Mark D. Mitchell
Vice President - Generation Construction
Dominion Generation

An operating segment of
Dominion Resources, Inc.
5000 Dominion Boulevard, Glen Allen, VA 23060

dom.com

Dominion®

July 31, 2015

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Serial No. NA3-15-018
Docket No. 52-017
COL/DBE

DOMINION VIRGINIA POWER
NORTH ANNA UNIT 3 COMBINED LICENSE APPLICATION
SUBMISSION OF REVISED SEISMIC RAI RESPONSES AND COLA MARKUPS

In accordance with the North Anna Unit 3 (NA3) Seismic Closure Plan (SCP) (ML14297A199), this letter transmits nine revised Request for Additional Information (RAI) responses and COLA markups scheduled for submittal in July 2015. In addition, one initial RAI response, RAI 7810, is included. The revised RAI responses supersede the responses previously submitted by Dominion. The responses to the RAI questions listed below are provided in Enclosures 1 through 10:

- RAI 7520, Question 03.07.01-7 — Effect of Backfill on FIRS
- RAI 7520, Question 03.07.01-11 — FWSC Response Spectra Modeling Basis
- RAI 7536, Question 03.07.02-10 — SASSI2010 Applicability for SSI Analysis
- RAI 7536, Question 03.07.02-13 — RB/FB, CB, and FWSC SSI Details
- RAI 7536, Question 03.07.02-14 — Cracked Concrete Stiffness and SSE Damping Properties
- RAI 7536, Question 03.07.02-15 — SSI Transfer Function Plots for RB/FB, CB, and FWSC
- RAI 7536, Question 03.07.02-16 — Site-Specific SSSI Effects
- RAI 7536, Question 03.07.02-23 — SDOF Oscillators in SSI Models
- RAI 7810, Question 03.07.02-26 — Seismic System Analysis
- RAI 7538, Question 03.08.05-6 — Evaluation of Sliding Stability

The SCP did not identify RAI 7520 Question 03.07.01-7 or RAI 7536 Question 03.07.02-10 as requiring revision. During the process of developing the initial response to RAI 7810 Question 03.07.02-26, it was determined that the response to RAI 7536 Question 03.07.02-10 required revision. RAI 7520 Question 03.07.01-7 was revised to address comments made from the NRC during an April 15, 2015 meeting.

Additional files in support of RAI 7520 Question 03.07.02-11 were requested by the NRC during an April 1, 2015 meeting, and are provided on a DVD in Enclosure 11. A brief report labeled SER-DMN-022 is provided on the DVD which explains the files included on the DVD.

D089
NRO

To facilitate the NRC's review, Dominion has provided a consolidated set of COLA markups in Enclosure 12 on a second DVD, rather than including individual markups after each RAI response.

Enclosure 11 of this letter contains proprietary information. An affidavit signed by GEH, the owner of the information, is provided in Enclosure 13. The affidavit sets forth the basis on which the information in the proprietary version of the report should be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (a)(4) of 10 CFR 2.390 of the Commission's regulations. Accordingly, it is respectfully requested that the information, which is proprietary to GEH, be withheld from public disclosure in accordance with 10 CFR 2.390 of the Commission's regulations. Correspondence with respect to the copyright or proprietary aspects of the GEH information noted above or the supporting GEH affidavit should be addressed to: David Hinds, Manager, New Units Engineering, GE Hitachi Nuclear Energy, 3901 Castle Hayne Road, Wilmington, NC 28401.

This information will be incorporated into a future submission of the NA3 COLA, as described in the enclosures. The schedule for making a COLA submission formally incorporating these changes will be discussed with the NRC project manager.

Please contact Regina Borsh at (804) 273-2247 (regina.borsh@dom.com) if you have questions.

Very truly yours,

Mark D. Mitchell

Mark D. Mitchell

LANA MARIE LEE
NOTARY PUBLIC
MY COMMISSION NUMBER 7152644
COMMONWEALTH OF VIRGINIA

Enclosures:

1. Revised Response to NRC RAI Letter No. 121, RAI 7520 Question 03.07.01-7
2. Revised Response to NRC RAI Letter No. 121, RAI 7520 Question 03.07.01-11
3. Revised Response to NRC RAI Letter No. 123, RAI 7536 Question 03.07.02-10
4. Revised Response to NRC RAI Letter No. 123, RAI 7536 Question 03.07.02-13

5. Revised Response to NRC RAI Letter No. 123, RAI 7536 Question 03.07.02-14
6. Revised Response to NRC RAI Letter No. 123, RAI 7536 Question 03.07.02-15
7. Revised Response to NRC RAI Letter No. 123, RAI 7536 Question 03.07.02-16
8. Revised Response to NRC RAI Letter No. 123, RAI 7536 Question 03.07.02-23
9. Response to NRC RAI Letter No. 154, RAI 7810 Question 03.07.02-26
10. Revised Response to NRC RAI Letter No. 125, RAI 7538 Question 03.08.05-6
11. Input Data and Output Echo Data Files for the SASSI2010 Program-Modules for FWSC Uncracked Models (RAI 7520 Q 03.07.01-11) (GEH Proprietary) (DVD)
12. FSAR Markups of Revised Sections (DVD)
13. GEH Affidavit

Commitments made by this letter:

This information will be incorporated into a future submission of the North Anna Unit 3 COLA, as described in the enclosures.

COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mark D. Mitchell, who is Vice President–Generation Construction of Virginia Electric and Power Company (Dominion Virginia Power). He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of the Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 31 day of July, 2015
My registration number is 7152644 and my
Commission expires: January 31, 2016

Lana Marie Lee
Notary Public

LANA MARIE LEE
NOTARY PUBLIC
MY COMMISSION NUMBER 7152644
COMMONWEALTH OF VIRGINIA

cc with all Enclosures (Two copies of Enclosure 11 and 12 DVDs):
J.J. Shea, Jr. NRC

cc without Enclosures 11 and 12:
U. S. Nuclear Regulatory Commission, Region II
T. S. Dozier, NRC
G. J. Kolcum, NRC
D. Paylor, VDEQ
W. T. Lough, SCC
P. W. Smith, DTE
M. K. Brandon, DTE
R. J. Bell, NEI

bc with all Enclosures:

Records Management - GOV 02-54B (paper copy; bc original; 2 copies of DVDs)
COL Project File

bc w/o Enclosures 11 and 12:

D. A. Kemp, Bechtel
S. D. Routh, Bechtel
L. M. Cuoco, Tredegar
S. W. Semmes, IN-2-SW
R. A. Borsh, IN-2-SW
D. R. Lewis, Pillsbury Winthrop Shaw Pittman
N. K. Martin, IN-2-SW
C. Richardson, IN-2-SW
P. Campbell, GEH
W. Schumitsch, GEH
C. Bagnal, GEH
D. Hinds, GEH
D. McDonald, GEH
B. R. Johnson, GEH
M. Arcaro, GEH
J. Hawkins, Fluor
J. Foelske, Fluor
L. Dusek, Fluor
P. Gaillard, Fluor
T. O'Neil, Fluor
K. Pumphrey, Fluor

CONCURRENCE

L. M. Cuoco/D. R. Lewis	DBE for DRL per 7/22/15 email
J. D. Hegner	JDH 7/30/2015
Mark A. Giles	JDH for MAG 7/30/2015

VERIFICATION OF ACCURACY

1. The revised response to RAI 7520 Question 03.07.01-7 was prepared by GEH and transmitted to Dominion via letter number ECO-0016276 dated July 17, 2015.
2. The revised response to RAI 7520 Question 03.07.01-11 was prepared by GEH and transmitted to Dominion via letter number ECO-0016920 dated July 12, 2015.
3. The revised response to RAI 7536 Question 03.07.02-10 was prepared by GEH and transmitted to Dominion via letter number ECO-0017002 dated July 13, 2015.
4. The revised response to RAI 7536 Question 03.07.02-13 was prepared by GEH and transmitted to Dominion via letter number ECO-0013940 dated July 2, 2015.
5. The revised response to RAI 7536 Question 03.07.02-14 was prepared by GEH and transmitted to Dominion via letter number ECO-0013944 dated July 12, 2015.
6. The revised response to RAI 7536 Question 03.07.02-15 was prepared by GEH and transmitted to Dominion via letter number ECO-0014014 dated July 9, 2015.
7. The revised response to RAI 7536 Question 03.07.02-16 was prepared by GEH and transmitted to Dominion via letter number ECO-0016842 dated July 15, 2015.
8. The revised response to RAI 7536 Question 03.07.02-23 was prepared by GEH and transmitted to Dominion via letter number ECO-0016844 dated July 12, 2015.
9. The response to RAI 7810 Question 03.07.02-26 was prepared by GEH and transmitted to Dominion via letter number ECO-0017005 dated July 14, 2015.
10. The revised response to RAI 7538 Question 03.08.05-6 was prepared by GEH and transmitted to Dominion via letter number ECO-0017006 dated July 16, 2015.
11. The files for Enclosure 11 were provided via GEH transmittal number WG3-DT-00880, SER-DMN-022, Rev. 0 Input Data and Output Echo Data Files for the SASSI2010 Program-Modules for FWSC Uncracked Models, dated July 22, 2015, and via email from Skip Schumitsch (GEH) dated July 9, 2015
12. The COLA revisions were processed using CCR packages NA3-15-7001, NA3-15-7004, NA3-15-7005, NA3-15-7006, and NA3-15-7007.

ACTION PLAN/COMMITMENTS (STATED OR IMPLIED)

The changes described in the enclosures to this letter will be incorporated into a future submission of the North Anna Unit 3 COLA.

REQUIRED CHANGES TO THE COL APPLICATION (STATED OR IMPLIED)

Proposed changes to the COLA are described in the enclosures to this letter.

ENCLOSURE 1

Revised Response to NRC RAI Letter No. 121

RAI No. 7520, Question 03.07.01-7

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7520 (RAI LETTER 121)

SRP SECTION: 03.07.01 – SEISMIC DESIGN PARAMETERS

DATE OF RAI ISSUE: 06/05/2014

QUESTION NO.: 03.07.01-7

FSAR Section 3.7.1.1.4.2 indicates that the Foundation Input Response Spectra (FIRS) and associated Performance Based Surface Response Spectra (PBSRS) for all Seismic Category I structures are presented in FSAR Section 2.5.2.6. It is also noted that the full and partial soil/rock columns used in the site response analyses described in FSAR Sections 2.5.2.5 and 2.5.2.6 consider only the effect of in situ saprolite soil above Zone III rock. Further, FSAR Section 3.7.1.1.4 indicates that this in situ soil material will be removed and replaced with granular fill or concrete fill as appropriate. However, FSAR Sections 2.5.2.5 and 2.5.2.6 do not provide the information on whether and how the effect of backfill material was considered in developing the FIRS and PBSRS. Because the FIRS are used as the input to the soil-structure interaction (SSI) analyses for the Category I structures, the development of the FIRS to consider structure specific soil properties is essential to the adequate seismic design as required by 10CFR50 Appendix S. Therefore, the staff requests that the applicant provide the technical basis for computing FIRS and PBSRS which only considers soil/rock columns with in-situ saprolite and not the granular or concrete fill that will be surrounding or beneath the Seismic Category I structures up to the finished grade elevation.

NRC Staff Comments on RAI Response (ADAMS Accession No. ML14233A063)

On June 5, 2014, the NRC requested additional information to support the review of the NA3 COLA, including Question 03.07.01-7. Dominion initially responded to this RAI in letter NA3-14-030 (ML14202A385) dated July 3, 2014. In a public teleconference held on July 10, 2014, the NRC provided feedback, which was later provided in a document entitled "Staff Comments on NA3 RAI Responses" (ML14233A063). Dominion later submitted a revised response in Dominion

Letter NA3-15-002, dated February 23, 2015 (ML15056A047) to address the NRC staff concerns. In a public meeting on April 15, 2015, the NRC requested that the RAI response be revised because the structure-soil-structure interaction (SSSI) results are found to be important in some cases. The NRC suggested that the revised response address the effects of backfill on the seismic responses of the CB and FWSC SSSI and explain the analyses that have been completed in this respect. This response is revised to provide additional information regarding the SSSI effects and to clarify which analyses have been completed.

NRC Follow-up Question Regarding RAI 03.07.01-7 - Effect of Backfill on FIRS/PBSRS:

The staff requested that the applicant provide the technical basis for computing FIRS and PBSRS which only considers soil/rock columns with in-situ saprolite and not the granular or concrete fill that will be surrounding or beneath the Seismic Category I structures up to the finished grade elevation. The applicant responded to this RAI in their July 3, 2014 letter (NA3-14-030). The staff provided feedback to the applicant on this response during the public conference call on July 10, 2014. The applicant was requested to further address the following and update the FSAR accordingly:

- Since the effect of backfill material on the structural response may be important the RAI response should reflect this.
- The extent of the backfill material could not be determined from the FSAR Figure 2.5.4-206. As such, the figure should be revised or additional figures should be referenced in the FSAR that provide the extent of the backfill.

Dominion Response

This response revises and supersedes the previous response ~~submitted in NA3-14-030, dated July 3, 2014 (ADAMS Accession No. ML14202A385), to address the NRC staff's comments on the original Dominion response~~submitted in NA3-15-002, dated February 23, 2015 (ML15056A047). ~~It also incorporates related information provided to the NRC in the North Anna Unit 3 Seismic Closure Plan (SCP) submitted by letter NA3-14-043, dated October 22, 2014 (ML14297A199).~~ To address a question from the NRC during a public meeting held April 15, 2015, this revision to the response includes information on the effects of backfill on the seismic response of the FWSC based on the results of the Structure-Soil-Structure Interactions (SSSI) analyses of the FWSC-CB combined model that includes the structural fill placed between the FWSC and CB and around the concrete fill supporting the FWSC basemat. For ease of review, revisions to the ~~original~~previous response ~~have been~~are presented using redline/strike-through formatting.

Part (a) of the response provides the technical basis for considering only the in-situ rock and saprolite columns in the computation of the FIRS and PBSRS for the Seismic Category I structures. Parts (b) and (c) of the response apply to the follow-up question described in the section above. Specifically, Part (b) describes how the fill materials are represented in the models used for the Soil Structure Interaction (SSI) and Structure-Soil-Structure (SSSI) analyses. It provides the technical basis for the approach used to address the effects of the variations in the extent of horizontal fill on the seismic response of the Seismic Category I structures. Part (c) addresses the NRC's question regarding the extent of the backfill materials.

Part (a): Computation of FIRS and PBSRS Using In-Situ Material

The consideration of backfill material (granular (structural) fill and concrete fill) is not included in the development of the FIRS and PBSRS because the effects of the backfill materials on the seismic response of Seismic Category I structures are evaluated in the SSI and SSSI analyses. The FIRS and associated PBSRS for the Seismic Category I structures presented in FSAR Section 2.5.3.6 are developed from the full and partial soil/rock columns, as described in FSAR Section 2.5.2.5, and consider only the free field conditions (in-situ saprolite soil and in-situ rock layers) away from the structures. This is consistent with the free-field conditions included in the SSI analysis of the Seismic Category I structures, as presented in FSAR Section 3.7.2.4. This approach follows the Interim Staff Guidance DC/COL-ISG-017 on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses, and NEI White Paper (Reference 1) recommendations that the same free-field conditions are used in the site response analysis and the SSI analysis.

The in-situ material surrounding or beneath the Seismic Category I structures to be replaced with granular (structural) fill and concrete fill, as indicated in FSAR Section 3.7.1.1.4, has limited lateral extent compared to the foundation dimensions of the buildings, as shown in FSAR Figure 2.5.4-206 and as described in Part (c) of this response. As described in Part (b) of this response, the effects of the replacement structural fill and concrete fill on the seismic response of Seismic Category I structures are addressed in the SSI and SSSI analyses by explicitly including the dynamic properties of the backfill in the structural SSI model using 3D solid finite elements. Therefore, the consideration of the backfill materials (granular (structural) fill and concrete fill) in the development of the FIRS and PBSRS is not warranted.

Part (b): Consideration of Backfill in SSI and SSSI Analyses

The backfill that is placed below and around the Reactor Building/Fuel Building (RB/FB), Control Building (CB) and Fire Water Service Complex (FWSC) foundations is limited in extent, which varies depending on the subgrade

variations, the plant configuration, and the construction demands (this is further described in Part (c) of this response). In order to capture the effects of the backfill limited extent on the response of the RB/FB, CB and FWSC, the dynamic models used for the seismic response (SSI and SSSI) analyses use near-field 3-D solid elements representing the dynamic properties of concrete and structural fill materials. A set of analyses is performed using lower bound (LB), best estimate (BE) and upper bound (UB) properties for the fill materials and different embedment configurations. The results of these analyses are enveloped to adequately address the effects of the variations of the lateral extent of the concrete and structural fill materials on the response of the Seismic Category I structures. The SSSI analyses are performed using combined models representing the actual backfill conditions between the Seismic Category I structures (RB/FB, CB and FWSC) to further address the effects of backfill on the seismic responses of the CB and the FWSC.

The seismic response analyses utilize the sub-structuring method (Reference 2) where the SSI system is divided in two parts: (1) structural (SASSI HOUSE) model representing the dynamic properties of the structure and near-field subgrade materials with a limited lateral extent; and (2) far-field (SASSI SITE) model representing the dynamic properties of the horizontally infinite subgrade. The SSI and SSSI analyses are performed using far-field (SASSI SITE) models representing LB, BE and UB dynamic properties of in-situ subgrade materials compatible with the strains generated by the input design ground motion. The structural (SASSI HOUSE) models use 3D solid finite elements attached to the below grade portion of the structure representing the limited extent of concrete and structural fill materials. The dynamic properties of the excavated volume of the in-situ soil that is replaced by the structure and the backfill materials are also included in the structural (SASSI HOUSE) models by using 3D solid finite elements.

LB, BE and UB dynamic properties of in-situ and structural fill materials compatible to strain generated by the design ground motion are developed from the results of the site response analyses of randomized profiles as described in FSAR Section 3.7.1. The dynamic properties used for the concrete fill are independent of strain, reflecting the linear elastic behavior of the concrete under the small earthquake-induced strains. Figures 1, 2, and 3 compare the strain-compatible properties, S-wave (shear wave) velocities, P-wave velocities and damping, of the far-field in-situ subgrade and backfill, which are presented in revised FSAR Tables 3.7.1-201 through 3.7.1-206.

The following describes the technical basis and the modeling approaches used in the different seismic response analyses to address the effects of the backfill on the structural response of the different Seismic Category I structures:

i. <u>Consideration of Backfill in RB/FB and CB SSI Analyses</u>

As explained in Unit 3 SCP, the site-specific seismic demands for the RB/FB and CB ~~will be~~are developed as the envelope of responses obtained from the SSI analyses of 'partial column' and 'full column' subgrade profiles representing dynamic properties of far-field in-situ subgrade materials. As described in FSAR Section 3.7.2.4~~.1~~, the SSI analyses are performed on SASSI HOUSE models that include near-field 3D solid finite elements representing the dynamic properties of the concrete fill placed around RB/FB and CB and below CB foundation. The SASSI HOUSE models being used for the RB/FB and CB SSI analyses of 'full column' subgrade profiles also include additional near-field 3D solid finite elements representing the structural fill placed above the concrete fill. A lower bound value is used for the extent of the near-field elements and is applied equally on all four sides of the structure.

The partial and full embedment configurations considered in the RB/FB and CB SSI analyses provide responses that bound the effects of subgrade stiffness variations related to the backfill horizontal extent and minimize the effects of dissipation of energy in the SSI system due to damping of the embedment materials. The partially embedded models provide a lower bound representation of the stiffness of the RB/FB and CB embedment because they do not consider the stiffness of the subgrade materials (saprolite and the structural fill) above Zone III rock surface. Because the structural fill has a lower shear wave velocity (and thus lower shear modulus and stiffness) than the surrounding in-situ saprolite, the fully embedded model with a minimum horizontal extent of the structural fill provides an upper bound representation of the stiffness of the RB/FB and CB embedment. Furthermore, the use of the minimum horizontal extent of the structural fill material <u>minimizes the dissipation of energy in the embedment soil</u> ~~is conservative~~ because<u>, as shown in Figures 2 and 3,</u> the structural fill has a higher material damping ratio than that of the in-situ saprolite. The comparisons between the shear wave velocity and damping ratio of the structural fill and in-situ saprolite are provided in Figures 2 and 3 below, which show that the structural fill has lower stiffness and higher damping properties than the surrounding in-situ saprolite. Therefore, the use of minimum values and LB dynamic properties for the structural fill horizontal extent results in SSI models of fully embedded RB/FB and CB that maximize the stiffness and minimize the damping of the embedment above Zone III rock. The envelope of responses obtained from site-specific SSI analyses of partially and fully embedded models bound variations of subgrade stiffness related to backfill horizontal extent and corresponds to a lower dissipation of energy in the SSI system due to damping of the subgrade materials located above Zone III rock surface.

The lateral extent of the fill in the RB/FB and CB models is taken to be the smaller of one-half of the fill width between adjacent structures or the actual fill width to the inside face of the sheet piling on the sides without adjacent

structures. This minimum value is used for the extent of the near-field concrete and structural fill elements and is applied equally on all four sides of the structure.

Two structural models are used for site-specific RB/FB SSI analyses performed for LB, BE and UB partial and full column subgrade profiles. The configurations of the partially embedded and fully embedded RB/FB SSI models are shown below in Figures 4 and 5. The minimum value of the lateral extent of backfill for the RB/FB SSI model is 3130 mm (10.27 ft) and is determined as one-half of the distance between the RB/FB and the adjacent Turbine Building (TB) as shown in Table 1, which is the same as the minimum distance to the inside face of the sheet piling on the South and West sides of the building. The concrete fill that will be placed under the northern edge and southeast corner of the RB/FB basemat is considered as part of the far-field in-situ Zone III/IV rock because, as described in FSAR Section 2.5.4.2.5, the dynamic properties of the concrete fill are very close to that of the Zone III/IV rock.

Two structural models are used for site-specific CB SSI analyses performed for LB, BE and UB partial and full column subgrade profiles. Figures 6 and 7 show the configurations of the partially embedded and fully embedded stand-alone CB SSI models. The minimum value of the lateral extent of backfill for the CB SSI model is 3730 mm (12.24 ft) and is determined as one-half of the distance between the CB and the adjacent Service Building (SB) as shown in Table 2, which is the same as the minimum distance to the inside face of the sheet piling on the North side of the building. A 4910 mm (16.1 ft) thick layer of solid elements at the bottom of the CB model represent the concrete fill placed between the CB foundation bottom elevation of 241.1 ft and the Zone III/IV rock top nominal elevation of 225 ft.

ii. Consideration of Backfill in FWSC SSI Analyses

The FWSC site-specific seismic design basis is developed as an envelope of the results of the site-specific SSI analyses of the stand-alone FWSC model and the results of the SSSI analyses of the FWSC-CB model. The site-specific SSI and SSSI ~~analysis~~analyses of the FWSC and FWSC-CB models ~~is~~are both performed for LB, BE and UB subgrade profiles using ~~a~~ SASSI HOUSE models that include~~s~~ a 18,990 mm (62.3 ft) thick block of solid elements representing the concrete fill placed below the FWSC foundation between the basemat bottom elevation of 282.3 ft and the Zone III/IV rock top nominal elevation of 220 ft (see Figure 8 below). The dynamic properties of the structural fill and in-situ saprolite are similar, as shown in Figure 1, which presents the comparison of the shear wave velocities, compression wave velocities, and damping of the in-situ soil and structural fill materials in the vicinity of the FWSC.

The SSI analyses of the stand-alone FWSC model do not include the structural fill and use the in-situ soil dynamic properties for the soil surrounding the concrete fill placed under the FWSC foundation. The FWSC-CB combined model used for the SSSI analyses includes the structural fill placed between the FWSC and CB and around the concrete block supporting the FWSC basemat, as discussed below. The envelope of the results of the site-specific SSI analyses of the standalone FWSC model and the results of the SSSI analyses of the FWSC-CB model ensure that the FWSC site-specific seismic design basis includes the effects of the structural fill and the effects of SSSI of the CB on the seismic response of the FWSC.The differences between dynamic properties of the structural fill and in-situ saprolite are not expected to significantly affect the SSI response of the FWSC because the FWSC foundation is supported by concrete fill placed on in-situ rock. This modeling simplification is addressed by the SSSI sensitivity analyses of the FWSC and CB that are performed on combined models that include the engineered fill as discussed below. Figure 1 presents the comparison of the shear wave velocities, compression wave velocities, and damping of the in situ soil and structural fill materials in the vicinity of the FWSC.

iii. Consideration of Backfill in SSSI Analyses

As explained in the SCP, FSAR Section 3.7.2 will be revised to present the evaluations of the SSSI effects between the Seismic Category I structures. These evaluations will beare based on the results of a set of SSSI analyses that are performed on combined models representing the actual site configuration between (1) the CB and RB/FB and (2) the CB and FWSC structures. As shown in DCD Figure 1.2-11, the access tunnel is located between the RB/FB and CB. The concrete fill placed between the two buildings will support the foundation of the access tunnel. The exterior walls of the access tunnel are seismically isolated from the nearby RB/FB and CB below-grade walls. In order to closely capture the actual site conditions that may affect the SSSI effects of the RB/FB on the CB seismic response, the CB-RB/FB combined model will includes the access tunnel structure that iswill be represented by shell elements and a block of 3D solid elements representing the concrete fill underneath the access tunnel foundation. The combined models of the CB and FWSC will use 3D solid elements to represent the dynamic properties of the backfill materials placed in the 12,040 mm (39.5 ft) gap between the two buildings (see Table 2 below).

In conclusion, the SSI analyses adequately address the effects of the limited extent of the fill materials on the seismic response of Seismic Category I structures by using near-field elements in the structural (SASSI HOUSE) models to represent the fill materials around the RB/FB and CB, and below the CB and FWSC foundations. The envelope of results obtained from the analyses of fully embedded models with minimum backfill width and partially embedded models that neglect the stiffness of the fill provides responses that bound the effect of the variations of the fill lateral extent on the seismic response of the RB/FB and CB.

The site-specific seismic response analyses of the FWSC use models that include a 18,990 mm (62.3 ft) thick block of solid elements representing the concrete fill placed below the FWSC foundation In the vicinity of the FWSC foundation, the differences between dynamic properties of the structural fill and in-situ saprolite are not expected to significantly affect the SSI response of the FWSC; thus, these two materials are represented by the FWSC far field (SASSI SITE) models.

The SSSI evaluations utilize combined models representing the actual site conditions between the RB/FB, CB and FWSC to further address the effects of fill materials on the response of the Seismic Category I structures. Results of the SSSI analyses of the FWSC-CB combined model, which includes the structural fill placed between the FWSC and CB and around the concrete block supporting the FWSC basemat, ensure that the FWSC site-specific seismic design basis captures the effects of the structural fill on the seismic response of the FWSC.

Part (c): Extent of Backfill Material

As described in FSAR Section 2.5.4, the in-situ materials will be excavated prior to construction to ensure that the Seismic Category I foundations are supported by Zone III/IV rock or concrete fill. The excavation will be secured by sheet piles installed around the power block area as shown on FSAR Figure 2.5.4-206. The excavation extent will vary depending on the subgrade variations, the plant configuration, and the construction demands. The south and the west supports of the excavation will be located at least 3130 mm (10.27 ft) away from the RB/FB foundation (see Table 1 below). The lateral distance between the CB foundation and the north support of the excavation will be at least 3730 mm (12.24 ft) (see Table 2 below). The east support of the excavation will be located at least 5990 mm (19.65 ft) from the FWSC foundation (see Table 3 below).

After construction excavation is completed, the excavation will be backfilled with concrete fill up to surface of the Zone III rock and structural fill from the Zone III rock surface up to the plant grade (elevation 290 ft NAVD88; reference FSAR Section 2.4.1.1). The Zone III rock top elevation varies as shown in the contour plots shown in FSAR Figure 2.5.4-203. FSAR Section 2.5.4.2.5 describes the variations of the thickness of the concrete fill placed under the different Seismic Category I foundations.

A paragraph will be added in FSAR Section 2.5.4.5.1 describing the minimum lateral extent of the excavation and fill materials with respect to the Seismic Category I structures.

Reference

1. NEI White Paper, "Consistent Site-Response/Soil-Structure Interaction Analysis and Evaluation," NEI, June 12, 2009. (ML091680715).

2. SASSI2010 User's Manual, F. Ostadan, N. Deng, May 2012.

Proposed COLA Revision

The COLA markups for changes to FSAR Section 2.5.4.5.1 and 3.7.1 ~~are~~ were submitted in Dominion letter Serial No. NA3-15-002, dated February 23, 2015, Enclosure 8 (ML15062A458).~~addressed in the COLA markup submitted with this RAI response.~~ The changes to FSAR Section 3.7.2 are addressed in the COLA markup submitted with this RAI response revision.~~will be submitted in accordance with the SCP.~~

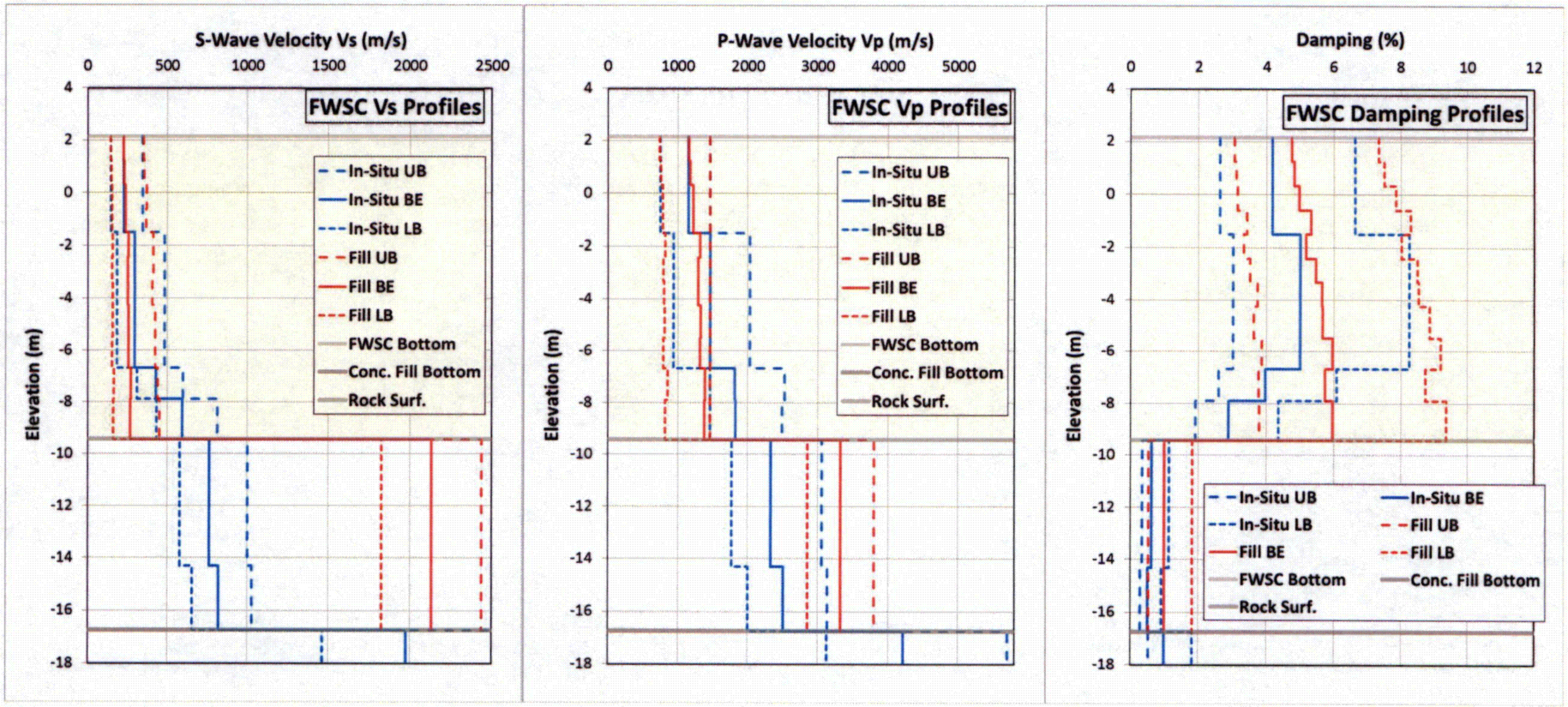

Figure 1 Comparison of Dynamic Properties of Fill and In-situ Subgrade Materials for FWSC (Illustrative Only) (Based on Revised FSAR Table 3.7.1-205 & Table 3.7.1-206)

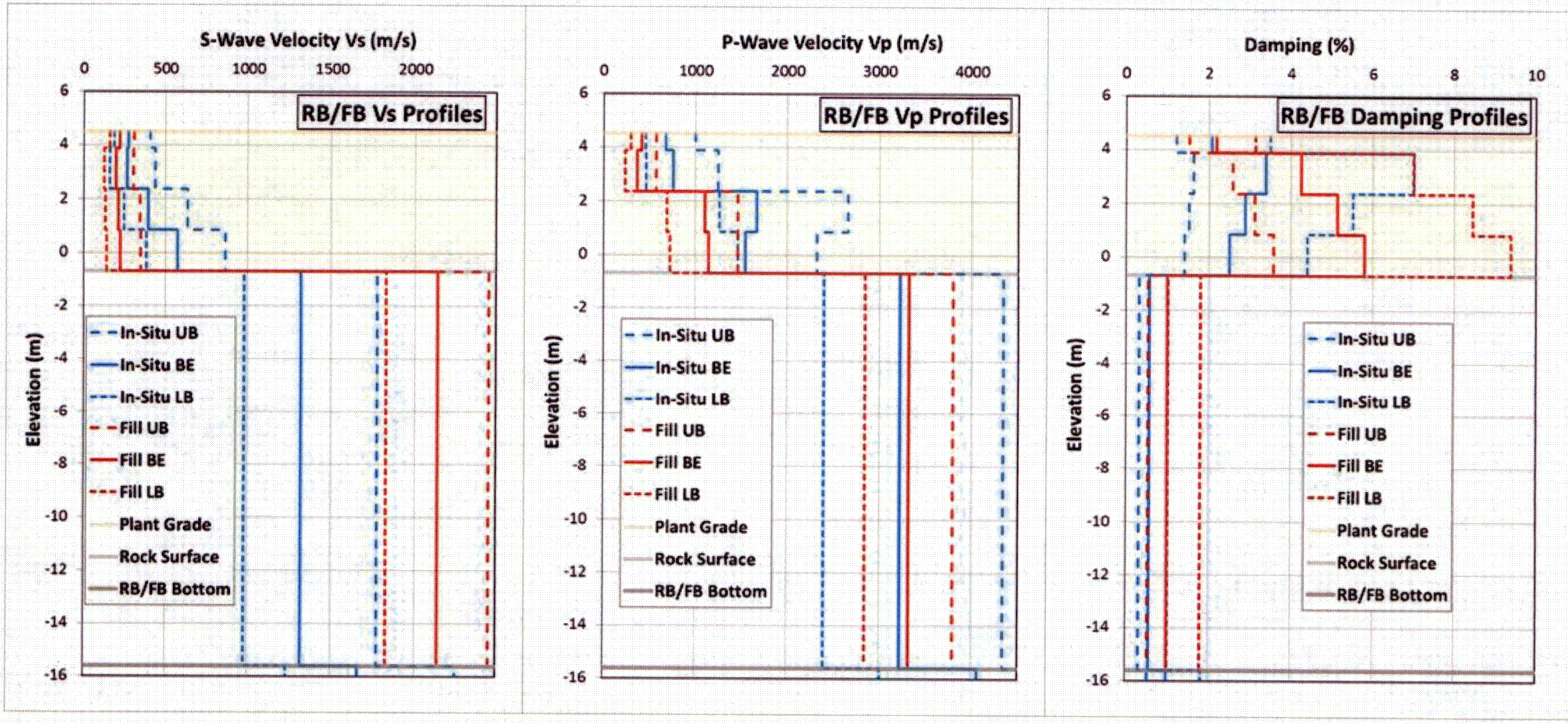

Figure 2 Comparison of Dynamic Properties of Fill and In-situ Subgrade Materials for RB/FB (Illustrative Only) (Based on Revised FSAR Table 3.7.1-201 & Table 3.7.1-202)

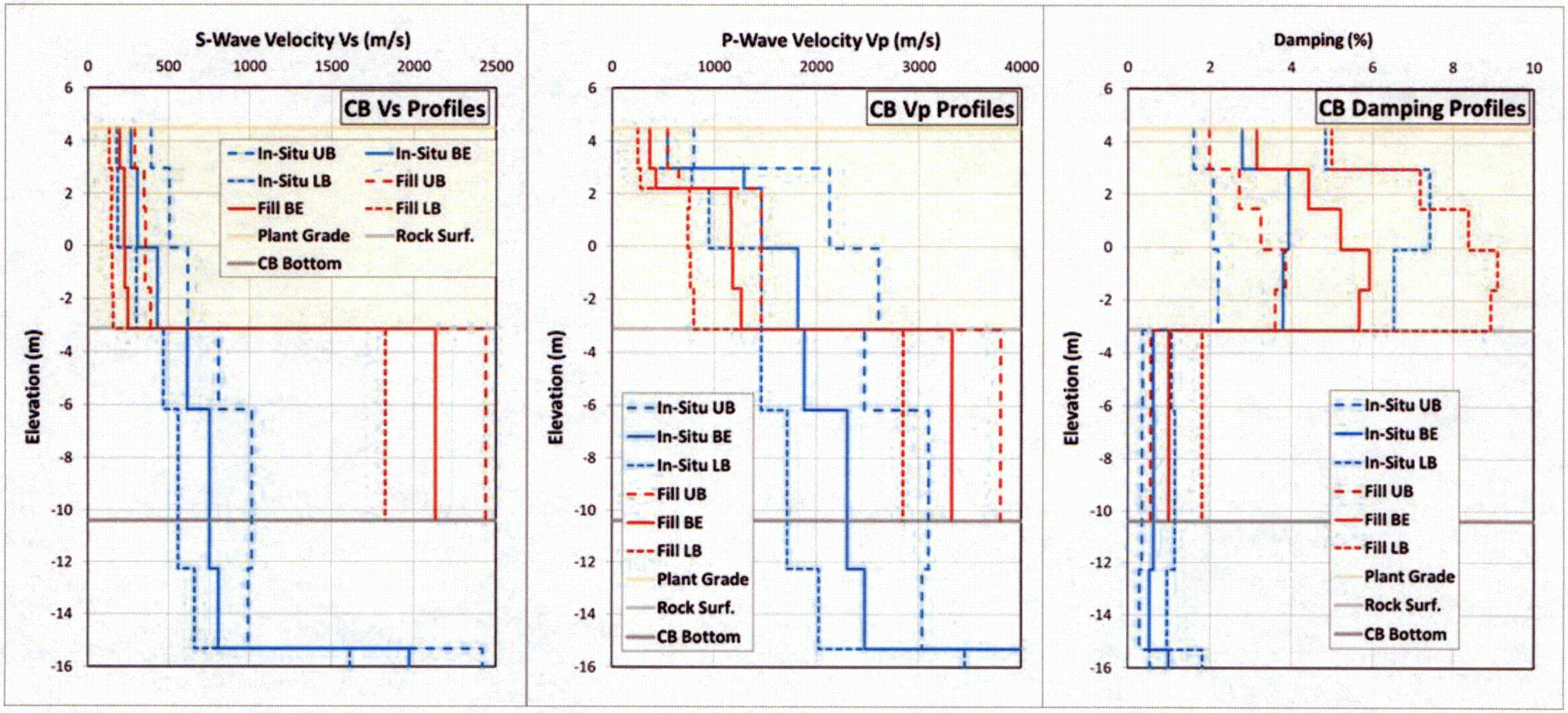

Figure 3 Comparison of Dynamic Properties of Fill and In-situ Subgrade Materials for CB (Illustrative Only)
(Based on Revised FSAR Table 3.7.1-203 & Table 3.7.1-204)

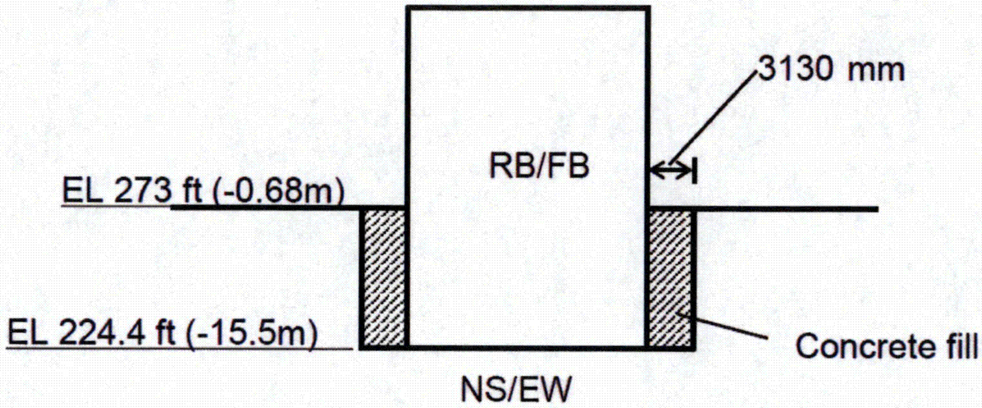

Figure 4 RB/FB SSI Stand-Alone Partially Embedded Model

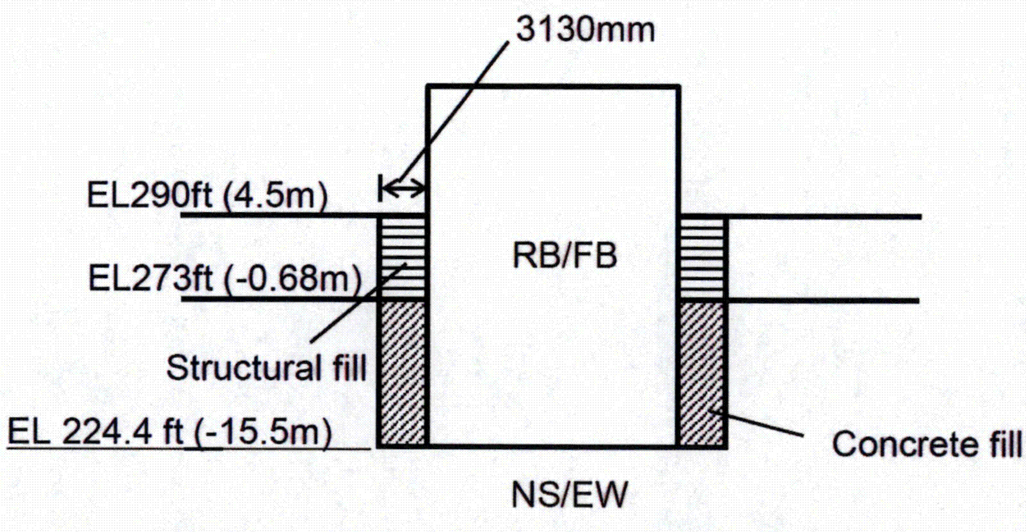

Figure 5 RB/FB SSI Stand-Alone Fully Embedded Model

NOTE: Figures 4 and 5 are for illustrative purposes. Metric values in parentheses represent the standard plant elevation.

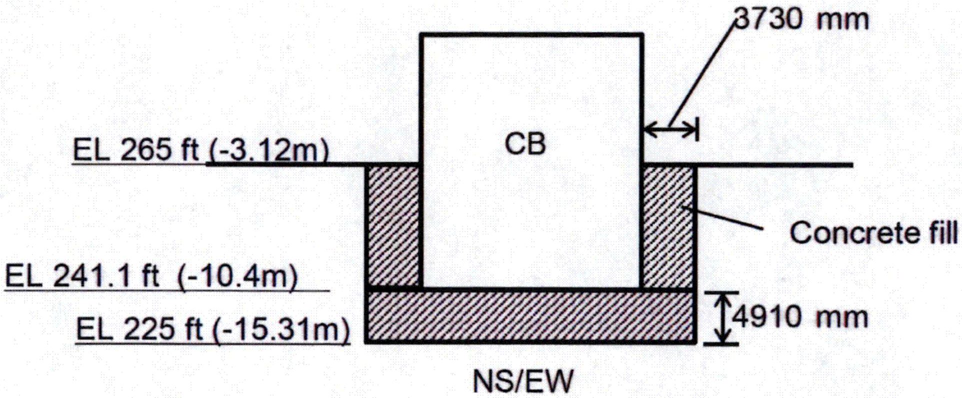

Figure 6 CB SSI Stand-Alone Partially Embedded Model

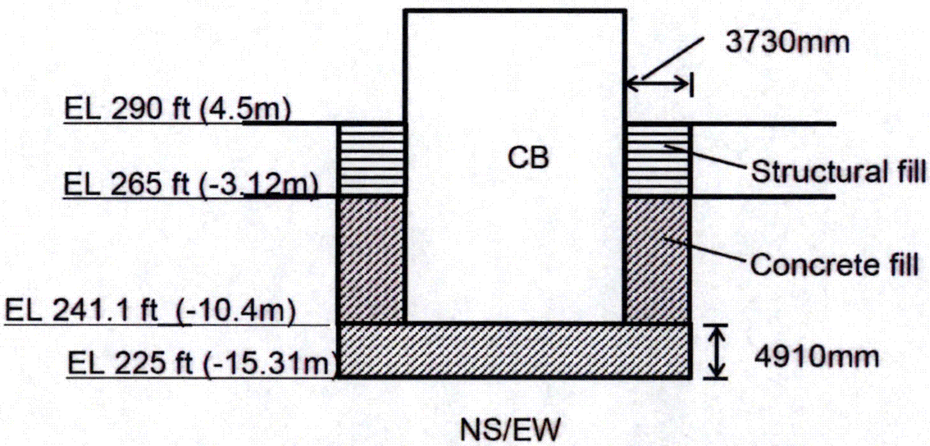

Figure 7 CB SSI Stand-Alone Fully Embedded Model

NOTE: Figures 6 and 7 are for illustrative purposes. Metric values in parentheses represent the standard plant elevation.

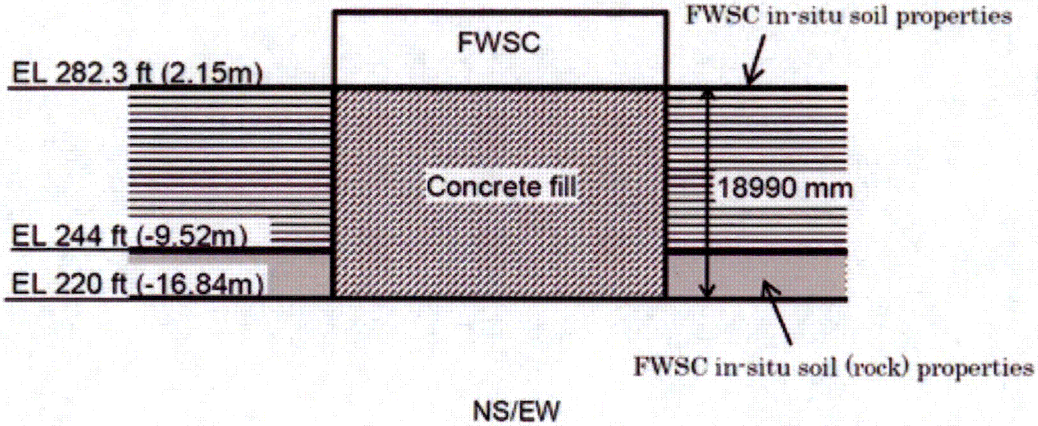

Figure 8 FWSC SSI Stand-Alone Model

NOTE: Figure 8 is for illustrative purposes. Metric values in parentheses represent the standard plant elevation.

Table 1 Lateral Extent of Structural Fill Around RB/FB

North	3130 mm (10.27 ft)	One-half the distance between RB/FB and Turbine Building 0.5 x 6260 mm (20.54 ft)
South	3130 mm (10.27 ft)	Minimum distance to inside face of Sheet Piling adjacent to RB/FB
East	6975 mm (22.88 ft)	One-half the distance between RB/FB and Control Building 0.5 x 13950 mm (45.77 ft)
West	3130 mm (10.27 ft)	Minimum distance to inside face of Sheet Piling adjacent to RB/FB
Minimum Distance	**3130 mm (10.27 ft)**	RB/FB lateral extent of backfill

Table 2 Lateral Extent of Structural Fill Around CB

North	3730 mm (12.24 ft)	Minimum distance to inside face of Sheet Piling adjacent to Control Building
South	3730 mm (12.24 ft)	One-half the distance between CB and Service Building (SB) 0.5 x 7460 mm (24.48 ft)
East	6020 mm (19.75 ft)	One-half the distance between CB and FWSC 0.5 x 12040 mm (39.5 ft)
West	6975 mm (22.88 ft)	One-half the distance between CB and RB/FB 0.5 x 13950 mm (45.77 ft)
Minimum Distance	**3730 mm (12.24 ft)**	Control Building lateral extent of backfill

Table 3 Lateral Extent of Structrual Fill Around FWSC

North	5990 mm (19.65 ft)	Minimum distance to inside face of Sheet Piling adjacent to FWSC
South	5990 mm (19.65 ft)	Minimum distance to inside face of Sheet Piling adjacent to FWSC
East	5990 mm (19.65 ft)	Minimum distance to inside face of Sheet Piling adjacent to FWSC
West	6020 mm (19.75 ft)	One-half the distance between CB and FWSC 0.5 x 12040 mm (39.5 ft)
Minimum Distance	**5990 mm (19.65 ft)**	FWCS lateral extent of backfill

NOTE: These tables are for purposes of identifying the minimum distances from the specific structures as used in SSI analyses.

NOTE: Directions are based on Plant North for Unit 3 (see Figure 2.5.4-205).

ENCLOSURE 2

Revised Response to NRC RAI Letter No. 121

RAI No. 7520, Question 03.07.01-11

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7520 (RAI LETTER 121)

SRP SECTION: 03.07.01 – SEISMIC DESIGN PARAMETERS

DATE OF RAI ISSUE: 06/05/2014

QUESTION NO.: 03.07.01-11

FSAR 3.7.1.1.4.2 indicates that the NEI check is not applicable to the development of SSI input response spectra for the FWSC because this structure is analyzed as a surface structure. However, FSAR Section 3.7.2 indicates that the concrete fill below the FWSC basemat is represented as an integral part of the structural model used in the SSI analysis (FSAR Figure 3.7.2-209-b). As such, the model for the concrete fill and the superstructure should be treated as an embedded structure and the SSI input motion should be specified at the bottom of the concrete fill. Therefore, the NEI check should be performed to ensure that the PBSRS is enveloped by the SSI input motion when convolved to the ground surface. The applicant is requested to provide the following information:

(a) Provide the technical justification for defining the control motions used in the SSI analysis at the bottom of the basemat and not at the bottom of the concrete fill. Staff notes that, from the point of view of the SSI analysis, the combined FWSC-concrete fill is an embedded structure and as such, the control motions for SSI analysis should be defined at the bottom of the concrete fill to be consistent with the NEI approach. The NEI check should be applicable in this case.

(b) Explain why the FWSC SSI input response spectra shown in FSAR Figure 3.7.1-234 differs substantially from the SSI input response spectra for the CB shown in FSAR Figure 3.7.1-231, both in amplitude (lower) and in frequency content (shift to lower frequencies), even though the FWSC is situated at a higher elevation and is supported on similarly stiff material.

Dominion Response

For ease of review, the revised text is shown with redline/strike-through formatting

To support the NRC's review, the response to this RAI Question has been divided into four submittals:

- The first submittal, submitted by Dominion Letter NA3-14-030A (ML14204A459) provided the description of the revised methodology for development of the input motions for the SSI analysis of the FWSC.

- The second submittal, Dominion Letter NA3-14-030C (ML 14239A541), revised the first submittal to provide the new SSI input response spectra for the FWSC and address the changes in FSAR Section 3.7.1 that describe the new methodology.

- ~~This~~ The third submittal revised ~~revises~~ the second submittal to reflect the EPRI 2013 update to the ground motion model (GMM) (Reference 2). The response was included in Dominion Letter NA3-15-002 (ML15056A047) as Enclosure 5.

- ~~A subsequent~~This fourth submittal ~~will~~ revises the previous submittals and supplements the SSI analysis results for the FWSC. ~~The schedule for the fourth~~ This submittal ~~is provided~~ provides information related to the results of the SSI analysis of the FWSC, as described in the October 22, 2014, Seismic Closure Plan. In addition, this submittal provides in digital format the (1) FWSC SSI models for SASSI soil profiles, (2) FWSC in-column input time histories, and (3) FWSC structural and concrete fill properties with this revised response, as requested by the NRC staff (see presentation slide 17, NRC Public Meeting April 1, 2015; ML15090A573).

~~For ease of review, the revised text is shown with redline/strike-through formatting~~.

As described in FSAR Section 3.7.2, the site specific soil-structure interaction (SSI) analyses consider the Fire Water Service Complex (FWSC) as a surface founded structure at Elevation 282 ft. Due to the limited horizontal extent of the fill concrete below the FWSC foundation, the SSI model includes the strain compatible in-situ soil profiles as the free-field material. It also explicitly includes (as 3D solid finite elements) the concrete fill below the footprint of the foundation on top of the Zone III-IV rock formation at the average elevation of 220 ft. The concrete fill is considered as a competent material supporting the foundation and not as an integral part of the

structural foundation. Nevertheless, to address potential deamplification of the high frequency input motion, the SSI analysis approach presented in the FSAR for the FWSC is being supplemented to include new SSI input response spectra (horizontal and vertical) at the average elevation of the bottom of concrete fill (Elevation 220 ft).

The responses to questions (a) and (b) are provided in parts (a) and (b) of this response. Part (a) provides justification for defining the control point at the bottom of the basemat (Elevation 282 ft) and describes the revised methodology which adds a new control point at the average elevation of the bottom of the concrete fill (Elevation 220 ft). It also addresses the applicability of the NEI check to the revised methodology. Part (b) explains the reasons for differences between the SSI input motions for the FWSC and the Control Building (CB) both in amplitude and frequency content.

A new Part (c) has been added to the response. Part (c) provides information related to results of the SSI analysis of the FWSC using control motion applied at the subgrade surface (Elevation 282 ft) and the bottom of the concrete fill (Elevation 220 ft).

Part (a)

As described in FSAR Section 3.7.1.1.4.2.3, the FIRS for the FWSC are calculated at the bottom of the building foundation at Elevation 282 ft from the results of probabilistic site response analysis of the FWSC in-situ soil profiles. The definition of FIRS at the bottom of the foundation follows the recommendations of DC/COL-ISG-017 and NEI White Paper (Reference 1) and is consistent with the ESBWR DCD definition of the input motion for the SSI analysis of the FWSC as part of the certified design. The control motion corresponding to the application of the FIRS in the SSI analysis of the FWSC is consistently applied at Elevation 282 ft.

A shift in the frequency content of the input motions towards lower frequencies and reduction of the high frequency amplitudes due to higher damping in the saprolitic soil layers is expected because the FIRS for the FWSC is calculated on top of 38 ft (best estimate thickness) of saprolite layers, which undergo significant softening due to seismically induced strains. When the SSI analysis is carried out using three deterministic strain compatible soil profiles (lower bound (LB), best estimate (BE), and upper bound (UB)), the high frequency shift may not be fully recovered in the site deconvolution from the control point down to the bottom of the concrete fill which may result in a deamplification of the high frequency motion.

To address this potential high frequency deamplification of the input motions, the FSAR methodology regarding the control motion for SSI analysis of the FWSC (FSAR Section 3.7.1.1.4.2.3) is supplemented by adding new horizontal and vertical SSI input response spectra at the average elevation of the bottom of the concrete fill at Elevation 220 ft (corresponding to the average elevation of the top of Zone III-IV rock). Furthermore, FSAR Section 3.7.2.4~~.1~~ will be supplemented to describe the new SSI analysis and design basis for the FWSC. The new SSI input response spectra are calculated as the envelope of the design response spectra (DRS) at Elevation 220 ft and the minimum

required response spectra (which are adopted from the broadband spectra defined in RG 1.60 and anchored at 0.1g at peak ground acceleration (PGA)). The DRS at Elevation 220 ft are calculated consistent with the existing FIRS for the FWSC (Elevation 282 ft) using the same methodology as described in FSAR Sections 2.5.2.5 and 2.5.2.6. The mean horizontal outcrop uniform hazard response spectra (UHRS) at 10^{-4} and 10^{-5} hazard levels and outcrop DRS for FWSC soil column at Elevation 220 ft are presented in Figure 5. The development of the horizontal and vertical SSI input response spectra at Elevation 220 ft is provided in Figures 6 and 7, respectively. The final SSI input response spectra at Elevation 220 ft are presented in Figure 8. An additional set of SSI analyses is performed~~will be performed~~ using the new SSI input response spectra with the control point at Elevation 220 ft corresponding to the bottom of the concrete fill in the SSI analysis model. Note that since the new SSI input response spectra (at Elevation 220 ft) is calculated to be consistent with the SSI input response spectra at Elevation 282 ft, the LB, BE, and UB strain compatible properties provided in FSAR Section 3.7.1.1.4.1.3 are applicable to the additional set of SSI analyses.

The new design basis for the FWSC ~~will be~~is defined as the envelope of the seismic results using the current FWSC SSI input motion defined at Elevation 282 ft and the new FWSC SSI input motion defined at Elevation 220 ft.

Following the approach presented above, additional NEI check is not warranted in the site response analysis, because:

- As described in DC/COL-ISG-017 and NEI White Paper (Reference 1), the intent of the NEI check is to ensure that the PBSRS are enveloped by deterministic SSI analysis at top of the considered soil columns
- Since the horizontal and vertical FIRS are calculated at the top of the considered FWSC soil column, they also represent the horizontal and vertical performance-based surface response spectra (PBSRS) for the FWSC.
- The SSI input motion at Elevation 282 ft envelops the FWSC PBSRS.
- The SSI results from the application of the SSI input motion at Elevation 282 ft will be enveloped by the design basis.

Part (b):

The FWSC SSI input response spectra shown in FSAR Figure 3.7.1-234 has lower amplitudes and lower frequency content when compared to the CB SSI input response spectra presented in FSAR Figure 3.7.1-231 most importantly because the FIRS elevations and supporting in-situ materials below the FIRS elevations for these two buildings are significantly different. Note that the best estimate soil profiles corresponding to the FWSC and the CB are close but not identical as presented in FSAR Figures 2.5.2-259 and 2.5.2-262.

The FWSC FIRS is calculated at Elevation 282 ft, on top of 38 ft (best estimate thickness) of saprolitic soil, which undergoes significant softening due to seismically induced strains, especially at the 10^{-5} hazard level. In contrast, the FIRS for the CB is calculated at Elevation 241 ft on much stiffer Zone III rock layers which experience little nonlinearity due to seismic inputs at 10^{-4} or 10^{-5} input levels. The higher nonlinearity in the saprolitic soil layers for FWSC results in softening of the soil profile and in a shift in the frequency content of the input motion towards lower frequencies as well as a reduction in the input motion amplitudes at higher frequencies due to additional damping in the saprolitic soil layers. These observations are supported by comparing the FSAR Figures 2.5.2-290 and 2.5.2-292 at 10^{-4} hazard level (relevant curves are overlaid in Figure 1) and FSAR Figures 2.5.2-291 and 2.5.2-293 at 10^{-5} hazard level (relevant curves are overlaid in Figure 2). The terms HF and LF in Figure 1 and Figure 2, refer to the high frequency and low frequency input response spectra, respectively. The term "FWSC BoF" refers to the bottom of foundation for FWSC (Elevation 282 ft) and the term "CB BoF" refers to the bottom of foundation for the CB (Elevation 241 ft).

The comparison of the 10^{-4} hazard level acceleration response spectra (ARS) in Figure 1 shows FWSC responses generally have higher amplitudes and lower frequencies, relative to the CB responses. At 10^{-5} hazard level, a more pronounced shift in frequency content is observed in Figure 2 for the FWSC motion as well as a slight reduction in the amplitude of the high frequency peaks due to nonlinearity effects in saprolitic soils. Following the RG 1.208 approach in calculation of design response spectra, these nonlinearity effects at 10^{-5} hazard level lead to a smaller ratio of 10^{-5} to 10^{-4} ARS (this ratio is referred to as AR) and significantly smaller design factor (DF) at higher frequencies for the FWSC. Comparisons of the AR and DF parameters for the FWSC FIRS at Elevation 282 ft and the CB FIRS at Elevation 241 ft are shown in Figure 3. Finally, FSAR Figures 2.5.2-301 and 2.5.2-306 of the FSAR are overlaid in Figure 4 which compares the envelope of the HF and LF ARS (denoted as Env ARS) at 10^{-4} and 10^{-5} hazard levels as well as the FWSC DRS (Elevation 282 ft) and the CB DRS (Elevation 241 ft). The comparison shows a similar amplitude of the FWSC DRS compared to the CB DRS and a notable shift towards lower frequencies which are consistent with the SSI input response spectra presented in FSAR figures 3.7.1-234 and 3.7.1-231.

Part (c)

The updated North Anna Unit 3 (NA3) site-specific SSI analyses performed for the FWSC are presented in Reference 3. The NA3 site-specific SSI analyses follow the methodology presented in the standard design (DCD Section 3.7.2 and Appendix 3A) using the Modified Subtraction Method (MSM) and SASSI2010 computer program.

The FWSC site-specific seismic design basis is developed based on the envelope of the results obtained from two sets of site-specific FWSC SSI analyses performed with the input control motion applied:

- as a surface motion compatible to the spectra defining the site-specific design motion at the bottom of the FWSC foundation at Elevation 282 ft and

- as an in-column motion compatible to the spectra defining the site-specific design motion at the bottom of the concrete fill at nominal Elevation 220 ft.

The consideration of these two different control motion elevations captures the effects of seismic wave propagation through concrete fill, and thus addresses potential deamplification of the high frequency input motion as the seismic waves propagate through the in-situ saprolite.

SSI analyses are performed using each input control motion for three subsurface profiles, namely, a best estimate (BE) profile, a lower bound (LB) profile, and an upper bound (UB) profile.

The site-specific structure-soil-structure interaction (SSSI) evaluation documented in Reference 4 shows that the responses obtained from the FWSC SSI analyses do not envelope the SSSI effects of the CB on the FWSC seismic response. Therefore, to account for amplifications due to CB SSSI effects on the seismic response of the FWSC, the site-specific FWSC seismic design basis is developed as an envelope of the FWSC stand-alone SSI analyses documented in Reference 3 with the results of the SSSI analyses of the FWSC-CB model documented in Reference 4.

In order to provide conservative seismic responses for the NA3 rock site with high frequency design ground motion, the NA3 FWSC structural models used for the SSI and SSSI analyses represent stiffness properties of uncracked reinforced concrete structures. Results obtained from the analyses of models of structures with full (uncracked concrete) stiffness and SSE damping are used for the calculation of the site-specific seismic load demands on the FWSC reinforced concrete structures. The results of the analyses of the models of FWSC structures with full (uncracked concrete) stiffness and OBE damping are used for the development of site-specific In-Structure Response Spectra (ISRS).

The results of the FWSC SSI and FWSC-CB SSSI analyses presented in References 3 and 4, respectively, show that the:

- analyses with deep input motions yield maximum response results that envelope the results of the analyses with surface input motion at Elevation 282 ft,

- NA3 high frequency design motion results in displacements that are enveloped by the standard design, and

- comparisons of the 5 percent damped ISRS in Section 5.3 of Reference 3 show that analyses performed using deep input control motion at the bottom of the concrete fill provide bounding results for the FWSC horizontal and vertical ISRS at frequencies higher than 10 Hz and 18 Hz, respectively.

Therefore, the development of the site-specific seismic load demands on the FWSC structures are based on the envelope of the maximum force and acceleration results obtained from the SSI and SSSI analyses of the FWSC stand-alone and FWSC-CB combined models with full (uncracked concrete) properties and SSE damping using the in-column control motion that is input at the bottom of the concrete fill Elevation 220 ft. The envelope of the results from the SSI and SSSI analyses performed on the FWSC model with full (uncracked concrete) stiffness properties and OBE damping using surface and in-column control motions are used for development of the FWSC site-specific ISRS as described in Reference 3.

Appendix 3A is being revised to describe results of the SSI and SSSI analyses.

Conclusion

In summary, in response to question (a), the justification for the FWSC control point at the bottom of the basemat (Elevation 282 ft) is provided. However, to address potential deamplification of the input motion at high frequencies an additional set of SSI analyses is ~~will be~~ performed using a new control point at the average elevation of the bottom of the concrete fill (Elevation 220 ft). The new design basis for the FWSC is ~~will be~~ defined as the envelope of the seismic results using the current FWSC SSI input motion defined at Elevation 282 ft and the new FWSC SSI input motion defined at Elevation 220 ft. Also, the applicability of the NEI check to the revised methodology is discussed and it is concluded that additional NEI check in the FWSC site response analysis is not warranted. In response to question (b), the reasons for differences between the SSI input motions for the FWSC and the Control Building (CB) both in amplitude and frequency content are explained. The updated SSI analyses and the SSSI analyses for the FWSC using the input motions at the two elevations and the results of these analyses are described in Item (c) of this response, with further details in the referenced reports.

References

1. NEI White Paper, "Consistent Site-Response/Soil-Structure Interaction Analysis and Evaluation," NEI, June 12, 2009. (ADAMS Accession No. ML091680715).
2. Electric Power Research Institute [EPRI], 2013, EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project: EPRI, Palo Alto, CA, 2013 Technical Report, 3002000717, NRC ADAMS Accession No. ML13155A553.
3. WG3-U63-ERD-S-0001,"Firewater Service Complex Seismic Analysis Report."
4. WG3-U73-ERD-S-0002, "Control Building and Firewater Service Complex Seismic Structure-Soil-Structure Interaction Analysis Report."

NOTE: Reference 3 was submitted in Dominion letter Serial No. NA3-15-014, dated June 30, 2015. Reference 4 was submitted in Dominion letter Serial No. NA3-15-009, dated May 29, 2015.

Proposed COLA Revision

The changes to FSAR Section 3.7.1 were submitted in Dominion letter Serial No. NA3-15-002, dated February 23, 2015, Enclosure 8. Changes to FSAR Appendix 3A are addressed in the COLA markup submitted with this RAI response.

In addition, a DVD is enclosed to provide the NRC with the information requested as part of the NRC public meeting held April 1, 2015. See Enclosure 11.

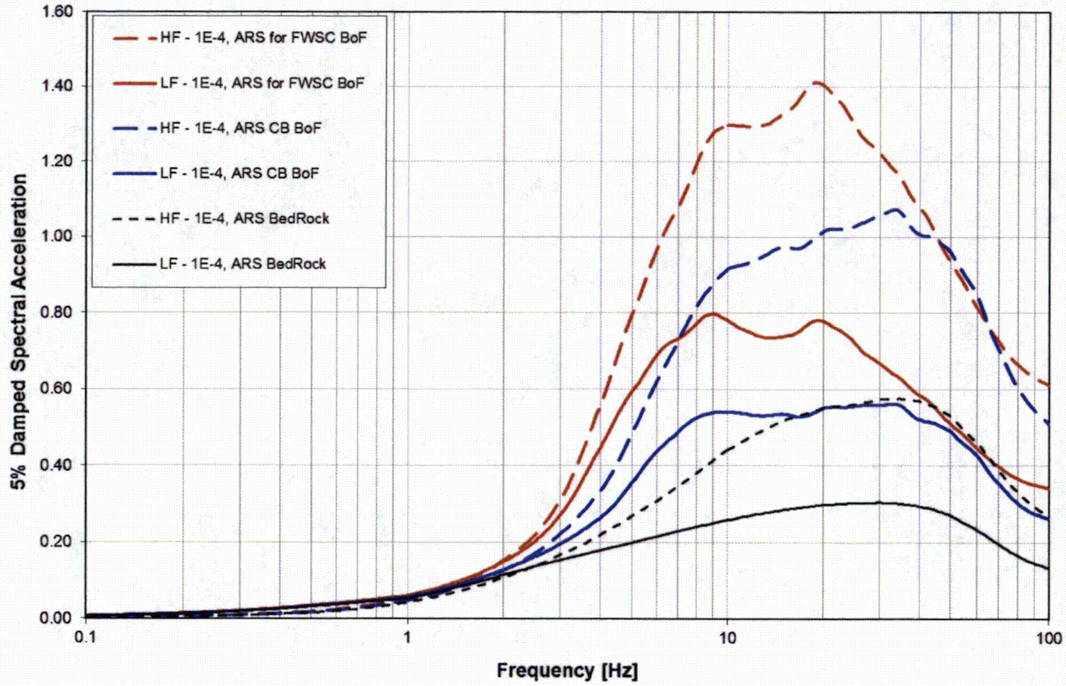

Figure 1. Overlay of FSAR Figures 2.5.2-290 and 2.5.2-292 (ARS at 10^{-4} hazard level)

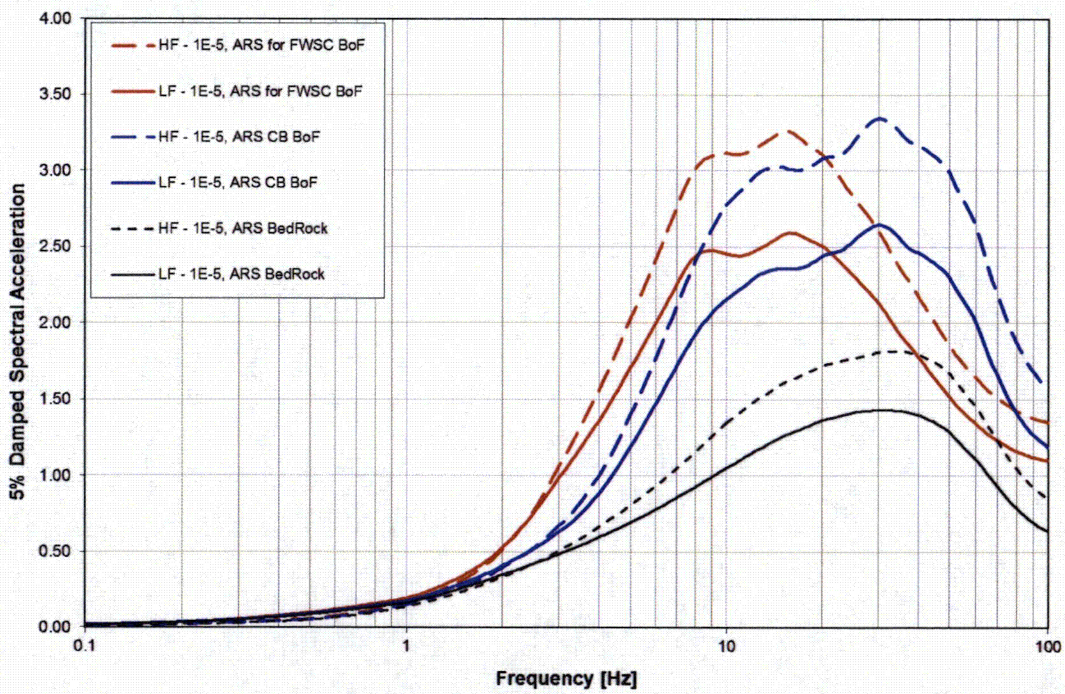

Figure 2. Overlay of FSAR Figures 2.5.2-291 and 2.5.2-293 (ARS at 10^{-5} hazard level)

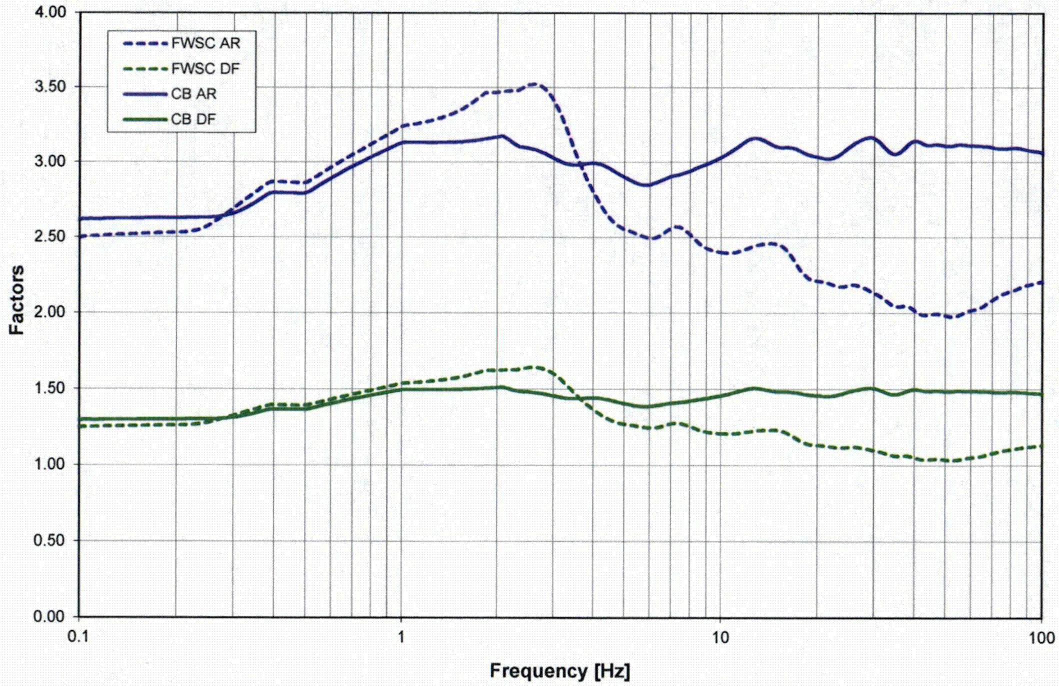

Figure 3. Comparison of DRS parameters for CB at Elevation 241 ft and FWSC at Elevation 282 ft

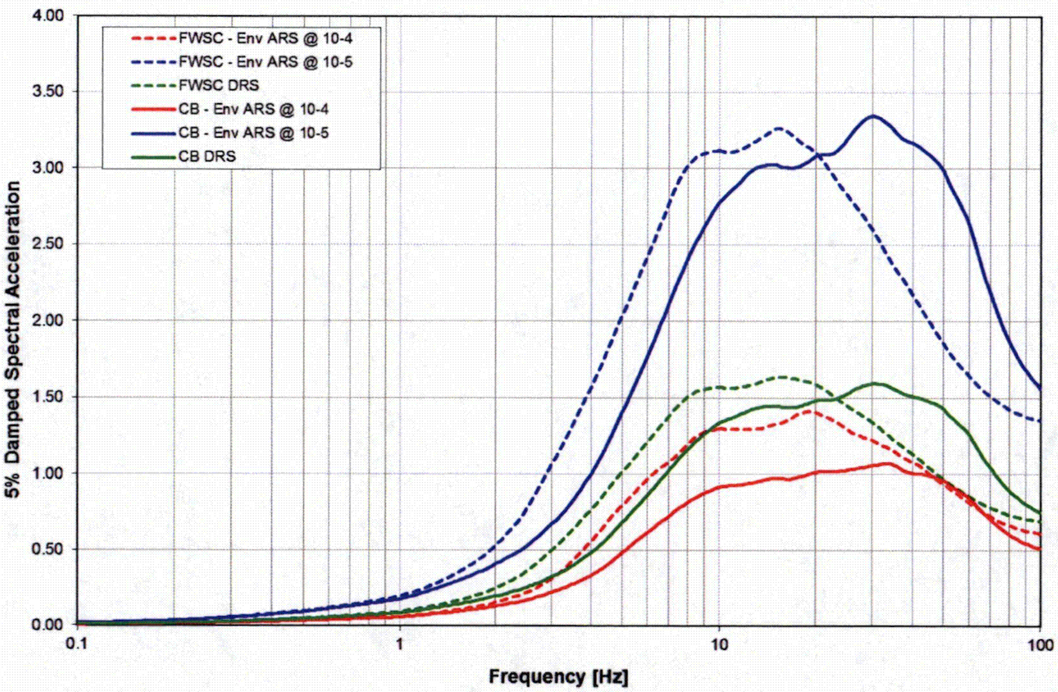

Figure 4. Overlay of FSAR Figures 2.5.2-301 and 2.5.2-306 (DRS for CB at Elevation 241 ft and FWSC at Elevation 282 ft)

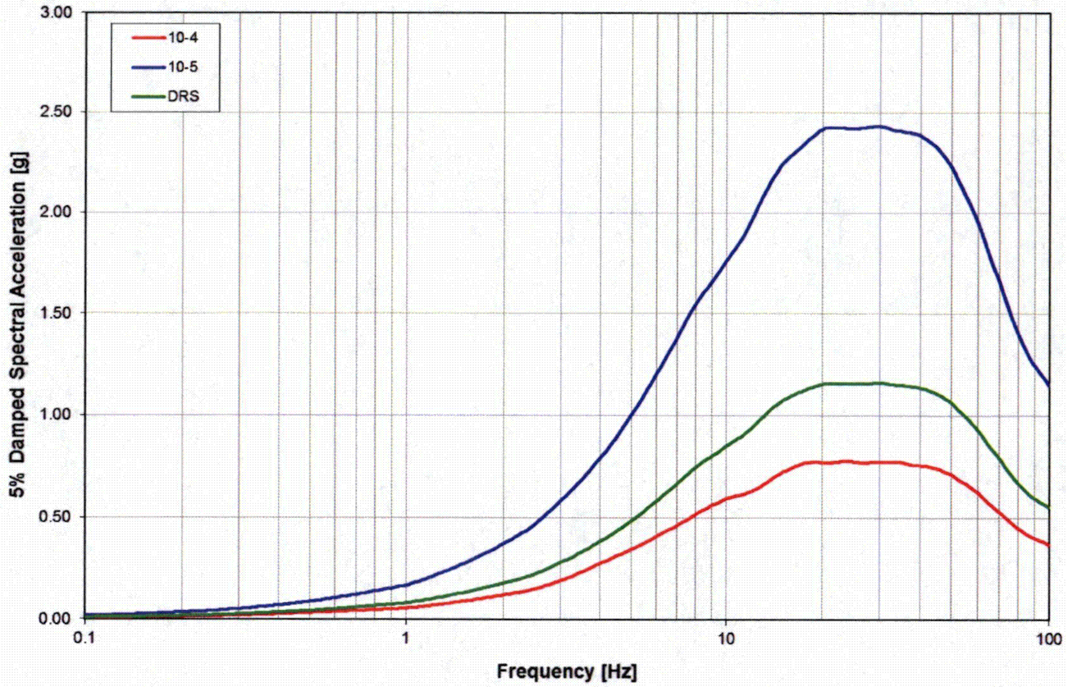

Figure 5. Mean Horizontal Outcrop UHRS at 10^{-4} and 10^{-5} Hazard Levels and Outcrop DRS for FWSC Soil Column at Elevation 220 ft (Average Elevation of Bottom of Concrete Fill)

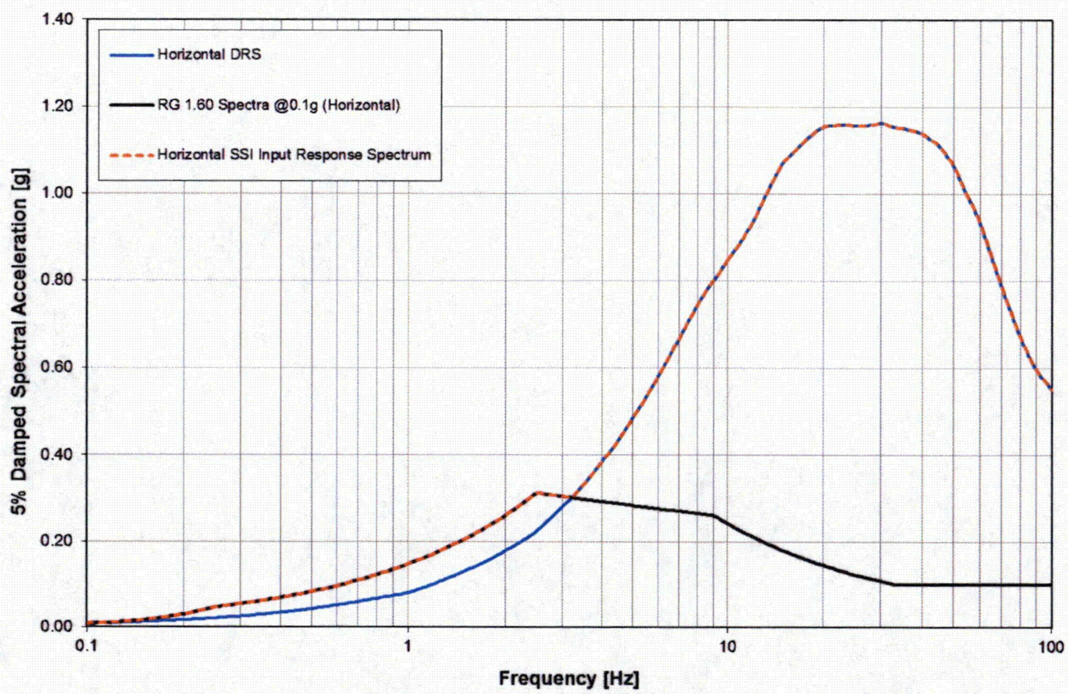

Figure 6. Development of 5% Damped Final Horizontal SSI Input Response Spectrum at Elevation 220 ft (Average Elevation of Bottom of Concrete Fill) for FWSC

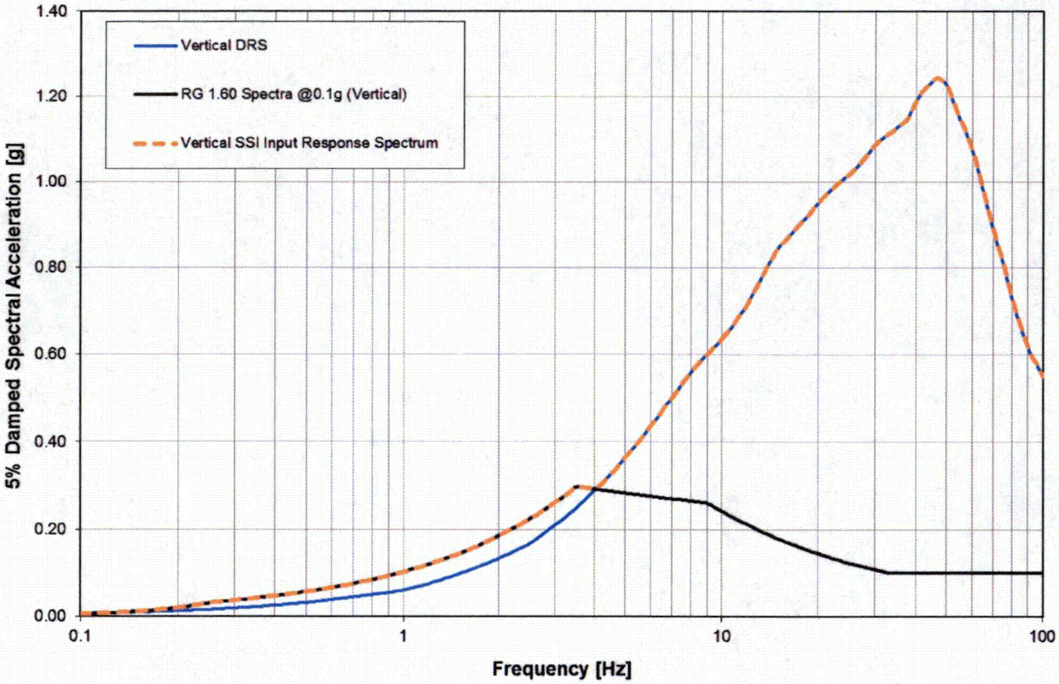

Figure 7. Development of 5% Damped Final Vertical SSI Input Response Spectrum at Elevation 220 ft (Average Elevation of Bottom of Concrete Fill) for FWSC

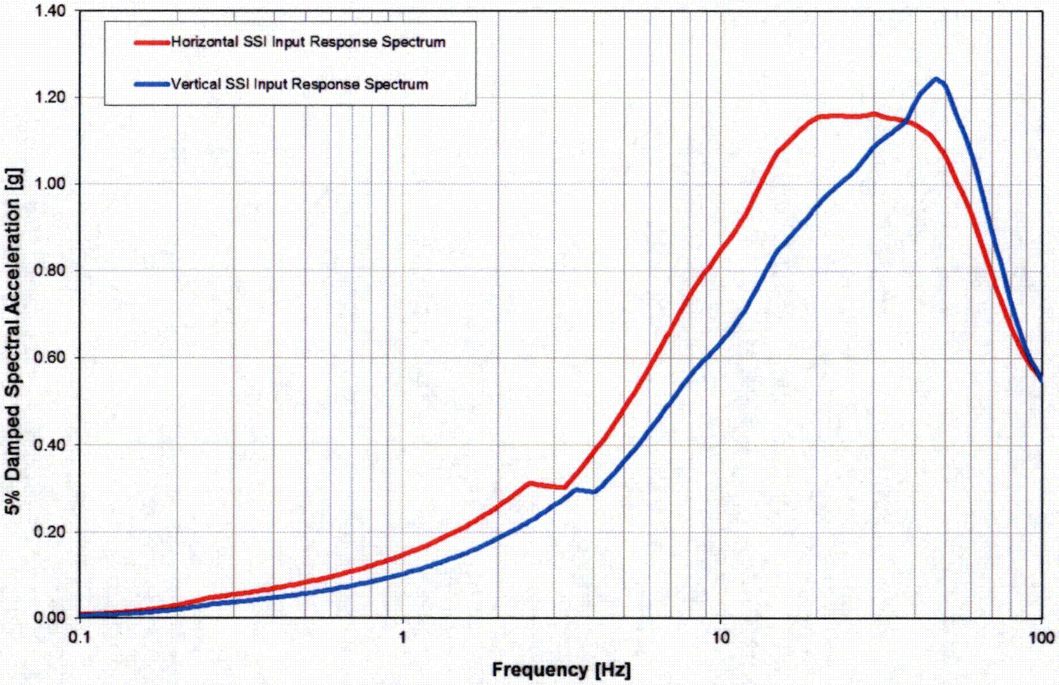

Figure 8. 5% Damped Final SSI Input Response Spectra at Elevation 220 ft (Average Elevation of Bottom of Concrete Fill) for FWSC

ENCLOSURE 3

Revised Response to NRC RAI Letter 123

RAI 7536 Question 03.07.02-10

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7536 (RAI Letter 123)

SRP SECTION: 3.7.2 - Seismic System Analysis

QUESTIONS for Seismic and Structural Branch

DATE OF RAI ISSUE: 06/05/2014

QUESTION NO.: 03.07.02-10

FSAR 3.7.2.4.1 indicates that the SASSI2010 computer program was used to perform the site-specific seismic SSI analysis for the NA3 application. However, SASSI2010 differs from the SASSI2000 program used in the SSI analyses documented in the ESBWR DCD. As a result, it is important to ensure that in demonstrating the ESBWR DCD to be adequate for the NA3 site, the use of the SASSI2010 computer code is acceptable for performing the seismic SSI analysis for the NA3 application. Therefore, the applicant is requested to provide the following information.

(a) Identify the use of the SASSI2010 computer program as a departure (NAPS DEP 3.7-1) to DCD Section 3.7.2, Table 3.7-3, "Summary of Methods of Seismic Analysis for Primary Building Structures," which only makes reference to SASSI2000, or explain why it was not identified as a departure.

(b) Describe how the SASSI2010 program was verified and validated for the NA3 application and for the SSI analyses with model passing frequencies of up to 50 Hz.

(c) Describe what method in SASSI2010 was utilized in the site-specific SSI analyses documented in FSAR 3.7.2.

(d) Include the above information in the relevant sections of the FSAR as appropriate.

Dominion Response

This response revises and supersedes the response submitted in NA3-14-030, dated July 3, 2014 (ADAMS Accession No. ML14202A385), to address information discussed with the NRC in a public meeting held April 15, 2015. It also incorporates related information provided to the NRC in the North Anna Unit 3 Seismic Closure Plan (SCP) (ML14297A199). In addition, on February 24, 2015, the NRC issued RAI 154-7810 Question 03.07.02-26 (ML15055A085). RAI 03.07.02-26 refers, in part, to Item (b) of RAI 03.07.02-10. A response to RAI 03.07.02-26 is submitted separately.

Finally, this response provides information regarding the use of ACS SASSI for sensitivity analyses of the Reactor Building/Fuel Building (RB/FB).

(a) The COLA will be revised to identify the use of the SASSI2010 computer program as a departure.

DCD Table 3.7-3 is a table of the methods used in performing the standard design seismic analyses for the various site conditions and remains applicable for the standard design and analyses of the Seismic Category I structures. SASSI2000 is listed as a computer program used in the standard design seismic analyses. DCD Table 3.7-3 is not updated in the FSAR to reflect the Unit 3 site-specific analyses; rather, SASSI2010 is currently described in Section 3C.7.4 of the FSAR, with a designation of "NAPS CDI.".

SASSI2010 is a later version of SASSI2000 and is based on the same methodology with essentially the same numerical solution algorithm but with an enhanced numerical solver and the capacity for analysis of larger SSI models. Information regarding the use of SASSI2010 in the site-specific SSI analyses is added to FSAR Appendix 3A in the discussions regarding the analyses methods for each of the Seismic Category I structures (RB/FB, CB, and FWSC). With the additional cases and site-specific subgrade properties described in the SCP, the site-specific SSI analyses have expanded. On this basis, Dominion has determined that the designation of computer programs in Appendix 3C used to perform site-specific design and analysis of Seismic Category I structures will be changed from "NAPS CDI" to "NAPS DEP 3.7-1" and listed in Table 1.8-201, "Departures from the Referenced Certified Design." This change is reflected in the COLA markups submitted with this response. As described in the SCP, changes to Part 7, "Departures Report," will be submitted in December 2015, and these changes will include the addition of SASSI2010 as part of NAPS DEP 3.7-1.

(b) Shimizu Corporation performed the SASSI2010 verification and validation of the SASSI2010 program modules used in the Unit 3 SSI analyses with passing frequencies above 50 Hz. The verification and validation are

performed in accordance with the Shimizu Quality Assurance Program and are documented in a report submitted separately (Reference 1). The report describes the methodology used to perform the verification and validation; provides the acceptance criteria; lists the capabilities, options, and limitations that are verified and validated; and provides the details and results of the validation problems. Verification methods include comparison with classical solutions, analytical results or experimental test data; comparisons with results from other software; and comparisons of results of various analysis problems. Acceptance criteria include numerical accuracy, good numerical agreement, and expected behavior.

Additional details regarding the verification and validation process for SASSI2010 are provided in the response to RAI 03.07.02-26. The process confirms that the SASSI2010 computer program is adequate for 3D seismic response analyses of SSI systems at NA3 and for SSI analyses with model passing frequencies above 50 Hz.

The validation report (Reference 1) is submitted to the NRC separately. A description of the SASSI2010 verification and validation is included in FSAR Section 3C.7.4.2, which is being updated to include additional details on the validation process.

(c) The SASSI2010 Direct Method and the Modified Subtraction Method are used for the Unit 3 SSI analyses described in FSAR Section 3.7.2.4.

(d) FSAR Appendix 3A describes how SASSI2010 is used for Unit 3 SSI analyses. FSAR Appendix 3C, Section 3C.7.4, describes SASSI2010 as a computer program used for the site-specific SSI analysis of Seismic Category I structures.

In addition to SASSI2010, the ACS SASSI program is used for certain Unit 3 site-specific sensitivity analyses and will be added to FSAR Section 3C.7.6. The RB/FB SSI analysis report (Reference 2), Section 4.1, explains the use of the SASSI methodology computer codes SASSI2010 and ACS SASSI. All of the site-specific SSI analyses of the RB/FB are performed using the SASSI2010 computer program, with the exception of the sensitivity analyses of the fully embedded RB/FB models with reduced stiffness properties, described in Appendix B of Reference 2, which use both the SASSI2010 and ACS SASSI computer programs. FSAR Table 3A.15-201 will list the cases for the RB/FB SSI analyses.

The SASSI2010 and ACS SASSI computer programs use the identical SASSI methodology to provide the solution for the seismic response of the structure-subgrade interaction system based on the frequency domain complex response method. The verification study presented in Appendix I of Reference 2 demonstrates that the two programs provide virtually identical numerical results for the SSI response of the RB/FB at the NA3 site. ACS SASSI will be added to

Appendix 3C as shown on the COLA markups submitted with this response and designated as a departure following the same approach described in Item (a) above for the SASSI2010 computer program.

References 1 and 2 are submitted separately from this RAI response and provide details of the validation of SASSI2010 for use in the site-specific SSI analyses and of the Unit 3 site-specific RB/FB SSI analyses, respectively. The SSI analyses information in FSAR Section 3.7.2.4 will be revised and new sections will be added to Appendix 3A to describe the updated SSI analyses.

References

1. SER-DMN-020, "Validation Summary Report for SASSI 2010 and Appendix with Validation Problems for RAI 03.07.02-10 / RAI 03.07.02-26 Response"

2. WG3-U71-ERD-S-0001, "Reactor /Fuel Building Complex Seismic Analysis Report"

Reference 1 are being submitted by Dominion letter Serial No. NA3-15-019. Reference 2 was submitted by Dominion letter Serial No. NA3-15-009, dated May 29, 2015.

Proposed COLA Revision

The changes to FSAR Appendices 3A and 3C are included in the FSAR markups submitted with this revised RAI response. The changes to COLA Part 7, Departures Report, will be submitted in December 2015.

ENCLOSURE 4

Revised Response to NRC RAI Letter No. 123

RAI No. 7536, Question 03.07.02-13

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7536 (RAI Letter 123)

SRP SECTION: 3.7.2 - Seismic System Analysis

QUESTIONS for Seismic and Structural Branch SEB2

DATE OF RAI ISSUE: 06/05/2014

QUESTION NO.: 03.07.02-13

FSAR 3.7.2.4.1.4 provides a description of the models used for the site-specific SSI analyses of the RB/FB, CB, and FWSC. The description does not provide sufficient details of the structural and soil/rock models used as discussed below. This information is needed to ensure the adequacy of the site-specific SSI analyses documented in FSAR 3.7.2. Therefore, the applicant is requested to provide the following information related to the SSI models:

(a) The aspect ratios of the finite elements used in the model can affect the accuracy of the calculated results. Therefore, provide the maximum aspect ratios of the plate and brick finite elements used to model the basemat, below-grade exterior walls, and excavated volume mesh of the embedded structures (including the concrete fill, which is considered part of the structural model). Confirm that the SASSI2010 program has been verified and validated for the range of aspect ratios used in the SSI models.

(b) The use of very high Poisson's ratios can lead to inaccuracies in the results obtained using the SASSI code. Therefore, provide the maximum value of Poisson's ratio considered in the site models used for the site-specific SSI analyses of the RB/FB, CB, and FWSC. Confirm that the SASSI2010 program has been verified and validated for the range of Poisson's ratios used in the SSI models.

(c) FSAR Table 3.7.2-201 provides model passing frequencies and analysis cut-off frequencies considered for the site-specific SSI analyses of the RB/FB, CB, and FWSC. Confirm that the model passing frequencies were estimated on the

basis of maximum horizontal dimensions (E-W and N-S) of the excavated volume mesh, in addition to maximum vertical dimensions of the soil/rock layers.

(d) FSAR Table 3.7.2-201 indicates that the SSI models of the FWSC coupled with the LB and BE subsurface profiles have passing frequencies of 19 Hz and 33 Hz respectively, which deviates from the 50 Hz minimum passing frequency stated by the guidance in ISG-01. Provide the technical basis for the deviation from the guidance in ISG-01.

(e) FSAR 3.7.2.4.1.4, pgs. 3-119 (bottom paragraph) and 120 (top paragraph), indicates that the site models used for the SSI analyses of the RB/FB, CB, and FWSC consist of 13, 17, and 22 layers respectively. This implies that shear and compression wave velocities, unit weights, and damping ratios were adjusted from the original strain iterated profiles documented in FSAR 3.7.1. Provide a graphical comparison between the adjusted profiles used in the SSI analysis, and the corresponding strain iterated profiles documented in FSAR 3.7.1, and discuss potential impact on the results of any differences between the profiles.

(f) FSAR 3.7.2.4.1.4 indicates that the total depth of the site soil/rock models used for SSI analyses of RB/FB, CB and FWSC are approximately 96 m, 104 m and 116 m, respectively, which are on the order of two times the footprint dimension of the corresponding structures. Since computed seismic responses may be sensitive to the location of the half-space interface, explain whether sensitivity studies were performed to determine if the selected depths are appropriate, or provide acceptable technical justification for the depths selected.

Dominion Response

This response addresses RAI questions (a) through (f) and describes the revised site-specific soil-structure interaction (SSI) analyses models, including the frequencies of analysis (cut-off frequencies and model passing frequencies), partially embedded cases, fully embedded cases, and the strain compatible subgrade properties. As explained in the Seismic Closure Plan (SCP) dated October 22, 2014 (ADAMS Accession Number ML14297A199), a summary of the results will be included in the FSAR.

The methodologies, models, and results obtained from the revised site-specific SSI analysis cases will be described in FSAR Appendix 3A (which replaces subsections of FSAR Section 3.7.2) and are provided in the seismic analyses reports (References 1, 2, and 3), which were submitted separately.

Validation and verification of the computer program SASSI2010, which is used for the seismic response analysis of structures considering SSI effects, is discussed in the revised response to NRC RAI 03.07.02-10 and in the response to NRC RAI 03.07.02-26, which are included in this submittal. The validation and

verification is also provided in "Validation Summary Report for SASSI 2010 and Appendix with Validation Problems for RAI 03.07.02-10 / RAI 03.07.02-26 Response" (Reference 4), which is submitted separately.

In addition to SASSI2010, the ACS SASSI computer code is used for sensitivity analyses. As explained in the Reactor Building/Fuel Building (RB/FB) seismic analysis report (Reference 1), the site-specific SSI analyses of the RB/FB are performed using the SASSI2010 computer program with exception of the sensitivity analyses of the fully embedded RB/FB models with reduced stiffness properties described in Appendix B of RB/FB report. These sensitivity analyses used both SASSI2010 and the ACS SASSI computer program. The SASSI2010 and ACS SASSI computer programs use exactly the same SASSI methodology to provide the solution for the seismic response of the structure-subgrade interaction system based on the frequency domain complex response method. The verification study presented in Appendix I of the RB/FB report (Reference 1) demonstrates that the two programs provide virtually identical numerical results for the SSI response of RB/FB at the NA3 site.

(a) The foundation basemat and below-grade exterior walls for the RB/FB, Control Building (CB), and Firewater Service Complex (FWSC) are modeled using 3-D thin shell finite elements, as required. The concrete fill surrounding and supporting the RB/FB, CB, and FWSC, as well as the excavated volume of the embedded structures, are modeled using 3-D solid brick finite elements, as required. A set of SSI analyses are performed of the RB/FB, CB, and FWSC for both partial and full column soil profiles. The models used for these analyses have aspect ratios less than 1:4 for the regular uniform elements.

    As explained in the SCP, the site-specific seismic demands for the RB/FB and CB are developed as the envelope of responses obtained from the SSI analyses of partially embedded and fully embedded models associated with 'partial column' and 'full column' subgrade profiles representing dynamic properties of far-field in-situ subgrade materials and used in the structural evaluations. In the partially embedded model, the excavated volume is modeled using a uniform and regular mesh. However, the top layers of soft soil and structural fill added to the fully embedded model between the Zone III rock and the grade level require a refined mesh in order to capture sufficient input motion energy. The fully embedded model also requires a coarser mesh of the rock and concrete fill below the Zone III rock level to ensure the overall model size does not exceed the program capabilities and limitations. Therefore, in the transitional layers below the rock surface elevation, the fully embedded models use non-uniform mesh with irregular triangular shell elements and prismatic, tetrahedral, and pyramidal solid elements.

As shown in the respective SSI analyses reports (References 1, 2, and 3), the maximum aspect ratios of the regular 3-D thin shell and solid brick finite elements in the dynamic models used for the RB/FB, CB, and FWSC SSI analyses are 1:3.5, 1:1.9 and 1:2.9, respectively.

Accuracy of the SASSI2010 program has been verified and validated for models with a maximum aspect ratio of 1:4 for both the 3-D thin shell and 3-D solid brick finite elements. The accuracy of using non-uniform irregular elements is demonstrated in Appendix C of the RB/FB and CB SSI analyses reports (References 1 and 2) by the results of comparative studies.

(b) The maximum value of soil Poisson's ratio considered in the site models used for the site-specific SSI analyses of the RB/FB, CB, and FWSC and presented in FSAR Appendix 3A is 0.48. Accuracy of the SASSI2010 program has been verified and validated for site models with a soil Poisson's ratio up to 0.48.

(c) Values for the passing frequencies that were previously presented in FSAR Table 3.7.2-201 for the RB/FB, CB and FWSC models have been revised and are calculated on the basis of both the maximum horizontal and vertical dimensions of the finite elements in the SASSI2010 structural (HOUSE) models. The maximum dimension of excavated volume mesh and the mesh of near-field elements representing the properties of the backfill materials determine the passing frequencies of the models used for the revised site-specific SSI analyses that are presented in FSAR Appendix 3A, which also includes the passing frequencies of the models used for the RB/FB and CB SSI analyses for the full column soil profiles. The minimum values for the passing frequencies are obtained for the models used for the analyses of the full column profiles. These minimum values are determined by the size of the near-field elements modeling the structural fill material, placed around the RB/FB and CB, which has lower stiffness than the stiffness of the excavated in-situ soil.

(d) In the revised site-specific analyses, the mesh size of the excavated volume elements and the near-field soil solid elements of the backfill surrounding the RB/FB, CB, and FWSC is set to ensure that, per SASSI2010 criteria, the maximum element size in all three directions is not more than one-fifth of the shear wave length of the excavated soil and backfill at the highest (cut-off) frequency of analysis in order to capture sufficient energy content of the Unit 3 high frequency input motion. SSI analyses of upper bound (UB) subgrade profiles that bound responses at high frequencies are performed using 70 Hz cut-off frequency to capture 99% of the input motion energy. The analyses of lower bound (LB) and best estimate (BE) profiles capture at least 81% and 92% of the input motion energy, respectively. The passing and cut-off frequencies for the RB/FB, CB, and FWSC site-specific SSI analyses are

documented in the respective SSI analyses reports listed above. For each analysis, the model maximum passing frequencies for all subsurface profiles are no smaller than the cut-off frequency of analysis. Tables are provided in Section 4.2 of the technical reports documenting the revised SSI analyses of the RB/FB, CB, and FWSC (References 1, 2, and 3) that provide, for each analysis case performed, the passing frequency of the models, the cut-off frequencies of the analysis, and the percentage of energy of input motion captured by the analysis.

As discussed in Section 4.2 of the technical reports, the envelope of responses from all analysis cases ensures that site-specific in-structure response spectra (ISRS) are adequate for frequencies up to 50 Hz as required by NRC interim staff guidance DC/COL-ISG-01, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications" (ADAMS Accession Number ML081400293).

(e) In the site models used for the SSI analyses of RB/FB for both partial and full column profiles, and CB for partial column profiles, the shear and compression wave velocities, unit weights, and damping ratios are adjusted, as needed, from the original strain-iterated soil profiles documented in FSAR Section 3.7.1 so that the site models used for site-specific SSI analyses can meet the passing frequency requirements. Section 4.3 in the technical reports documenting the SSI analyses of the RB/FB and CB (References 1 and 2), provides the equations used to adjust the shear and compression wave velocities using the equivalent wave travel time procedure. The unit weight and damping ratios of the adjusted layers are determined as weighted averages with respect to the layer thickness.

In the site models used for the SSI analyses of the CB for full column profiles, and the FWSC for all soil profiles, the shear and compression wave velocities, unit weights, and damping ratios are not adjusted from the original strain-iterated soil profiles documented in FSAR 3.7.1. Instead, the layering of the profiles of strain compatible properties presented in FSAR 3.7.1 that were developed from the results of the site response analysis is used and some layers are either combined or divided so the site models used for site-specific SSI analyses can meet the passing frequency requirements.

Graphical comparisons between the adjusted soil profiles used in the SSI analyses and the corresponding strain-iterated soil profiles from the site response analyses documented in FSAR Section 3.7.1 are provided in the figures of Section 4.3 of the respective SSI analyses reports (References 1, 2, and 3). The comparisons show that the profiles of subgrade dynamic properties match the profiles obtained from the site response analyses.

(f) Results of a sensitivity study performed on the RB/FB model for the BE partial column subgrade profile demonstrate that the selected total depths of the site models used for the site-specific SSI analyses that were previously presented in FSAR Section 3.7.2 do not affect the accuracy of the SASSI2010 results.

The sensitivity study was performed for the RB/FB, which has the largest footprint dimensions among all of the Seismic Category I buildings, and, as such, would be the most sensitive to model lower boundary effects.

As documented in Appendix H of the Unit 3 site-specific RB/FB SSI analysis report (Reference 1), the effects of the model lower boundary are evaluated by comparing transfer function results and 5% damped ISRS results obtained from the analyses of the RB/FB models that differ only in the location of the lower boundary. Comparison of transfer function results are made for the responses of the RB/FB at lower elevations which will be most affected by the different lower boundary locations. These comparisons show that the two models yielded virtually identical results, thus demonstrating that the lower boundary locations of the models used for the site-specific SSI analyses are adequate and do not affect the accuracy of the calculated SSI responses.

References

1. WG3-U71-ERD-S-0001, Reactor/Fuel Building Complex Seismic Analysis Report.

2. WG3-U73-ERD-S-0001, Control Building Seismic Analysis Report.

3. WG3-U63-ERD-S-0001, Firewater Service Complex Seismic Analysis Report.

4. SER-DMN-020, Validation Summary Report for SASSI 2010 and Appendix with Validation Problems for RAI 03.07.02-10 / RAI 03.07.02-26 Response.

NOTE: Reference 1 was submitted by Dominion letter Serial No. NA3-15-009, dated May 29, 2015. References 2 and 3 were submitted by Dominion letter Serial No. NA3-15-014, dated June 30, 2015. Reference 4 are being submitted by Dominion letter Serial No. NA3-15-019.

Proposed COLA Revision

The changes to FSAR Section 3.7.2 and Appendix 3A are included in the COLA markup submitted with this RAI response.

ENCLOSURE 5

Revised Response to NRC RAI Letter No. 123

RAI No. 7536, Question 03.07.02-14

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7536 (RAI Letter 123)

SRP SECTION: 3.7.2 - Seismic System Analysis

QUESTIONS for Structural Engineering Branch SEB2

DATE OF RAI ISSUE: 06/05/2014

Question No.: 03.07.02-14

FSAR 3.7.2.4.1.4 indicates that cracked concrete stiffness and SSE damping properties were assigned to the various lumped mass stick models used in the site-specific SSI analyses of the RB/FB, CB, and FWSC, on the basis of SASSI stress results for in-plane shear and out-of-plane bending moments. FSAR Tables 3.7.2-202 through 204 indicate that: (i) the RB/FB was modeled as partially cracked (cracked elements are identified in FSAR Figure 3.7.2-210); (ii) the CB was modeled as completely cracked; and (iii) the FWSC was modeled as completely uncracked.

The selection of cracked or uncracked concrete stiffness and damping properties can affect the adequacy of the site-specific SSI analyses documented in FSAR 3.7.2. In addition, the applicant's approach deviates from ESBWR DCD Appendix 3A, where cracked and uncracked cases were considered and enveloped to determine the enveloped seismic loads and the In-Structure Response Spectra (ISRS). Therefore, the applicant is requested to provide the following information related to the SSI modeling of concrete cracking.

(a) Explain the magnitude of the reduction in in-plane shear stiffness assigned to concrete structural elements where the average in-plane shear stress exceeds $3 \times \sqrt{(f'c)}$. Provide the technical basis for this cracking threshold.

(b) Explain the magnitude of the reduction in out-of-plane bending stiffness assigned to concrete structural elements where the bending moments exceeds the cracking moment criterion specified in ACI 349-01, Section 9.5.2.3.

(c) Provide the technical justification for determining whether concrete structural elements are cracked or uncracked only on the basis of the SSI analysis results for the BE subsurface profile case, as indicated in FSAR 3.7.2.4.1.4 (pg. 3-120). Explain how the seismic response obtained by this approach compares to the seismic response obtained by assuming (i) a cracked structure with LB subsurface profile, and (ii) an uncracked structure with UB subsurface profile.

(d) Provide a detailed explanation of the methodology used to identify which concrete structural elements are cracked and which are not, and how the reduced stiffness properties are implemented in the structural model (e.g., reduced factors for each stiffness component, applied to what modeling parameter, done on an element by element basis, etc.).

(e) Describe how SSE/OBE damping was assigned to all structural elements that were determined to be cracked and uncracked based on the seismic stress level.

(f) Because the site-specific seismic demand exceeds the corresponding DCD seismic demand, there is a potential for increased out-of- plane cracking effect on the floor slabs and walls (when subjected to site-specific ground motion), thereby further decreasing their out of plane stiffness and changing the damping characteristics. Therefore, confirm that the frequency ranges and the damping values of the oscillators selected for the DCD model are still adequate to capture the out-of-plane seismic response of the walls and slabs for NA 3 site-specific ground motion. Also confirm that if any other slabs and walls which are considered to be rigid in the out of plane direction in the DCD analysis would require modeling as SDOF oscillators in the stick model.

(g) Explain whether the plate finite elements used to model the basemat and below-grade exterior walls of the RB/FB, CB, and FWSC were assigned uncracked or cracked properties along with their justification for use.

(h) The diaphragm floor and the vent wall inside containment are constructed from steel plates filled with concrete. For the ESBWR design certification, these structures were modeled and evaluated separately for three cases having 0 percent, 50 percent, and 100 percent concrete stiffness contribution to the steel plates, while the full mass contribution of the concrete fill was always included. All three cases were considered to develop the floor response spectra and to design the structural members. Explain whether the same approach is used for the NA3 analysis and design or justify any deviation taken.

(i) Provide in FSAR Section 3.7.1.2 a description of the stress criteria that determines the acceptability of using SSE damping values in conjunction with cracked concrete stiffness properties for reinforced concrete members, as described under FSAR Section 3.7.2.4.1.4.

Dominion Response

The questions in this RAI are based on the December 2013 Unit 3 (NA3) COLA submittal, which assigned cracked concrete stiffness and safe shutdown earthquake (SSE) damping properties to the lumped mass stick models that were used to perform the site-specific soil-structure interaction (SSI) analyses of the Reactor Building/Fuel Building (RB/FB), Control Building (CB), and Firewater Service Complex (FWSC). As described in the Seismic Closure Plan (SCP), which was submitted to the NRC by letter NA3-14-043, dated October 22, 2014 (ML14297A199), Dominion is revising the approach used to perform the SSI analyses to be more consistent with the approach described in the ESBWR Design Control Document (DCD). The responses to the questions in this RAI are based on this new approach, which is summarized below.

This response describes the dynamic models, which use an upper bound (UB) (uncracked concrete) stiffness to obtain conservative responses for the NA3 rock site with high frequency motion. As described in the SCP, additional sensitivity analyses are performed on models with reduced stiffness to address the effects of stiffness variation on the seismic response of ESBWR Seismic Category I structures at the NA3 site. A response to each subpart is provided below. A summary of the results is included in technical reports (References 1, 2, and 3), which describe the site-specific SSI analyses of the ESBWR Seismic Category I structures, and in FSAR Appendix 3A markups that are included in a separate enclosure of this submittal. Reference 4 describes additional oscillators for the fully cracked models. Also, as described in the SCP, a submittal scheduled for December 2015 will include markups to the NA3 COLA Part 7, "Departures Report."

As described in the SCP, a conservative approach is taken to address the concrete stiffness and structural damping properties used in the site-specific seismic analyses for the NA3 rock site with high frequency design ground motion. The dynamic models are assigned UB stiffness properties, which are associated with fully uncracked concrete and full (100 percent) stiffness contribution of concrete infill to the stiffness of concrete fill steel structures in the RB/FB. The use of models representing UB stiffness properties of the structures shifts the responses of the RB/FB, CB and FWSC to higher frequencies, where the energy content of the NA3 site-specific design ground motion is higher.

Sensitivity studies are performed for the RB/FB, CB, and FWSC to evaluate the effects of concrete cracking on the site-specific SSI responses of these

structures, following a methodology that is consistent with the methodology used in the standard design. These sensitivity analyses are based on the results of site-specific SSI analyses performed on dynamic models representing the lower bound stiffness of the RB/FB, CB, and FWSC structures under fully cracked concrete conditions. Safe Shutdown Earthquake (SSE) damping values are assigned to these models in conjunction with the reduced (cracked concrete) stiffness properties to represent the higher dissipation of energy in the structures when subjected to high stresses corresponding to the fully cracked concrete condition. In the models with lower bound stiffness, the stiffness properties of all concrete structural members are reduced in accordance with the guidelines provided in ASCE 43-05 (Reference 5). The effects of concrete cracking on the site-specific seismic responses and design of the RB/FB, CB and FWSC are evaluated by comparing the responses obtained from the licensing basis analyses of models with full (uncracked concrete) stiffness properties and sensitivity analyses of models with lower bound (fully cracked concrete) stiffness properties.

The site-specific sensitivity study performed for the RB/FB also addresses the effects of stiffness variation of the Vent Wall (VW) and Diaphragm Floor (D/F) of the ESBWR Containment Internal Structures. Consistent with the methodology used in the standard design, the site-specific sensitivity studies on the effects of stiffness variation on the seismic response of RB/FB separately consider two additional levels (0 percent and 50 percent) of the concrete infill stiffness contribution to the stiffness of these concrete filled steel structures. Sensitivity SSI analyses are performed on two models representing dynamic properties of fully cracked reinforced members and 50 percent and 0 percent of the concrete infill stiffness contribution to the stiffness of the VW and D/F concrete-filled steel structures. The comparison of responses obtained from the sensitivity analyses of these two models with reduced stiffness properties and the analyses of the licensing basis model with upper bound stiffness properties are used to demonstrate that the RB/FB site-specific design bases analyses results envelope the effects of structural stiffness variations.

The site-specific SSI analyses use three-dimensional lumped mass-stick models (LMSMs) to represent the dynamic properties of the RB/FB, CB and FWSC structures and single degree of freedom (SDOF) oscillators to capture the local out-of-plane vibrations of flexible slabs and walls. The configuration and the stiffness properties of the structural models used for the site-specific SSI analyses are identical to the models used for the standard design seismic response analyses in the standard design, with the following exceptions:

- Upper bound stiffness is assigned to concrete and steel internal structures in the RB/FB dynamic model reflecting a 100 percent stiffness contribution of concrete inside the steel plates

- Outriggers installed to facilitate calculation of in-structure response spectra (ISRS) and displacements at floor edges

Details of the dynamic model properties, methodology and results for the licensing basis and sensitivity studies are provided in the following reports, which are submitted separately:

- "Reactor/Fuel Building Complex Seismic Analysis Report" (Reference 1)
- "Control Building Seismic Analysis Report" (Reference 2)
- "Firewater Service Complex Seismic Analysis Report" (Reference 3)

Results of the sensitivity analyses detailed in the technical reports show that the site-specific seismic design basis that is based on the models with upper bound stiffness properties envelopes the effects of the structural stiffness variations, with limited small and local exceedances, which are addressed in the site-specific design bases evaluations, as described in Appendices B of References 1, 2, and 3. In addition, FSAR Section 3A.17.9 describes the effects of concrete cracking for the RB/FB, CB, and FWSC.

The responses below address the questions in Sub-parts (a) through (i) of this RAI. The changes to the analyses that are described below will be incorporated in FSAR Section 3.7.1.2 and Appendix 3A, as shown on the COLA markups included with this RAI response.

(a) Explain the magnitude of the reduction in in-plane shear stiffness assigned to concrete structural elements where the average in-plane shear stress exceeds 3 x $\sqrt{(f'c)}$. Provide the technical basis for this cracking threshold.

In the dynamic models used for the site-specific SSI analyses, all concrete structural members are assigned full (uncracked concrete) stiffness properties with no reduction of the in-plane shear stiffness. Therefore, the NA3 site-specific seismic design of the RB/FB, CB and FWSC is based on SSI responses of concrete structural members with full (uncracked concrete) stiffness regardless of the level of shear stresses the structures may experience during the postulated design ground motion. This results in conservative responses for the RB/FB, CB and FWSC at the NA3 site.

To evaluate the effects of structural stiffness variation on the site-specific seismic responses and design of ESBWR Seismic Category I structures, site-specific sensitivity analyses are performed on models with lower bound stiffness properties representing the dynamic properties of the RB/FB, CB and FWSC structures under fully cracked concrete conditions. The shear stiffness of all reinforced concrete members in these models is reduced by 50 percent in accordance with the recommendations of ASCE 43-05 (Reference 5). The results

of these sensitivity analyses are included in the referenced reports and summarized in FSAR Section 3A.17.9 of the COLA markups submitted with this response.

(b) Explain the magnitude of the reduction in out-of-plane bending stiffness assigned to concrete structural elements where the bending moments exceeds the cracking moment criterion specified in ACI 349-01, Section 9.5.2.3.

As discussed in the response to Sub-part (a), all of the concrete structural members in the dynamic models used for the site-specific SSI analyses of the RB/FB, CB and FWSC are assigned full (uncracked concrete) stiffness properties. Therefore, the NA3 site-specific seismic design of the RB/FB, CB and FWSC is based on SSI responses of structures with full (uncracked concrete) stiffness properties with no reductions in out-of-plane bending stiffness assigned to the concrete structural elements, regardless of the level of bending stresses that the structures may experience during the postulated design ground motion.

The sensitivity analyses performed to evaluate the effects of concrete cracking on the site-specific seismic responses and design of the RB/FB, CB and FWSC use models with lower bound structural stiffness properties, representing the fully cracked concrete condition. In accordance with ASCE 43-05 (Reference 5), the effects of concrete cracking on the out-of-plane bending stiffness of the reinforced concrete walls are captured in these models by reducing the flexural stiffness of all stick elements by 50 percent. The cracking of concrete also reduces the flexural stiffness of walls and slabs lowering their natural frequencies of local out-of-plane vibrations. In accordance with the recommendations of ASCE 43-05, the SDOF oscillators in the models with lower bound stiffness are adjusted as discussed in the response to Sub-part (f) to reflect the 50 percent reduction of the flexural stiffness of slabs and walls under fully cracked conditions.

(c) Provide the technical justification for determining whether concrete structural elements are cracked or uncracked only on the basis of the SSI analysis results for the BE subsurface profile case, as indicated in FSAR 3.7.2.4.1.4 (pg. 3-120). Explain how the seismic response obtained by this approach compares to the seismic response obtained by assuming (i) a cracked structure with LB subsurface profile, and (ii) an uncracked structure with UB subsurface profile.

As discussed in the response to Sub-parts (a) and (b), the NA3 site-specific seismic design of the RB/FB, CB and FWSC is based on SSI responses of structures with full (uncracked concrete) stiffness properties, regardless of the level of stresses the concrete structural elements may experience during the postulated design ground motion.

The NA3 site-specific sensitivity evaluations of structural stiffness variations on the responses of the RB/FB and CB, (described in Appendices B of References 1 and 2), are based on the results of sensitivity SSI analyses performed on models with reduced stiffness properties for all of the six subgrade profiles that were used for the licensing basis analyses of the RB/FB and CB dynamic models. The sensitivity SSI analyses are performed for LB, BE, and UB, full and partial column profiles, so that the site-specific evaluations completely address the possible effects of different embedment configurations and subgrade property variations on the responses of the RB/FB and CB structures under fully cracked concrete conditions.

The site-specific evaluations of effects of structural stiffness variations on the response of the FWSC, described in Appendix B of Reference 3, are based on the results of the sensitivity analyses of the FWSC model representing fully cracked concrete conditions. Four analysis cases of the FWSC reduced stiffness model are performed for the LB and UB subgrade profiles using the surface input motion at the bottom of the FWSC basemat and the deep input motion at the bottom of the concrete fill located at Elevation 282 ft and Elevation 220 ft NAVD 88, respectively. The consideration of the LB and UB subgrade profiles representing two bounding subgrade stiffness conditions captures the effect of subgrade dynamic property variations on the response of the FWSC structures under fully cracked concrete conditions.

(d) Provide a detailed explanation of the methodology used to identify which concrete structural elements are cracked and which are not, and how the reduced stiffness properties are implemented in the structural model (e.g., reduced factors for each stiffness component, applied to what modeling parameter, done on an element by element basis, etc.).

As discussed in the responses to Sub-parts (a) and (b), the NA3 site-specific seismic designs of the RB/FB, CB and FWSC are based on SSI responses of structures with full (uncracked concrete) stiffness properties regardless of the level of stresses that the concrete structural elements may experience during the postulated design ground motion.

The sensitivity analyses performed to evaluate the effects of concrete cracking on the site-specific seismic response and design of RB/FB, CB and FWSC use models with lower bound structural stiffness properties representing the fully cracked concrete condition, i.e. conditions where all of the concrete structural members are cracked with reduced stiffness. In these models, the effects of concrete cracking on the shear, flexural, and torsional stiffness of the reinforced concrete walls are captured by reducing the section properties for the shear areas, torsional moment of inertia, and flexural moments of inertia of the stick elements by 50 percent. In order to simulate full 100 percent axial stiffness of the

cracked walls as recommended by ASCE 43-05 (Reference 5), the axial areas of the stick members are the same as the areas of the stick members in the licensing basis models with upper bound stiffness properties.

(e) Describe how SSE/OBE damping was assigned to all structural elements that were determined to be cracked and uncracked based on the seismic stress level.

In accordance with the guidance in RG 1.61 Revision 1, and SRP 3.7.2, Revision 4, the RB/FB, CB and FWSC dynamic models used for developing site-specific ISRS are assigned full (uncracked concrete) stiffness properties and OBE structural damping. The use of lower OBE structural damping values ensures that the ISRS peaks envelope the condition when the stresses and the dissipation of energy in the structures are lower than those associated with the SSE damping values reflecting stresses close to the stress limits considered by the applicable structural design codes (Section C.1.2 of RG 1.61).

The development of site-specific seismic structural load demands, foundation uplift, and stability evaluations are based on responses obtained from models with upper bound (uncracked concrete) stiffness properties in conjunction with the following structural damping properties:

- OBE structural damping for RB/FB
- SSE structural damping for CB and FWSC

The use of OBE damping for development of the RB/FB structural load demands, foundation uplift, and stability evaluations is conservative because the use of lower damping values underestimates the dissipation of energy in the structures associated with the stress limits considered by the design codes. Per Section C.1.2 of RG 1.61, the use of SSE damping for the development of CB and FWSC structural loads is adequate because the stresses obtained from models with SSE damping will remain lower than the stress limits considered by the applicable structural design codes. The use of SSE damping for the foundation uplift and stability evaluations is adequate because these analyses generate foundation reaction forces and moments at the bottom of basemat that are consistent with the seismic structural load demands generated from UC_{SSE} model. In addition, the use of SSE damping for the foundation uplift and stability evaluations is adequate because these analyses also consider limiting conditions that are associated with the high dissipation of energy in the SSI dynamic system.

Sensitivity studies performed to evaluate the effects of concrete cracking on the site-specific SSI response and design of RB/FB, CB and FWSC are based on responses of models representing fully cracked concrete conditions when all of the concrete structural members are cracked with reduced stiffness. SSE damping values are assigned to these models in conjunction with the reduced

(cracked concrete) stiffness properties to represent the higher dissipation of energy in the structures when subjected to high stresses corresponding to the fully cracked concrete condition.

(f) Because the site-specific seismic demand exceeds the corresponding DCD seismic demand, there is a potential for increased out-of-plane cracking effect on the floor slabs and walls (when subjected to site-specific ground motion), thereby further decreasing their out of plane stiffness and changing the damping characteristics. Therefore, confirm that the frequency ranges and the damping values of the oscillators selected for the DCD model are still adequate to capture the out-of-plane seismic response of the walls and slabs for NA3 site-specific ground motion. Also confirm that if any other slabs and walls which are considered to be rigid in the out of plane direction in the DCD analysis would require modeling as SDOF oscillators in the stick model.

As discussed in the responses to Sub-parts (a) and (b), the NA3 site-specific seismic designs of the RB/FB, CB and FWSC are based on SSI responses of structures representing full stiffness (uncracked concrete) properties. The use of these models with upper bound stiffness properties provides conservative site-specific seismic design because it shifts the structural responses to higher frequencies where the energy content of the NA3 site-specific design ground motion is higher. The stiffness properties and configurations of the SDOF oscillators in the models used for the site-specific licensing basis analyses are identical to those of the standard design models and are adequate to capture the out-of-plane modes of vibration of slabs and walls up to 50 Hz under full (uncracked) stiffness conditions. As discussed in the response to Sub-part (e), OBE damping is assigned to the SDOF oscillators in the models used for the calculations of the site-specific design bases ISRS.

The cracking of the concrete reduces the flexural stiffness of the walls and slabs, thus lowering the natural frequencies of out-of-plane vibrations. As discussed in the response to Sub-part (b), ASCE 43-05 (Reference 5) recommends a 50 percent reduction of the flexural stiffness of the slabs and walls under fully cracked conditions, resulting in the reduction of the natural frequencies of the out-of-plane vibrations of the slabs and walls by $\sqrt{2}$. Therefore, in order to address the effects of concrete cracking on the local out-of-plane responses of slabs and walls, sensitivity analyses are performed on models with:

- 50 percent reduction applied to the stiffness of all existing SDOF oscillators in the licensing basis models with full (uncracked concrete) properties, and
- Additional SDOF oscillators added to capture the modes of out-of-plane vibrations of cracked slabs and walls with frequencies ranging from $50/\sqrt{2} = 35$ Hz to 50 Hz

As discussed in the response to Sub-part (e), SSE damping is assigned to the SDOF oscillators in the models used for the sensitivity analyses.

Development of these additional SDOF oscillators representing the out-of-plane vibrations of flexible slabs and walls under fully cracked conditions is presented in Technical Report SER-DMN-014 (Reference 4). The properties of the additional oscillators are developed based on the results of eigenvalue analyses, which follow the methodology used in the standard design for the development of oscillators for out-of-plane vibrations of slabs and walls under uncracked concrete conditions. The floor lumped mass inertia properties are adjusted to account for the mass of the additional oscillators as described in Reference 4. FSAR Sections 3A.16 and 3A.17.9 indicate that additional oscillators are used in the fully cracked models.

(g) Explain whether the plate finite elements used to model the basemat and below-grade exterior walls of the RB/FB, CB, and FWSC were assigned uncracked or cracked properties along with their justification for use.

As discussed in the response to Sub-parts (a) and (b), the NA3 site-specific seismic designs of the RB/FB, CB and FWSC are based on the SSI responses of structures representing full (uncracked concrete) stiffness properties. The shell elements representing the basemat and below-grade exterior walls in the RB/FB, CB, and FWSC licensing basis models for the site-specific SSI analyses are assigned upper bound properties reflecting full (uncracked concrete) stiffness properties.

For the purposes of evaluating the effects of structural stiffness variation on the SSI response and design of NA3 Seismic Category I structures, the overall stiffness of the shell elements modeling the below grade exterior walls and basemat is reduced by 50 percent, which results in reduced shear, flexural and axial stiffness of these walls. Because the contribution of the exterior walls to the axial stiffness of the below grade portion of the RB/FB is small, this deviation from the ASCE 43-05 (Reference 5) recommendations has a negligible effect on the vertical response of the RB/FB reinforced concrete structures under fully cracked conditions.

Because the contribution of the exterior walls on the overall axial stiffness of the CB is significant, the reduction of the shell elements' in-plane stiffness affects the overall axial stiffness of the below grade portion of the CB model representing the fully cracked concrete conditions. The axial area of the stick element that models the axial stiffness of the CB interior walls below plant grade elevation is increased to account for the reduction of the shell elements' stiffness. This modeling approach ensures that the CB model used for the evaluation of concrete cracking effects has an axial stiffness that is 100 percent of the full (uncracked concrete) stiffness as recommended by ASCE 43-05 (Reference 5).

The plate finite elements used to model the basemat of the FWSC were assigned cracked properties with an overall stiffness reduction of the shell elements by 50 percent, which results in reduced shear, flexural and axial stiffness. The FWSC is a surface mounted structure with no below-grade exterior walls.

(h) The diaphragm floor and the vent wall inside containment are constructed from steel plates filled with concrete. For the ESBWR design certification, these structures were modeled and evaluated separately for three cases having 0 percent, 50 percent, and 100 percent concrete stiffness contribution to the steel plates, while the full mass contribution of the concrete fill was always included. All three cases were considered to develop the floor response spectra and to design the structural members. Explain whether the same approach is used for the NA3 analysis and design or justify any deviation taken.

The site-specific analyses use an approach for modeling the dynamic properties of the RB/FB structures that is adequate for the NA3 site conditions and consistent with the approach used for the standard design.

The NA3 site-specific seismic design basis of the RB/FB is based on the responses obtained from the site-specific SSI analyses of a model representing the upper bound stiffness properties of the RB/FB structures. The model represents full (uncracked concrete) stiffness of the reinforced concrete members and 100% contribution of the concrete fill to the stiffness of the concrete filled steel members of the RB internal structures. The model with the upper bound stiffness properties provides a conservative site-specific seismic design because it shifts the structural responses of the RB/FB structures to higher frequencies, where the energy content of the NA3 site-specific design ground motion is higher.

The sensitivity evaluation is presented in Appendix B of Reference 1, which addresses the effects of the concrete fill stiffness on the stiffness of the VW and D/F and follows an approach that is consistent with the standard design. The effects of the stiffness variation on the site-specific RB/FB SSI response are evaluated by performing sensitivity SSI analyses on two separate RB/FB models:

CR00 Model, with SSE damping, representing:

- Fully cracked reinforced concrete structures with 50 percent reduced shear and bending stiffness
- No (0 percent) in-fill concrete contribution to the stiffness of the concrete-filled VW and D/F steel structures

CR50 Model, with SSE damping, representing:

- Fully cracked reinforced concrete structures with 50 percent reduced shear and bending stiffness
- 50 percent in-fill concrete contribution to the stiffness of the concrete-filled VW and D/F steel structures

The sensitivity analyses of CR00 and CR50 RB/FB models are performed for the six subgrade (LB, BE and UB partial and full column) profiles so the evaluation fully addresses the possible effects of different embedment configurations and subgrade property variations on the response of the RB/FB models with reduced stiffness properties. The results of the evaluation presented in Appendix B of Reference 1 and discussed in FSAR Section 3A.17.9 show that the site-specific SSI analyses of the RB/FB uncracked model with upper bound stiffness and OBE damping provide a site-specific seismic design basis that generally envelopes the structural stiffness variation effects. FSAR Appendix 3A addresses the treatment of exceedances from the standard design and the process for determining when adjustments to seismic loads used as input for the NA3 structural evaluation are necessary.

(i) Provide in FSAR Section 3.7.1.2 a description of the stress criteria that determines the acceptability of using SSE damping values in conjunction with cracked concrete stiffness properties for reinforced concrete members, as described under FSAR Section 3.7.2.4.1.4.

Stress criteria for determining the acceptability of using SSE damping are based on NRC guidance in RG 1.61 and SRP 3.7.2. Per Section C.1.2 of RG 1.61, the use of SSE damping for the development of structural loads is adequate because the stresses obtained from models with SSE damping will remain lower than the stress limits considered by the applicable structural design codes.

The NA3 site-specific seismic design is based on responses obtained from the site-specific SSI analyses of models representing full (uncracked concrete) stiffness properties. The development of site-specific seismic structural load demands, foundation uplift, and stability evaluations for the CB and FWSC are based on responses obtained from models with upper bound (uncracked concrete) stiffness properties in conjunction with SSE structural damping. As discussed in the response to Sub-part (e), the use of SSE damping for the development of structural loads, foundation uplift, and stability evaluation is adequate because these analyses consider stress limits that are associated with the high dissipation of energy in the structures.

SSE damping is assigned to the models used for evaluating the structural stiffness effects in conjunction with reduced (cracked concrete) stiffness properties to represent the higher dissipation of energy in the structures when

subjected to high stresses, which correspond to the fully cracked concrete condition.

FSAR markups are provided in a separate enclosure and show the revisions that describe the details of the damping values used in the analyses. Specifically, FSAR Section 3A.13.2 provides information on damping values used in the analyses. Also, FSAR sections describing the models used in the analyses include information on the justification for using damping values in different analysis cases. FSAR Section 3A.15 includes tables of the analysis cases for each of the structures and indicates the damping (i.e., OBE or SSE) for the cases.

References

1. WG3-U71-ERD-S-0001, "Reactor/Fuel Building Complex Seismic Analysis Report"

2. WG3-U73-ERD-S-0001, "Control Building Seismic Analysis Report"

3. WG3-U63-ERD-S-0001, "Firewater Service Complex Seismic Analysis Report"

4. SER-DMN-014, "Additional Oscillators for Fully Cracked Model for RAI 3.7.2-14(f) Response"

5. ASCE 43-05: "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities"

NOTE: Reference 1 was submitted by Dominion letter Serial No. NA3-15-009, dated May 29, 2015. References 2 and 3 were submitted by Dominion Serial No. NA3-15-014, dated June 30, 2015. Reference 4 was submitted by Dominion Serial No. NA3-15-011, dated June 3, 2015.

Proposed COLA Revision

The changes to FSAR Section 3.7.1.2 and Appendix 3A are addressed in the COLA markup package submitted with this RAI response.

ENCLOSURE 6

Revised Response to NRC RAI Letter No. 123

RAI No. 7536, Question 03.07.02-15

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7536 (RAI LETTER 123)

SRP SECTION: 3.7.2 - SEISMIC SYSTEM ANALYSIS

DATE OF RAI ISSUE: 06/05/2014

QUESTION NO.: 03.07.02-15

FSAR Section 3.7.2.4 describes the site-specific SSI analyses of the RB/FB, CB, and FWSC structures, performed in support of the NA3 application. The FSAR does not provide any discussion of SSI transfer functions computed for the various site-specific SSI analysis cases. The review of transfer functions is essential to ensure that the numerical implementation of the SSI analysis methodology is acceptable and consistent with the guidance in SRP 3.7.2. Therefore, the applicant is requested to provide plots of transfer functions computed at the key locations in the RB/FB, CB, and FWSC documented in FSAR 3.7.2.4, for all site-specific SSI analysis cases considered in the NA3 application. In these plots, the computed values of the transfer functions should be clearly distinguished from the values obtained by interpolation. Explain whether any numerical anomalies are observed in the transfer functions (e.g., sharp narrow spikes) and explain their potential impact on the computed seismic response.

<u>Dominion Response</u>

This response revises and supersedes the previous response submitted by Dominion on July 18, 2014 (ADAMS Accession No. ML14204A459). This revised response incorporates changes that are a result of the revised analyses that are described in the Seismic Closure Plan (SCP) (ML14297A199), and addresses comments that the NRC staff provided in meetings on August 21, 2014, and November 20, 2014.

This response discusses the updated transfer functions from the cut-off frequency evaluations that were performed for the updated SSI analysis cases, as described in the SCP. The revised SSI analyses cases bound the in-structure response spectra (ISRS) results at high frequencies for a range of frequencies

covering at least 90% of the energy of the input ground motion. Plots of acceleration transfer function amplitudes obtained from the site-specific SSI analysis cases are provided in References 1 through 3.

The plots in these referenced reports clearly distinguish the computed values of the transfer functions from the values obtained by interpolation. As described below and in the reports, the transfer function results show that the numerical implementation of the SSI analysis methodology is acceptable and consistent with the guidance in SRP 3.7.2 (Reference 4).

<u>*Discussion:*</u>

In a public teleconference held on August 21, 2014, and in a public meeting held on November 20, 2014, the NRC commented that there were peaks in the interpolated values shown in the transfer function plots and that computed values were not provided to confirm their accuracy. These peaks occur mostly at the first mode in all three directions. The NRC also commented that the ranges of the vertical axes in most of the plots in the original response were too small to show the peaks of the soil column modes, and therefore, the impact of these peaks on the structural response predictions could not be assessed.

Plots of the transfer functions in the SSI analyses reports include both the interpolated and computed values. The interpolated peaks in the transfer functions are consistent with the computed values, and this confirms their accuracy. These peaks occasionally occur in the interpolated transfer functions due to the interpolation scheme built into the SASSI2010 program.

The ranges of the vertical axes in the transfer function plots have been increased to show the peaks of the soil column modes to better assess the impact of these peaks on the structural response predictions. The sharp and isolated peaks do not impact the seismic response based on the results of the corresponding response spectra plots, which do not have sharp peaks or show unreasonable behavior at those frequencies.

The NRC commented that there were peaks close to the cut-off frequency of 50 Hz. As explained during the November 20, 2014 (ML14325A662), public meeting, the SSI analyses of the Upper Bound (UB) subgrade profiles that bound responses at high frequencies are performed using a 70 Hz cut-off frequency to capture the energy content of the Unit 3 high frequency input motion. Preliminary results of a sensitivity study of the RB/FB (using the Updated EPRI 2004/2006 Ground Motion Model) had shown that input motion content above 50 Hz could amplify the ISRS close to 50 Hz and affect maximum vertical accelerations. Therefore, as shown on the updated plots in the SSI analyses reports, for the Reactor Building/Fuel Building (RB/FB) (Reference 1) and Control Building (CB) (Reference 2) UB profiles, the cut-off frequency was increased to 70 Hz, which helps to better assess transfer function peaks at frequencies greater than 50 Hz. For the Firewater Service Complex (FWSC) (Reference 3) UB profile, the cut-off

frequency was increased to 70 Hz. Cut-off frequencies, which were previously discussed in FSAR Section 3.7.2.4.1.3, will be revised and included in FSAR Section 3A.15. Information regarding the passing frequencies of SSI analyses is provided in response to RAI 03.07.02-13.

The NRC further commented that in the original response, Figures 6, 12, and 18 (the RB/FB basemat at the BE, LB, and UB subsurface profiles, respectively) showed transfer functions at the center of the basemat for responses in three orthogonal directions, including the potential effect of cross-coupling. The plots showed inconsistencies between the soil profiles. To respond to this comment, the effect of variations of the Unit 3 subgrade conditions on responses was examined using the outcrop motion transfer function results from the SSI analyses, which are provided in the referenced SSI analyses reports. It is concluded that variations of subgrade conditions do not affect cross-coupling responses.

Conclusions:

Plots of transfer functions computed at the key locations in the RB/FB, CB, and FWSC, for all key site-specific SSI analysis cases considered, are provided in the referenced seismic analyses reports. These plots demonstrate the accuracy of the site-specific SSI analyses results. Results of these SSI analyses will be documented in FSAR Section 3.7.2 and Appendix 3A.

For the reasons explained above, the figures show no numerical anomalies in the transfer functions results (narrow spikes) that impact the Unit 3 design ISRS, which will be documented in Appendix 3A, or the results of the structural and stability evaluations, which will be documented in FSAR Appendices 3A and 3G. The few spurious narrow spikes that can be observed in some of the transfer function results (mainly for cross-directional response) were examined and found not to impact the computed seismic response. Comparisons of transfer function results obtained from the analyses of different subgrade profiles show consistent results.

In conclusion, the plots show that the numerical implementation of the SSI analysis methodology is acceptable and consistent with the guidance in SRP 3.7.2.

References

1. WG3-U71-ERD-S-0001, Reactor/Fuel Building Complex Seismic Analysis Report

2. WG3-U73-ERD-S-0001, Control Building Seismic Analysis Report

3. WG3-U63-ERD-S-0001, Firewater Service Complex Seismic Analysis Report

4. NRC NUREG-0800, Standard Review Plan (SRP) 3.7.2, Seismic System Analysis, Rev. 4 (Sept. 2013)

   NOTE: Reference 1 was submitted by Dominion letter Serial Number NA3-15-009 on May 29, 2015. References 2 and 3 were submitted by Dominion letter Serial Number NA3-15-014 on June 30, 2015.

Proposed COLA Revision

The changes to FSAR Section 3.7.2 and Appendix 3A are included in the COLA markup submitted with this RAI response.

ENCLOSURE 7

Revised Response to NRC RAI Letter No. 123

RAI No. 7536 Question 03.07.02-16

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7536 (RAI Letter 123)

SRP SECTION: 3.7.2 - Seismic System Analysis

QUESTIONS for Seismic and Structural Branch SEB2

DATE OF RAI ISSUE: 06/05/2014

Question 03.07.02-16:

ESBWR DCD Section 3A.8.11 describes the evaluation of structure-soil-structure interaction (SSSI) effects considered in the generic design; specifically, the effect of the RB/FB on the CB, and the effect of the CB and FWSC on each other. FSAR Section 3.7.2, however, does not describe any site-specific SSSI analyses performed in support of the NA3 application. Although DCD Section 3A.8.11 is incorporated by reference in the FSAR, without supplements or departures, this DCD section does not provide any information related to potential site-specific SSSI effects. To ensure that the site-specific SSSI effects have been adequately addressed in the NA3 application, the applicant is requested to provide an evaluation of any potential site-specific SSSI effects, or provide the technical basis for not considering site-specific SSSI effects. Also, the applicant is requested to incorporate the evaluation or basis in the FSAR.

Dominion Response

This response describes the site-specific evaluations of the effects of structure-soil-structure interaction (SSSI) between the Seismic Category I structures on their seismic responses and the site-specific design basis that defines the seismic load demands on the ESBWR Seismic Category I structures, equipment and components at the NA3 site. This response provides an overview of the details that are provided in the referenced reports.

The site-specific evaluations of SSSI effects between the CB and FWSC that are of similar size and weight follow a methodology that is consistent with the

methodology used in the ESBWR DCD for addressing the SSSI effects of the FWSC on the seismic response of the CB, and the SSSI effects of the CB on the seismic response of the FWSC. These evaluations are based on the results of site-specific SSSI sensitivity analyses performed on the CB-FWSC, and FWSC-CB combined models representing the NA3 site-specific subgrade conditions and plant configuration. To evaluate the effects of SSSI on the seismic response of the CB and FWSC at the NA3 site, the SSSI analyses results for the seismic responses of the CB and FWSC structures in the combined models are compared to the responses obtained from the corresponding soil-structure interaction (SSI) analyses of the CB and FWSC stand-alone models. Comparisons are also made of the SSSI analyses results with the site-specific and standard seismic design envelopes to evaluate the SSSI effects on the CB and FWSC site-specific seismic design basis.

The site-specific evaluations of the SSSI effects of the large and heavy RB/FB on the seismic response of the small and light CB are based on the results of site-specific SSSI analyses using the CB-RB/FB combined model. This explicit approach that captures the effects of dynamic coupling between the RB/FB and CB at the NA3 site, which is different from the approximate approach used for the standard design SSSI evaluation that considered only the effect of the RB/FB on the seismic ground motion at the CB location. A two-step approach was used for the standard design evaluation in which the ground surface motion at the CB location was first determined from the SSI analysis of the RB/FB stand-alone model. The calculated ground surface motion at the CB location was then used as input motion to the SSI analysis of the CB stand-alone model to obtain the seismic response of the CB that included the effects of the RB/FB on the ground motion. The standard design approach to evaluate the SSSI effects of RB/FB on the CB cannot be directly implemented for the NA3 site-specific evaluations because the SSI analyses of RB/FB and CB stand-alone models use different subgrade profiles representing the subgrade conditions in the vicinity of the two buildings. Therefore, in order to explicitly capture the conditions between the two buildings and address the effect of subgrade properties variations across the NA3 site, the site-specific evaluations are based on the comparisons of the seismic response of the CB obtained from the CB-RB/FB SSSI analyses with the responses obtained from the corresponding site-specific SSI analyses of the CB stand-alone model.

The combined models used for the site-specific SSSI analyses are developed from the standard design dynamic models coupled with site-specific strain compatible dynamic subsurface properties. The SSSI evaluations are based on responses obtained from combined models representing full (uncracked concrete) stiffness properties that provide bounding results for the response of the ESBWR Seismic Category I structures at the NA3 rock site with high frequency design motion. The combined models include solid near-field subgrade elements which explicitly represent the subgrade conditions existing between the structures. More specific to the FWSC-CB SSSI, the subgrade

dynamic properties and the input motions used for the site-specific FWSC-CB SSSI analyses are identical to those used for the site-specific FWSC stand-alone model SSI analyses. The only difference between the FWSC-CB combined model and the FWSC stand-alone model is that the structural fill placed in the gap between the two buildings and around the concrete fill below the FWSC foundation is explicitly included in the FWSC-CB combined model and is neglected in the FWSC stand-alone model. The inclusion of the structural fill in the combined model is intended to address the effects of the structural fill on the FWSC seismic response, in particular the structural fill placed between the two buildings. The consideration of the site conditions at the FWSC location enables the SSSI effect of the CB on the FWSC seismic response to be directly evaluated by comparing the results obtained from the SSSI analyses of the FWSC-CB combined model with the results of the SSI analyses of the FWSC stand-alone model.

The access tunnel, which is seismically isolated from the below grade exterior walls of the RB/FB and the CB, is also included in the CB-RB/FB combined model (note that the standard design used a simplified approach to evaluate the SSSI effects of the RB/FB on the CB rather than directly analyzing the dynamic interaction between the two buildings). This approach is to provide a close representation of the actual plant layout and embedment conditions existing between the CB and RB/FB at the NA3 site. This difference in the modeling will be reflected in an update to NAPS DEP 3.7-1, as described in the Seismic Closure Plan.

The site-specific SSSI analyses are performed using the SASSI2010 computer program and the Modified Subtraction Method (MSM). Results of the SSSI sensitivity studies are provided in the referenced technical reports, which are submitted separately:

- "Control Building and Reactor/Fuel Building Complex Seismic Structure-Soil-Structure Interaction Analysis Report" (Reference 1)
- "Control Building and Firewater Service Complex Seismic Structure-Soil-Structure Interaction Analysis Report" (Reference 2)

Comparisons of the SSSI analyses results with the corresponding results of the site-specific SSI analyses show that, in general, the SSSI between the ESBWR Seismic Category I structures have small effects on the site-specific seismic responses of the CB and FWSC. Results show that the SSSI with nearby foundations can amplify the rocking and torsional responses of the FWSC and CB resulting in relatively small and local exceedances in the site-specific in-structure response spectra (ISRS) and load demands on the FWSC and CB structures.

As described in References 1 and 2, the CB site-specific design basis that is developed as the envelope of the results obtained from the SSI analyses of the CB stand-alone partially and fully embedded models envelopes the SSSI effects of the RB/FB and FWSC on the CB seismic response. The SSSI evaluations also show that the FWSC site-specific design basis that is developed solely on the responses obtained from the SSI analysis of the FWSC stand-alone model do not envelope the exceedances due to the CB SSSI effects. These exceedances are incorporated into the FWSC site-specific seismic design basis. The results from the SSSI analyses of the FWSC-CB combined model are used to develop the FWSC site-specific design ISRS. Evaluations of the Fire Water Storage Tanks (FWS) and Fire Pump Enclosure (FPE) structures (which together are the FWSC) are being performed based on the structural load demands that include the SSSI effects of the CB on the FWSC seismic response. As explained in the Seismic Closure Plan, results from these structural evaluations will be submitted in December 2015, and a summary of both the SSSI analyses and the structural evaluation results will be included in the FSAR.

Structure-Soil-Structure Interaction Effects of RB/FB on CB

The SSSI effects of the larger RB/FB on the CB seismic response are evaluated based on the results of three analyses of the CB-RB/FB combined model:

(1) Lower bound (LB) partial column profile, which is representative of the lower bound subgrade stiffness conditions at the CB location, with the in-column input control motion applied at the CB basemat bottom elevation

(2) Upper bound (UB) full column profile, which is representative of the upper bound subgrade stiffness conditions at the CB location, with the in-column input control motion applied at the CB basemat bottom elevation

(3) Upper bound (UB) partial column profile, which is the analysis case that governs the overall seismic response of the CB stand-alone model

The subgrade profiles and input motions used for these CB-RB/FB SSSI analyses are identical to those used for the SSI analysis of the CB stand-alone model. The evaluation of SSSI effects of the RB/FB on the CB seismic response is based on the comparisons of the results of the site-specific SSSI analyses of the CB-RB/FB combined model for the response of the CB with the corresponding results obtained from the site-specific SSI analyses of the stand-alone CB models for the LB and UB partial column, and UB full column profiles.

Results of the site-specific evaluation show that the effects of the larger RB/FB structure on the smaller CB are bounded by the CB stand-alone site-specific

seismic design basis and the standard design seismic design basis. These results are documented in Reference 1.

FSAR Appendix 3A will include a summary of this SSSI evaluation.

Structure-Soil-Structure-Interaction Effects of FWSC on CB

SSSI effects of the FWSC on the CB seismic response are evaluated based on results of the SSSI analyses of the CB-FWSC combined model. To account for the effects of the potential variability in the properties of the soil and rock, the CB-FWSC SSSI analyses are performed using the UB and LB CB full column profiles representing the NA3 subgrade conditions at the CB location and corresponding in-layer input motions defined by the CB SSI design response spectra applied at the bottom of the CB foundation. The full column subgrade profiles and input motions used for the CB-FWSC SSSI analysis are identical to those used for the SSI analysis of the CB stand-alone model. The evaluation of SSSI effects of the FWSC on the CB seismic response is based on the comparisons of the results of the site-specific SSSI analyses of the CB-FWSC combined model for the response of the CB with the corresponding results obtained from the site-specific SSI analyses of the stand-alone CB models.

The results of the CB-FWSC SSSI evaluation show that the effects of the FWSC structure on the CB are bounded by the site-specific seismic design basis that is developed as the envelope of responses obtained from the SSI analyses of the CB stand-alone models. The results are documented in Reference 2.

FSAR Appendix 3A will include a summary of this SSSI evaluation.

Structure-Soil-Structure-Interaction Effects of CB on FWSC

The SSSI effects of the CB on the FWSC seismic response are evaluated based on the results of the SSSI analyses of the FWSC-CB combined model. The SSSI effects on the FWSC site-specific seismic design basis are evaluated by comparing the results of the site-specific FWSC-CB SSSI analyses with the corresponding site-specific seismic load demands on the FWS and FPE structures and the site-specific design ISRS developed as the envelope of SSI responses obtained from the analyses of the stand-alone FWSC model. Results of the FWSC-CB SSSI evaluation indicate that SSSI effects of the CB can amplify the FWSC seismic response, resulting in relatively small exceedances that are not bounded by the envelope of results obtained from the site-specific SSI analyses of the stand-alone FWSC model. As a result, the FWSC seismic responses obtained from the site-specific SSSI analyses of the FWSC-CB combined model, together with the responses obtained from the stand-alone FWSC model SSI analyses, are used to develop the FWSC site-specific seismic design basis structural loads and ISRS and are documented in Reference 3. The

results of the SSSI analyses of the FWSC-CB combined model are also considered for the seismic stability and bearing pressure evaluations presented in Reference 4.

In order to capture the effects of the variability of the soil and rock properties and of different elevations of input control motion on the FWSC site-specific seismic design basis, the SSSI analyses of the FWSC-CB combined model are performed for the same set of input subgrade properties and design ground motions as those used for the SSI analysis of the FWSC stand-alone model. For the development of the FWSC site-specific design ISRS, the following six sets of SSSI analyses cases were performed on the FWSC-CB combined model with full (uncracked concrete) stiffness properties and OBE damping values:

- LB, best estimate (BE), and UB full column profiles using the surface outcrop input motion compatible with the FWSC foundation input response spectra (FIRS) that governs the FWSC ISRS at lower frequencies
- LB, BE, and UB full column profiles using the corresponding in-column input motion compatible to the SSI design spectra at the bottom of the concrete fill placed below the FWSC foundation that governs the FWSC ISRS at high frequencies.

Three additional SSSI analysis cases are also performed on the FWSC-CB combined model with SSE damping values assigned to the FWSC structural model for the LB, BE, and UB full column profiles, using the in-column input motion applied at the bottom of the concrete fill placed below the FWSC foundation, which are the cases that govern the overall seismic response of the FWSC at the NA3 site. The results of these analyses are used for development of site-specific seismic load demands on the FWSC structures and for calculation of the seismic driving forces used as input for the seismic stability and bearing pressure evaluation of the FWSC.

Exceedances in ISRS and seismic load demands for the FWSC from the SSSI analyses using the FWSC-CB model, together with the responses obtained from the stand-alone FWSC model SSI analyses, are used to develop the seismic design response envelope for the site-specific evaluation of the NA3 FWSC.

FSAR Appendix 3A will include a summary of the SSSI analyses, a discussion of the exceedances, and the seismic design response envelope for the FWSC.

Further evaluations will be performed using NASTRAN Finite Element Analysis based on the structural load demands, including site-specific seismic loads, for comparison to the standard design. Results from these structural evaluations will be transmitted as described in the Seismic Closure Plan.

Potential SSSI Effects of Other Structures on Category I Structures

During the NRC public meeting held April 15, 2015, preliminary results of the FWSC-CB SSSI effects were presented (Slide 122; ML15110A046), indicating that the SSSI between the CB and FWSC have small interaction effects on the site-specific seismic responses of these two structures. The NRC asked that Dominion explain the potential effect of neighboring buildings' SSSI on Seismic Category I structures, considering the structures aligned in another direction [e.g., RB/FB-Turbine Building (TB)]. As explained below, the SSSI effects of the buildings in close proximity to the Seismic Category I buildings are addressed in the DCD for the standard design conditions and in the FSAR and ITAAC for site-specific conditions.

The ESBWR Seismic Category II structures and the Radwaste Building (RWB) are not at the level of design completion that allows seismic and structural analysis using the methodologies for the Seismic Category I structures. The NRC has accepted the approach described in the ESBWR certified standard design control document for finalizing the design and analysis of each of these buildings. The seismic interactions are to be addressed as part of completing the standard detailed design. In addition, the Seismic Category II structures and RWB will be analyzed for Unit 3 site conditions and subgrade properties, as specified in the COLA. The effects of SSSI between buildings will be analyzed for the Unit 3 site conditions, including the effects of the Seismic Category II structures and RWB on the Seismic Category I structures. Both the standard design and the Unit 3 analyses are verified through ITAAC (DCD Tier 1 and site-specific ITAAC) for the Seismic Category II and RW buildings.

The ESBWR design certification addresses the interactions between structures, and FSAR Section 3.7.2.8 provides site-specific information consistent with the approach approved for the standard design for the interaction of non-Category I structures with Seismic Category I structures. The buildings close to the Seismic Category I buildings are specifically designated as Seismic Category II buildings, except that the RWB is designed in accordance with RG 1.143 Classification RW-IIa. The site-specific SSI and SSSI analyses and seismic evaluation of these buildings will be performed following the same methodology as used for the Seismic Category I buildings, consistent with SRP 3.7.2.II.8.C, as approved for the standard design certification (NUREG-1966, Vol. 1, Chapter 3).

The TB and the Service Building (SB) are in close proximity to the RB/FB complex. The FSAR explains that the seismic gaps between the TB and the RB/FB and between the SB and the RB/FB are no less than the calculated maximum relative displacements between the two buildings during an SSE event, considering the out-of-phase motion. The RWB is located at least 10 meters from the RB and the Ancillary Diesel Building is at least 15.2 meters from the FB. Other buildings on site are at least a distance of one building height above grade from Seismic Category I structures.

FSAR Section 3.7.2.8 addresses two sets of site-specific seismic response analyses to demonstrate the adequacy of the design and analyses of these Seismic Category II buildings and the RWB: SSI analyses of the structures and SSSI analyses to evaluate any adverse effects of seismic interaction between these building and adjacent Seismic Category I structures are performed to ensure that the design of these buildings preclude adverse interaction. The design acceptance criteria will be verified through ITAAC, and the results of these analyses will be discussed as part of the ITAAC completion package for each of the buildings.

Based on the results of the site-specific SSSI analyses detailed in the referenced reports, FSAR Section 3.7.2.8 will be revised to indicate that the SSSI effects are evaluated for these buildings and that the site-specific design precludes adverse interaction with Seismic Category I buildings. COLA Part 10 will be revised to include site-specific ITAAC to verify through analyses that such interactions are precluded by the design of these Seismic Category I buildings and RWB. These revisions are shown on the COLA markups submitted with this RAI response.

References

1. WG3-U73-ERD-S-0005, "Control Building and Reactor/Fuel Building Complex Seismic Structure-Soil-Structure Interaction Analysis Report"

2. WG3-U73-ERD-S-0002, "Control Building and Firewater Service Complex Seismic Structure-Soil-Structure Interaction Analysis Report"

3. WG3-U63-ERD-S-0001, "Firewater Service Complex Seismic Analysis Report"

4. WG3-U63-ERD-S-0003, "Firewater Service Complex Stability Analysis Report"

NOTE: References 1 and 2 are being submitted by Dominion Letter No. NA3-15-019. References 3 and 4 were submitted by Dominion Letter No. NA3-15-014, dated June 30, 2015.

Proposed COLA Revision

The changes to COLA Part 10 and FSAR Section 3.7.2.8 and Appendix 3A are included in the COLA markup submitted with this RAI response. The changes to COLA Part 7 will be submitted in December 2015.

ENCLOSURE 8

Revised Response to NRC RAI Letter No. 123

RAI No. 7536, Question 03.07.02-23

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7536 (RAI LETTER 123)

SRP SECTION: 3.7.2 - SEISMIC SYSTEM ANALYSIS

DATE OF RAI ISSUE: 06/05/2014

QUESTION NO.: 03.07.02-23

The site-specific ISRS documented in the FSAR Section 3.7.2.4.1.6.2 do not include response spectra for the single-degree-of-freedom (SDOF) oscillators that are used to represent the dynamic response of flexible walls and slabs in the SSI models of the RB/FB and CB. To ensure the adequacy of the seismic design and qualification of substructures, systems, and components that are supported on flexible walls and slabs in the RB/FB and CB, provide the following information.

(a) Provide a comparison of 5 percent damping site-specific ISRS with the corresponding standard design ISRS, for all SDOF oscillators in the RB/FB and CB (walls and slabs), similar to the comparisons shown in FSAR Figures 3.7.2-211 through 228 (for the RB/FB), Figures 3.7.2-247 through 252 (for the CB), and Figures 3.7.2-259 through 270 (for the FWSC).

(b) Provide the peak-broadened site-specific design ISRS for all SDOF oscillators in the RB/FB and CB (walls and slabs), similar to those shown in FSAR Figures 3.7.2-229 through 246 (for the RB/FB), Figures 3.7.2-253 through 258 (for the CB), and Figures 3.7.2-271 through 282 (for the FWSC).

Furthermore, the staff identified the following inconsistencies and requests the applicant to provide further clarifications:

(c) FSAR Figures 3.7.2-211 and 3.7.2-212 compare the 5 percent damping site-specific ISRS obtained from the site-specific SSI analysis of the RB/FB refueling floor and RCCV top slab in the X-direction with the corresponding DCD spectra. However, the staff noted that with the exception of the titles, the figures are the same including the identification of node number and elevation. The applicant is requested to clarify this inconsistency.

(d) FSAR Figure 3.7.2-261 compares the 5 percent damping site-specific ISRS obtained from the site-specific SSI analysis of the FWSC model with the corresponding standard design ISRS in ESBWR DCD Section 3A.9.2, for the FPE top in the X-direction. The staff's review of this figure, however, indicates that standard design ISRS shown in FSAR Figure 3.7.2-261 does not appear to match the one shown in ESBWR DCD Figure 3A.9-1k. The applicant is requested to revise this figure.

Dominion Response

This response revises and supersedes the previous response submitted by Dominion on July 3, 2014 (NA3-14-030; ADAMS Accession No. ML14202A385). The purpose of this revised response is to provide updated in-structure response spectra (ISRS) results for the Seismic Category I structures from the updated analyses, which are based on the 2013 Ground Motion Model (GMM), as described in the Seismic Closure Plan (ML14297A199).

(a) The comparison of 5 percent damping site-specific ISRS with the corresponding standard design ISRS, for all SDOF oscillators in the RB/FB, CB, and FWSC (walls and slabs), similar to the comparisons shown in FSAR Figures 3.7.2-211 through 228 (for the RB/FB), Figures 3.7.2-247 through 252 (for the CB), and Figures 3.7.2-259 through 270 (for the FWSC) are presented in the seismic analysis reports for each structure (References 1, 2 and 3). The figures present the site-specific ISRS obtained from the analyses of the partially embedded (PE) and fully embedded (FE) models.

    The figures referenced in the RAI question will be moved from FSAR Section 3.7.2 to Appendix 3A, and Appendix 3A will be revised to include the new figures.

(b) The peak-broadened site-specific design ISRS for all SDOF oscillators in the RB/FB, CB, and FWSC (walls and slabs) are presented in References 1, 2, and 3, respectively. These reports present figures of site-specific enveloping ISRS for critical damping ratios 2, 3, 4, 5, 7, 10, and 20 percent at all locations in the RB/FB, CB, and FWSC that are peak broadened by +/-15 percent and valley filled. These ISRS represent the envelope of ISRS results from the site-specific SSI analyses of the RB/FB, CB, and FWSC models.

    The figures referenced in the RAI question will be moved from FSAR Section 3.7.2 to Appendix 3A, and Appendix 3A will be revised to include the new figures.

(c) FSAR Figure 3.7.2-212 was replaced with the appropriate figure in the May 20, 2014 markups to FSAR submitted in Dominion transmittal letter NA3-14-012.

(d) FSAR Figure 3.7.2-261 will be replaced with the appropriate figure.

References

1. WG3-U71-ERD-S-0001, "Reactor/Fuel Building Complex Seismic Analysis Report"

2. WG3-U73-ERD-S-0001, "Control Building Seismic Analysis Report"

3. WG3-U63-ERD-S-0001, "Firewater Service Complex Seismic Analysis Report"

NOTE: Reference 1 was submitted by Dominion letter Serial No. NA3-15-009, dated May 29, 2015. References 2 and 3 were submitted by Dominion letter Serial No. NA3-15-014, dated June 30, 2015.

Proposed COLA Revision

The changes to FSAR 3.7.2 and Appendix 3A are included in the COLA markup submitted with this RAI response.

ENCLOSURE 9

Response to NRC RAI Letter No. 154

RAI No. 7810 Question 03.07.02-26

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7810 (RAI Letter 154)

SRP SECTION: 3.7.2 - Seismic System Analysis

QUESTIONS for Structural Engineering Branch SEB2

DATE OF RAI ISSUE: 02/24/2015

QUESTION NO.: 03.07.02-26

In the July 3, 2014, response to item (b) of RAI 03.07.02-10, the applicant indicated that the verification and validation of SASSI2010 program modules used in the NA3 SSI analyses with passing frequency up to 50 Hz are performed in accordance with the Shimizu Quality Assurance Program. The applicant also stated that the Shimizu Corporation proprietary report that documents details of verification and validation will be made available to the NRC for audit. Accordingly, the applicant made available Shimizu Proprietary Report S/VTR-SAS, Revision F, "Validation Test Report for SASSI2010 Version 1" (designed herein as the NA3 V&V Report) for staff's review in the Dominion electronic reading room.

The staff requests that the applicant provide a non-proprietary summary of the NA3 V&V Report regarding the critical characteristics of SASSI2010 applicable for the NA3 SSI analyses that have been validated.

In addition, on August 11, 2014, the applicant also submitted to the staff Shimizu Engineering Report SER-DMN-011, Rev. 0, "Benchmarking of SASSI 2010 MSM Results from NA3 Site-Specific SSI Analysis" (designed herein as the NA3 MSM Benchmark Report). The staff has reviewed NA3 V&V and MSM Benchmark reports and determined that the information requested below is needed in order to determine the acceptability of SASSI2010 for SSI/SSSI analyses for the NA3 application.

The NA3 V&V Report includes 14 test problems; all were solved using the direct method (DM) of SASSI as stated in Section 4.3 of this report, "Tested Application Range". The NA3 MSM Benchmark report indicated that MSM is used for the

NA3 SSI and SSSI analyses of fully embedded models. The staff review focused on problems with critical characteristics that are applicable to the NA3 site-specific SSI analyses.

a) Validation of SASSI 2010 Solutions Up To 50 Hz

The NA3 V&V Report problem 9 is intended to validate SSI solution for frequencies up to 50 Hz. However, Section A.9.5.3 indicates that the model mesh constructed for this problem (also for problem 3) is valid up to a frequency of 33.3 Hz. In addition, the maximum frequency of analysis was 40 Hz, as shown in Table A.9-2. Figures A.9-13 and A.9-14 show a comparison of translational and rocking responses from SASSI2010 and Day's solution. Based on review of these comparisons it appears that above an a0 value of 2 (which corresponds to a frequency of about 10 Hz) there are some deviations between the Day's solution and the SASSI2010 results (where in general, Day's solution predicting a higher response than SASSI2010 results). As such, the applicant is requested to provide further justification to validate that use of SASSI2010 solutions would be adequate up to a frequency of 50 Hz for application at the NA3 site and as applicable, to update all test problems associated with this issue.

The staff noted that the NA3 V&V Report did not include a test problem to validate the SASSI kinematic SSI solution for frequencies up to 50 Hz on a layered soil profile similar to NA3 site conditions for frequencies up to about 50 Hz. As such, the applicant is requested to provide a basis that the applicability of SASSI2010 for the SSI analyses to layered profiles is adequate for the NA3 application.

b) Validation of Symmetry/Anti-Symmetry Conditions

The NA3 V&V Report problem 3 is intended to validate the capability of SASSI 2010 in its treatment of symmetric and anti-symmetric conditions. Three cases that utilized symmetry or anti-symmetry conditions, identified as "XZ-Symmetry X-Dire (SASSI2010 EX2)", "XZ-Symmetry X-Dir (SHIMIZU)", and "Y-Anti-Symmetry Y-Dir (SHIMIZU)" in Figures A.3-13 and -14, produced visually identical solutions, as expected. However, the case of "Full Model X-Dir (SHIMIZU)" deviates from these three cases beyond about 20 Hz (dimensionless frequency a0=4). In particular, there is a prominent difference in the rocking transfer function between the full model and the other three cases for frequencies between 20 Hz and 30 Hz.

It should be noted that application of symmetric/anti-symmetric conditions in a model is not expected to cause any nontrivial difference in the solution. Therefore, the staff requests that the applicant explain the solution difference between the full model and the model with symmetric/anti-symmetric conditions.

c) Validation of Maximum Aspect Ratio for 3D Brick and Thin Shell Elements

The NA3 V&V Report problem 10 is to determine the maximum aspect ratio for 3D solid brick elements and 3D thin shell elements for SASSI models. The ESBWR CB model was used in this test problem. The aspect ratios implemented in various cases are 1:1.3, 1:1.5, 1:2, 1:3, and 1:4. The cutoff frequency was 50 Hz. Maximum absolute accelerations and acceleration response spectra (ARS) were compared at the top of the stick outer walls and at the top of the basemat. The maximum absolute accelerations at the top of the stick outer walls agree very well (the maximum difference is about 1%). The ARS for all cases are visually identical as shown in Figures A.10-7 through A.10-18. Based on these comparisons, the report concludes that the maximum aspect ratio of 1:4 is validated for 3D solid brick elements and 3D thin shell elements in the NA3 SSI analyses.

However, these comparisons were performed at locations away from the elements with large aspect ratios, as shown in Figures A.10-3 through -6. No comparison of responses at locations close to the elements of large aspect ratios was provided. The element shape and size could potentially affect more local responses. Therefore, to assist the evaluation of appropriate element aspect ratio, the staff requests that the applicant also provide comparisons of the maximum absolute accelerations and ARS for the elements (circled in red) identified in Figures A.10-5 and -6 to have the maximum large aspect ratios.

The locations of the elements with the maximum aspect ratios shown in Figures A.10-5 and -6 appear to be inconsistent with Table A.10-3 (e.g., case 5 by using H1 and W1, or case 6 by using H2 and H3). The applicant is requested to revise the table and/or figures for consistency.

d) Only UB Soil Properties Used for MSM Benchmarking

As compared to Direct Method (DM), SASSI Modified Subtraction Method (MSM) may yield transfer functions with spurious spikes. To demonstrate the adequacy of the MSM for the NA3 application, the FWSC model was analyzed with full embedment and the Upper Bound (UB) soil profile. Since the UB soil profile cannot capture low frequency responses, the staff requests that the applicant justify the same MSM also yields adequate solutions compared with DM for lower bound (LB) soil profile.

<u>Dominion Response</u>

As described in the Seismic Closure Plan (ADAMS Accession Number ML142997A199), the approach taken for site-specific SSI analyses of ESBWR

Seismic Category I structures has been revised to include the input ground motion and strain compatible subgrade properties based on 2013 Ground Motion Prediction Equations (GMPE) and corresponding SASSI2010 analyses for frequencies up to 70 Hz using the direct method (DM) or the modified subtraction method (MSM). Dominion's revised response to RAI 03.07.02-10 indicates that both the DM and MSM are used for the site-specific SSI analyses (a revised response to RAI 03.07.02-10 is provided in a separate enclosure). The benchmarking analyses are performed for the standalone and combined models with revised subgrade properties to demonstrate the accuracy of the SSI and SSSI analyses MSM solutions for frequencies up to 70 Hz. The NA3 V&V Report has been revised to address the issues identified in this RAI and validate the SASSI2010 solutions for frequencies up to 70 Hz. The MSM Benchmarking Report is revised as explained below. FSAR Section 3C.7.4.2 is being revised to reflect passing frequencies up to 70 Hz.

This response is formatted to address each item of the RAI separately.

General:

The staff requests that the applicant provide a non-proprietary summary of the NA3 V&V Report regarding the critical characteristics of SASSI2010 applicable for the NA3 SSI analyses that have been validated.

A non-proprietary summary of the NA3 V&V Report (Reference 1) is being submitted separately. This report describes the critical characteristics of SASSI2010 applicable for the NA3 SSI analyses that have been validated. The proprietary version of the report (Reference 2) was previously provided for NRC audit.

Responses to RAI Subsections:

Response to Subsection a) Validation of SASSI 2010 Solutions Up To 50 Hz/ Applicability to Layered Profiles

The NA3 V&V report S/VTR-SAS has been revised to accommodate a refined mesh model with passing frequencies up to 70 Hz. The previous shear wave velocity equal to 2000 ft/sec of the soil in Problems 3 and 9 has been changed to 3700 ft/sec to be consistent with properties of the NA3 rock, which is capable of transmitting high frequency ground motions. The associated dimensionless frequency a_o is 7.7 for a 65 ft radius cylinder embedded in a half space with 3700 ft/sec shear wave velocity. FSAR Section 3C.7.4.2 is being revised to clarify that the validation report addresses passing frequencies up to 70 Hz.

In order to achieve a better comparison with Day's solution, additional soil layers are added to reach the depth at 325 ft below the ground surface in the site data in order to be consistent with the FE model in Day's paper. The results obtained

for both translation and rocking responses are in good agreement with Day's solution.

Based on a comparison to the DTE Energy response to RAI Letter No. 85, RAI Question No. 03.07.02-11 on July 9, 2013 (Attachment 1 to DTE Letter NRC3-13-0023, Accession Number ML13192A302), the applicability of SASSI2010 for the SSI analyses to layered profiles is also adequate for the NA3 site. It was concluded for problem number 47 in the DTE RAI response that, based on the comparison of SASSI2010 results with the results generated by the DIMFU program, the impedance functions calculated by SASSI2010 for a layered soil profile are adequate for the SSI analysis of the RB/FB and CB at the Fermi 3 site. Based upon comparisons between the Fermi 3 and NA3 site characteristics, the same conclusion can be made regarding the applicability of SSI analyses to layered profiles at the NA3 site.

The comparisons provided in Section 5.2 of the MSM Benchmarking Report (SER-DMN-011; Reference 3) show that the subgrade conditions at the Fermi 3 and NA3 are similar. Both sites are characterized with softer soil resting on a surface of rock. The comparisons presented of the S-wave velocity and P-wave velocity profiles in Figure 5.2-1 of SER-DMN-011 (Reference 3) show that the contrast between the stiffness properties of the soft soil and the underlying rock at Fermi 3 site are more pronounced than those for the NA3 site, making the SASSI2010 analyses of the Fermi 3 layered site model more susceptible to numerical instabilities. Therefore, the results of the validation of the SASSI2010 solution for the Fermi 3 layered soil profile are applicable for the NA3 site.

Response to Subsection b) Validation of Symmetry/Anti-Symmetry Conditions

The differences observed between the results obtained from the full model and the half model were due to the different coordinate systems. The coordinate system of the full model is modified to a cylindrical coordinate system from an orthogonal coordinate system to be consistent with the coordinate system of the half model. The comparisons of the revised results show that the deviations between the results obtained from the full model and the half model are negligible when the two models use consistent coordinate systems.

Response to Subsection c) Validation of Maximum Aspect Ratio for 3D Brick and Thin Shell Elements

Section A.10 of NA3 V&V report S/VTR-SAS, presenting the validation of the accuracy of the SASSI 2010 solutions obtained from models with maximum value of finite element mesh aspect ratio of 1:4, has been revised. The validation is based on comparisons of maximum absolute accelerations and 5% damped ARS

results obtained from models of the Control Building (CB) with different finite element mesh for the response at the top of the CB lumped mass stick model, at the top of the CB basemat, and at additional nodes pertaining to the 3D solid brick elements and 3D thin shell elements identified to have the maximum large aspect ratios. The negligible (< 2%) difference between the maximum acceleration results obtained from models with different finite element meshes for the different node locations demonstrates that the numerical accuracy criterion is satisfied. The comparison of the 5% damped ARS shows that the good agreement criterion is met for all node locations for all models with different mesh sizes.

Response to Subsection d) Only UB Soil Properties Used for MSM Benchmarking

In addition to the upper bound (UB) soil profile, the MSM benchmarking for the FWSC has been expanded to include the lower bound (LB) soil profile. Section 4 of the revised MSM Benchmarking report (Reference 3) contains a summary of the results from the SASSI2010 benchmarking analysis of the FWSC standalone model with revised 2013 GMPE based subgrade properties. The configuration, properties, and mesh of the models used for the MSM benchmarking analysis are the same as those of the half model used for the Unit 3 site-specific seismic analyses of the FWSC for the UB and LB subgrade profiles documented in the FWSC seismic analyses report (Reference 4). The benchmarking analyses of the FWSC model for the LB and UB subgrade profiles are performed for frequencies up to 36 and 70 Hz, respectively.

The results in Section 4.2 of Reference 3 show that the transfer functions obtained from the MSM analysis are almost identical to those obtained from the DM analysis. The ISRS comparisons demonstrate that the ISRS results from the MSM and DM analyses are virtually identical (with very small differences of 4% at 0.71 Hz) and are negligible. The maximum absolute acceleration comparisons show that the differences between the DM and the MSM analyses are less than 2%. The maximum force and moment comparisons show that the differences between the DM and the MSM results for maximum element shear forces and bending moments are less than 3% and are negligible. The maximum difference of 5% occurs in the results for torsion of the FWS stick model. The maximum relative displacement comparison shows negligible differences between the DM and the MSM displacements (less than 2%). The close agreement with the DM results for both UB and LB profiles demonstrate the adequacy of the MSM application to the NA3 site.

References

1. SER-DMN-020, "Validation Summary Report for SASSI2010 and Appendix with Validation Problems for RAI 03.07.02-10 / RAI 03.07.02-26 Response"

2. S/VTR-SAS, "Validation Test Report for SASSI2010 Version 1"

3. SER-DMN-011, "Benchmarking of SASSI2010 MSM Results from NA3 Site-Specific SSI Analysis"

4. WG3-U63-ERD-S-0001, "Firewater Service Complex Seismic Analysis Report"

NOTE: References 1 and 3 are being submitted by Dominion letter Serial Number NA3-15-019. Reference 4 was submitted by Dominion letter Serial Number NA3-15-014 on June 30, 2015. Reference 2 was previously provided to the NRC for audit in the Dominion Electronic Reading Room, and the revised version will be available for NRC audit.

Proposed COLA Revision

The changes to FSAR Section 3C.7.4.2 are included in the COLA markup submitted with this RAI response.

ENCLOSURE 10

Revised Response to NRC RAI Letter No. 125

RAI No. 7536 Question 03.08.05-6

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

North Anna Unit 3

Dominion

Docket No. 52-017

RAI NO.: 7538 (RAI Letter 125)

SRP SECTION: 3.8.5 – Foundations

QUESTIONS for Seismic and Structural Branch

DATE OF RAI ISSUE: 06/05/2014

QUESTION NO.: 03.08.05-6

FSAR Section 3.8.5.5.1 indicates that, for evaluation of sliding stability, a 0.03 second moving average window is applied to obtain the lateral resisting forces for the RB/FB, CB, and FWSC foundations. FSAR Section 3.8.5.5.1 states that the moving average window "helps to filter out the spurious peak in the vertical reaction time history when the magnitude of the upward seismic force is near or exceeds the effective weight of the building." Similar statements are repeated in FSAR Section 3.8.5.5.2, in the context of the evaluation of dynamic bearing pressures for the CB foundation.

The staff could not identify in the FSAR a discussion regarding the technical basis for the above approach, which appears to deviate from the ESBWR DCD, or for the choice of the 0.03 second window. Therefore, the applicant is requested to address the following:

(a) Why the moving average window is physically needed and justify that the choice of 0.03 seconds is appropriate for that need. In particular, explain why it is considered spurious that the upward seismic force is near or exceeds the effective weight of the buildings. The staff notes that a 0.03 second moving average window applied in the time domain could filter out the energy content above approximately 17 Hz in the frequency domain. As such also discuss the potential impact of this filter on the results of the stability analysis.

In addition, FSAR Section 3.8.5.5.1 describes the site-specific stability evaluations against overturning and sliding for the RB/FB, CB, and FWSC, based on the results from the site-specific SSI analyses for the RB/FB, CB, and FWSC presented in FSAR Section 3.7.2.4.1. The FSAR indicates that stability

evaluations for overturning and sliding follow the methodology in ESBWR DCD Section 3.8.5.5. The calculated site-specific factors of safety (FS) against sliding for the RB/FB, CB and FWSC are shown in Tables 3.8.5-201 through 3.8.5-203. However, the staff's review of these tables indicates that FS for sliding are not explicitly provided, it is only indicated that the FS are larger than 1.1. Therefore, to determine the adequacy of the applicant's implementation of the sliding stability evaluation methodology in ESBWR DCD Section 3.8.5.5, the applicant is requested to provide the following information:

(b) The FSAR is not clear on whether sliding stability is evaluated for the two horizontal directions separately, or using the maximum (combined) horizontal base shear. Explain which method is used.

(c) Provide the technical basis for the site-specific static coefficient of friction of 0.60 assumed at the critical sliding planes of the RB/FB, CB, and FWSC, for the underlying concrete fill or rock. In the case of concrete fill, explain whether shear-friction reinforcement within the concrete fill (e.g., at cold joints) is needed to achieve this value.

(d) To achieve a minimum FS of 1.1 for sliding stability, the lateral resisting forces required for RB/FB, CB, and FWSC include (i) static friction at the critical sliding planes, and (ii) lateral passive pressures on walls, sides of the basemats, and shear keys opposite to the direction of motion. Provide a detailed description and magnitude of each of the lateral resisting forces required for RB/FB, CB, and FWSC.

(e) The FSAR states that the required lateral passive pressures for the RB/FB and CB are "well within the allowable bearing pressure of the concrete fill, Zone III rock, and the lateral pressure capacity of the buildings' below-grade walls." The FSAR also states that the required lateral passive pressures for the FWSC are "well within the allowable bearing pressure of structural fill, Zone II rock and the lateral pressure capacity of the shear key." Provide the technical basis for these statements. In particular, provide the allowable bearing pressures of the surrounding structural fill, concrete fill, and rock media that are appropriate for lateral loading conditions, as well as the magnitude of the lateral deformations that justify the static friction (as opposed to kinematic friction) assumption.

(f) Provide the results of a site-specific evaluation of the shear keys for the various structures, which demonstrates that these structural elements are able to resist the site-specific seismic demands, and are able to effectively lower the critical sliding planes.

Dominion Response

The questions in this RAI are based on the December 2013 North Anna Unit 3 (NA3) COLA submittal, which applied a 0.03 second moving average window to obtain the lateral resisting forces for the RB/FB, CB, and FWSC foundations. As described in the Seismic Closure Plan (SCP), which was submitted to the NRC by letter NA3-14-043, dated October 22, 2014 (ADAMS Accession Number ML14297A199), Dominion revised the approach used for the site-specific evaluations of the seismic stability and dynamic bearing pressures of Seismic Category I foundations. The responses to the questions in this RAI are based on the revised site-specific evaluations that demonstrate all aspects related to the seismic stability of RB/FB, CB and FWSC at the NA3 site by following a methodology that is consistent with the methodology described in the ESBWR Design Control Document (DCD).

The revised site-specific seismic stability and dynamic bearing pressure evaluations are documented in the following Technical Reports, which are submitted separately:

- "Reactor/Fuel Building Complex Stability Analysis Report" (Reference 1)
- "Control Building Stability Analysis Report" (Reference 2)
- "Firewater Service Complex Stability Analysis Report" (Reference 3)

These seismic stability and bearing pressure evaluations are based on the results obtained from the revised set of site-specific seismic response analyses of the RB/FB, CB and FWSC, which are documented in:

- "Reactor/Fuel Building Complex Seismic Analysis Report" (Reference 4)
- "Control Building Seismic Analysis Report" (Reference 5)
- "Firewater Service Complex Seismic Analysis Report" (Reference 6)

The models used for the seismic response analyses have 3-D contact spring elements established at the interfaces that are critical for the stability of the RB/FB, CB and FWSC at the NA3 site. The contact spring elements provide the input for calculation of the time histories of the global seismic driving forces and moments in three orthogonal directions for the seismic stability and bearing pressure evaluations with respect to the following critical planes located at:

a. The bottom of the RB/FB basemat that provide:
    - the lateral pressure demands on the surrounding concrete fill and Zone III rock required for sliding stability of the RB/FB
    - Bearing pressure demands on the Zone III/IV rock subgrade supporting the RB/FB basemat
b. The bottom of the CB basemat that provide:

- the lateral pressure demands on the surrounding concrete fill and Zone III rock required for sliding stability of the CB
- Bearing pressure demands on the concrete fill layer supporting the CB basemat

c. The interface between the top surface of the Zone III/IV rock and bottom surface of the concrete fill block below the CB basemat that provide:
   - the lateral pressure demands on the surrounding concrete fill and Zone III rock required for the global sliding stability of the CB and supporting concrete fill
   - Bearing pressure demands on the Zone III/IV rock subgrade supporting the CB and underlying concrete fill

d. The bottom of the FWSC basemat that provide:
   - the lateral force demands on the shear keys required for sliding stability of the FWSC
   - Bearing pressure demands on the concrete fill layer supporting the FWSC basemat

e. The surface of the Zone III/IV rock and bottom of the concrete fill block below the FWSC basemat that provide:
   - the lateral pressure demands on the surrounding concrete fill and Zone III rock required for the global sliding stability of the FWSC and supporting concrete fill
   - Bearing pressure demands on the Zone III/IV rock subgrade supporting the FWSC and underlying concrete fill

The seismic stability and dynamic bearing pressure evaluations are performed for each SSI and SSSI analysis case that provided responses used for development of the site-specific enveloping seismic load demands on RB/FB, CB and FWSC structures.

The responses to the questions (a) through (f) of this RAI are provided below. Part (a) explains that the revised stability and bearing pressure evaluation do not apply a 0.03 sec moving average window to filter out the high frequency content from the global base reaction time histories. Part (b) of the response clarifies that consistent with the DCD methodology, the sliding stability evaluations are performed separately for the two orthogonal horizontal directions. The maximum (combined) horizontal base shear method is not used. Part (c) provides the technical basis for using 0.60 for the site-specific static coefficient of friction, and addresses the need for shear reinforcement. Part (d) briefly explains the lateral resistance forces considered in the sliding stability evaluations and provides reference to Technical Reports for the maximum values of the seismic driving forces and lateral resistance forces. The response in Part (e) provides the maximum calculated lateral pressure demands required for the sliding stability of Seismic Category I foundations and compares them with the allowable lateral pressure capacity of the NA3 subgrade. Part (e) also demonstrates that the use of the static friction coefficient for the site-specific sliding stability evaluations is

adequate. Based on the results of the site-specific SSI analyses, it is shown that the deformations required to mobilize the lateral resistance of the subgrade are very small, thus preventing the relative motion at sliding plane interfaces that can reduce the frictional resistance. The response in Part (f) clarifies that the shear keys are required only to ensure the sliding stability of the FWSC at the NA3 site and that the structural evaluation of the shear keys will be provided as part of the site-specific evaluation of FWSC structures.

(a) Use of Moving Average Window for Sliding Stability

The NRC question is based on the method which was used previously and which is not used in the updated evaluations. As described in the SCP and References 1, 2 and 3, the site-specific seismic stability and bearing pressure evaluations of Seismic Category I foundations are performed using the same methodology as that used for the standard design. The revised seismic stability and bearing pressure evaluations are based on seismic driving forces that include the high frequency energy content of the input ground motion.

Because the revised stability and bearing pressure evaluations do not apply a 0.03 second moving average window that could filter out the high frequency content from the global base reaction time histories, filtering out the energy content above ~17 Hz in the frequency domain is no longer a concern.

(b) Method Used to Evaluate Sliding Stability

The site-specific evaluations of the sliding stability of Seismic Category I foundations follow a methodology that is consistent with the methodology used for the standard design sliding stability evaluations in DCD Tier 2 Subsection 3.7.2.14. In accordance with SRP 3.8.5, the sliding evaluation is performed for two orthogonal horizontal directions separately using a linear time history analysis approach. In each direction, the phasing between the horizontal shear and vertical seismic forces is considered at each time step to compute the sliding Factor of Safety (FS(t)) in the time domain for different instances of time as the ratio between the base friction resistance and the horizontal driving force. The minimum value obtained during the duration of the site-specific ground motion is adopted as the factor of safety for sliding stability of the foundation.

The lateral resistance force demands on the surrounding subgrade or the shear keys are computed if, at the particular instance of time, the base friction resistance alone is not sufficient to achieve a minimum factor of safety of 1.1 against sliding. The maximum values of the lateral pressure demands that are required to maintain a sliding stability factor of safety of 1.1 are compared with the values of the allowable dynamic lateral bearing pressures of the subgrade to demonstrate that the subgrade has the required lateral capacity to resist the sliding of the foundation.

Appendix 3G is being revised to provide information regarding the methodology and results of the stability evaluations for the Seismic Category I structures.

(c) Site-Specific Static Coefficient of Friction and Shear Friction Reinforcement

The site-specific evaluations of the sliding stability of Category I foundations use a value of 0.6 for the static coefficient of friction to account for the friction resistance at the critical sliding planes. The value of 0.6 for the base friction coefficient is the lowest of the site-specific friction coefficient values provided in FSAR Table 2.5.4-208 for the concrete fill, in-situ Zone III rock and Zone III-IV rock. FSAR Table 2.5.4-208 specifies a value of 0.7 for the coefficient of friction of the concrete fill. In the same table, the values of the coefficient of friction for NA3 Zone III rock and Zone III-IV rock are specified at 0.6 and 0.65, respectively. For simplicity, the site-specific sliding stability evaluations use a conservative value of 0.6 for the coefficient of friction representing the frictional resistance at all critical sliding plane interfaces. The value of 0.6 is less than the value used in the DCD and in the R-COLA. A coefficient of friction value of 0.7 was used in the standard design sliding evaluations, as described in DCD Section 3.8.6.5, and in the R-COLA stability evaluations for the RB/FB and CB (See ADAMS Accession Number ML13360A177).

Due to the high stiffness of the surrounding concrete fill and Zone III rock, small deformations are needed to engage the required lateral resistance of the concrete fill/rock strata or the FWSC shear keys with no relative motion occurring at the sliding plane interfaces. As shown in Part (e) of this RAI response, the seismic response of the Seismic Category I structures to the NA3 high frequency motion is characterized with only very small deformations of the subgrade. Therefore, the use of a static friction coefficient of 0.6 for the calculation of the resistance force at the critical sliding plane interfaces is appropriate.

The construction of the mass concrete fill below the FWSC is governed by ACI 207.1R (Reference 7). ACI 207.1R sets the requirements for joint placement, including heights of lifts, time intervals between lifts and proper preparation of construction joints before placing fresh concrete upon the construction joint surfaces. Per Section 3.8 of ACI 207.1R, utilizing the shear strength relationship, the shear resistance of the concrete fill is higher than the equivalent friction resistance corresponding to coefficient of friction of 0.6. Additionally, Section 3.8 of ACI 207.1R states that "If no tests are conducted, the coefficient of internal friction can be taken at 1.0 and the cohesion as 0, for unbonded joints." Therefore, shear-friction reinforcement is not required to achieve the coefficient of friction of 0.6.

(d) Required Lateral Resisting Forces

The detailed description and magnitude of the lateral resisting forces required for the sliding stability of the RB/FB, CB and FWSC at NA3 site are presented in Section 5.0 of References 1, 2 and 3. As described in these technical reports, in addition to the friction resistance along the critical sliding planes, the sliding stability evaluations also consider the lateral resistance provided by the surrounding subgrade and FWSC shear keys. The sliding stability of the RB/FB and CB is ensured by the lateral passive pressures developed along the embedded exterior wall and basemat opposite to the direction of motion. The FWSC shear keys provide the lateral resistance required to ensure the stability of the FWSC foundation against sliding along the sliding plane located at the bottom of the FWSC basemat. The lateral passive pressure resistance developed along the vertical planes of the concrete fill blocks supporting the FWSC and CB basemats opposite to the direction of motion are also considered for the evaluations of the global sliding stability of these two Seismic Category I structures.

The following resistances are conservatively neglected in the sliding stability calculations, as applicable to each structure:

- Lateral passive resistance pressure from structural fill and in-situ saprolite located above the Zone III rock
- Lateral resistance provided by the RB/FB shear keys
- Skin friction resistance force provided by the vertical surfaces of embedded exterior walls and/or basemat sides parallel to the direction of motion
- Skin friction resistance force provided by the FWSC shear key vertical sides parallel to the direction of motion
- Pull-out resistance of the FWSC shear keys that contributes to the base friction resistance by resisting the upward forces that reduce the friction of the sliding plane located at the bottom of the concrete fill

The magnitude of the seismic driving forces and the lateral resistance forces ensuring the sliding stability of the RB/FB, CB and FWSC at critical instances of time are provided in Section 5.0 of References 1, 2 and 3, respectively.

(e) Allowable Bearing Pressures of Surrounding Material and Lateral Deformations

The site-specific parameters of the RB/FB, CB and FWSC, including allowable lateral and dynamic bearing pressures of the surrounding subgrade, are provided in Table 3-1 of References 1, 2 and 3.

The lateral passive pressure resistance provided by the subgrade surrounding the RB/FB and CB is calculated for the instance of time when the maximum

lateral resistance force (Fr) is required for achieving the Factor of Safety against sliding of 1.1. The maximum value of the lateral passive pressure is calculated by assuming that the lateral resistance against sliding is provided only by the concrete fill and the Zone III rock. The lateral resistance provided by the softer structural fill and in-situ saprolite located above the Zone III rock is conservatively neglected. A triangular lateral passive pressure distribution is assumed along the depth of the concrete fill and Zone III rock embedment to conservatively calculate the maximum lateral passive pressure on the surrounding subgrade required for sliding stability of the RB/FB and CB.

The site-specific evaluations in Section 5.0 of Reference 1 yield a value of 1.14 MPa (23.8 ksf) for the maximum lateral passive resistance pressure at the bottom of the basemat that is required to ensure the RB/FB stability against sliding with a minimum Factor of Safety of 1.1. This value of the site-specific lateral passive pressure demand is below the allowable dynamic lateral bearing pressure of 1.57 MPa (32.8 ksf) of the NA3 Zone III rock at the RB/FB basemat bottom elevation 224.4 ft NAVD88 (standard design elevation of -15.5 m). Section 7 of Reference 1 provides comparisons of the site-specific lateral load demands on the RB/FB below grade walls with the corresponding lateral loads used for the standard design of the RB/FB structures. The maximum lateral load demands presented in Reference 1 are used as input for the site-specific evaluations of the RB/FB structures to demonstrate that the capacities of the RB/FB below-grade exterior walls are sufficient to resist the NA3 site-specific lateral pressure demands.

The site-specific evaluations in Section 5.0 of Reference 2 yield the following values of the maximum lateral passive resistance pressure required for the sliding stability of the CB:

- 1.17 MPa (24.4 ksf) for the passive pressure at the bottom of the CB basemat, which is lower than the allowable dynamic lateral bearing pressure of 1.39 MPa (29.0 ksf) of the NA3 Zone III rock at the CB basemat bottom elevation 241 ft NAVD88 (standard design elevation of -10.4 m)

- 0.74 MPa (15.4 ksf) for the passive pressure at the bottom of the concrete fill supporting the CB basemat, which is lower than the allowable dynamic lateral bearing pressure of 1.47 MPa (30.7 ksf) of the NA3 Zone III rock at the concrete fill bottom elevation 225 ft NAVD88 (standard design elevation of -15.31 m).

Section 7 of Reference 2 provides comparisons of the site-specific lateral load demands on the CB below grade walls with the corresponding lateral loads used for the standard design of the CB structure. The maximum lateral load demands presented in Reference 2 are used as input for the site-specific evaluations of the

CB structure to demonstrate that the capacities of the CB below-grade exterior walls are sufficient to resist the NA3 site-specific lateral pressure demands.

Section 5.1 of Reference 3 presents the site-specific evaluations of the sliding stability of the FWSC with respect to the critical sliding plane located at the bottom of the FWSC basemat at elevation 282 ft NAVD88 (standard design elevation of 2.15 m). These site-specific sliding stability calculations provide the lateral load demands on the FWSC shear keys at the NA3 site. The maximum site-specific lateral force demands on the FWSC shear keys in NS and EW direction are 56 MN and 63 MN, respectively. These site-specific lateral force demands exceed the magnitude of lateral seismic loads used for the standard design of FWSC shear keys. The maximum site-specific lateral load demands on the FWSC shear keys calculated are used as input loads for the site-specific evaluation of the FWSC structures to demonstrate that their standard design is adequate for the NA3 site. The site-specific structural evaluation of the FWSC shear keys to resist the site-specific seismic lateral load demands will be completed in December 2015 as part of the site-specific evaluation of the FWSC structures.

The resulting maximum lateral pressure demands from the shear keys to the concrete fill subgrade are calculated for the instance of time when the shear keys are required to provide the maximum lateral resistance force for achieving the factor of safety against sliding of 1.1. The resulting pressure is distributed along the shear key height in a triangular shape to calculate the maximum lateral pressure demand from the shear key on the concrete fill. The maximum lateral pressure demand from the FWSC shear keys on the concrete fill placed below the basemat is 0.87 MPa (18.2 ksf) which is considerably lower than 8.0 MPa (167 ksf) specified in Sections 9.3.5 and 22.5.5 of ACI 318-05 (Reference 8) for concrete fill material with a compressive strength of 2,500 psi.

Section 5.2 of Reference 3 presents the site-specific evaluations of the global sliding stability of the FWSC with respect to the critical sliding plane located at the bottom of the concrete fill supporting the FWSC basemat at elevation 220 ft NAVD88 (standard design elevation of -16.84 m). These calculations provide the maximum passive lateral pressure demands on the subgrade surrounding the FWSC required to maintain a sliding stability safety factor of 1.1. The calculations assume that the lateral resistance against sliding is provided only by the concrete fill and the Zone III rock. The lateral resistance provided by the softer structural fill and in-situ saprolite located above the Zone III rock is conservatively neglected. The lateral resistance pressure is uniformly distributed to the face of concrete fill embedded in the Zone III rock which is an appropriate approximation of the distribution of the lateral pressures on the rock that is supporting 14 m (46 ft.) thick strata of in-situ saprolite. These calculations show that the maximum lateral passive pressure on the subgrade required for the overall sliding stability of the FWSC and supporting concrete fill block is 0.89

MPa (18.6 ksf), which is lower than the allowable dynamic lateral bearing pressure of 1.44 MPa (30.1 ksf) of the NA3 Zone III rock at elevation 220 ft NAVD88 (standard design elevation of -16.84 m).

The results of the site-specific seismic response analyses documented in References, 4, 5 and 6 show that the responses of the Seismic Category I structures to the NA3 high frequency motion are characterized by very small deformations of the subgrade. Table 6.2-2 of Reference 4 and Table 6.2-1 of Reference 5 show that the displacements of the below plant grade portions of the RB/FB and CB relative to the free field motion are very small, less than 2.5 mm. Table 6.2-1 of Reference 6 shows that the maximum horizontal displacement values of the FWSC basemat bottom relative to the free-field motion are very small (approximately 5 mm).

As shown in Section 7.0 of References 1 and 2, the magnitudes of the lateral pressures on the RB/FB and CB below-grade exterior walls associated with these small displacements are similar to the magnitudes of the lateral passive pressures required for the sliding stability of the RB/FB and CB. Therefore, the deformations associated with the passive resistance pressures required for the sliding stability of Seismic Category I structures will also be very small and will not result in relative motion to reduce the friction resistance at the sliding plane interfaces.

(f) Site-Specific Evaluation of Shear Keys

The sliding stability factor of safety of 1.1 of the RB/FB at the NA3 site can be maintained without the shear keys that are part of the standard design of the RB/FB foundation. Consistent with the standard design, shear keys are not required for the site-specific stability of the CB. As discussed in Part (e), the site-specific structural evaluation of the FWSC shear keys to resist the site-specific seismic lateral load demands will be completed in December 2015 as part of the site-specific evaluation of the FWSC structures.

References

1. WG3-U71-ERD-S-0003, "Reactor/Fuel Building Complex Stability Analysis Report"
2. WG3-U73-ERD-S-0003, "Control Building Stability Analysis Report"
3. WG3-U63-ERD-S-0002, "Firewater Service Complex Stability Analysis Report"
4. WG3-U71-ERD-S-0001, "Reactor/Fuel Building Complex Seismic Analysis Report"

5. WG3-U73-ERD-S-0001, "Control Building Seismic Analysis Report"

6. WG3-U63-ERD-S-0001, "Firewater Service Complex Seismic Analysis Report"

7. ACI 207.1R-05: Guide to Mass Concrete

NOTE: References 1 through 6 were submitted separately. Reference 4 was submitted by Dominion letter Serial No. NA3-15-009, dated May 29, 2015. References 1, 3, 5, and 6 were submitted by Dominion letter Serial No. NA3-15-014, dated June 30, 2015. Reference 2 is being submitted by Dominion letter Serial No. NA3-15-019.

Proposed COLA Revision

The changes to FSAR Appendix 3G are included in the FSAR markups submitted with this revised RAI response.

ENCLOSURE 11

Input Data and Output Echo Data Files for the SASSI2010 Program-Modules for FWSC Uncracked Models

(RAI 7520 Q 03.07.01-11)

(DVD)

ENCLOSURE 12

FSAR Markups of Revised Sections

(DVD)

ENCLOSURE 13

GEH Affidavit

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, Patricia L. Campbell, state as follows:

(1) I am the Vice President, Washington Regulatory Affairs, of GE-Hitachi Nuclear Energy Americas LLC (GEH), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 11 of Dominion Letter NA3-15-018, signed by Mark D. Mitchell, Vice President – Generation Construction, Dominion Generation, to the U.S. Nuclear Regulatory Commission Document Control Desk, entitled "Submission of Revised RAI Response and COLA Markup." Enclosure 11 of this submission is in digital format on a computer disk labeled "GEH Proprietary Information," and entitled "Input Data and Output Echo Data Files for the SASSI2010 Program – Modules for FWSC Uncracked Models," which GEH provided to Dominion via secured transmittal WG3-DT-00800. This information relates to the North Anna Unit 3 Combined License Application (COLA), Docket No. 52-017, revised response to NRC Request for Additional Information 03.07.01-11, was requested by the NRC staff in a public meeting held on April 1, 2015, and is provided for NRC use and audit of the information in the conduct of its review of the Dominion COLA.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act (FOIA), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for trade secrets (Exemption 4). The material for which exemption from disclosure is here sought also qualifies under the narrower definition of trade secret, within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, <u>Critical Mass Energy Project v. Nuclear Regulatory Commission</u>, 975 F2d 871 (DC Cir. 1992), and <u>Public Citizen Health Research Group v. FDA</u>, 704 F2d 1280 (DC Cir. 1983).

(4) The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. Some examples of categories of information that fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without license from GEH constitutes a competitive economic advantage over GEH and/or other companies.

b. Information that, if used by a competitor, would reduce their expenditure of resources or improve their competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

c. Information that reveals aspects of past, present, or future GEH customer-funded development plans and programs, that may include potential products of GEH.

d. Information that discloses trade secret and/or potentially patentable subject matter for which it may be desirable to obtain patent protection.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to the NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, not been disclosed publicly, and not been made available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary and/or confidentiality agreements that provide for maintaining the information in confidence. The initial designation of this information as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in the following paragraphs (6) and (7).

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, who is the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or who is the person most likely to be subject to the terms under which it was licensed to GEH.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary and/or confidentiality agreements.

(8) The information identified in paragraph (2) above is classified as proprietary because it contains details of structural and soil interactions analysis methods, models, and techniques developed by GEH for evaluations of Seismic Class I structures that are part of the GEH ESBWR design certification, which is referenced in the North Anna Unit 3 COLA, Docket No. 52-017. Development of these methods, models, techniques, and information and their application for the design, modification, and analyses methodologies of such structures was achieved at a significant cost to GEH. The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply

the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH. The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial. GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 30th day of July 2015.

Patricia L. Campbell

Patricia L. Campbell
Vice President, Washington Regulatory Affairs
GE-Hitachi Nuclear Energy Americas LLC
1299 Pennsylvania Avenue, NW, 9th Floor
Washington, DC 20004
patricial.campbell@ge.com