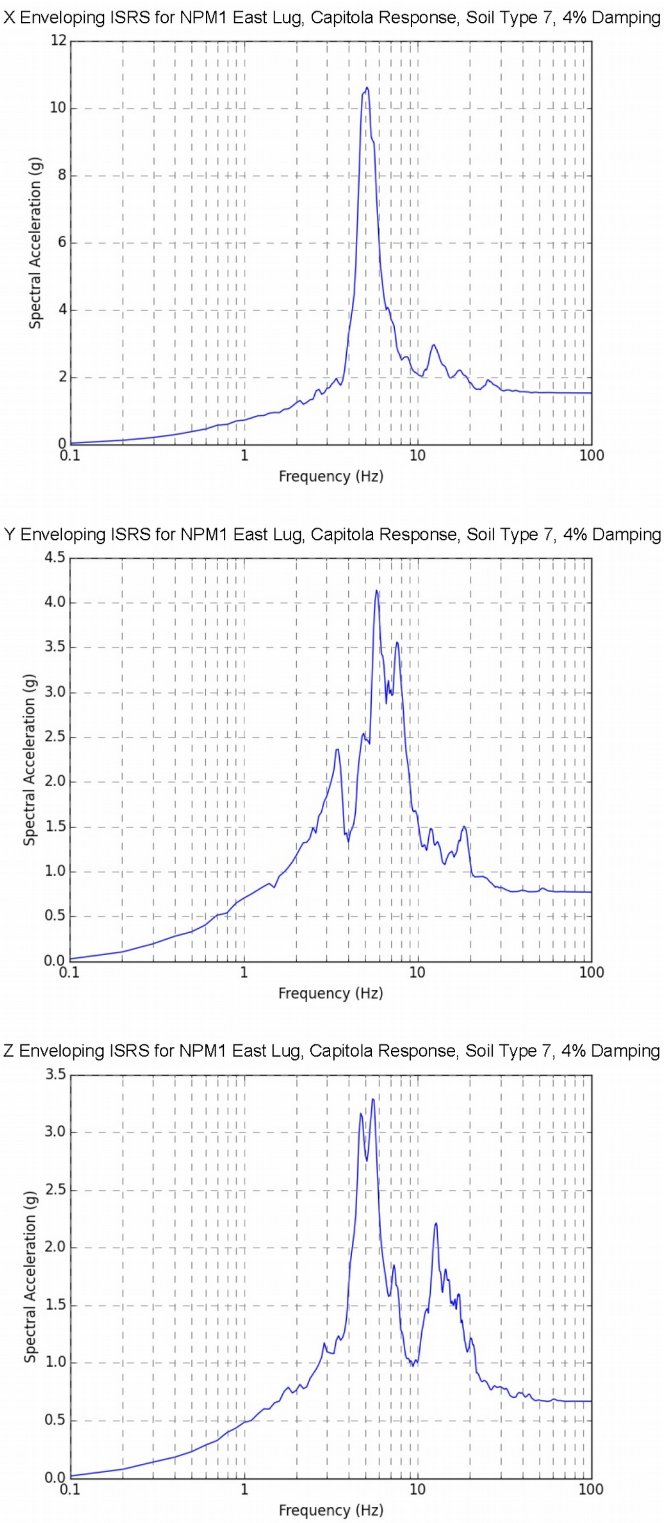


Figure 3 - Enveloping ISRS of cases 1,2 and 3 at the East Lug of NPM1

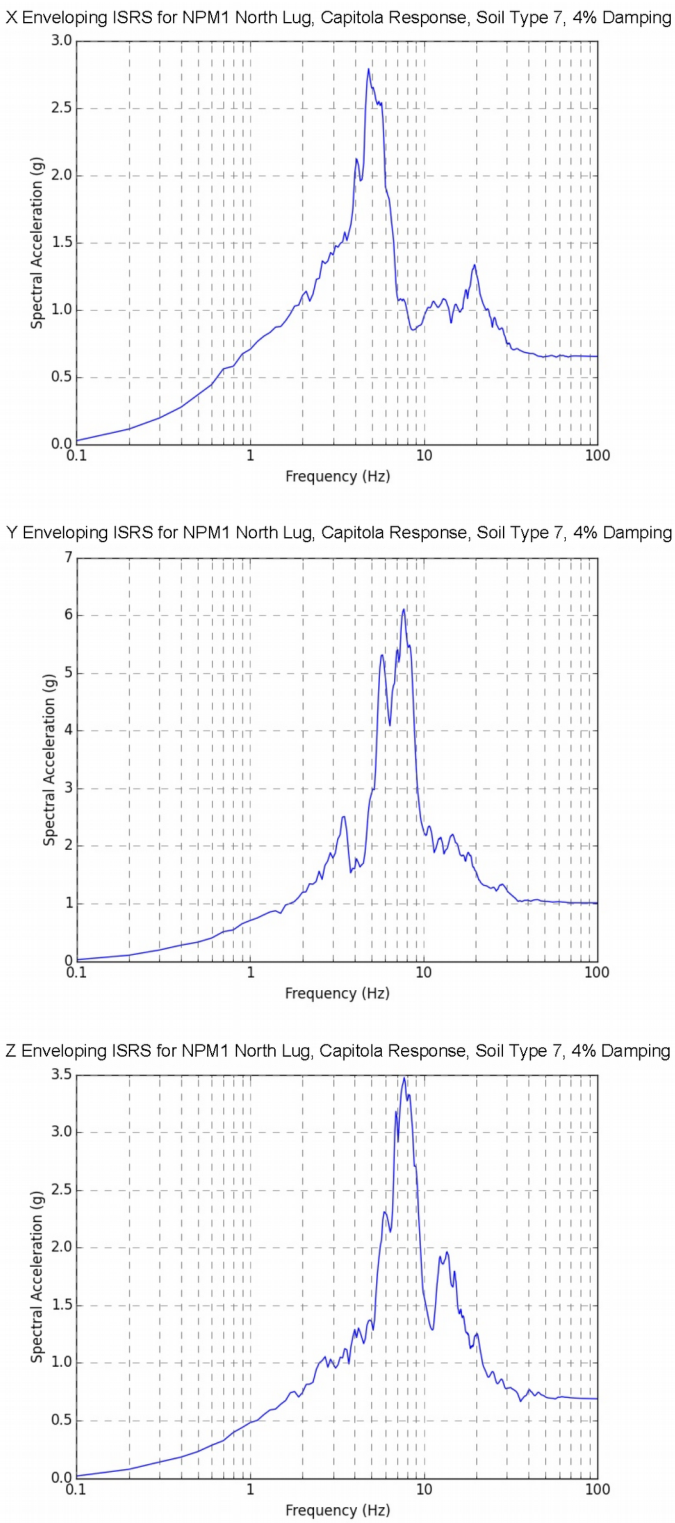


Figure 4 - Enveloping ISRS of cases 1,2 and 3 at the North Lug of NPM1

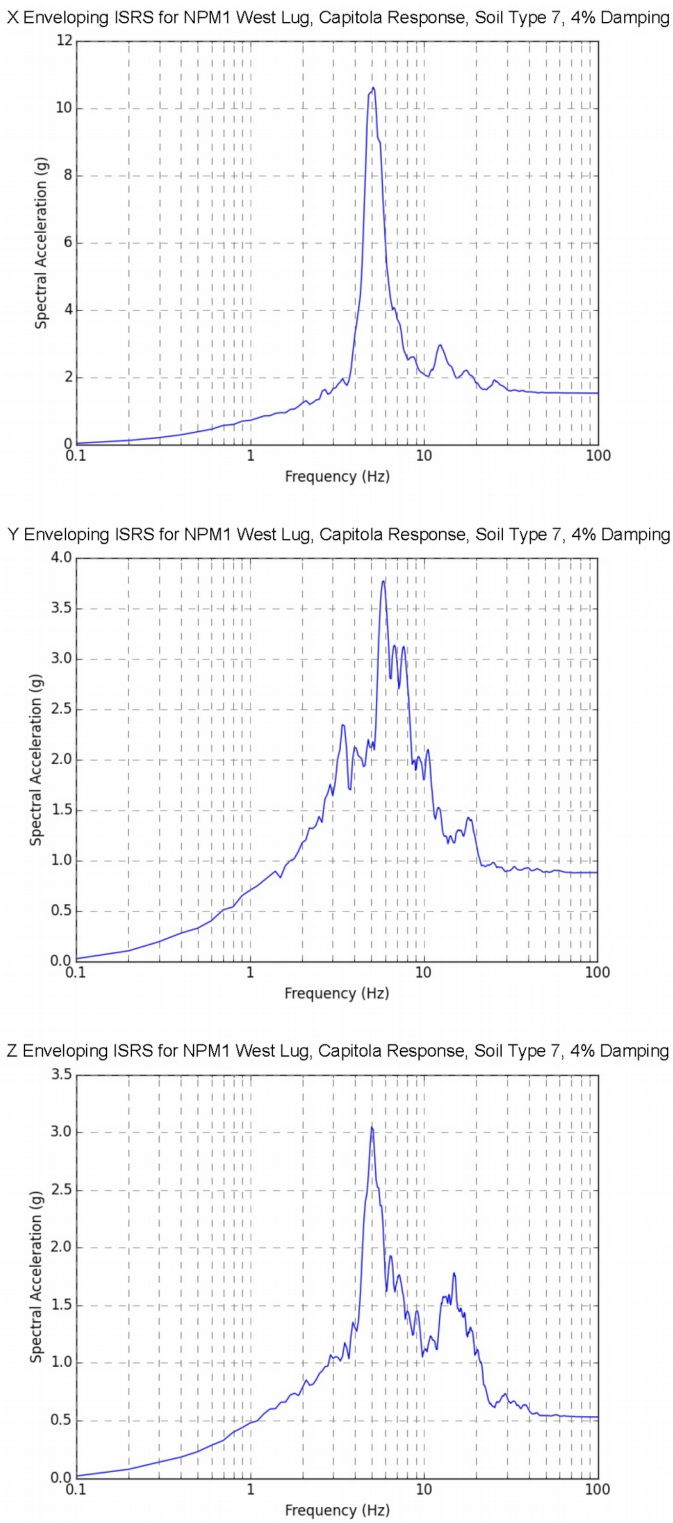


Figure 5 - Enveloping ISRS of cases 1,2 and 3 at the West Lug of NPM1

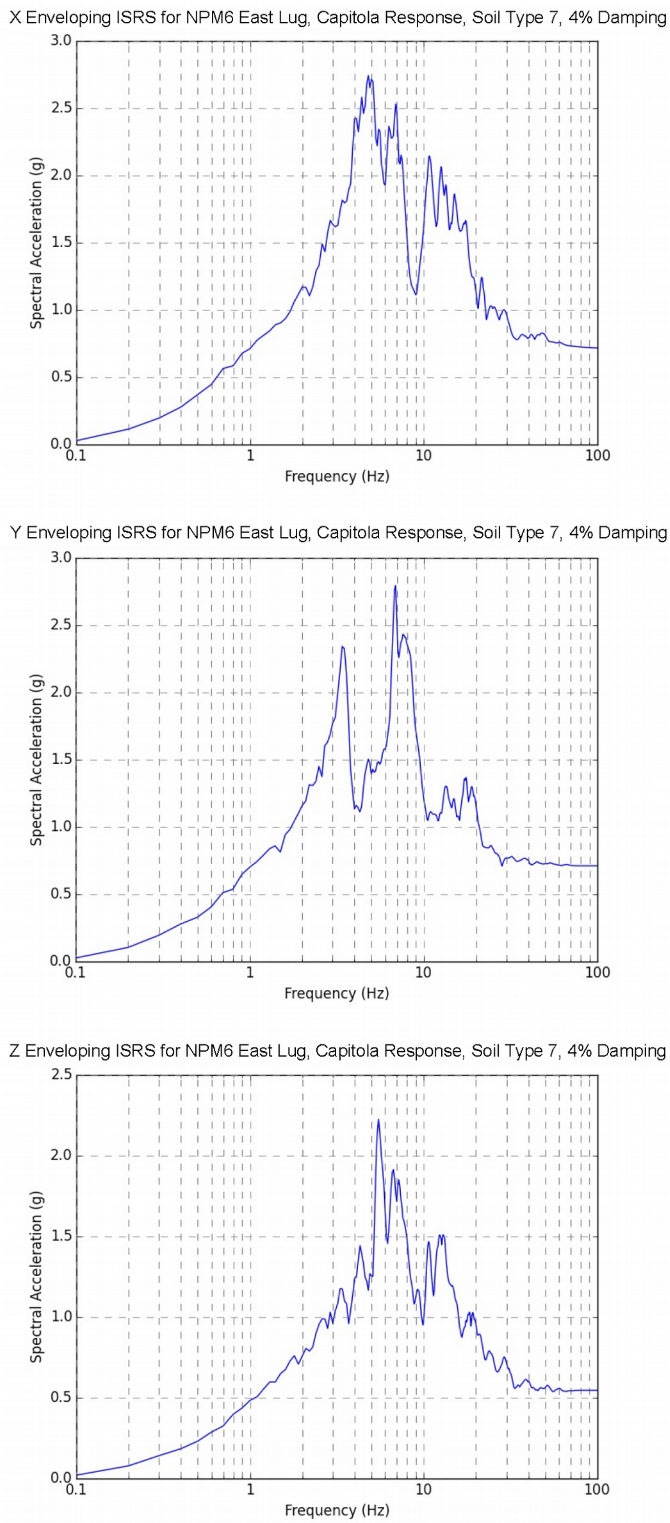


Figure 6 - Enveloping ISRS of cases 1,2 and 3 at the East Lug of NPM6

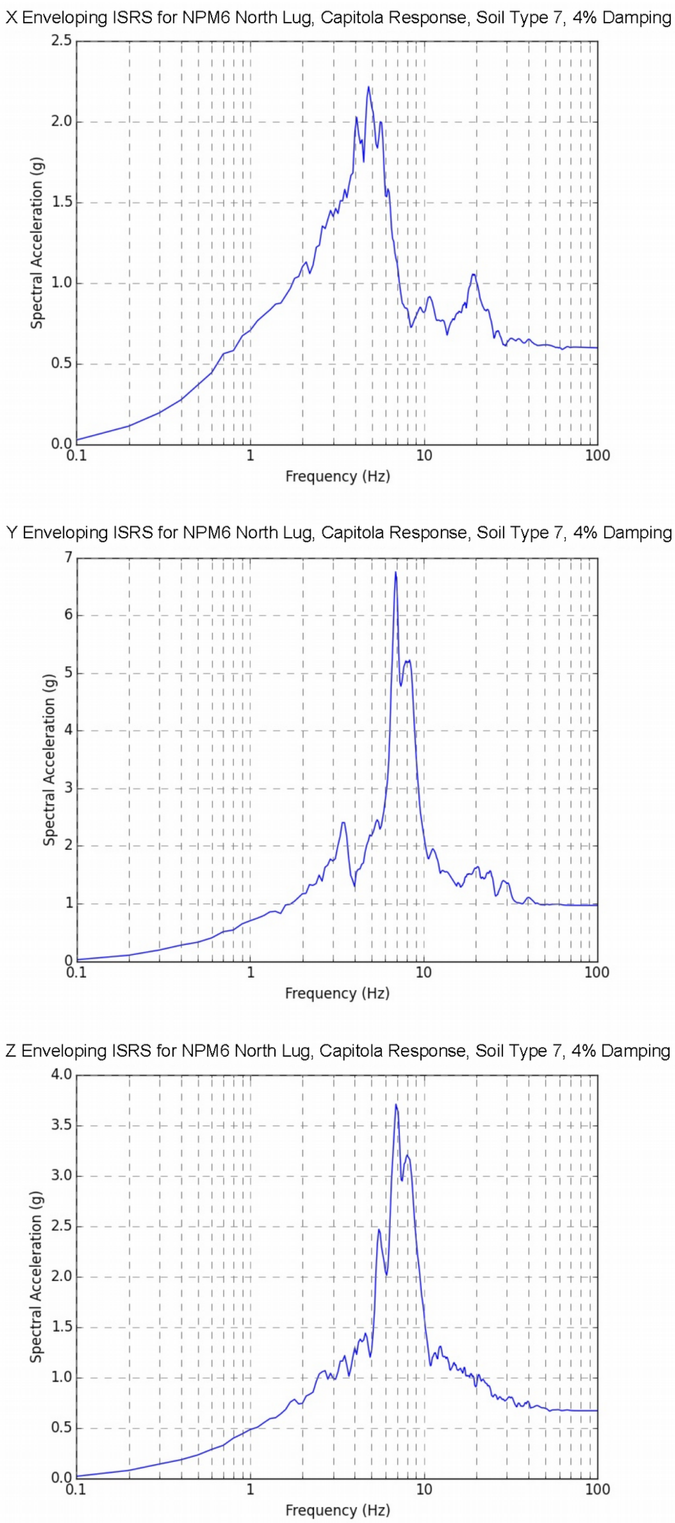


Figure 7 - Enveloping ISRS of cases 1,2 and 3 at the North Lug of NPM6

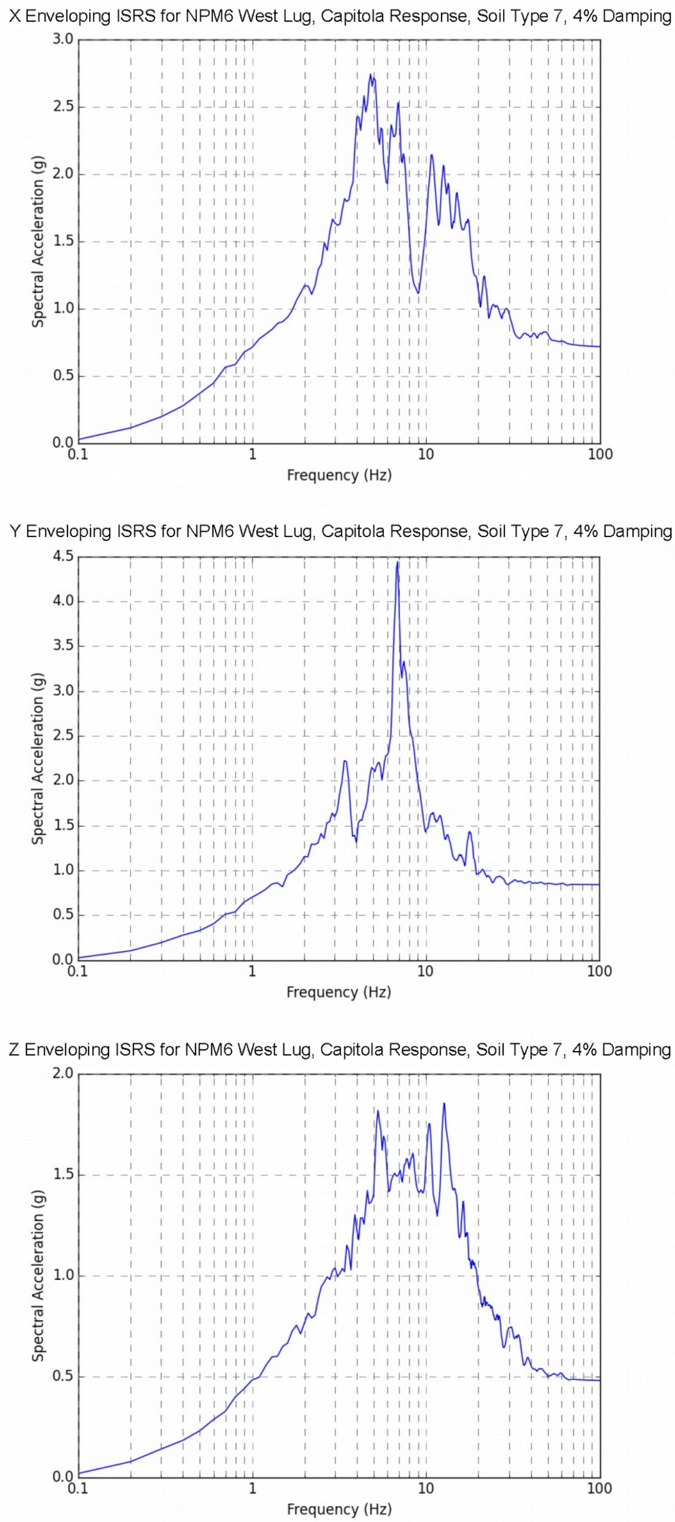


Figure 8 - Enveloping ISRS of cases 1,2 and 3 at the West Lug of NPM6

6. The staff requests the applicant to provide FSAR markups identifying the specific FSAR Figures and/or Tables and/or Sections containing the standard design responses for Items 1), 2), and 4) of COL Item 3.7-10.

a. ISRS of standard design at foundation and roof.

Response: Foundation ISRS can be found in FSAR Figures 3.7.2-107 and 3.7.2-108. The roof ISRS can be found in Figure 3.7.2-113.

b. Maximum forces in NPM lug restraints and skirts.

Response: NuScale provided the maximum forces in NPM lug restraints and skirts in RAI 8936 Question 03.07.02-10.

c. Max forces and moments in the east and west wing walls and pool walls.

Response: Max forces and moments in the east and west wing walls and pool walls can be found in FSAR Table 3.7.2-32.

Impact on DCA:

FSAR Tier 2, Section 3.7.2 has been revised as described in the response above and as shown in the markup provided in this response.

RAI 01-61, RAI 02.04.13-1, RAI 03.04.01-4, RAI 03.04.02-1, RAI 03.04.02-2, RAI 03.04.02-3, RAI 03.05.01.04-1, RAI 03.05.02-2, RAI 03.06.02-15, RAI 03.06.03-11, RAI 03.07.01-2, RAI 03.07.01-3, RAI 03.07.02-8, RAI 03.07.02-12, RAI 03.08.04-23S1, RAI 03.08.04-23S2, RAI 03.08.05-14S1, RAI 03.09.02-15, RAI 03.09.02-48, RAI 03.09.02-67, RAI 03.09.02-69, RAI 03.09.03-12, RAI 03.09.06-5, RAI 03.09.06-6, RAI 03.09.06-16, RAI 03.09.06-16S1, RAI 03.09.06-27, RAI 03.11-8, RAI 03.11-14, RAI 03.11-14S1, RAI 03.11-18, RAI 03.13-3, RAI 04.02-1S2, RAI 05.02.03-19, RAI 05.02.05-8, RAI 05.04.02.01-13, RAI 05.04.02.01-14, RAI 06.02.06-22, RAI 06.02.06-23, RAI 06.04-1, RAI 09.01.02-4, RAI 09.01.05-3, RAI 09.01.05-6, RAI 09.03.02-3, RAI 09.03.02-4, RAI 09.03.02-5, RAI 09.03.02-6, RAI 09.03.02-8, RAI 10.02-1, RAI 10.02-2, RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2, RAI 10.03.06-1, RAI 10.03.06-5, RAI 10.04.06-1, RAI 10.04.06-2, RAI 10.04.06-3, RAI 10.04.10-2, RAI 11.01-2, RAI 13.01.01-1, RAI 13.01.01-1S1, RAI 13.02.02-1, RAI 13.03-4, RAI 13.05.02.01-2, RAI 13.05.02.01-2S1, RAI 13.05.02.01-3, RAI 13.05.02.01-3S1, RAI 13.05.02.01-4, RAI 13.05.02.01-4S1, RAI 14.02-7, RAI 19-31, RAI 19-31S1, RAI 19-38, RAI 20.01-13

Table 1.8-2: Combined License Information Items

Item No.	Description of COL Information Item	Section
COL Item 1.1-1:	A COL applicant that references the NuScale Power Plant design certification will identify the site-specific plant location.	1.1
COL Item 1.1-2:	A COL applicant that references the NuScale Power Plant design certification will provide the schedules for completion of construction and commercial operation of each power module.	1.1
COL Item 1.4-1:	A COL applicant that references the NuScale Power Plant design certification will identify the prime agents or contractors for the construction and operation of the nuclear power plant.	1.4
COL Item 1.7-1:	A COL applicant that references the NuScale Power Plant design certification will provide site-specific diagrams and legends, as applicable.	1.7
COL Item 1.7-2:	A COL applicant that references the NuScale Power Plant design certification will list additional site-specific piping and instrumentation diagrams and legends as applicable.	1.7
COL Item 1.8-1:	A COL applicant that references the NuScale Power Plant design certification will provide a list of departures from the certified design.	1.8
COL Item 1.9-1:	A COL applicant that references the NuScale Power Plant design certification will review and address the conformance with regulatory criteria in effect six months before the docket date of the COL application for the site-specific portions and operational aspects of the facility design.	1.9
COL Item 1.10-1:	A COL applicant that references the NuScale Power Plant design certification will evaluate the potential hazards resulting from construction activities of the new NuScale facility to the safety-related and risk significant structures, systems, and components of existing operating unit(s) and newly constructed operating unit(s) at the co-located site per 10 CFR 52.79(a)(31). The evaluation will include identification of management and administrative controls necessary to eliminate or mitigate the consequences of potential hazards and demonstration that the limiting conditions for operation of an operating unit would not be exceeded. This COL item is not applicable for construction activities (build-out of the facility) at an individual NuScale Power Plant with operating NuScale Power Modules.	1.10
COL Item 2.0-1:	A COL applicant that references the NuScale Power Plant design certification will demonstrate that site-specific characteristics are bounded by the design parameters specified in Table 2.0-1. If site-specific values are not bounded by the values in Table 2.0-1, the COL applicant will demonstrate the acceptability of the site-specific values in the appropriate sections of its combined license application.	2.0
COL Item 2.1-1:	A COL applicant that references the NuScale Power Plant design certification will describe the site geographic and demographic characteristics.	2.1
COL Item 2.2-1:	A COL applicant that references the NuScale Power Plant design certification will describe nearby industrial, transportation, and military facilities. The COL applicant will demonstrate that the design is acceptable for each potential accident, or provide site-specific design alternatives.	2.2
COL Item 2.3-1:	A COL applicant that references the NuScale Power Plant design certification will describe the site-specific meteorological characteristics for Section 2.3.1 through Section 2.3.5, as applicable.	2.3
COL Item 2.4-1:	A COL applicant that references the NuScale Power Plant design certification will investigate and describe the site-specific hydrologic characteristics for Section 2.4.1 through Section 2.4.14, ~~as applicable~~except Section 2.4.8 and Section 2.4.10.	2.4
COL Item 2.5-1:	A COL applicant that references the NuScale Power Plant design certification will describe the site-specific geology, seismology, and geotechnical characteristics for Section 2.5.1 through Section 2.5.5, below.	2.5

Table 1.8-2: Combined License Information Items (Continued)

Item No.	Description of COL Information Item	Section
COL Item 3.6-2:	A COL applicant that references the NuScale Power Plant design certification will verify that the pipe rupture hazards analysis (including dynamic and environmental effects) of the high- and moderate-energy lines in the reactor pool bay is applicable. If changes are required, the COL applicant will update the pipe rupture hazards analysis, design additional protection features as necessary, and update Table 3.6-2, Figure 3.6-12, Figure 3.6-13, Figure 3.6-14, and Figure 3.6-15 as appropriate.	3.6
COL Item 3.6-3:	A COL applicant that references the NuScale Power Plant design certification will perform the pipe rupture hazards analysis (including dynamic and environmental effects) of the high- and moderate-energy lines outside the reactor pool bay and design appropriate protection features. This includes an evaluation and disposition of multi-module impacts in common pipe galleries, the identification of any new detection and auto-isolation functions for mitigating an auxiliary boiler high-energy line break, and evaluations regarding subcompartment pressurization. The COL applicant will update Table 3.6-2, Figure 3.6-16, and Figure 3.6-17 as appropriate.	3.6
COL Item 3.6-4:	Not used.	3.6
COL Item 3.7-1:	A COL applicant that references the NuScale Power Plant design certification will describe the site-specific structures, systems, and components.	3.7
COL Item 3.7-2:	A COL applicant that references the NuScale Power Plant design certification will provide site-specific time histories. In addition to the above criteria for cross correlation coefficients, time step and earthquake duration, strong motion durations, comparison to response spectra and power spectra density, the applicant will also confirm that site-specific ratios V/A and AD/V2 (A, V, D, are peak ground acceleration, ground velocity, and ground displacement, respectively) are consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the site-specific uniform hazard response spectra.	3.7
COL Item 3.7-3:	A COL applicant that references the NuScale Power Plant design certification will: • develop a site-specific strain compatible soil profile. • confirm that the criterion for the minimum required response spectrum has been satisfied. • determine whether the seismic site characteristics fall within the seismic design parameters such as soil layering assumptions used in the certified design, range of soil parameters, shear wave velocity values, and minimum soil bearing capacity.	3.7
COL Item 3.7-4:	A COL applicant that references the NuScale Power Plant design certification will confirm that nearby structures exposed to a site-specific safe shutdown earthquake will not collapse and adversely affect the Reactor Building or Seismic Category I portion of the Control Building.	3.7
COL Item 3.7-5:	A COL applicant that references the NuScale Power Plant design certification will perform a soil-structure interaction analysis of the Reactor Building and the Control Building using the NuScale SASSI2010 models for those structures. The COL applicant will confirm that the site-specific seismic demands of the standard design for critical structures, systems, and components in Appendix 3B are bounded by the corresponding design certified seismic demands and, if not, the standard design for critical structures, systems, and components will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands. Seismic demands investigated shall include forces, moments, deformations, in-structure response spectra, and seismic stability of the structures.	3.7
COL Item 3.7-6:	A COL applicant that references the NuScale Power Plant design certification will perform a structure-soil-structure interaction analysis that includes the Reactor Building, Control Building, Radioactive Waste Building and both Turbine Generator Buildings. The COL applicant will confirm that the site-specific seismic demands of the standard design structures, systems, and components are bounded by the corresponding design certified seismic demands and, if not, the standard design structures, systems, and components will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands.	3.7
COL Item 3.7-7:	A COL applicant that references the NuScale Power Plant design certification will provide a seismic monitoring system and a seismic monitoring program that satisfies Regulatory Guide 1.12 "Nuclear Power Plant Instrumentation for Earthquakes," Rev. 2 (or later) and Regulatory Guide 1.166 "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," Rev. 0 (or later). This information is to be provided as noted below.	3.7

Table 1.8-2: Combined License Information Items (Continued)

Item No.	Description of COL Information Item	Section
COL Item 3.7-8:	A COL applicant that references the NuScale Power Plant design certification will identify the implementation milestone for the seismic monitoring program. In addition, a COL applicant that references the NuScale Power Plant design certification will prepare site-specific procedures for activities following an earthquake. These procedures and the data from the seismic instrumentation system will provide sufficient information to determine if the level of earthquake ground motion requiring shutdown has been exceeded. An activity of the procedures will be to address measurement of the post-seismic event gaps between the fuel racks and the pool walls and between the individual fuel racks and to take appropriate corrective action if needed (such as repositioning the racks or assuring that the as-found condition of the racks is acceptable based on the assumptions of the racks' design basis analysis). Acceptable guidance for procedure development is contained in Regulatory Guide 1.166 "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," Rev. 0 (or later) and 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event," Rev. 0 (or later).	3.7
COL Item 3.7-9:	A COL applicant that references the NuScale Power Plant design certification will include an analysis of performance-based response spectra established at the surface and intermediate depth(s) that take into account the complexities of the subsurface layer profiles of the site and provide a technical justification for the adequacy of V/H spectral ratios used in establishing the site-specific foundation input response spectra and performance-based response spectra for the vertical direction.	3.7
COL Item 3.7-10:	A COL applicant that references the NuScale Power Plant design certification will perform a site-specific configuration analysis that includes the Reactor Building with applicable configuration layout of the desired NuScale Power Modules. The COL applicant will confirm the following are bounded by the corresponding design certified seismic demands: 1) The in-structure response spectra of the standard design at the foundation and roof. See FSAR Figure 3.7.2-107 and Figure 3.7.2-108 for foundation in-structure response spectra and Figure 3.7.2-113 for roof in-structure response spectra. 2) The maximum forces in the NuScale Power Module lug restraints and skirts. 3) The site-specific in-structure response spectra for the NuScale Power Module at the skirt support will be shown to be bounded by the in-structure response spectra in Figure 3.7.2-156 and Figure 3.7.2-157. The site-specific in-structure response spectra for the NuScale Power Module at the lug restraints will be shown to be bounded by the in-structure response spectra in Figure 3.7.2-158 through Figure 3.7.2-163. 4) The maximum forces and moments in the east and west wing walls and pool walls. See FSAR Table 3.7.2-32. 5) The site-specific in-structure response spectra for the fuel storage racks will be shown to be bounded by the in-structure response spectra in Figure 3-6 through Figure 3-14 of TR-0816-49833. 6) The site-specific in-structure response spectra shown immediately below will be shown to be bounded by their corresponding certified in-structure response spectra: • Reactor Building north exterior wall at EL 75′-0″: bounded by in-structure response spectra in Figure 3.7.2-110 • Reactor Building west exterior wall at EL 126′-0″: bounded by in-structure response spectra in Figure 3.7.2-112 • Reactor Building crane wheels at EL 145′-6″: bounded by in-structure response spectra in Figure 3.7.2-114 • Control Building east wall at EL 76′-6″: bounded by in-structure response spectra in Figure 3.7.2-119 • Control Building south wall at EL 120′-0″: bounded by in-structure response spectra in Figure 3.7.2-121 If not, the standard design will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands.	3.7

Step 4. For each selected area, all of the ISRS (this usually includes more than one node) are combined and the envelope obtained for each of the three directions.

Step 5. Each envelope response spectra is broadened by ±15%.

Step 6. Steps 1 through 5 are repeated to generate ISRS at damping ratios of 2%, 3%, 4%, 5%, 7%, and 10%.

This process is shown for a single node in Figure 3.7.2-99 through Figure 3.7.2-103. The first three figures show the development of the average ISRS for the three soil cases (7, 8, and 9) and two stiffnesses (cracked and uncracked). Figure 3.7.2-102 shows the combination of averages and the development of the ISRS envelope. The upper three plots show this process for the CSDRS compatible time histories and soil cases and the bottom three plots show the process for the ISRS from the CSDRS-HF compatible time histories and soil cases. Figure 3.7.2-103 shows the development of the broadened spectra at various damping values. The upper three plots show the envelop ISRS for each direction and the different damping ratios. In these plots the broadening of the 2 percent damping results is shown. The bottom three plots provide the broadened results for all damping ratios.

3.7.2.5.2 Comparison of In-Structure Response Spectra between Single and Triple Building Models

The structure-soil-structure interaction of the triple model has an effect on the ISRS of the RXB. Other than the ISRS at top of basemat, the ISRS of the standalone model are higher than those of the triple building model. The reduction in the ISRS of the triple building model is attributed to the extra damping effect provided by the close presence of the RWB and the CRB on the sides of the RXB.

This can be seen in Figure 3.7.2-104, Figure 3.7.2-105 and Figure 3.7.2-106.

The ISRS from the triple building model were not created for the CRB.

Because neither the standalone nor triple building model produce bounding results at all locations, ISRS enveloping the two models are used for design of structures, systems, and components in the RXB.

3.7.2.5.3 Reactor Building In-Structure Response Spectra

RAI 03.08.04-23, RAI 03.08.04-23S2

For convenience in design of components and supports that need to be Seismic Category I or Seismic Category II, ISRS at multiple nodes at each floor are combined to develop a single ISRS for each floor. The ISRS corresponding to each main floor of the RXB identified below are provided ~~o~~in the listed figures. Although ISRS are provided at the NPM base (floor at EL. 25' 0"), time histories were used as input for the evaluation of the NPMs as described in Appendix 3A. The governing ISRS envelop the ISRS taken from node locations on the corners of the buildings to capture the torsional and rocking components. See Table 3.7.2-53 for a list of nodes

enveloped at each floor to produce the floor ISRS. Figure 3.7.2-142 through Figure 3.7.2-148 show the locations of the nodes selected for floor ISRS generation.

Floor	Figure
24’-0”	Figure 3.7.2-107
25’-0”	Figure 3.7.2-108
50’-0”	Figure 3.7.2-109
75’-0”	Figure 3.7.2-110
100’-0”	Figure 3.7.2-111
126’-0”	Figure 3.7.2-112
181’-0”	Figure 3.7.2-113

3.7.2.5.4 Reactor Building Crane In-Structure Response Spectra

The seismic analysis of the RBC uses ISRS for input. ISRS are generated at four selected individual crane wheel locations. These locations are on the reactor pool wall at the crane rail slab at elevation 145' 6”. The enveloping ISRS for these four locations are provide in Figure 3.7.2-114. The seismic analysis of the RBC is completed per ASME NOG-1 (Reference 3.7.2-4).

3.7.2.5.5 NuScale Power Module Bay Wall In-Structure Response Spectra

The NPM lug restraints transfer the horizontal forces between the NPMs and the walls of the bay. These restraints ensure that the NPM will not fall as a result of a seismic event. Because of the significance of the restraints, bounding ISRS are provided. These ISRS are not used for the design of any of the restraints, nor any specific components. However they are used in Section 3.8.4.8 to confirm acceptability of the site independent Reactor Building for use at specific sites.

Figure 3.7.2-96 provides node locations that were used to develop the ISRS for the NPM bay walls at the pool floor. The enveloping ISRS for these locations are provided in Figure 3.7.2-115.

Figure 3.7.2-97 provides node locations that were used to develop the ISRS for the NPM bay walls at the lug restraints. The enveloping ISRS for these locations are provided in Figure 3.7.2-116.

3.7.2.5.6 Control Building In-Structure Response Spectra

RAI 03.08.04-23

The ISRS corresponding to each main floor of the CRB identified below are provided on the listed figures. The governing ISRS envelop the ISRS taken from node locations on the corners of the buildings to capture the torsional and rocking components.

Figure 3.7.2-97 provides node locations that were used to develop the ISRS for the NPM bay walls at the lug restraints. The enveloping ISRS for these locations are provided in Figure 3.7.2-116.

RAI 03.08.04-23S2

3.7.2.5.6 NuScale Power Module Skirt and Lug Supports ISRS

RAI 03.08.04-23S2

At the CNV skirts of NPM1 and NPM6, response spectra are generated for the time histories at the eight spider nodes, corresponding to the eight spider elements. The SASSI node numbers are listed in Table 3.7.2-54.

RAI 03.08.04-23S2

The resulting spider node spectra are then averaged for each module. This results in nine averaged skirt response spectra for each module, based on the three seismic cases provided (Soil Type 7, Capitola time history, cracked concrete nominal stiffness, cracked concrete reduced stiffness, uncracked concrete nominal stiffness), each with three components (X,Y, and Z). The ISRS of the nine averaged skirt response spectra is then enveloped for NPM1 and NPM6 in the X, Y, and Z directions. The six resulting enveloping ISRS (two modules x one skirt support x three directions) for the NPM1 and NPM6 CNV skirts are shown in Figure 3.7.2-156 and Figure 3.7.2-157.

RAI 03.08.04-23S2

At the CNV lugs of NPM1 and NPM6, response spectra are generated for the time histories at the nodes listed in Table 3.7.2-55. The spectra are then enveloped at each of the lugs on NPM1 and NPM6, resulting in 18 total enveloping spectra (two modules x three lugs x three directions). These spectra are shown in Figure 3.7.2-158 through Figure 3.7.2-163.

3.7.2.5.7 Control Building In-Structure Response Spectra

RAI 03.08.04-23

The ISRS corresponding to each main floor of the CRB identified below are provided on the listed figures. The governing ISRS envelop the ISRS taken from node locations on the corners of the buildings to capture the torsional and rocking components.

Floor	**Figure**
50'-0"	Figure 3.7.2-117
63'-3"	Figure 3.7.2-118
76'-6"	Figure 3.7.2-119
100'-0"	Figure 3.7.2-120

3.7.2.14 Determination of Dynamic Stability of Seismic Category I Structures

Section 3.8.5 provides discussion regarding bearing pressure, lateral wall pressure, overturning, sliding, and flotation.

3.7.2.15 Analysis Procedure for Damping

RAI 03.07.02-11

Section 3.7.1.2 describes the damping ratios used for seismic analysis of the RXB and CRB. As stated in Section 3.7.1.2.1, for analyses of Seismic Category I SSC, the damping values of RG 1.61, Revision 1 are used. These values are presented in Table 3.7.1-6. For the soil and rock materials, the damping ratio is obtained based on strain-compatible soil properties generated for each soil profile. Soil material damping ratios are shown on Table 3.7.1-15 through Table 3.7.1-19 for each soil type considered. Soil damping ratio is limited to 15 percent.

RAI 03.07.02-11

The implementation of these damping values in the dynamic analyses of the NuScale RXB and CRB does not follow guidance from DSRS Section 3.7.2.II.13. Instead, damping procedures that are more suitable with the type of analysis performed are followed. For transient analysis with ANSYS, Rayleigh material damping is used. For soil-structure interaction analysis with SASSI2010, hysteretic material damping is used. Both Rayleigh and hysteretic damping provide responses equivalent to the composite modal damping approach. Only major components, such as the NPM and the RBC, are included in the dynamic models. For other systems and components, their mass is applied to the model and ISRS are calculated at the corresponding damping level in Table 3.7.1-6.

3.7.2.16 Site Specific Seismic Analysis

RAI 03.08.04-23S1

Site-specific seismic analysis is performed by the COL applicant to confirm that the site-independent Seismic Category I structures may be constructed without modification, or to identify where modifications are necessary. This comparison is performed in Section 3.8.4.8. The site specific analysis is performed using the site specific SSE developed in Section 3.7.1.1.3 (COL Item 3.7-1) and the site specific soil profile developed in Section 3.7.1.3.3 (COL Item 3.7-3). Appendix 3B critical sections include RXB and CRB exterior walls that are subject to earth pressures. Therefore, by comparing seismic demand in these walls per COL Item 3.7-5, site-specific versus lateral certified standard soil pressures are also compared.

RAI 03.07.02-12, RAI 03.08.04-23S1, RAI 03.08.04-23S2

COL Item 3.7-5: A COL applicant that references the NuScale Power Plant design certification will perform a soil-structure interaction analysis of the Reactor Building and the Control Building using the NuScale SASSI2010 models for those structures. The COL applicant will confirm that the site-specific seismic demands of the standard design for critical structures, systems, and components in Appendix 3B are bounded by

the corresponding design certified seismic demands and, if not, the standard design for critical structures, systems, and components will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands. Seismic demands investigated shall include forces, moments, deformations, in-structure response spectra, and seismic stability of the structures.

RAI 03.07.02-12

COL Item 3.7-6: A COL applicant that references the NuScale Power Plant design certification will perform a structure-soil-structure interaction analysis that includes the Reactor Building, the Control Building, the Radioactive Waste Building and both Turbine Generator Buildings. The COL applicant will confirm that the site-specific seismic demands of the standard design structures, systems, and components are bounded by the corresponding design certified seismic demands and, if not, the standard design structures, systems, and components will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands.

3.7.2.17 References

3.7.2-1 SAP2000 Advanced Version 17.1.1, 2015, Computers and Structures, Inc., Walnut Creek, California.

3.7.2-2 SASSI2010 Version 1.0, May 2012, Berkeley, California.

3.7.2-3 ANSYS Computer Program, Release 16.0, January 2015. ANSYS Incorporated, Canonsburg, Pennsylvania.

3.7.2-4 American Society of Mechanical Engineers, ASME NOG-1, “Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder),” 2004.

the west of the bay. With the removal of the module for the 7 NPM case. The bending moments increased by 30 to 40 percent. This increase is attributed to the larger water volume. The Bay 6 pool wall was essentially unaffected. Bay 6 contains a module in the 7 NPM case.

3.7.2.9.1.5 Conclusion of the Study

RAI 03.07.02-8

The 7 NPM case did not produce a tangible change in the reaction of the building as a whole (Section 3.7.2.9.1.1 and Section 3.7.2.9.1.2). The 6 NPM case, which would cause a slightly more asymmetric load, is expected to produce similar results. The mass of the overall structure is relatively unaffected by the mass difference between a NPM and the water. Therefore the quantity of modules installed in the building is expected to have no effect on the building.

Similarly, the absence of modules did not significantly affect the forces that are transmitted to an installed NPM (Section 3.7.2.9.1.3). Therefore removing individual modules for refueling does not impact the installed and operating modules.

The walls of bays without an installed module do see an increase in the forces, principally in bending moment. These increases are on the order of 40 percent. However, the wing walls are all designed the same. As such, they are designed for the highest loaded wall, which is the west wing wall. The increases seen in the west wing wall when an NPM is not present in Bay 1 do not exceed the capacity of the wall. In addition, the increase is less significant because there is no module supported by the wall.

The pool wall in an empty bay also sees an increase of about 40 percent. Again, the highest forces occur at the west end of the pool. The forces at the pool wall in Bay 1 when it is empty are similar to those in the reactor pool area. Since the entire pool wall is a consistent design, these forces are also acceptable.

RAI 03.07.02-8

The difference in results between operation with twelve NPMs and operation with fewer NPMs in place is small and within the capacity of the building design. Site-specific configurations, outside of the scope of the presented 12 NPM and 7 NPM cases, require additional analysis to be performed by the COL applicant.

RAI 03.07.02-8

COL Item 3.7-10: A COL applicant that references the NuScale Power Plant design certification will perform a site-specific configuration analysis that includes the Reactor Building with applicable configuration layout of the desired NuScale Power Modules. The COL applicant will confirm the following are bounded by the corresponding design certified seismic demands:

RAI 03.07.02-8, RAI 03.08.04-23S2

1) The in-structure response spectra of the standard design at the foundation and roof. See FSAR Figure 3.7.2-107 and Figure 3.7.2-108 for foundation in-structure response spectra and Figure 3.7.2-113 for roof in-structure response spectra.

RAI 03.07.02-8, RAI 03.08.04-23S2

2) The maximum forces in the NuScale Power Module lug restraints and skirts.

RAI 03.08.04-23S1, RAI 03.08.04-23S2

3) The site-specific in-structure response spectra for the NuScale Power Module at the skirt support will be shown to be bounded by the in-structure response spectra in Figure 3.7.2-156 and Figure 3.7.2-157. The site-specific in-structure response spectra for the NuScale Power Module at the lug restraints will be shown to be bounded by the in-structure response spectra in Figure 3.7.2-158 through Figure 3.7.2-163.

RAI 03.07.02-8, RAI 03.08.04-23S2

4) The maximum forces and moments in the east and west wing walls and pool walls. See FSAR Table 3.7.2-32.

RAI 03.08.04-23S1, RAI 03.08.04-23S2

5) The site-specific in-structure response spectra for the fuel storage racks will be shown to be bounded by the in-structure response spectra in Figure 3-6 through Figure 3-14 of TR-0816-49833.

RAI 03.08.04-23S1, RAI 03.08.04-23S2

6) The site-specific in-structure response spectra shown immediately below will be shown to be bounded by their corresponding certified in-structure response spectra:

RAI 03.08.04-23S1, RAI 03.08.04-23S2

- Reactor Building north exterior wall at EL 75′-0″: bounded by in-structure response spectra in Figure 3.7.2-110

RAI 03.08.04-23S1, RAI 03.08.04-23S2

- Reactor Building west exterior wall at EL 126′-0″: bounded by in-structure response spectra in Figure 3.7.2-112

RAI 03.08.04-23S1, RAI 03.08.04-23S2

- Reactor Building crane wheels at EL 145′-6″: bounded by in-structure response spectra in Figure 3.7.2-114

RAI 03.08.04-23S1, RAI 03.08.04-23S2

- Control Building east wall at EL 76′-6″: bounded by in-structure response spectra in Figure 3.7.2-119

RAI 03.08.04-23S1, RAI 03.08.04-23S2

- Control Building south wall at EL 120′-0″: bounded by in-structure response spectra in Figure 3.7.2-121

RAI 03.07.02-8

If not, the standard design will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands.

RAI 03.08.04-23S2

Table 3.7.2-53: Floor Elevation and Nodes for Floor ISRS Generation

Floor No.	TOC Elevation	Note	Standalone RXB Node	Triple Model Node	Coordinates (inch)		
					X	Y	Z
1	EL 24'-0"	Top of Basemat	3996	3652	0	873	120
			4741	4325	1872	873	120
			5642	5142	4092	873	120
2	EL. 25'-0"	Pool Floor (NPM Base)	6041	5525	2019.5	305.5	132
			6093	5577	2314.5	305.5	132
			6145	5629	2609.5	305.5	132
			6197	5681	2904.5	305.5	132
			6249	5733	3199.5	305.5	132
			6301	5785	3509.5	305.5	132
			6065	5549	2167	177	132
			6013	5497	1872	177	132
			6069	5553	2167	453	132
			6017	5501	1872	453	132
			6325	5809	3672	177	132
			6273	5757	3347	177	132
			6329	5813	3672	453	132
			6277	5761	3347	453	132
			6317	5801	3672	-453	132
			6265	5749	3347	-453	132
			6321	5808	3672	-177	132
			6269	5753	3347	-177	132
			6057	5541	2167	-453	132
			6005	5489	1872	-453	132
			6061	5545	2167	-177	132
			6009	5493	1872	-177	132
3	EL. 50'-0"		10974	9955	0	873	420
			11050	10022	216	0	420
			11054	10026	216	279	420
			11234	10185	824	705	420
			11542	10451	1872	453	420
			11675	10566	2314.6	621	420
			11995	10844	3347	621	420
			12174	11002	3924	88.5	420
			12178	11006	3924	360	420
			12242	11067	4092	873	420
4	EL. 75'-0"		16925	14941	0	-873	720
			16947	14963	0	873	720
			17207	15193	824	705	720
			17630	15556	2314.5	621	720
			17942	15826	3347	621	720
			18031	15903	3672	453	720
			18123	15986	3924	360	720

Table 3.7.2-53: Floor Elevation and Nodes for Floor ISRS Generation (Continued)

Floor No.	TOC Elevation	Note	Standalone RXB Node	Triple Model Node	Coordinates (inch)		
					X	Y	Z
5	EL. 100'-0"	Grade Floor	22810	19886	0	-837	1020
			22821	19897	0	0	1020
			22832	19908	0	837	1020
			22905	19972	216	-228	1020
			23092	20138	824	705	1020
			23517	20503	2314.5	621	1020
			23829	20773	3347	621	1020
			24008	20931	3924	88.5	1020
			24012	20935	3924	360	1020
			23386	20390	1872	453	1020
			23915	20847	3672	177	1020
			23919	20851	3672	453	1020
6	EL. 126'-0"		25487	22328	0	-873	1320
			25509	22350	0	873	1320
			25625	22466	824	705	1320
			25826	22667	1872	453	1320
			25831	22672	1872	873	1320
			25952	22793	2314.5	621	1320
			26258	23099	3347	621	1320
			26345	23186	3672	453	1320
			26419	23260	3924	88.5	1320
			26423	23264	3924	360	1320
			26471	23312	4092	873	1320
Roof	EL. 181'-0"	Top of Roof	29953	26794	0	-537	1980
			29960	26801	0	0	1980
			29967	26808	0	537	1980
			30110	26951	824	0	1980
			30350	27191	2019.5	0	1980
			30357	27198	2019.5	537	1980
			30515	27356	2830.75	0	1980
			30748	27589	4092	-537	1980
			30755	27596	4092	0	1980
			30762	27603	4092	537	1980

RAI 03.08.04-23S2

Table 3.7.2-54: SASSI CNV Skirt Nodes

NPM1	NPM6
6027	6287
6028	6288
6029	6289
6039	6299
6042	6302
6053	6307
6054	6308
6055	6309

RAI 03.08.04-23S2

Table 3.7.2-55: SASSI CNV Lug Nodes

	NPM1	NPM6
West Lug	6477	31081
North Lug	6483	31087
East Lug	6486	31090

RAI 03.08.04-23S2

Figure 3.7.2-142: Floor ISRS Locations at TOC EL 24'-0"

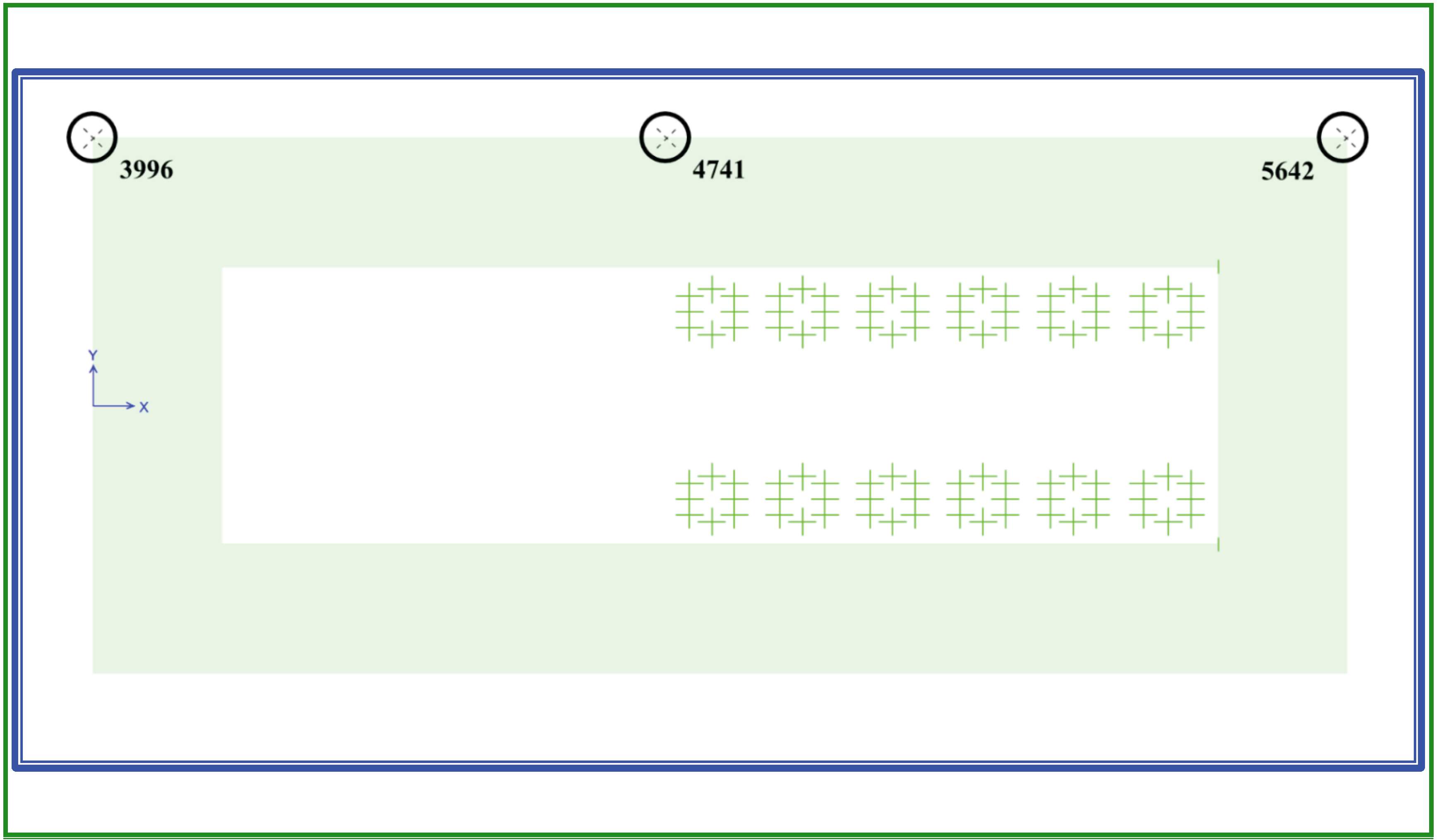
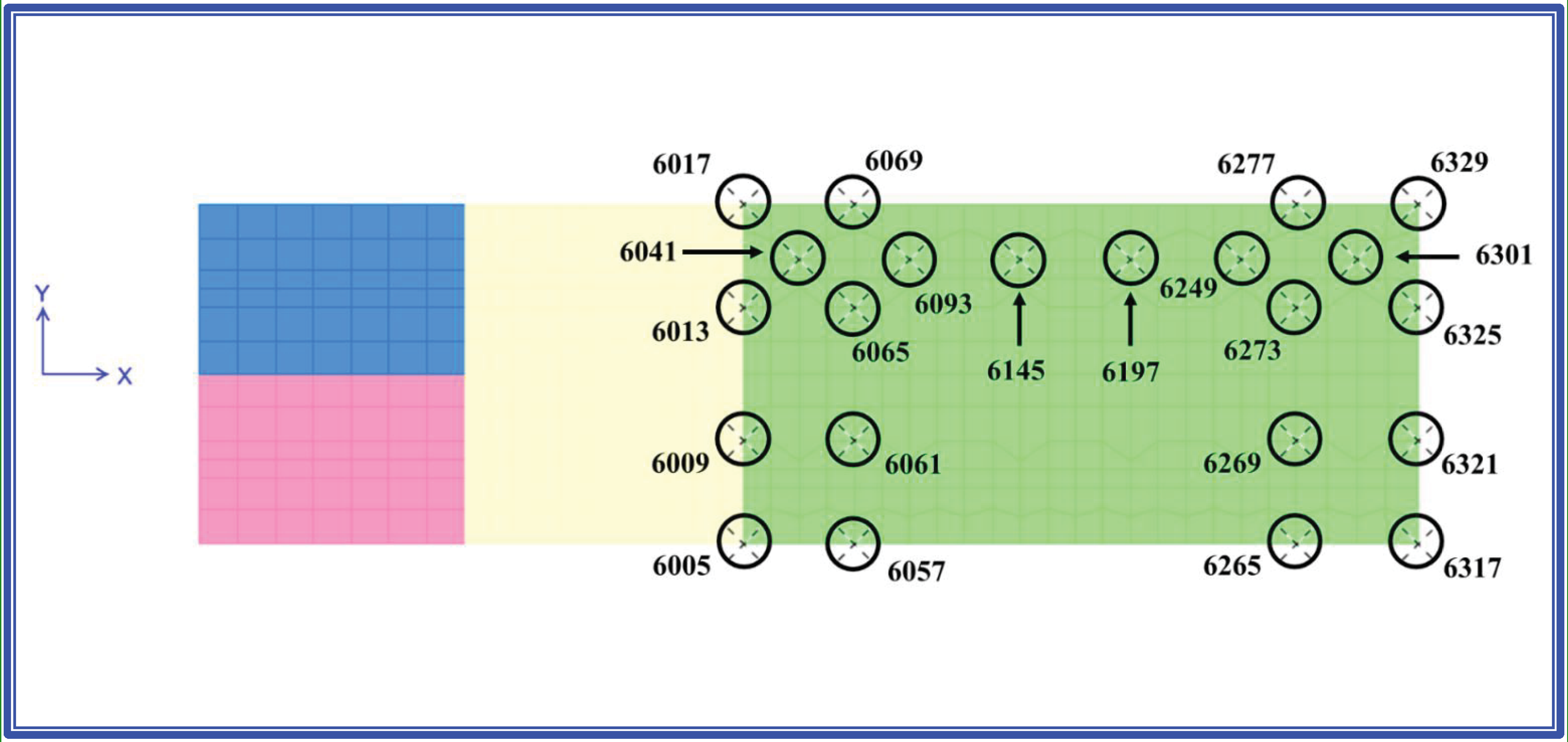
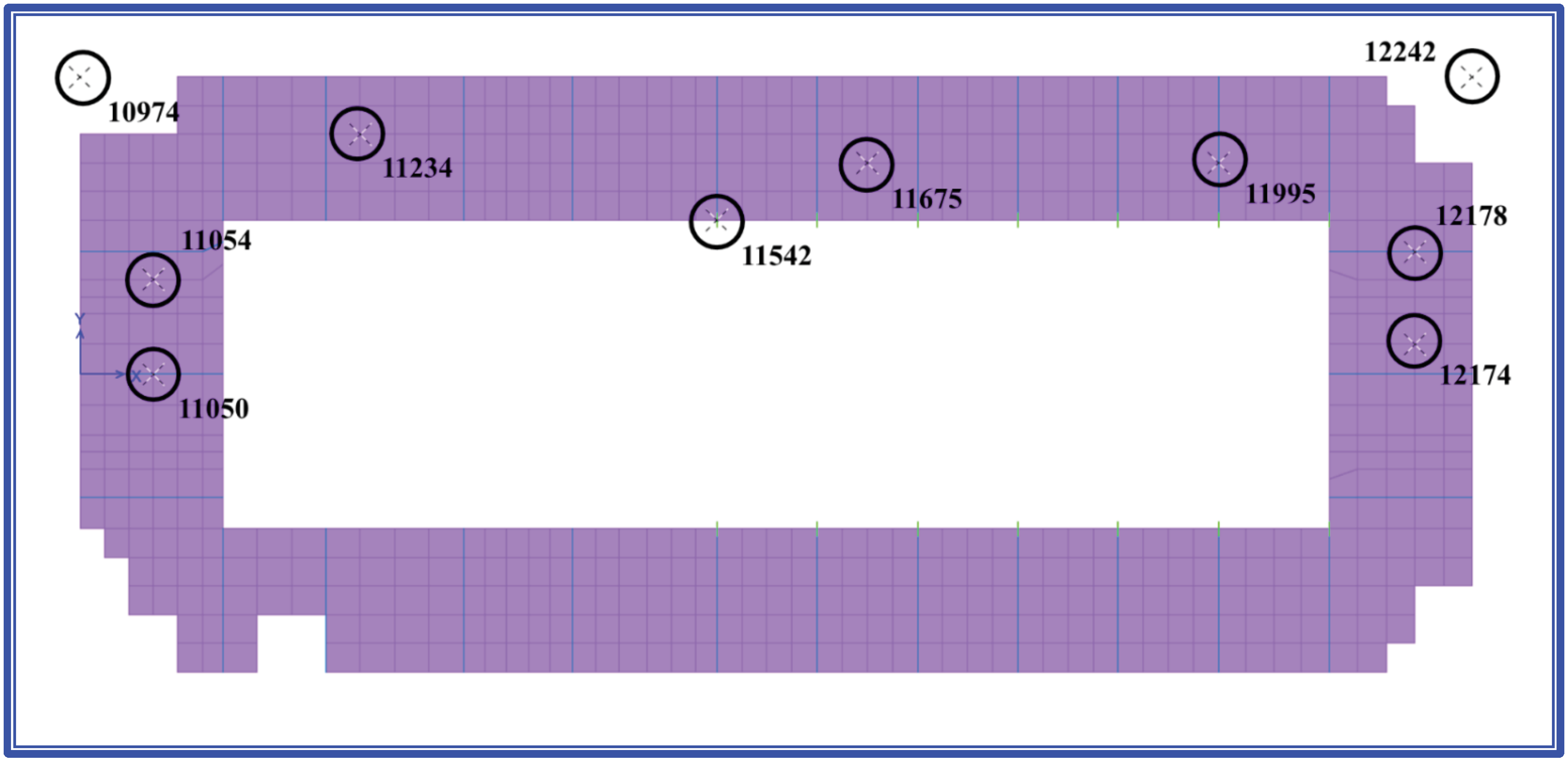


Figure 3.7.2-143: Floor Locations at TOC EL 25'-0"



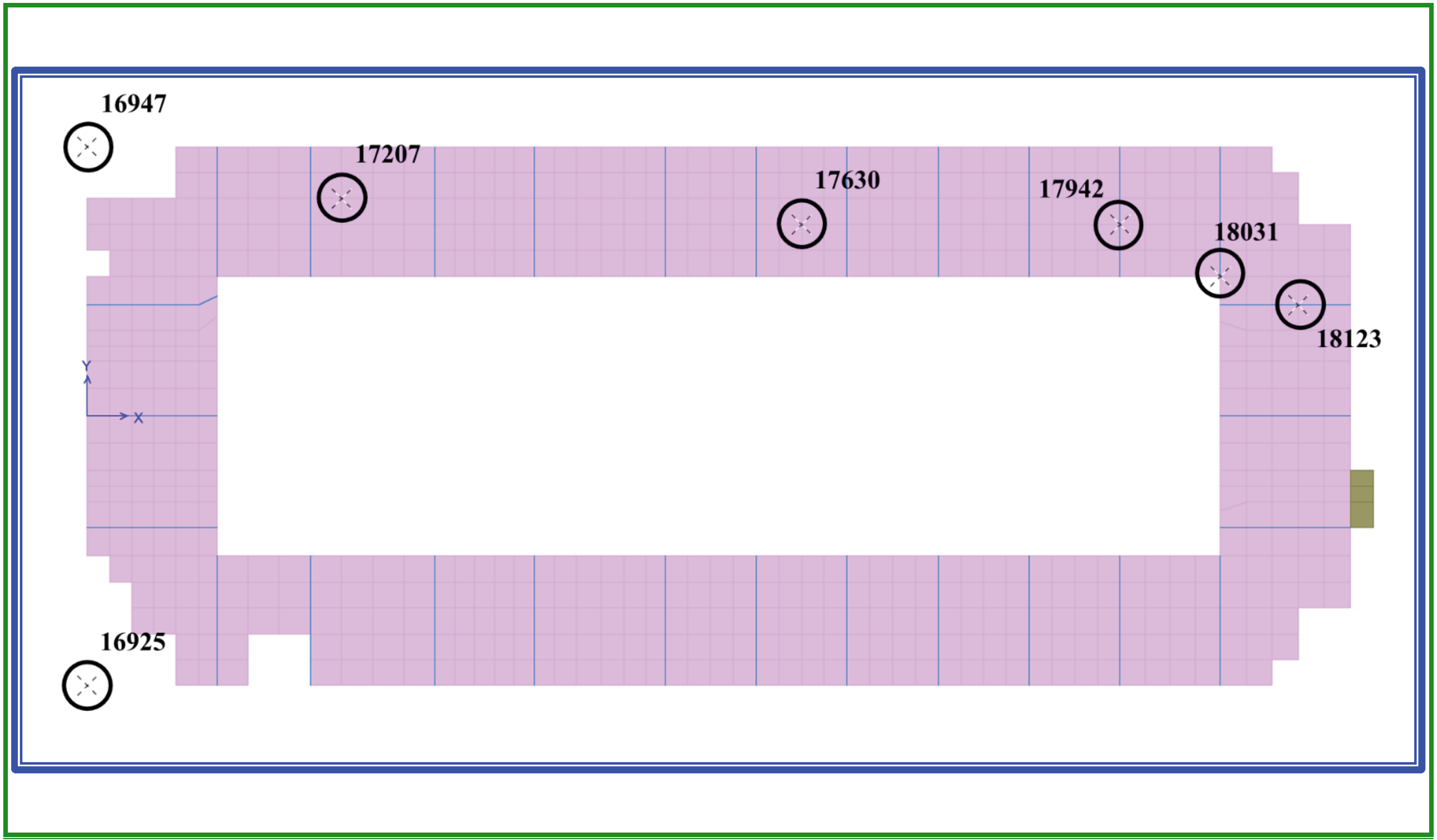
RAI 03.08.04-23S2

Figure 3.7.2-144: Floor ISRS Locations at TOC EL 50'-0"



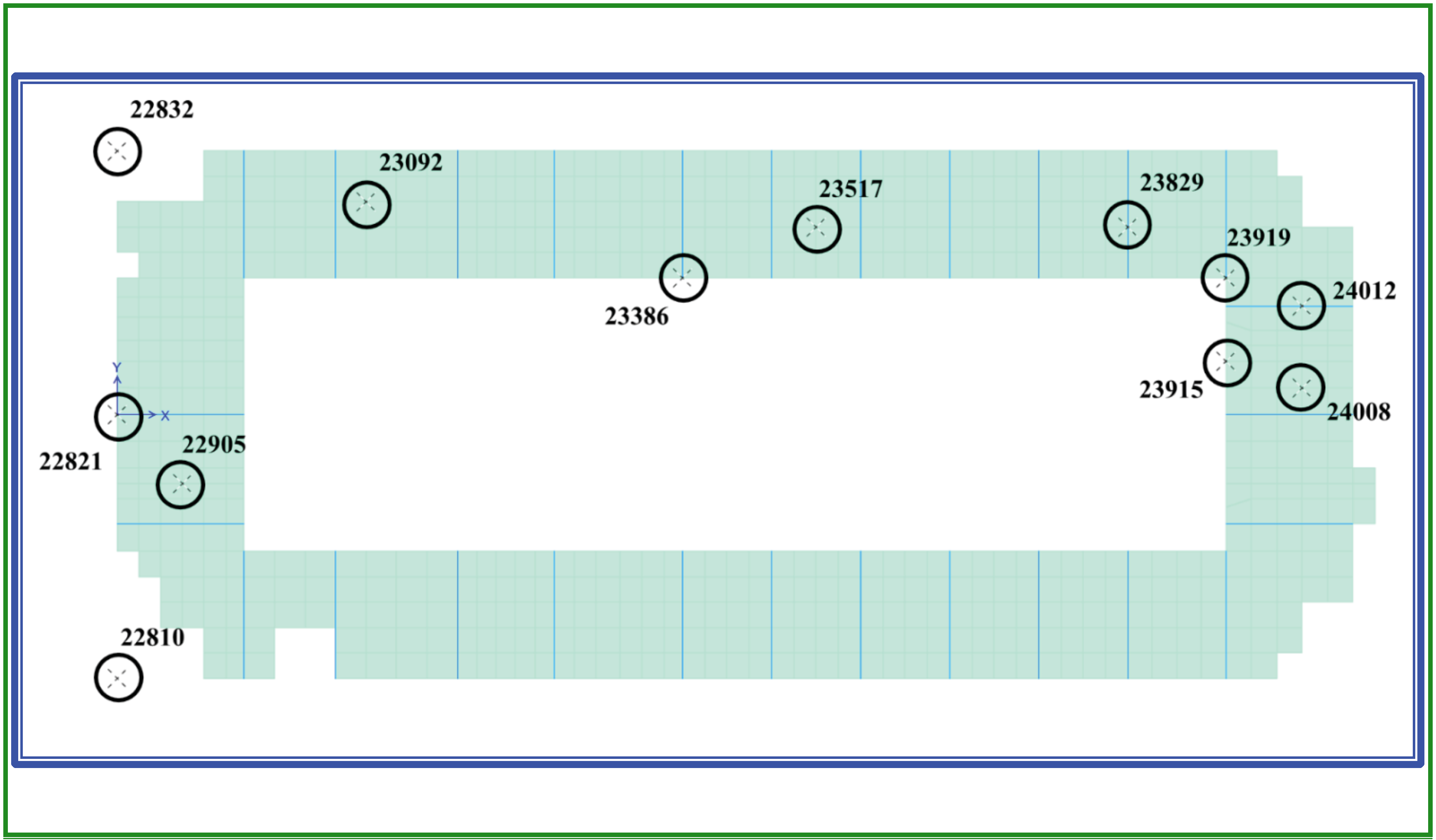
RAI 03.08.04-23S2

Figure 3.7.2-145: Floor ISRS Locations at TOC EL 75' - 0"



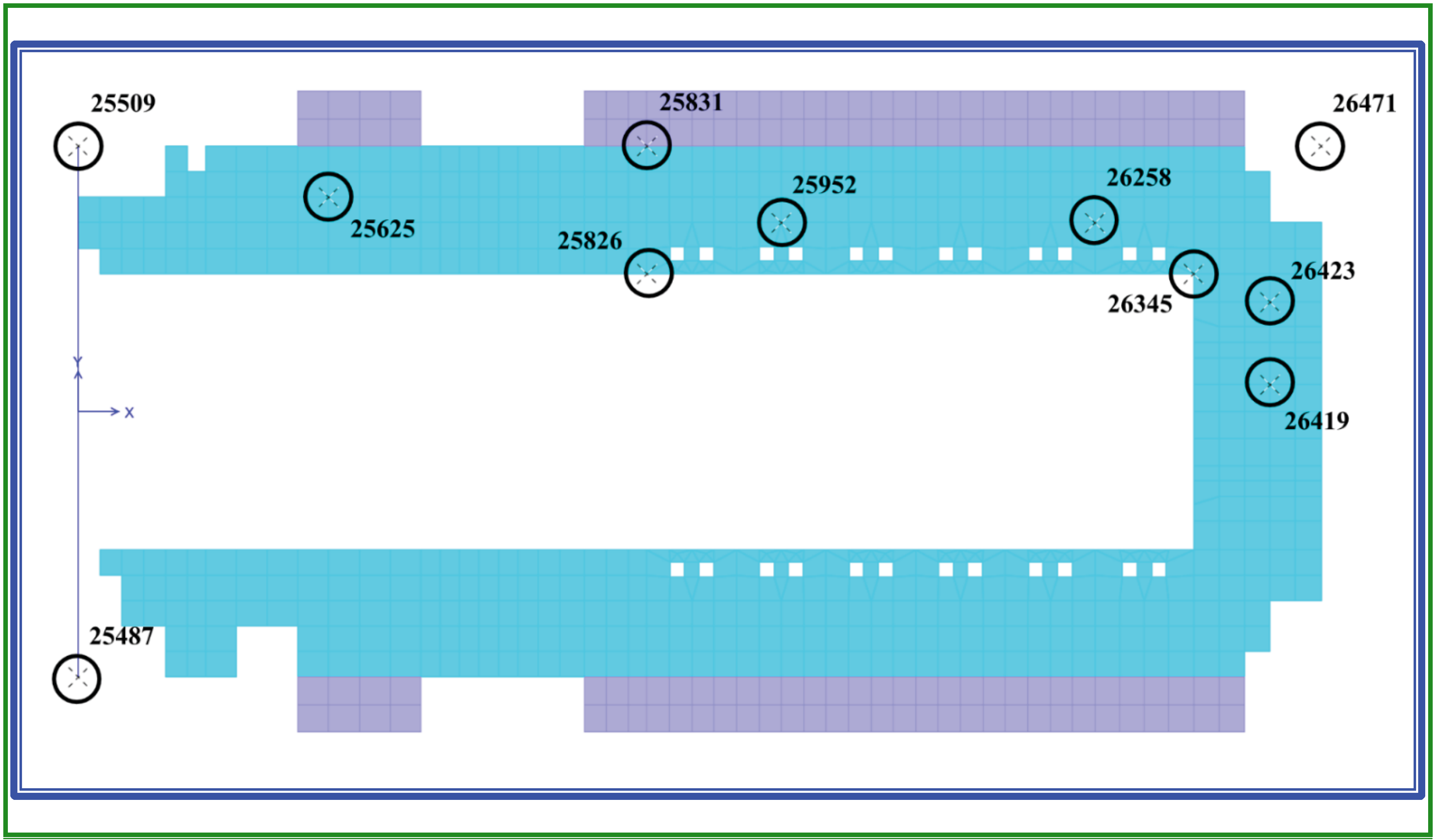
RAI 03.08.04-23S2

Figure 3.7.2-146: Floor ISRS Locations at TOC EL 100'-0"



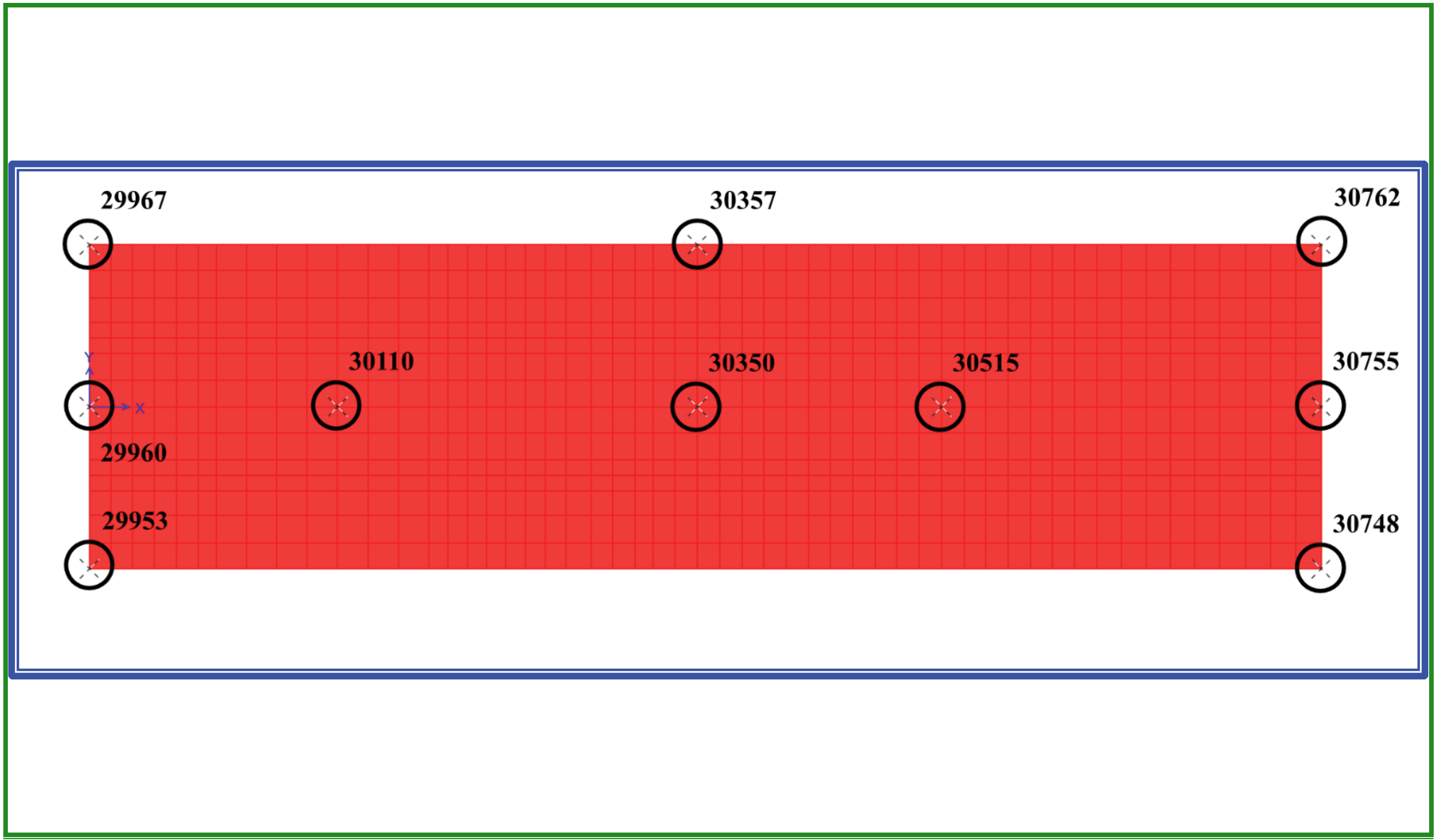
RAI 03.08.04-23S2

Figure 3.7.2-147: Floor ISRS Locations at TOC EL 126'-0"



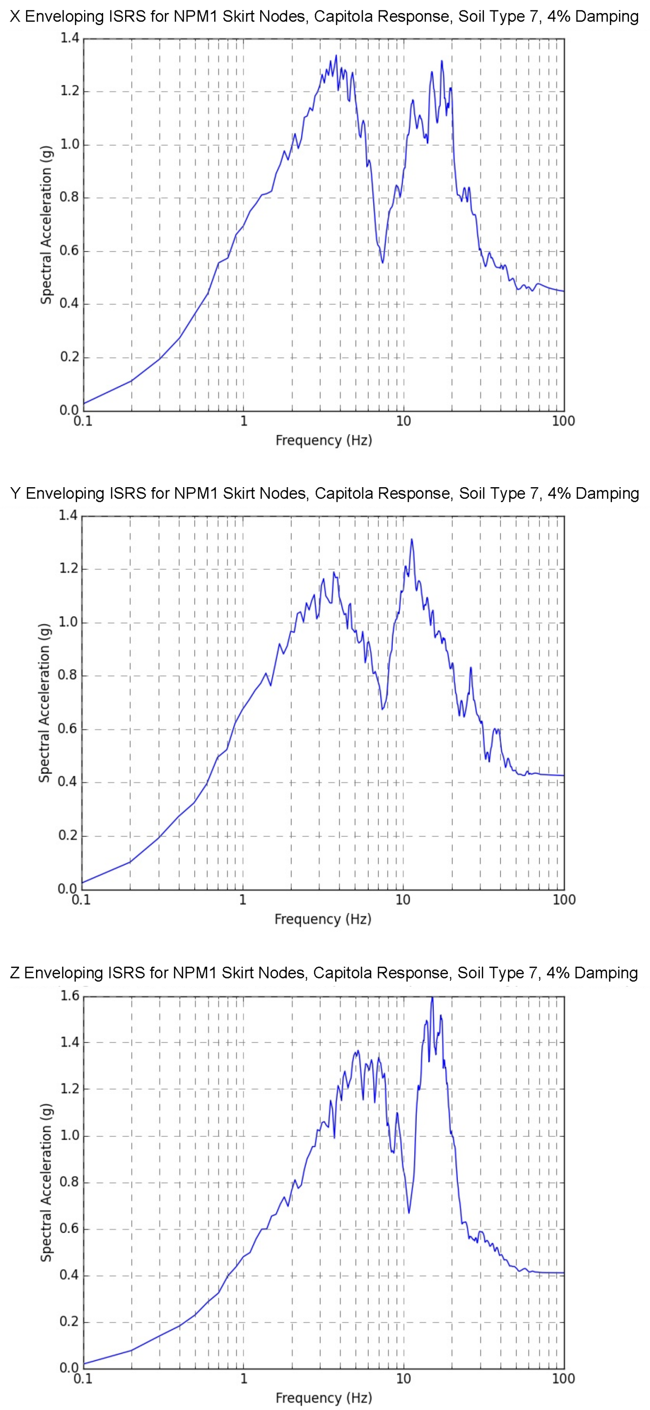
RAI 03.08.04-23S2

Figure 3.7.2-148: Roof ISRS Locations at TOC EL 181'-0"



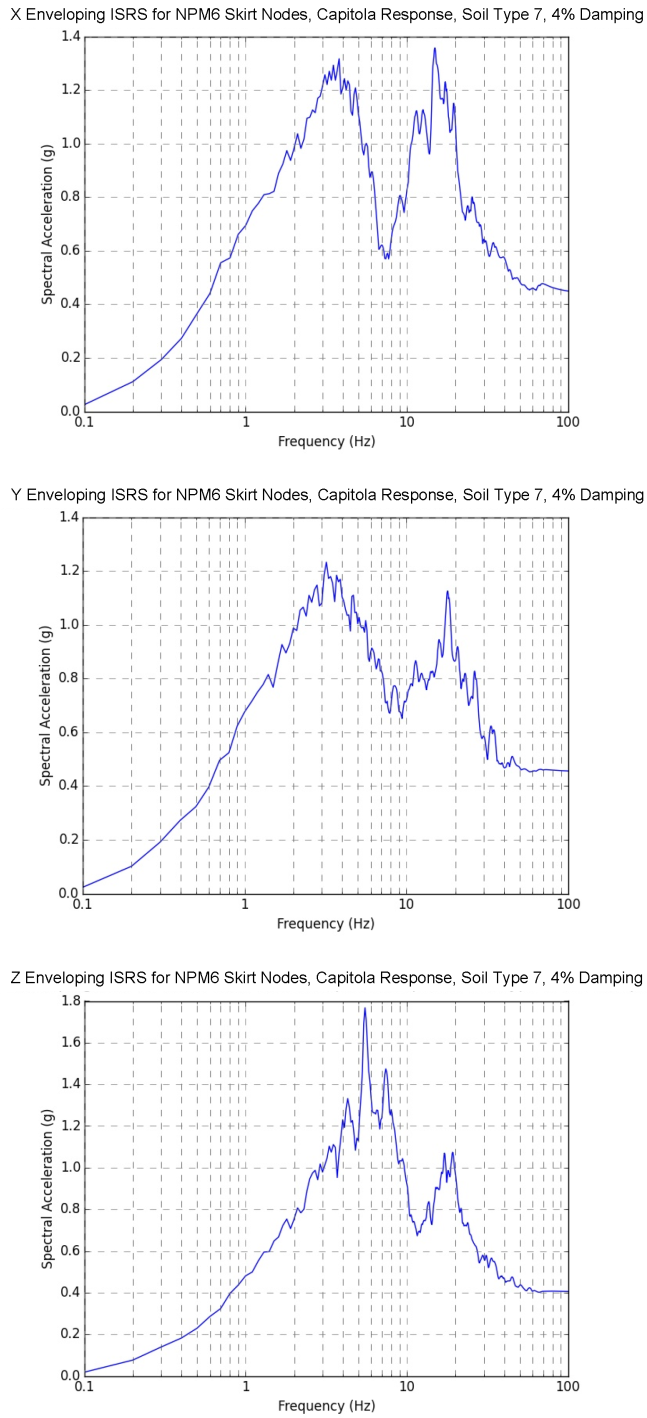
RAI 03.08.04-23S2

Figure 3.7.2-156: Enveloping ISRS of Cases 1, 2, and 3 at the CNV Skirt of NPM1



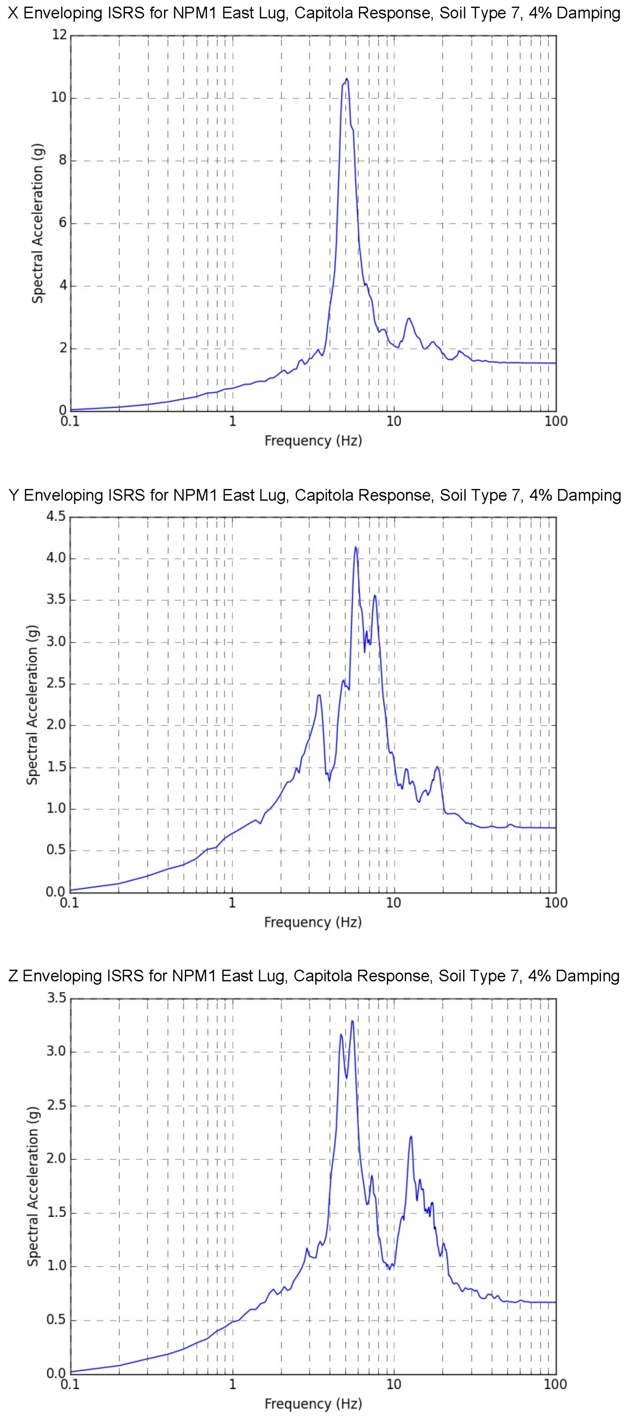
RAI 03.08.04-23S2

Figure 3.7.2-157: Enveloping ISRS of Cases 1, 2, and 3 at the CNV Skirt of NPM6



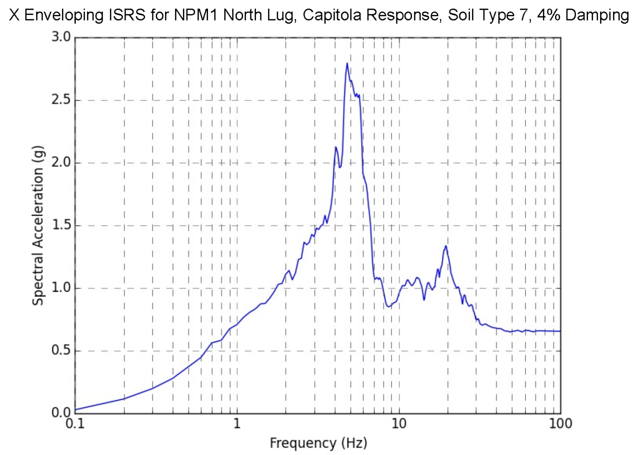
RAI 03.08.04-23S2

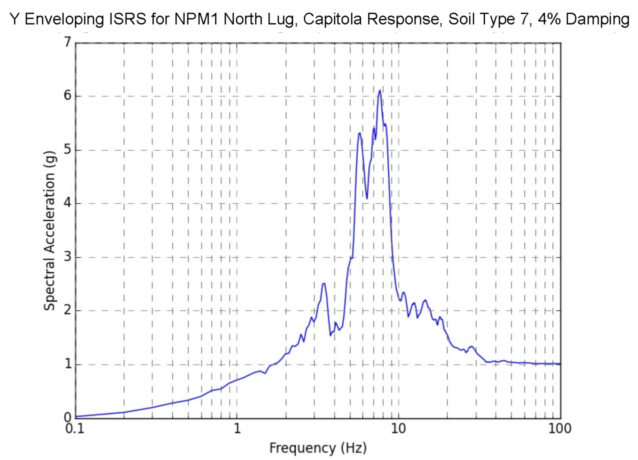
Figure 3.7.2-158: Enveloping ISRS of Cases 1, 2, and 3 at the East Lug of NPM1

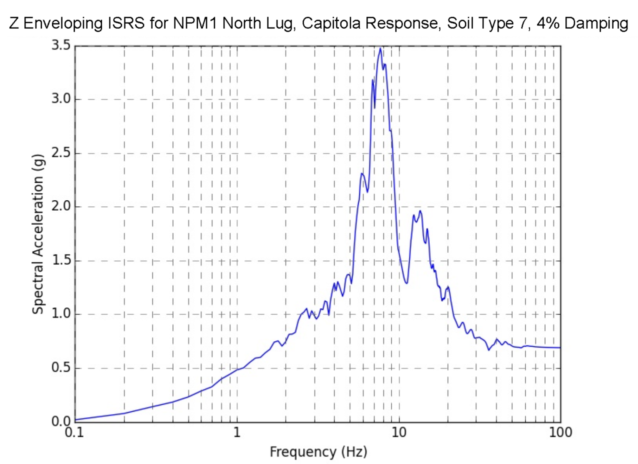


RAI 03.08.04-23S2

Figure 3.7.2-159: Enveloping ISRS of Cases 1, 2, and 3 at the North Lug of NPM1

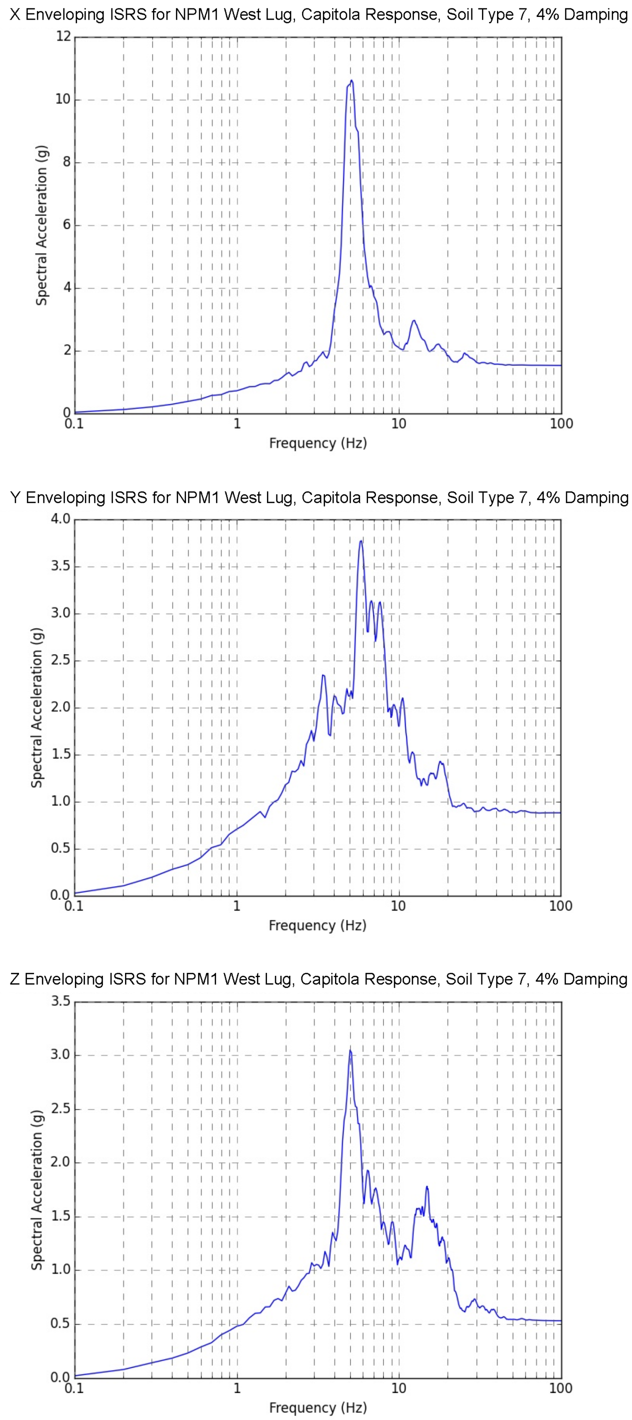






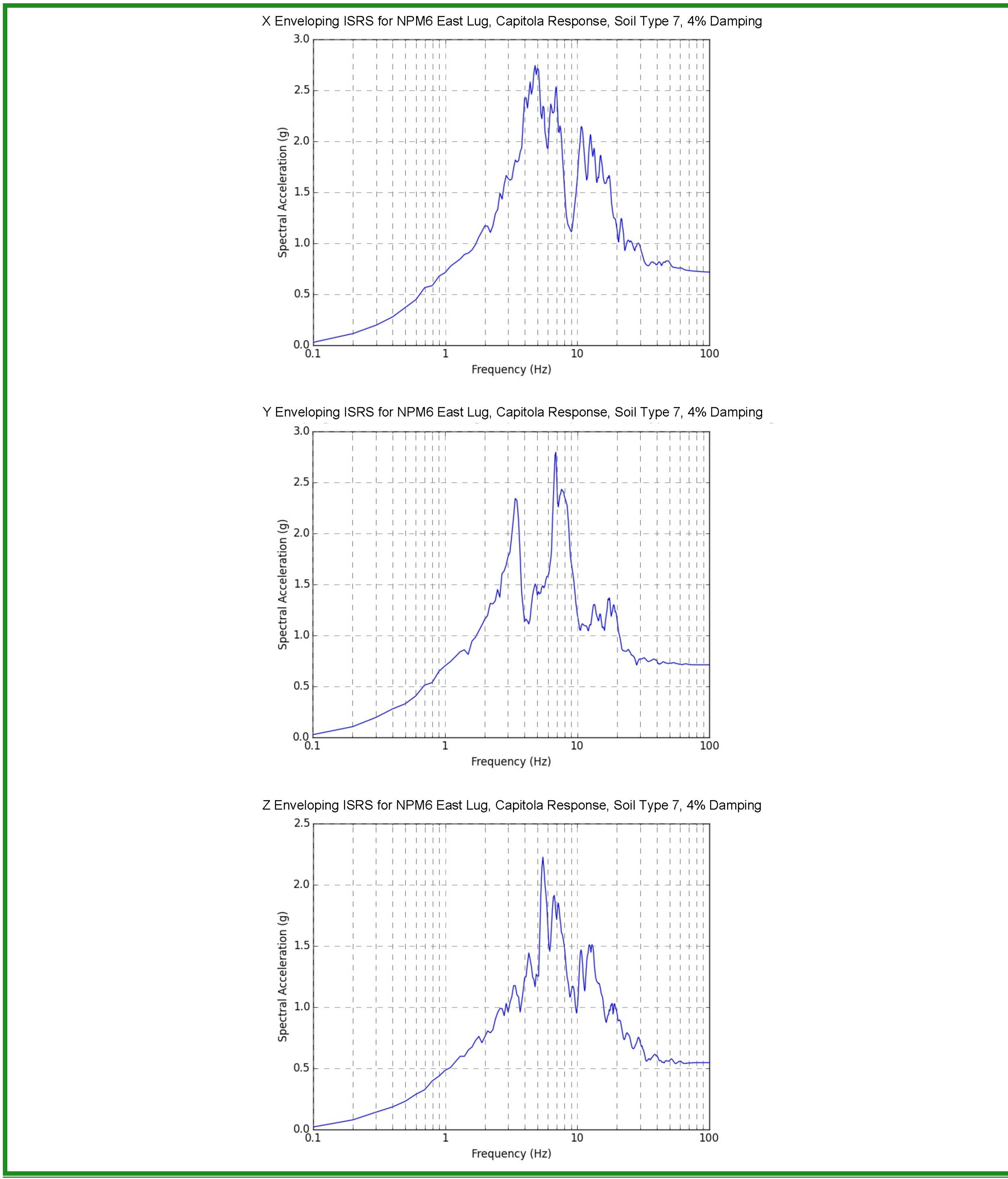
RAI 03.08.04-23S2

Figure 3.7.2-160: Enveloping ISRS of Cases 1, 2, and 3 at the West Lug of NPM1



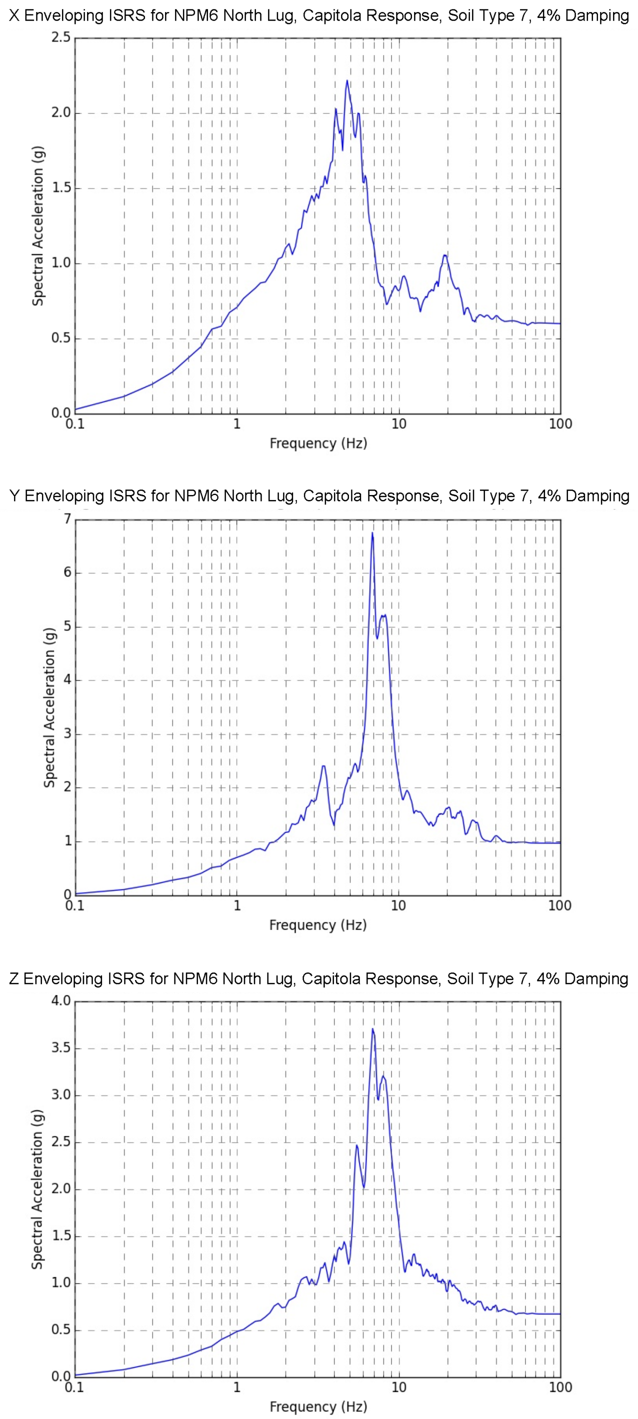
RAI 03.08.04-23S2

Figure 3.7.2-161: Enveloping ISRS of Cases 1, 2, and 3 at the East Lug of NPM6



RAI 03.08.04-23S2

Figure 3.7.2-162: Enveloping ISRS of Cases 1, 2, and 3 at the North Lug of NPM6



RAI 03.08.04-23S2

Figure 3.7.2-163: Enveloping ISRS of Cases 1, 2, and 3 at the West Lug of NPM6