North Anna 3

North Anna 3 COLA: NRC Briefing: June 2010 S-COLA: Seismic Analysis

July 27,2010

Dominion

Introduction

- Purpose – Provide NRC with overview of:
  - Summary of changes in FSAR Chap 2.5
  - Layout of the US-APWR at North Anna
  - Additional subsurface data collected
  - Methodology used to determine Unit 3 FIRS for the US-APWR
  - Methodology for US-APWR seismic analysis
  - Piping and equipment qualification plans for Unit 3
  - Seismic related departures presented in the S-COLA

Dominion

Summary of FSAR 2.5 Changes

- Incorporated results of supplemental boring campaign
- Moved GMRS control point to top of hard rock
- Increased frequency points used to characterize GMRS
- Moved FIRS development to FSAR 3.7.1
- Deleted information on granular backfill beneath seismic category I structures
- Added and revised slopes
- Moved definition of OBE to FSAR 3.7.1
- Moved dynamic at rest lateral earth pressure to FSAR Appendix 3NN

Dominion

Subsurface Investigation In Support Of the US-APWR

- Layout of US-APWR safety-related structures at North Anna
- Additional subsurface data obtained to provide FIRS for all the safety-related structures
- Location of new borings
  - Location, spacing and depth of new borings conform to RG 1.132 for safety-related structures
- Summary of data obtained from new borings
  - New shear wave data obtained
  - Other data obtained (borehole data & limited lab tests)
  - New data are consistent with data previously obtained

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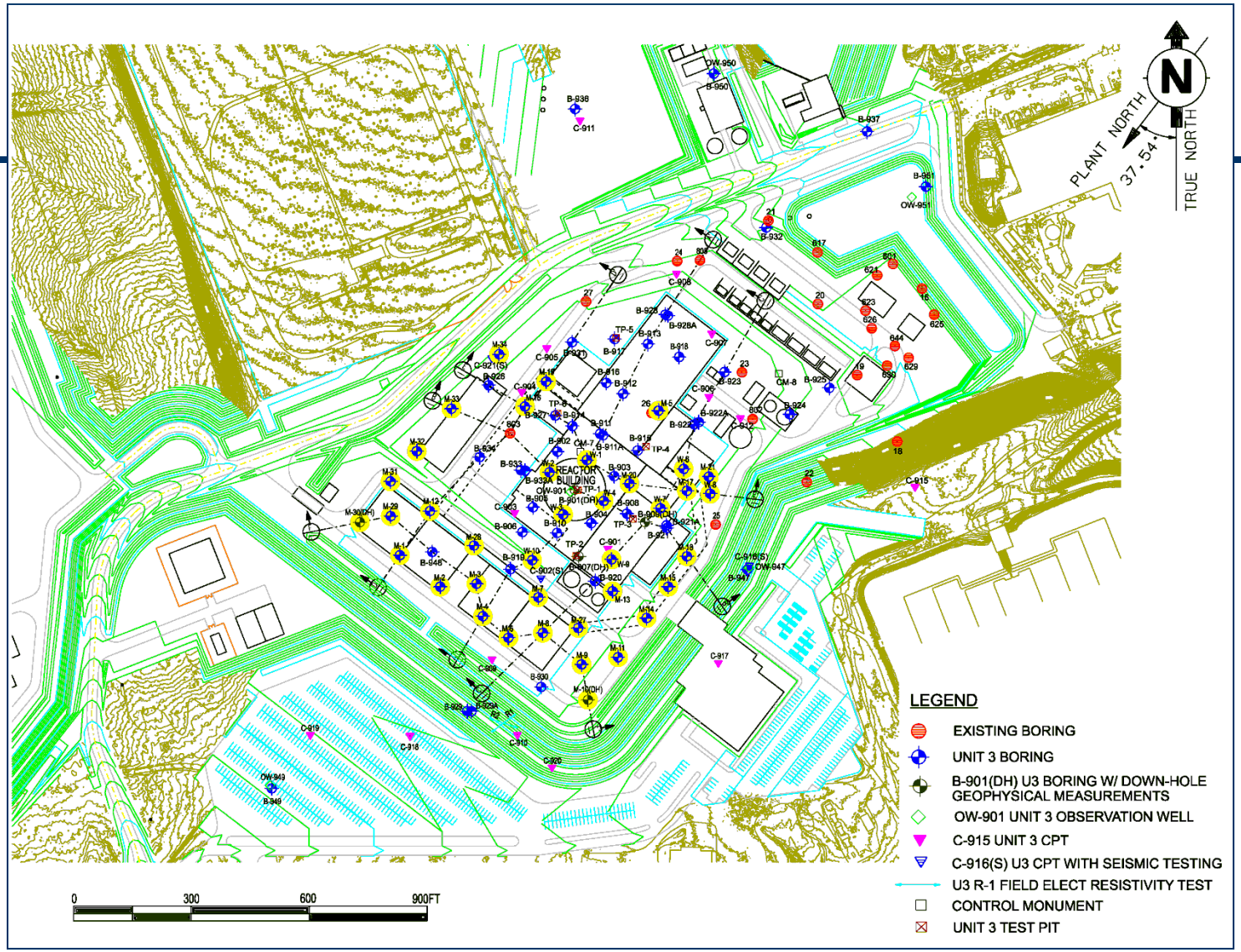
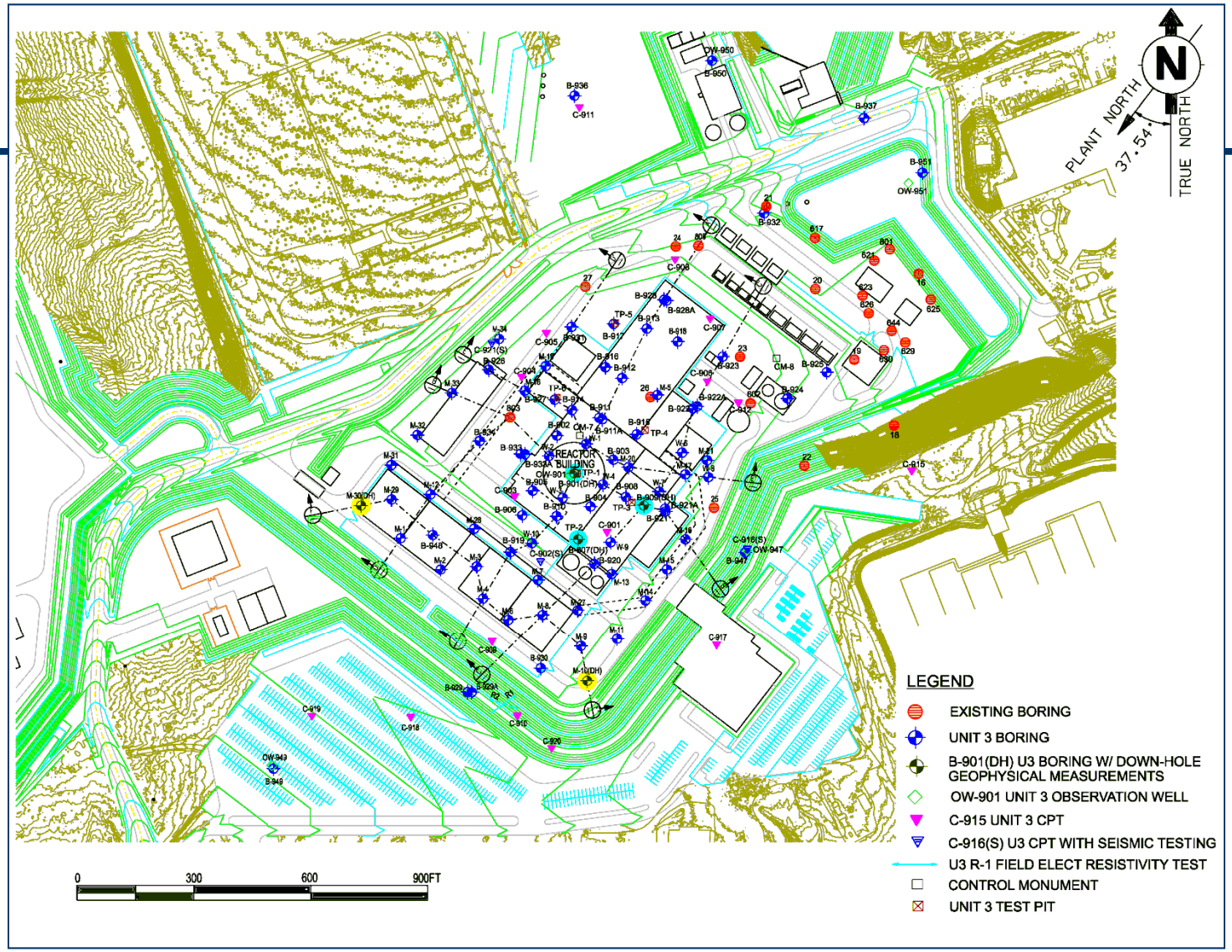
Locations of 38 Supplemental Borings (Yellow)



Locations of 2 Supplemental Geophysical Borings (Yellow)



Development of SSEs, GMRS, and FIRS

Define “SSE” as used in ESPA SSAR

- Two horizons – Hard rock and Top of Zone III-IV

Transition to ESBWR R-COLA

- “Hard rock SSE” motion unchanged.
- Foundation response spectra (“FIRS”) given at bottom of basemats for seismic Category I structures.

Transition to US-APWR S-COLA

- Hard rock motion unchanged => Explicitly “GMRS.”
- “FIRS” at many horizons and in accordance with ISG-017.

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Development of SSEs, GMRS, and FIRS
- Licensing Timeline -

Reg. Guide 1.165	March 1997
NUREG-0800 (2.5.2), Rev. 3	March 1997
NUREG/CR-6728	October 2001
---------- **ESPA** ----------	
ESPA SSAR, Rev. 0	**September 2003**
ASCE 43-05	2005
NRC Final SER ESP, NUREG-1835	September 2005
ESPA SSAR, Rev. 9	**September 2006**
Supplement 1, FSER, NUREG-1835	November 2006
Reg. Guide 1.208	March 2007
NUREG-0800 (2.5.2), Rev. 4	March 2007
North Anna Early Site Permit	**November 2007**
---------- **R-COLA** ----------	
ESBWR R-COLA FSAR, Rev. 1	**December 2008**
NRC COLA SER w/OI	July 2009
ISG-017	March 2010
---------- **S-COLA** ----------	
US-APWR S-COLA FSAR	**June 2010**

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Development of SSEs, GMRS, and FIRS

- All design motions are derived from the ESPA SSAR hard rock “SSE,” which has not changed in any licensing document.
  - No changes in seismic source characterization
  - No changes in attenuation models
  - => No changes in site PSHA
  - => No changes in hard rock “SSE”
- These hard rock motions become the “GMRS” of the US-APWR S-COLA
- Foundation Input Response Spectra (FIRS) vary between the ESBWR R-COLA and US APWR S-COLA, but…
- All are derived from ESPA SSAR hard rock SSE.

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Development of SSEs, GMRS, and FIRS

- Methods used in ESBWR R-COLA FSAR Section 2.5.2 to develop updated Top of Zone III-IV SSE and CB, RB/FB, FWSC foundation response spectra [“FIRS”] are identical to methods used in ESPA SSAR Section 2.5.2 to develop hard rock and Top of Zone III-IV SSEs.

- In the US-APWR S-COLA FSAR the GMRS (hard rock SSE of the ESPA SSAR) is presented in Section 2.5.2 while multiple FIRS are developed in Section 3.7.1 and are developed from the Section 2.5.2 GMRS.

- Some refinements do occur for FIRS development between the ESBWR R-COLA and the US-APWR S-COLA.

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Development of US-APWR S-COLA GMRS & FIRS

- Varying SC I structure horizons and foundations suggested re-defining the FSAR 2.5.2 SSE, now referred to as GMRS, from the Top of III-IV in ESBWR R-COLA to the hard rock horizon for the US-APWR S-COLA:
  - GMRS are defined as equal to the hard rock site-specific SSE of the ESPA SSAR.
  - Hard rock material is defined as having a shear-wave velocity ≥ 9,200 ft/s.
  - Horizontal and vertical GMRS define free-field motion as if it were at ground surface.
  - GMRS horizon is below the excavation depths of any Unit 3 SC I structures.
  - All FIRS and at grade ground motions are developed from, and are consistent with, this definition of the GMRS.
- GMRS are defined in FSAR Section 2.5.2; all FIRS are defined in FSAR Section 3.7.1

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Development of SSI Input Profiles and Motions for Seismic Category I Structures

Building	Foundation Bottom Elevation [ft]	Embedment Depth to Bottom of Foundation [ft]	SSI Analysis Approach
R/B Complex	+251	39	Embedded and surface foundation
PS/B (East & West)	+251	39	Embedded and surface foundation
PSFSV (East & West)	+272	18	Embedded and surface foundation
UHSRS (4 units)	+277	13	Surface foundation
UHSRS Pipe Chase (btw/ UHSRS B & UHSRS C)	+286	4	Embedded foundation
ESWPT (East & West)	+259	31	Underground structure (embedded foundation)

Development of SSI Input Profiles and Motions for Seismic Category I Structures

- Consistent with ESPA SSAR Section 2.5.2 and ESBWR R-COLA FSAR Section 2.5.2, the FIRS at each foundation elevation are developed by propagating the GMRS (hard-rock SSE) through site-specific simulated soil/rock profiles.
- The step-by-step methodology is presented in FSAR Section 3.7.1 for R/B Complex
- Same methodology is employed for PS/B, PSFSV, UHSRS, and ESWPT

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Development of SSI Input Profiles and Motions for Seismic Category I Structures

- Step-by-step Methodology:
  - Soil Profile Simulation
  - Site Response Analysis
  - Horizontal and Vertical FIRS Development
  - SSI Soil Profile Development
  - SSI Input Response Spectra Development
    - NEI Check (ISG-017), Upward Smoothing
    - Minimum Required Spectrum (per 10 CFR 50, App. S) if applicable
  - Time History Generation
    - Outcrop Time-Histories (Matched to SSI Input Response Spectra)
    - In-Column Time-Histories (for SSI Analysis as Embedded)

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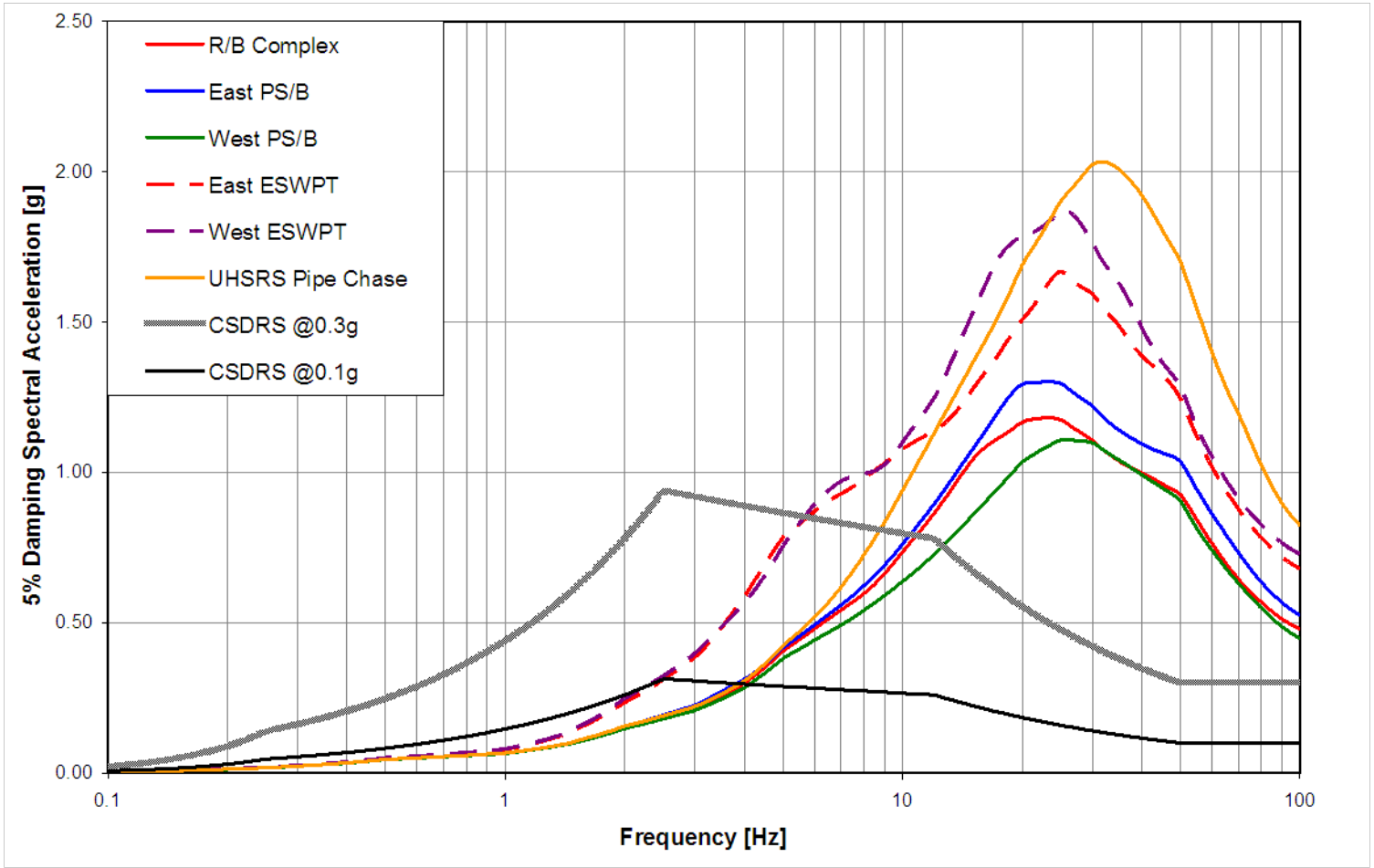
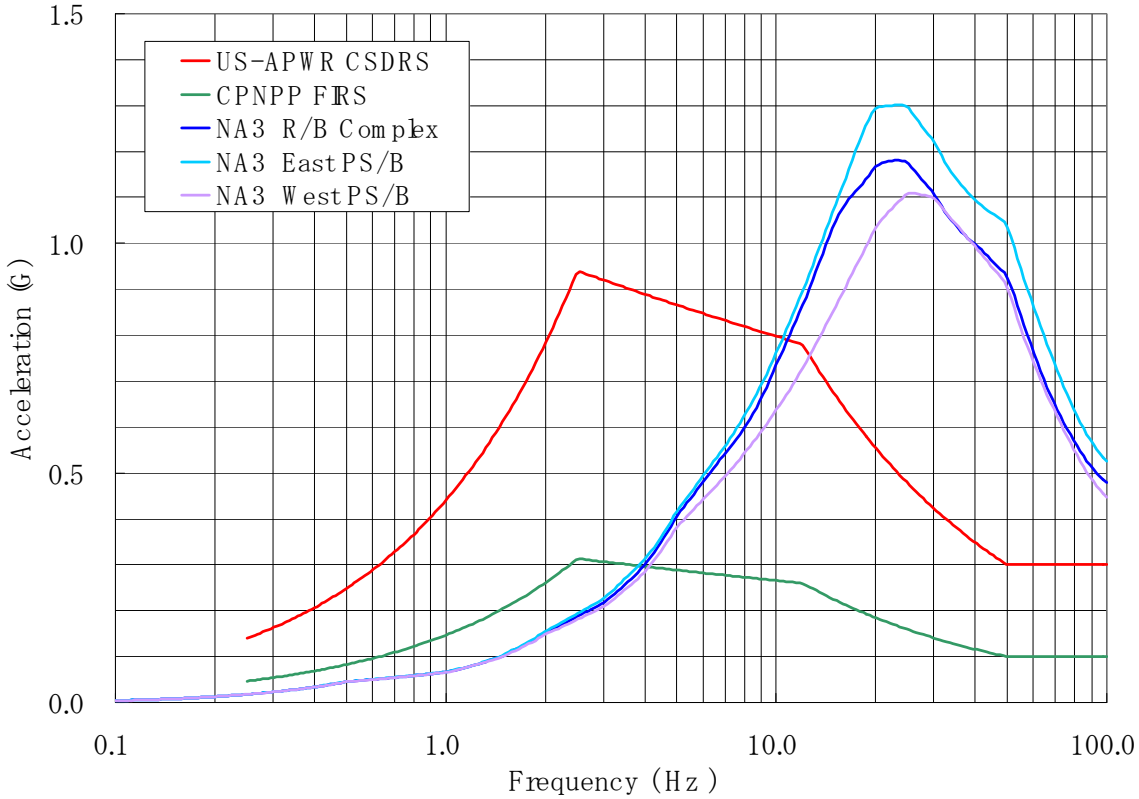
Full Column Outcrop FIRS at Bottom of Basemat – Horizontal



Applicability of US-APWR Standard Design to NAPS Unit 3

- US-APWR CSDRS is enhanced RG 1.60 with PGA of 0.3g.
- CSDRS does not envelope Unit 3 design ground motion response spectra. Structural margins in standard design help meet Unit 3 seismic demands.



Note: Unit 3 FIRS is full column outcrop FIRS

Standard Design Basis

- Comparison of responses obtained from Unit 3 site-specific SSI analyses and revised site-independent SSI analyses serve to demonstrate applicability of standard design for Unit 3
- Technical Reports currently under NRC review:
  - MUAP-10001, Rev. 1 (May 2010) documents revised seismic design basis
  - MUAP-10006, Rev.0 (April 2010) documents results from revised set of site-independent SSI analyses

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Standard Design Basis

- Revised Standard Seismic Design:
  - Standard seismic design is based on site-independent SSI analyses using SASSI Methodology to address effects of: soil layering, foundation flexibility and SSI frequency dependence
  - New set of generic layered soil profiles considered to envelope SSI response at a wide range of potential sites
  - Enhanced structural modeling implemented to capture local high frequency responses and address effects of concrete cracking

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Site-Specific SSI Analyses

- Objectives
  - Demonstrate that site-specific demands are enveloped by standard design seismic loads
  - Demonstrate that site-specific dynamic earth pressures are enveloped by standard design loads
  - Demonstrate that maximum seismic displacements do not result in interaction between adjacent structures
  - Compare site-specific ISRS with standard design ISRS and determine high frequency exceedances

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Site-Specific SSI Analyses

- SSI analyses consider effects of Unit 3 site conditions on seismic response
  - Site subgrade dynamic properties and layering
  - Foundation embedment (input strain compatible soil properties from site response analyses)
  - Ground water table
  - Frequency content and characteristics of site-specific ground motion
  - Incoherency and scattering of input ground motion
  - Part 11 contains site specific seismic analyses of site-specific Seismic Category I structures

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Site-Specific SSI Analyses

Types of site specific SSI analyses

Surface Foundation	Coherent Ground Motion
Embedded Foundation	
Surface Foundation	Incoherent Ground Motion

Site-Specific SSI Analyses

- Incoherency Model
  - 2007 Abrahamson hard-rock plane-wave coherency functions (EPRI TR-102631)
  - Response obtained as mean average of results of 10 stochastic simulations using random field realizations of incoherent free-field motion
  - Stochastic simulations include all incoherent spatial modes

Site-Specific SSI Analyses

- R/B Complex Response
  - Site-specific ground motion has small intensity at frequencies near natural frequencies of R/B complex structures, hence, structural response governed by higher modes of vibration.
  - High frequency content of input ground motion results in smaller displacements and stresses than those considered in standard plant design.
  - ISRS exceedances at high frequencies are reduced due to input ground motion incoherency.

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Site-Specific SSI Analyses

- PS/B Response
  - Response is higher than R/B complex due to higher natural frequency of PS/B structure.
  - High frequency content of input ground motion results in small displacement.
  - Stresses in structural members are enveloped by standard plant design loads.
  - Smaller size of PS/B foundation results in relatively small reduction of ISRS exceedances due to ground motion incoherency.

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Site-Specific SSI Analyses

Structure	Max. Seismic Displacements	
	Site Independent	Unit 3 Site Dependent
Prestressed Concrete Containment Structure	2.10 in.	0.44 in.
Containment Internal Structure	1.57 in.	0.56 in.
Reactor Building	1.50 in.	0.33 in.
Power Source Building	0.41 in.	0.12 in.

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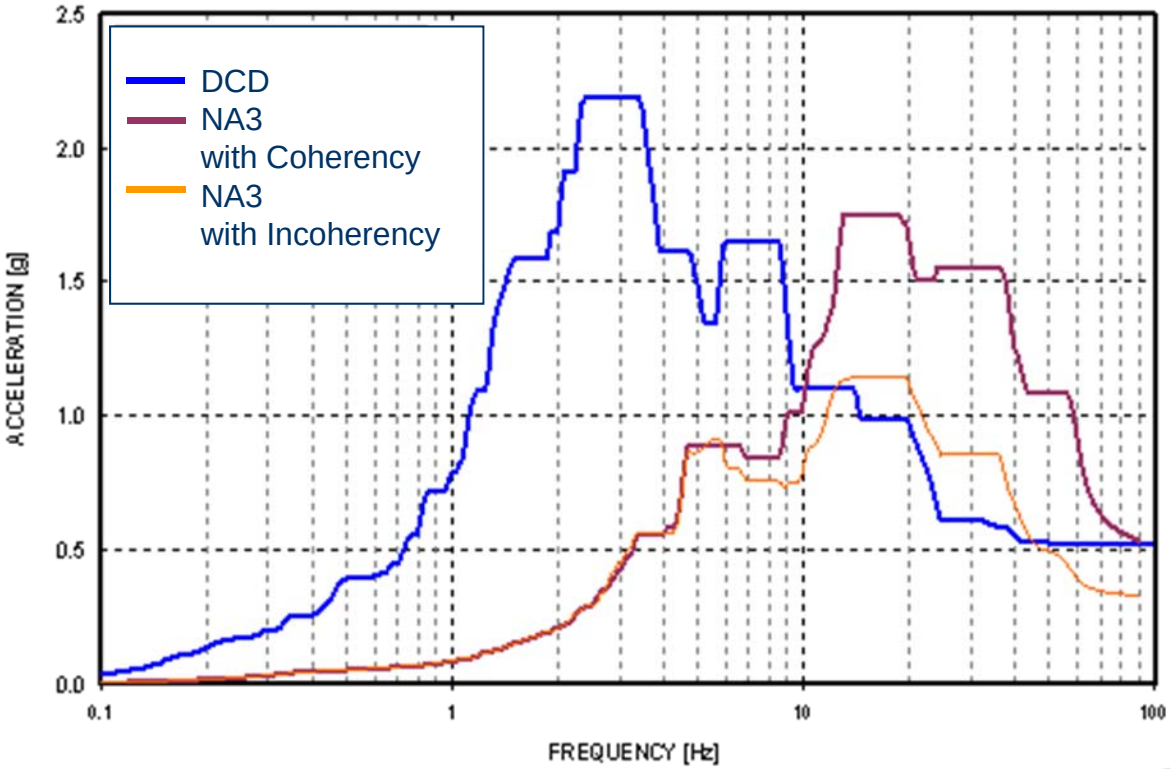
Site-Specific SSI Validation Analyses

Horizontal ISRS at Reactor Vessel Support with 5% Damping



High Frequency Response-Equipment Qualification

Program summarized by Technical Report MUAP-08015(R1)

- Guidance for frequency sensitive components such as relays and other devices that could be affected by high frequency excitation.
- Consistent with NRC DC/COL-ISG-01, “Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined Operating License Applications” May 2008
- Will require screening to identify equipment and components affected by ISRS exceedances and if needed additional testing for seismic qualification.

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Piping Analysis –Risk Significant Systems

- Addressed in Section 3.12 of FSAR
- Stress report for typical risk significant piping systems and components to be prepared in 2010.
  - Seismic input defined by:
    - Standard design site independent ISRS
    - Unit 3 site-specific ISRS
  - Design margins introduced in standard design will meet Unit 3 seismic demands.

S-COLA Seismic Departures

Departure	Impact
DEP 3.7(1) Seismic Site-Specific Spectra High Frequency Exceedance	• Standard design of PS/Bs foundation reinforcement modified to meet Unit 3 site specific seismic demands for sliding stability resistance • Screening of equipment and components for ISRS high frequency exceedances will be performed and additional qualification testing of impacted items will be performed as necessary. • Probabilistic Risk Assessment (PRA) based Seismic Margin Analyses (SMA) in COLA will be performed based on site specific FIRS/GMRS which exceed DCD CSDRS in high frequency.
DEP 3.7(2) Seismic GMRS Approach	• No impact on Seismic Structural Analysis
DEP 3.7(3) Seismic Analysis Method Improvements (MUAP-10001, Rev. 1 and MUAP-10006, Rev. 0)	• Applied new set of generic layered soil profiles • Updated SSI analysis methodology which considers SSI frequency dependence and foundation flexibility • Enhanced structural models with increased number of DOF that consider concrete cracking effects and out-of-plane vibrations of flexible slabs and walls

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Summary and Conclusions

- Containment location for the US-APWR is the same as that of the ESBWR.
- Additional site subsurface information was obtained in accordance with the applicable regulatory guidance and is incorporated in the S-COLA.
- Site seismic analysis approach is fully consistent with ESPA and the methodology of the ESBWR R-COLA.
- Development of seismic inputs follows accepted methodology.
- Standard plant and site-specific structures consider effects of Unit 3 site conditions on seismic response.
- Methodology for structural analysis is in accordance with NRC regulatory requirements and acceptable methods.
- Site-specific SSI performed to demonstrate applicability of design.
- Standard design structural loads and displacements envelope Unit 3 site-specific conditions.
- Piping and component analyses to be prepared in 2010 using standard design site independent and Unit 3 site specific ISRS.

Dominion