North Anna 3

NRC Presentation – North Anna Unit 3 Seismic Analysis

September 28, 2010

Dominion

Purpose of Meeting

- Provide NRC with overview of
  - Layout of the US-APWR at North Anna Unit 3
  - Additional subsurface data collected
  - Unit 3 SSEs, GMRS and FIRS for the US-APWR technology
  - US-APWR seismic analysis and design for Unit 3 including high frequency spectral exceedances

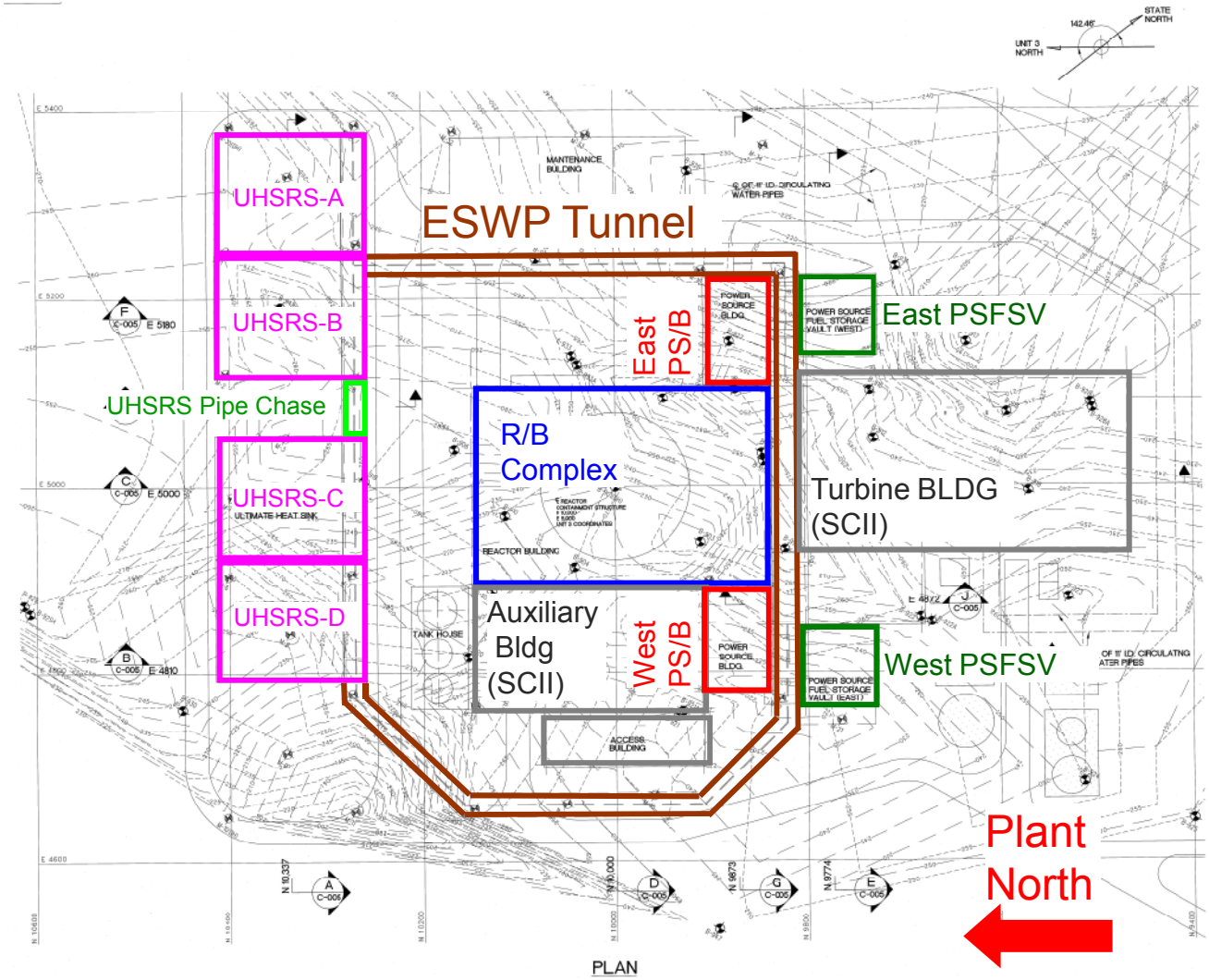
- Provide discussions for topics brought up in July 27th presentation

Dominion

Layout of US-APWR at North Anna

Unit 3 US-APWR
Seismic Category I Structures

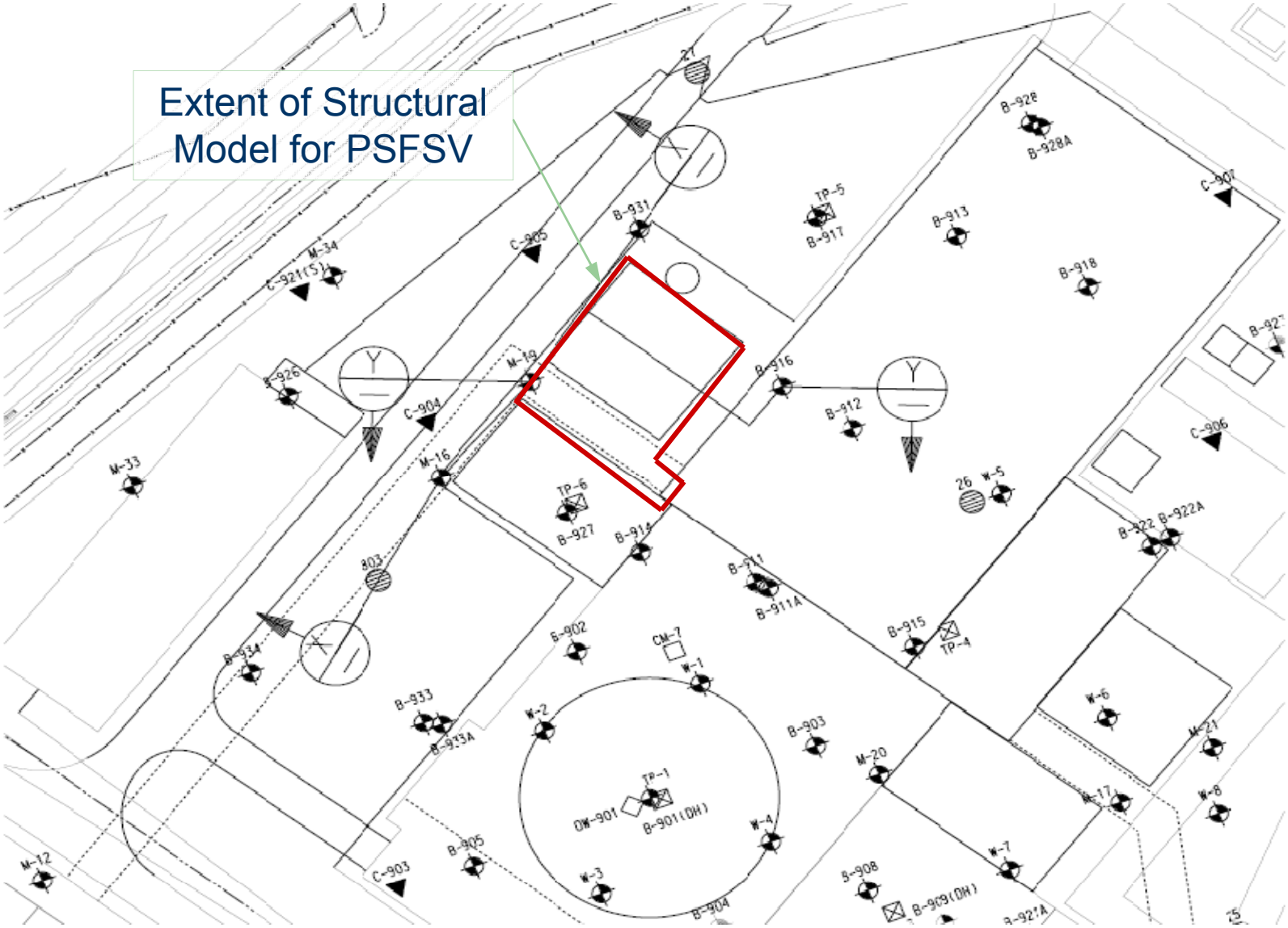
Note that the containment location for the APWR is the same as that of the ESBWR



Subsurface Investigation in Support of US-APWR

- Layout of US-APWR safety-related structures at North Anna
- Additional subsurface data obtained to provide FIRS for all safety-related structures
- Locations of new borings
- 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
- East PSFSV Borings (M-19 and B-931) and RG 1.132
  - M-19 under edge of integral E.PSFSV / ESWPT
  - B-931 is in Zone of Support for the E. PSFSV
  - Boring locations comply with the intent of RG 1.132
  - Response to NRC comment from July 27th meeting

Dominion


Extent of Structural
Model for PSFSV

Supplemental Subsurface Investigation

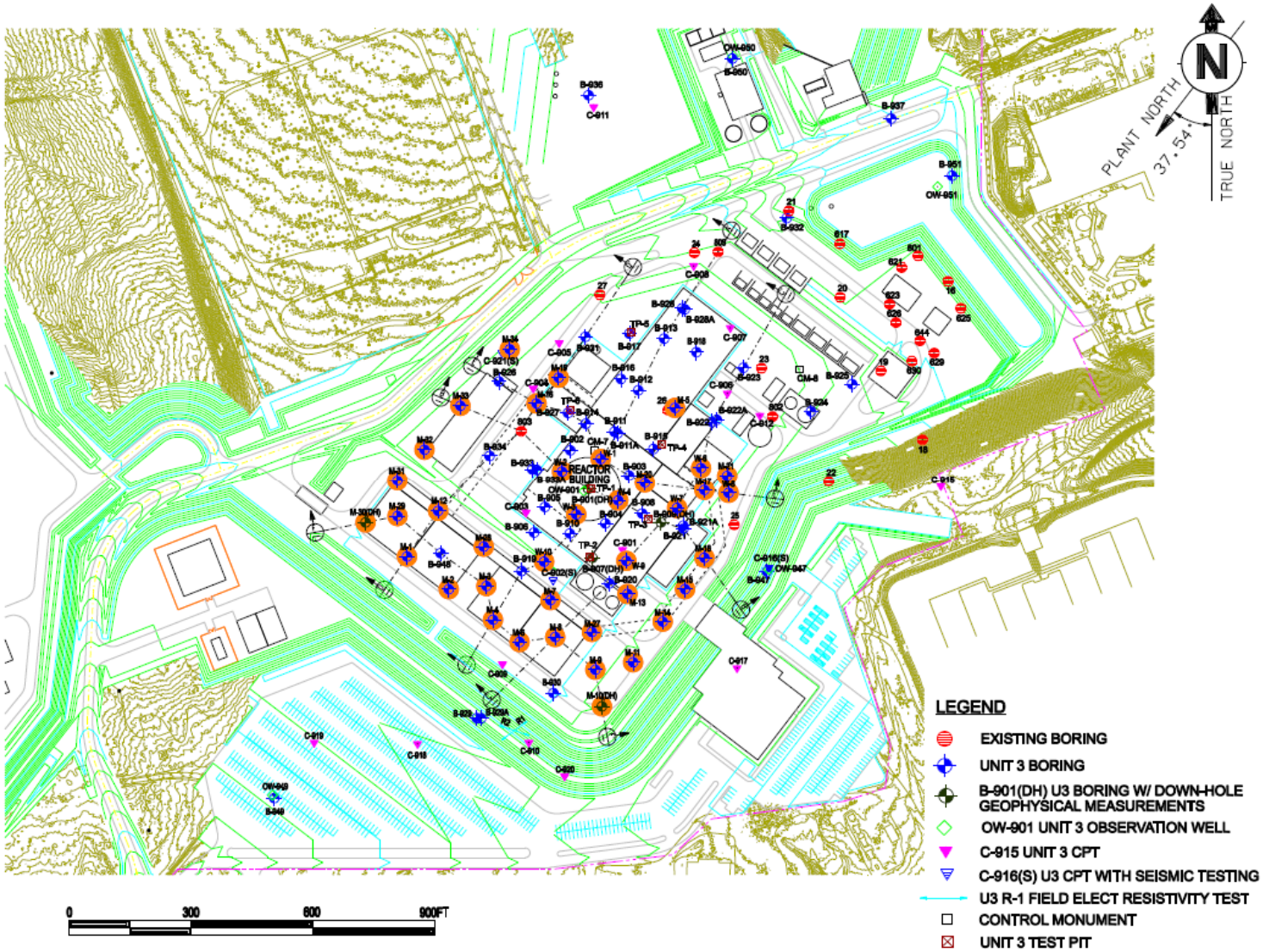
- Field investigation
  - 38 soil & rock core borings (60 ft to 200 ft depth)
  - 2 sets of downhole geophysical tests (200 ft depth with velocity measurements)

- Laboratory tests on soil & rock samples
  - 8 sieve analyses
  - 5 sieve & hydrometer analyses
  - 5 Atterberg limits
  - 10 unconfined compression tests on rock core samples

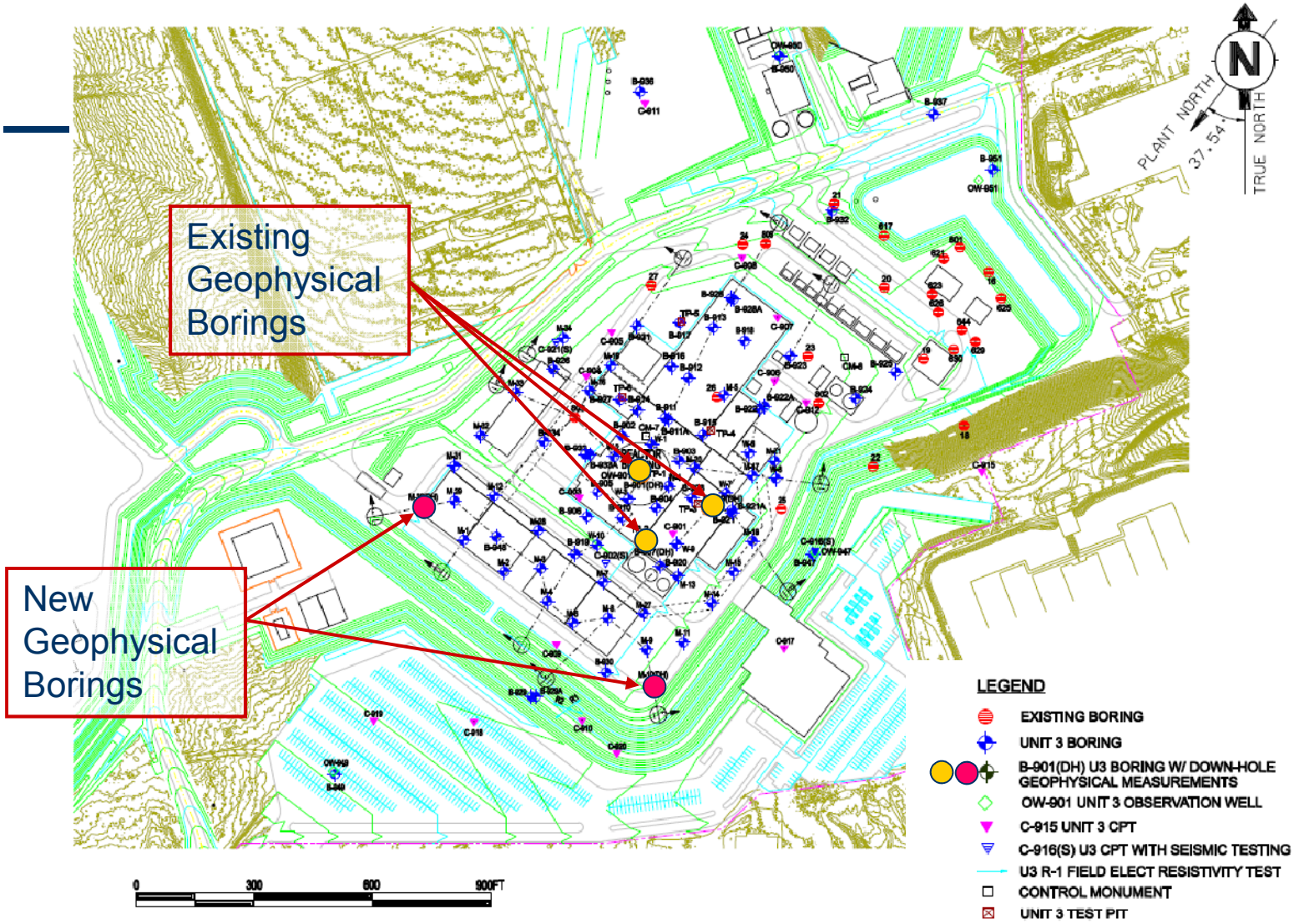
- Supplemental Subsurface Data are contained in FSAR Appendices 2.5.4BB and 2.5.4CC and are discussed in FSAR Section 2.5.4

Dominion

Locations of 38 Supplemental Borings (Highlighted in orange)



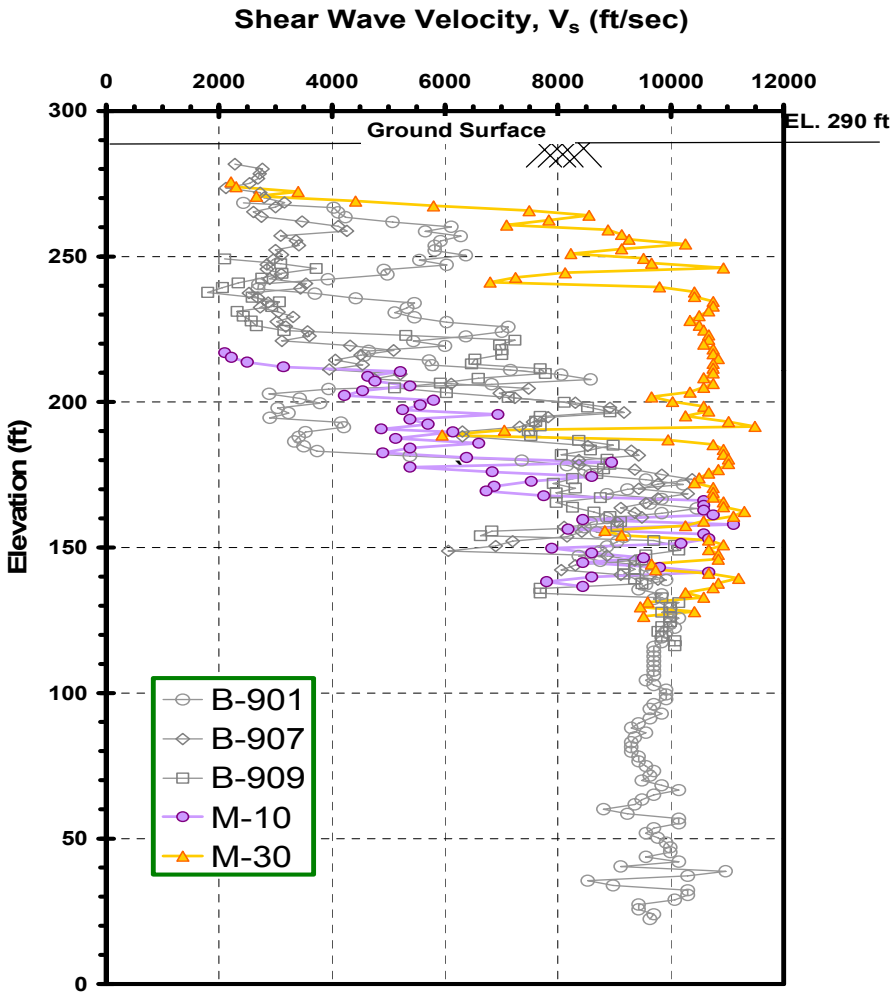
Locations of 2 Supplemental Geophysical Borings



Unit 3 Subsurface Profile

- Subsurface Profile
  - I Residual Clays and Clay Silts
    - Essentially absent at the Unit 3 site
  - IIA Saprolite
    - Residual soil, classified primarily as medium dense silty sand
  - IIB Saprolite
    - Residual soil, mostly dense to very dense silty sand
  - III Weathered Rock
    - Moderately to highly weathered rock (gneiss and schist)
  - IV Sound Rock
    - Slightly weathered to fresh rock (gneiss and schist)
- In addition, Zone III-IV is slightly to moderately weathered rock, frequently forming a transition zone between Zone III and Zone IV

Rock Shear Wave Velocity Measurements



Summary of Supplemental Subsurface Investigation

- Additional data (including velocity measurements) were obtained and included for FIRS development
- Number, spacing, and depth of borings meet the intent of RG 1.132
- New data are consistent with data previously obtained

Dominion

Summary of FSAR 2.5 Changes

- Incorporated results of supplemental boring data
- 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

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

Dominion

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	**June 2010**

Dominion

Development of SSEs, GMRS, and FIRS

- All design motions are derived from 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 "GMRS" of US-APWR S-COLA
- Foundation Input Response Spectra (FIRS) vary between ESBWR R-COLA and US APWR S-COLA, but…
- All are derived from ESPA SSAR hard rock SSE

Dominion

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”] were identical to methods used in ESPA SSAR Section 2.5.2 to develop hard rock and Top of Zone III-IV SSEs
- In US-APWR S-COLA FSAR, GMRS (hard rock SSE of ESPA SSAR) is presented in Section 2.5.2, while multiple FIRS are developed in Section 3.7.1 and are developed from Section 2.5.2 GMRS
- Some refinements do occur for FIRS development between ESBWR R-COLA and US-APWR S-COLA

Dominion

Development of SSEs, GMRS, and FIRS

Refinements used to develop FIRS, consistent with current regulatory direction:

- Site response: ESPA/ESBWR used SHAKE2000 with input time histories; US-APWR used P-SHAKE with input response spectra
- ISG-017: For checks of minimum seismic input requirements at the foundation
- Smoothing process: additional tool implemented as part of ISG-017 check for US-APWR S-COLA

Dominion

Development of ESPA SSAR SSEs

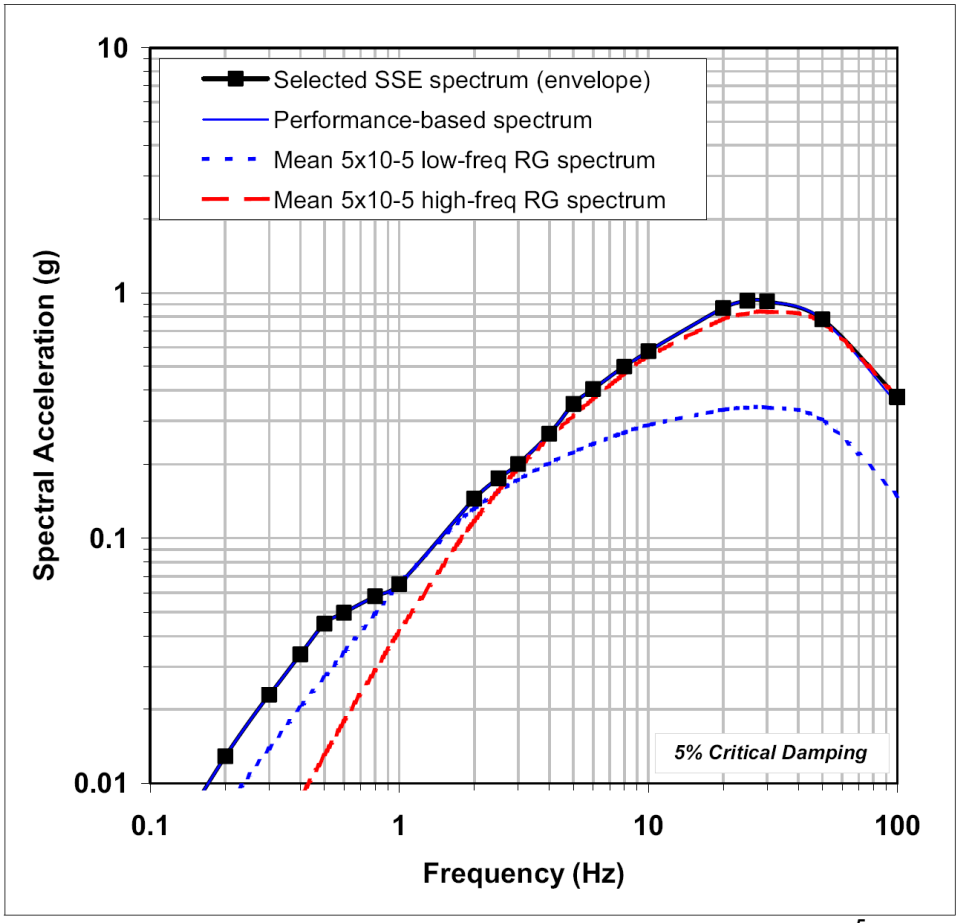
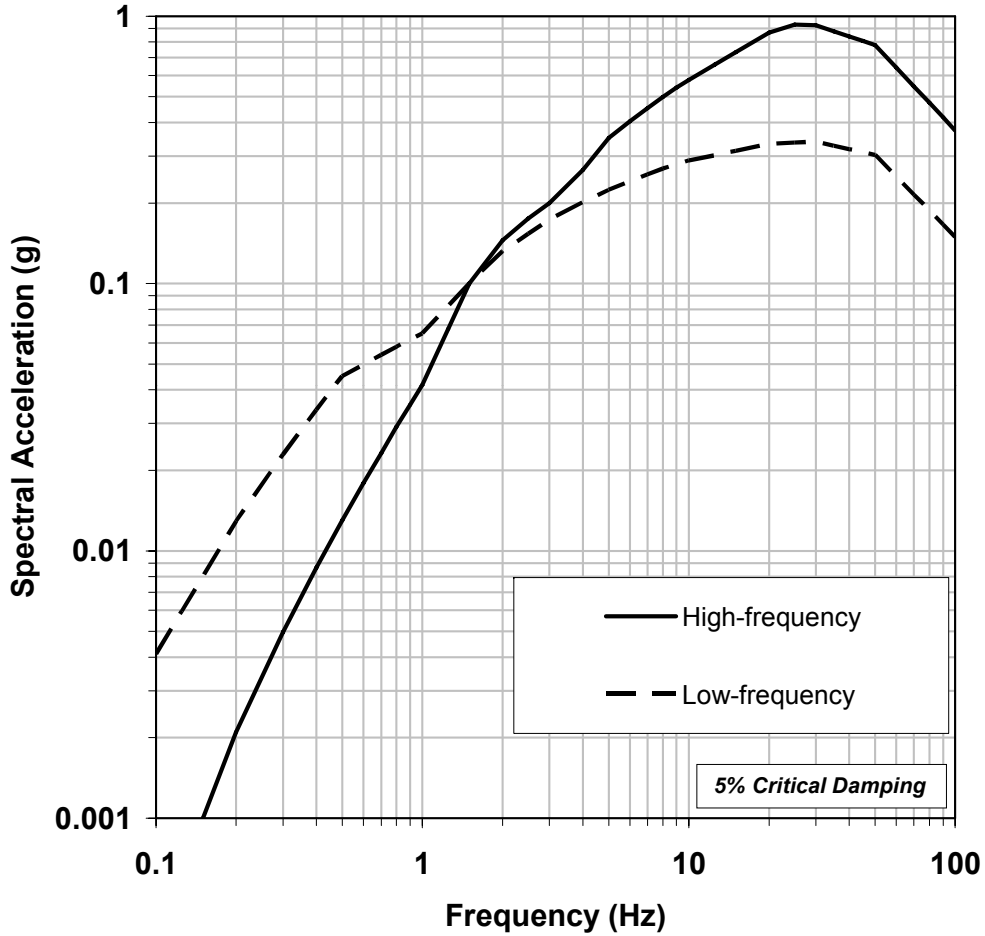


Figure 2.5-54A Comparison of Performance-Based Spectrum, Mean 5×10^{-5} Scaled Spectra, and Selected Hard Rock SSE Spectrum (Which Envelops the Other Three)

Horizontal Hard Rock SSE

Envelope of Modified RG 1.165 Reference Probability Approach and Performance-based Approach

Development of ESPA SSAR SSEs



* Plotted in the S-COLA FSAR 2.5.2

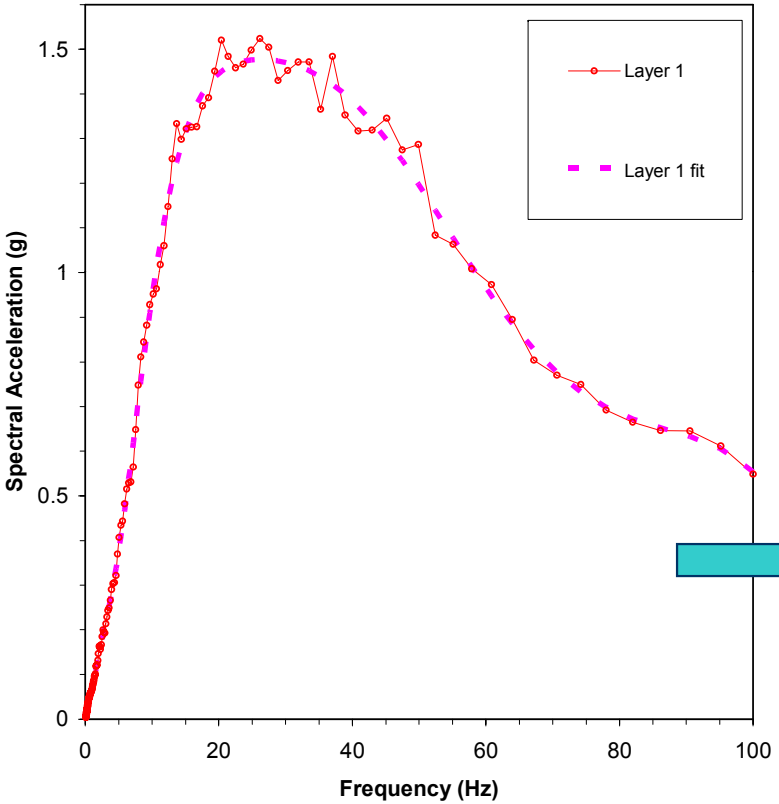
Horizontal Hard Rock SSE

Horizontal response spectrum deaggregated to low- [LF] and high frequency [HF] component response spectra for input to site response analysis.

Envelope gives back Hard Rock SSE.

Definition described* in the ESPA SSAR 2.5.2. Low frequency portion of HF spectrum and high frequency portion of LF spectrum based on RG 1.165 HF & LF spectra.

Development of ESPA SSAR SSEs



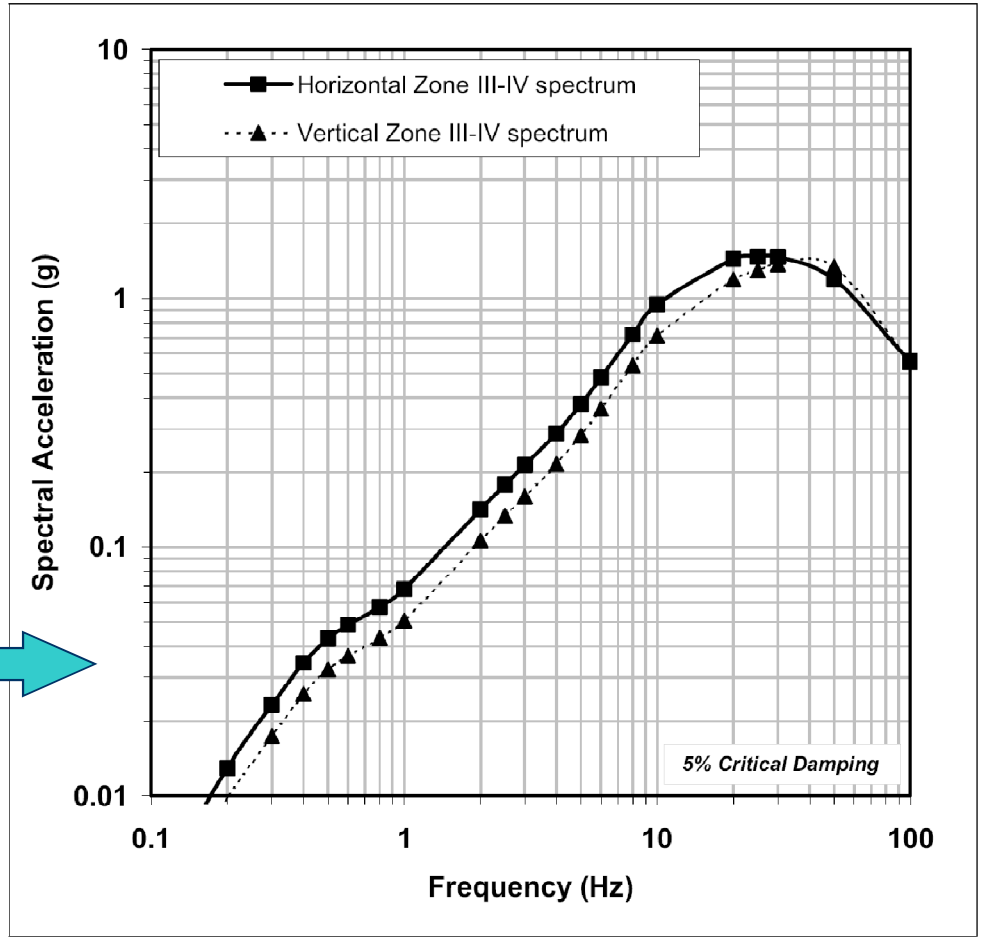


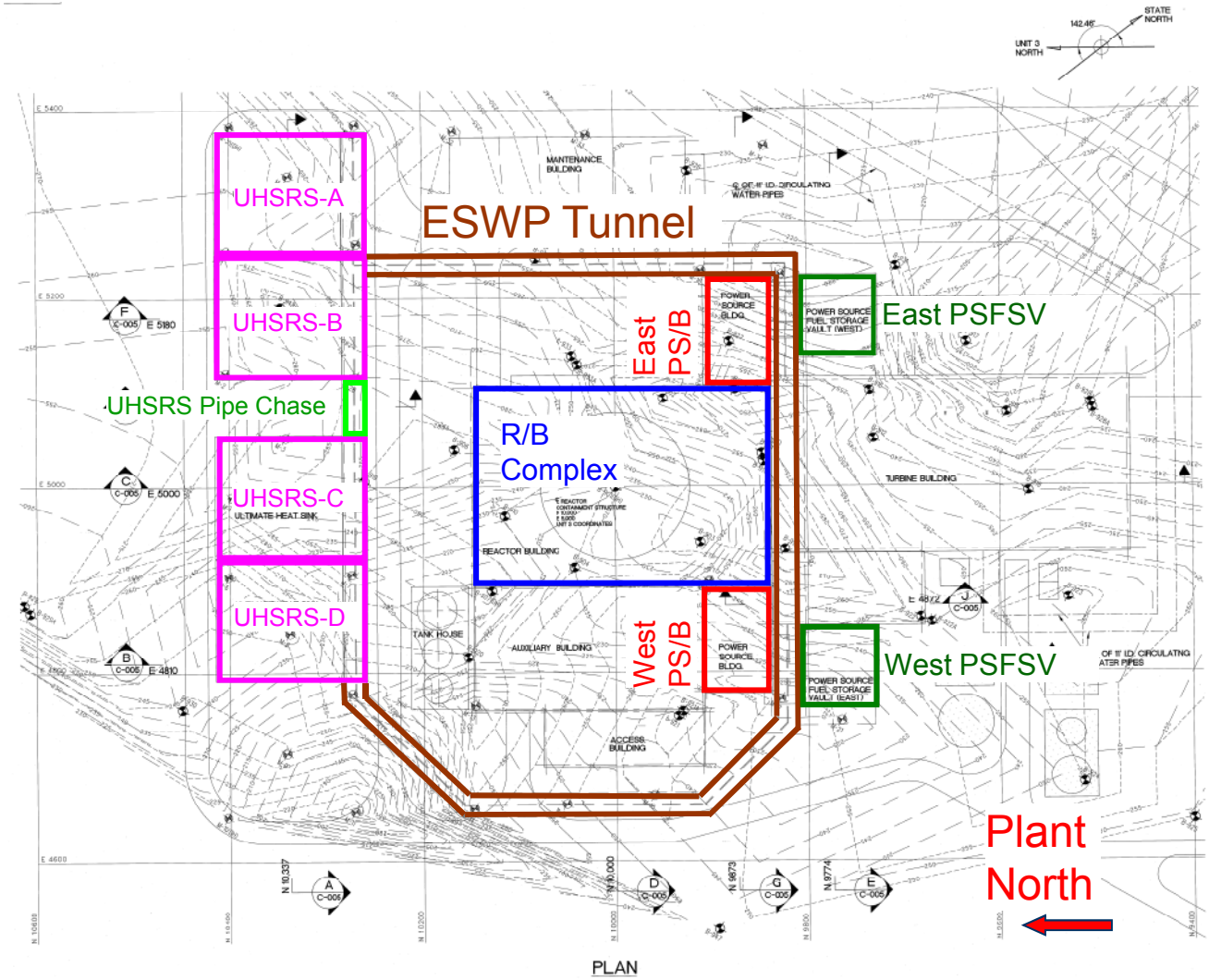
Figure 2.5-48A Selected Horizontal and Vertical Response Spectra for the Hypothetical Rock Outcrop Control Point SSE at the Top of Zone III-IV Material (Representative Elevation 250 ft, 3,300 ft/sec Shear Wave Velocity)

Development of US-APWR S-COLA GMRS & FIRS [Departure 3.7(2)]

- 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 all 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

Dominion

Unit 3 US-APWR
Seismic Category I Structures



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)

Note that finished grade is at Elevation +290 ft

Dominion

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, FIRS at each foundation elevation are developed by propagating the GMRS (hard-rock SSE) through site-specific simulated soil/rock profiles
- 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

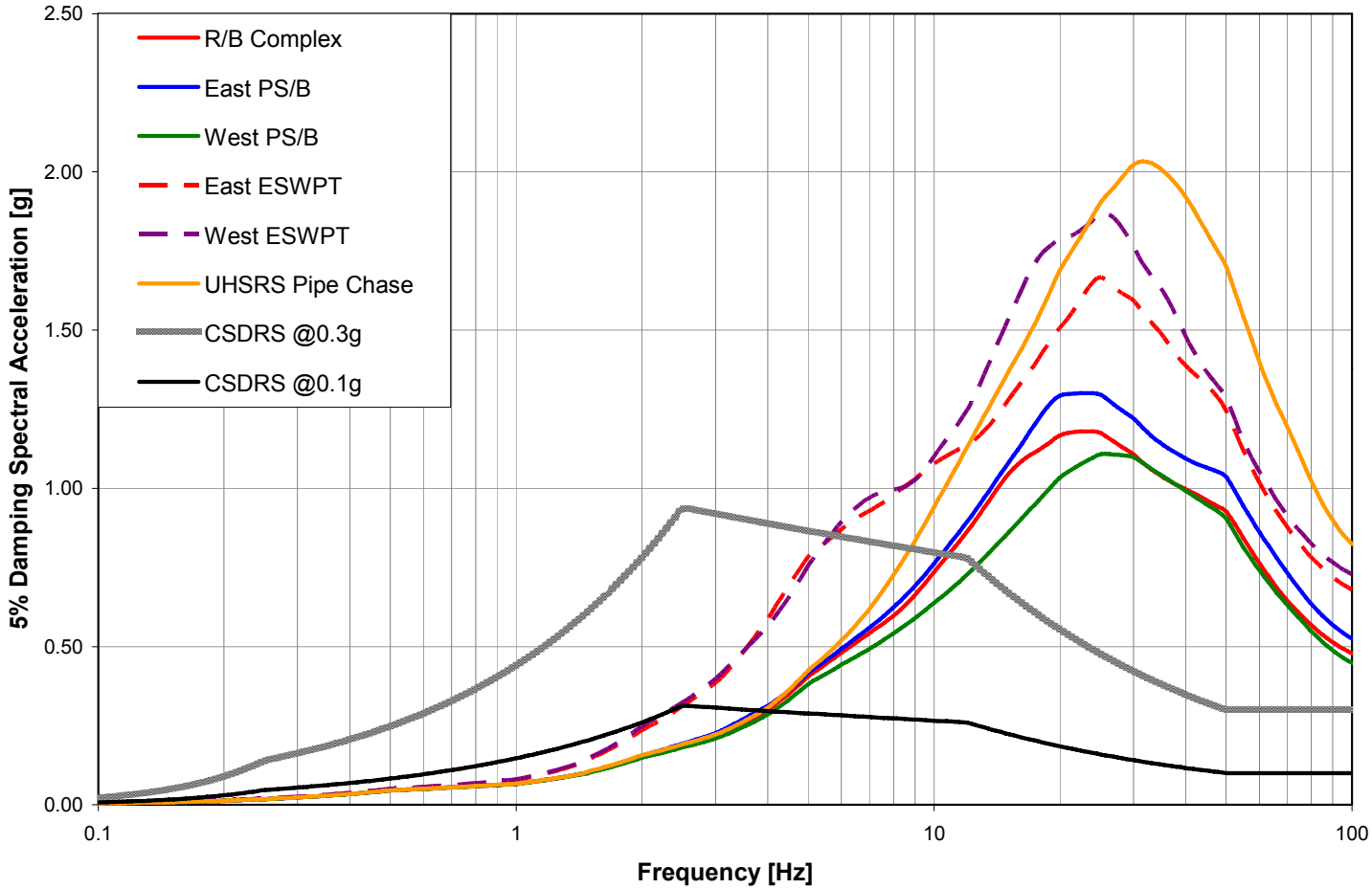
Dominion

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

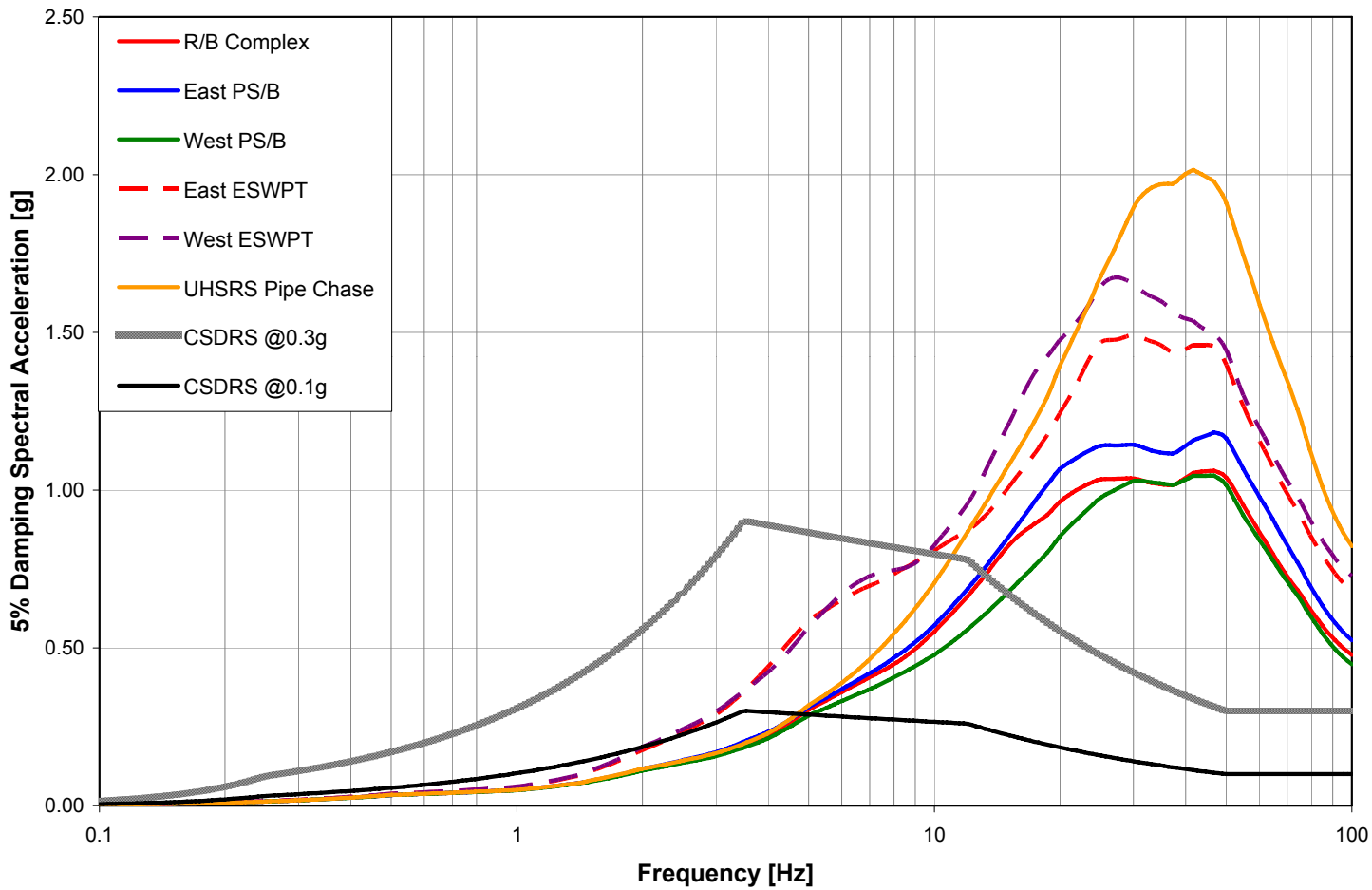
- Step-by-step Methodology:
  - Soil Profile Simulation
  - Site Response Analysis
  - Horizontal and Vertical FIRS Development
  - SSI Soil Profile Development
  - SSI Input Response Spectra Development
    - NEI Check (ISG-017), Upward Smoothing
    - Minimum Required Spectrum (per 10 CFR 50, App.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

Dominion

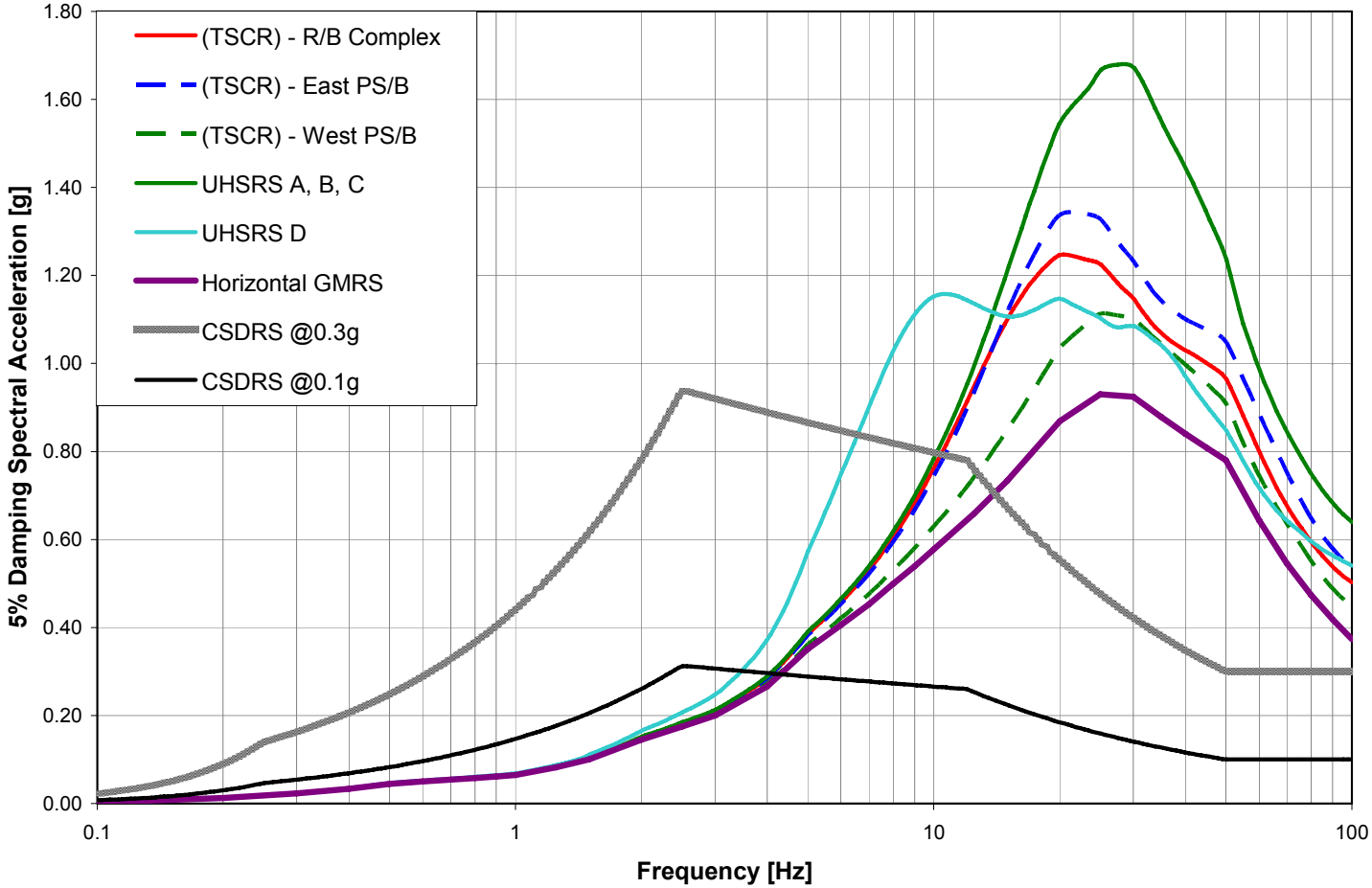
Full Column Outcrop FIRS at Bottom of Basemat – Horizontal



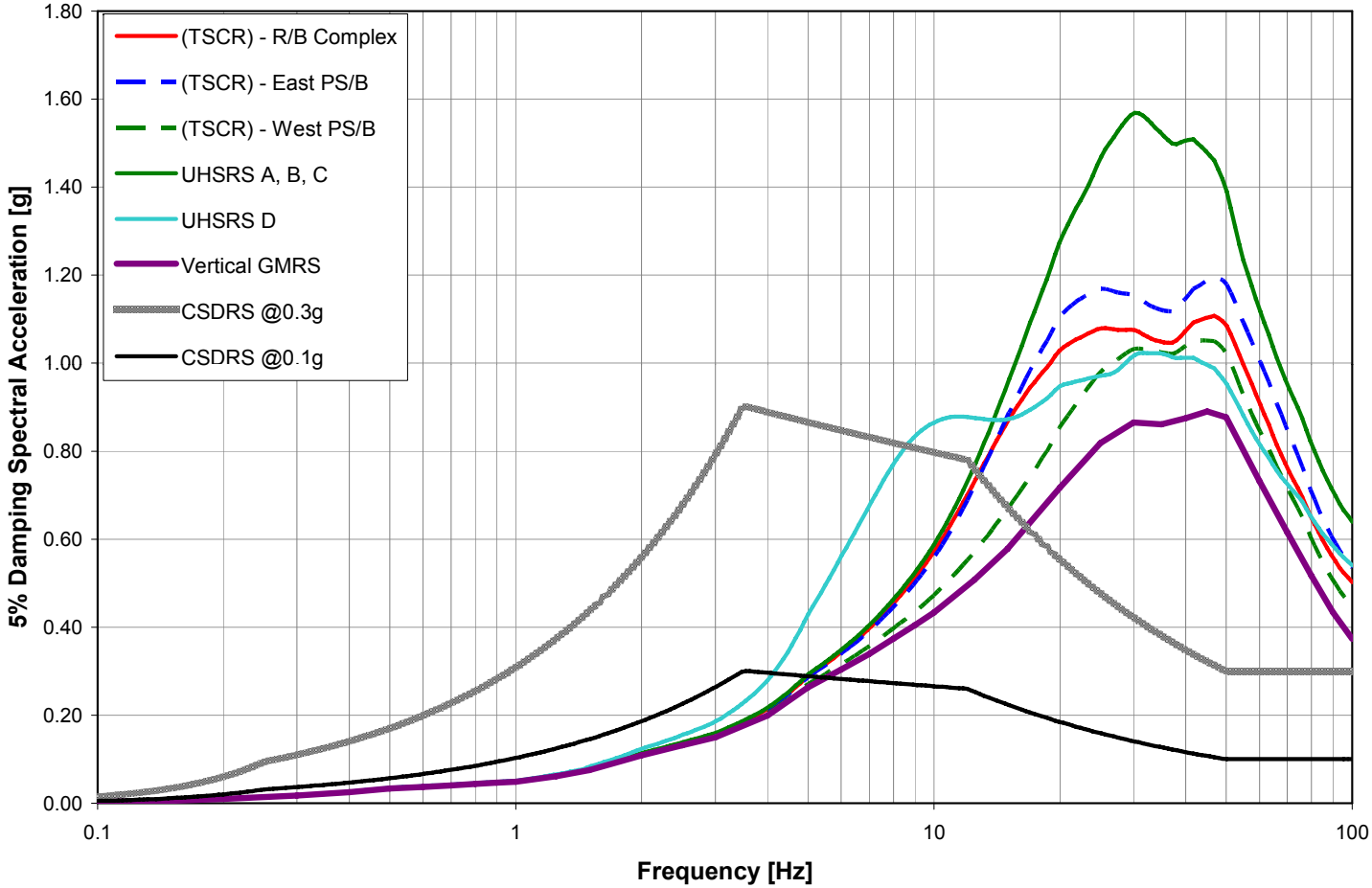
Full Column Outcrop FIRS at Bottom of Basemat – Vertical



Geologic Outcrop FIRS at Bottom of Basemat – Horizontal



Geologic Outcrop FIRS at Bottom of Basemat – Vertical

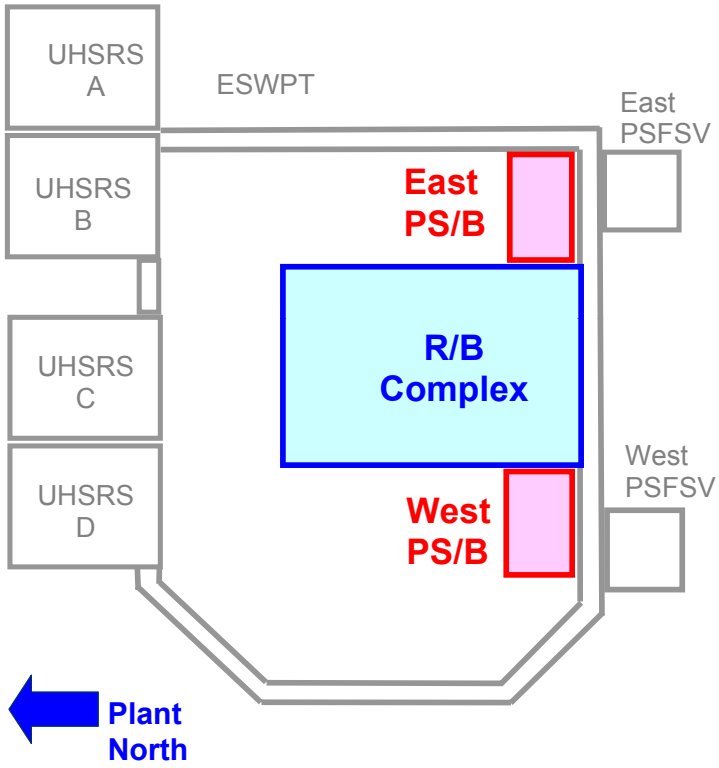


Seismic Design of Unit 3 US-APWR Category I Structures

- Standard Plant Structures (R/B Complex and PS/Bs)
  - Standard Plant Design Basis
  - Site-Specific SSI Analyses
  - Reconciliation of Standard Plant Seismic Design for Unit 3
  - Unit 3 Site Specific ISRS
- Site-Specific Structures (PSFSV, UHSRS and ESWPT)
  - SSI Analyses
  - Basic Design

Dominion

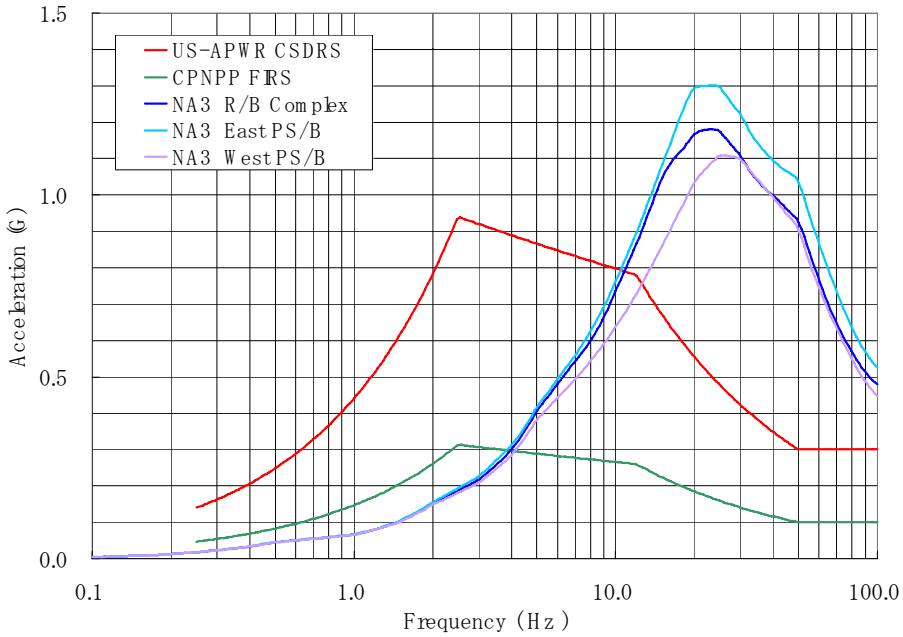
Unit 3 US-APWR Standard Plant Category I Structures



- Unit 3 Seismic Category I Structures included in Standard Plant Seismic Design
  - R/B Complex including PCCV, CIS and R/B with FHA
  - East and West PS/B
- FSAR Appendix 3NN presents reconciliation of Standard Plant Seismic Design for Unit 3 based on results of site-specific SSI analyses

Applicability of US-APWR Standard Design for Unit 3

- US-APWR CSDRS uses enhanced RG 1.60 spectra with PGA of 0.3g
- CSDRS does not envelope Unit 3 design ground motion response spectra S-COLA DEP 3.7(1)
- Applicability of standard plant design for Unit 3 demonstrated based on responses obtained from site-specific SSI analyses



Note: Unit 3 FIRS is full column outcrop FIRS

Updated Standard Plant Design Basis

- Updated seismic design basis documented in technical reports currently under NRC review:
  - MUAP-10001, Rev. 1 (May 2010) documents updated seismic design basis
  - MUAP-10006, Rev.0 (April 2010) documents results from updated set of site-independent SSI analyses
- Comparison of responses obtained from Unit 3 site-specific SSI analyses and updated site-independent SSI analyses serve to reconcile standard plant design for Unit 3
- S-COLA DEP 3.7(3) will be eliminated after updated seismic design basis is incorporated in the next revision of US APWR DCD

Dominion

Updates to Standard Plant Seismic Design Methodology

- Standard plant seismic design is based on site-independent SSI analyses using SASSI methodology to address effects of:
  - soil layering
  - foundation flexibility
  - SSI frequency dependence
- New set of generic layered soil profiles
- Enhanced structural modeling implemented to capture local high frequency responses and address effects of concrete cracking

Dominion

Reconciliation of Standard Plant Seismic Design for Unit 3

Objectives of site-specific SSI analysis:

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

Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

- **Site specific SSI analyses include Unit 3 site characteristics**:
  - Site subgrade dynamic properties and layering
  - Frequency content and characteristics of site-specific ground motion
  - Foundation embedment (input strain compatible soil properties from site response analyses)
  - Ground water table
  - Incoherency and scattering of input ground motion

Dominion

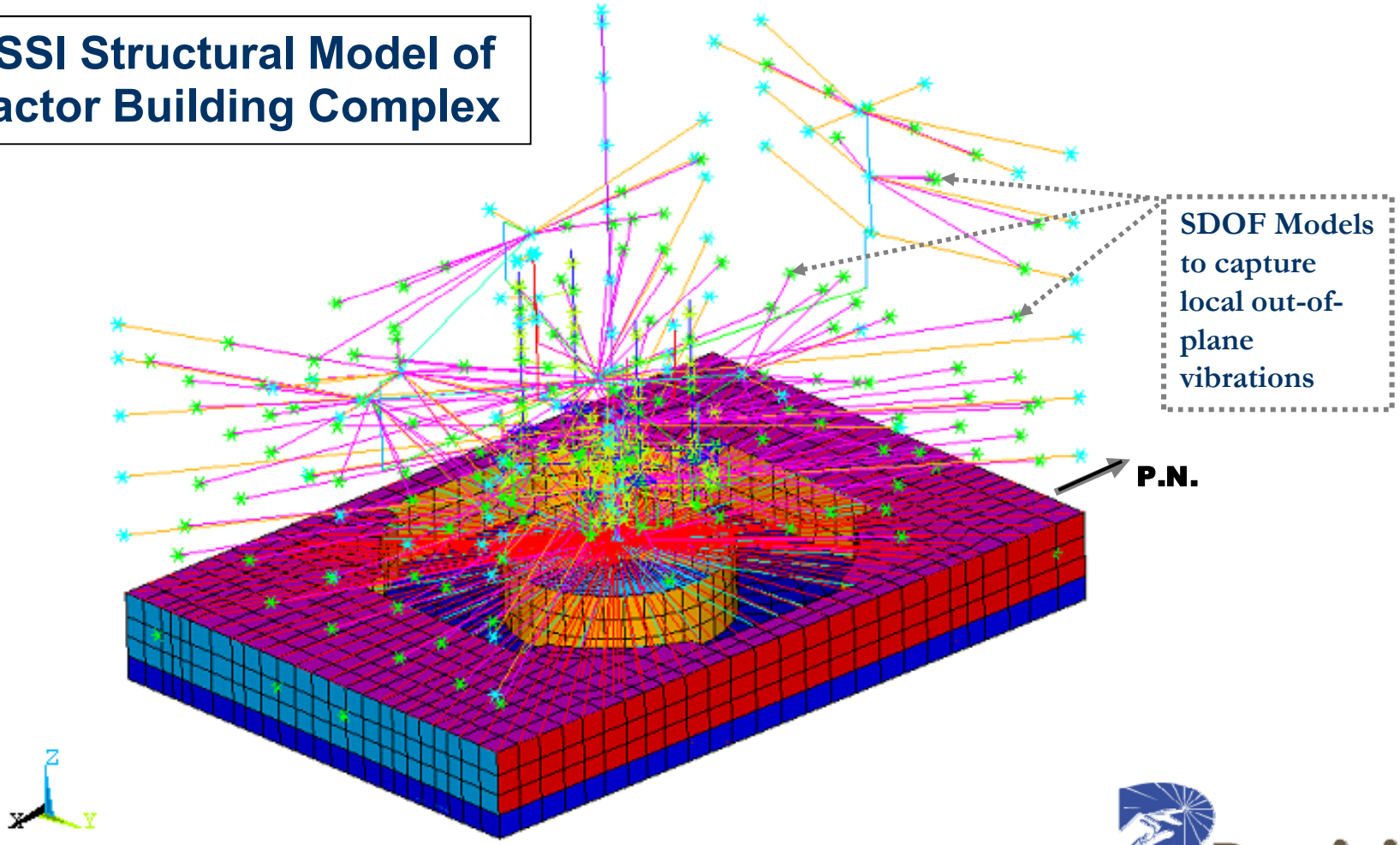
Site-Specific SSI Analyses of Standard Plant Category I Structures

- **Methodology**
  - SASSI structural models of standard plant Category I buildings identical to models used for updated site-independent SSI analyses
  - Site-specific demands (SSE loads and ISRS) are calculated at all locations within the buildings using identical methodology as that used for development of design parameters for standard plant seismic design
  - Methodology used to develop ISRS includes effects of foundation embedment and ground motion incoherency

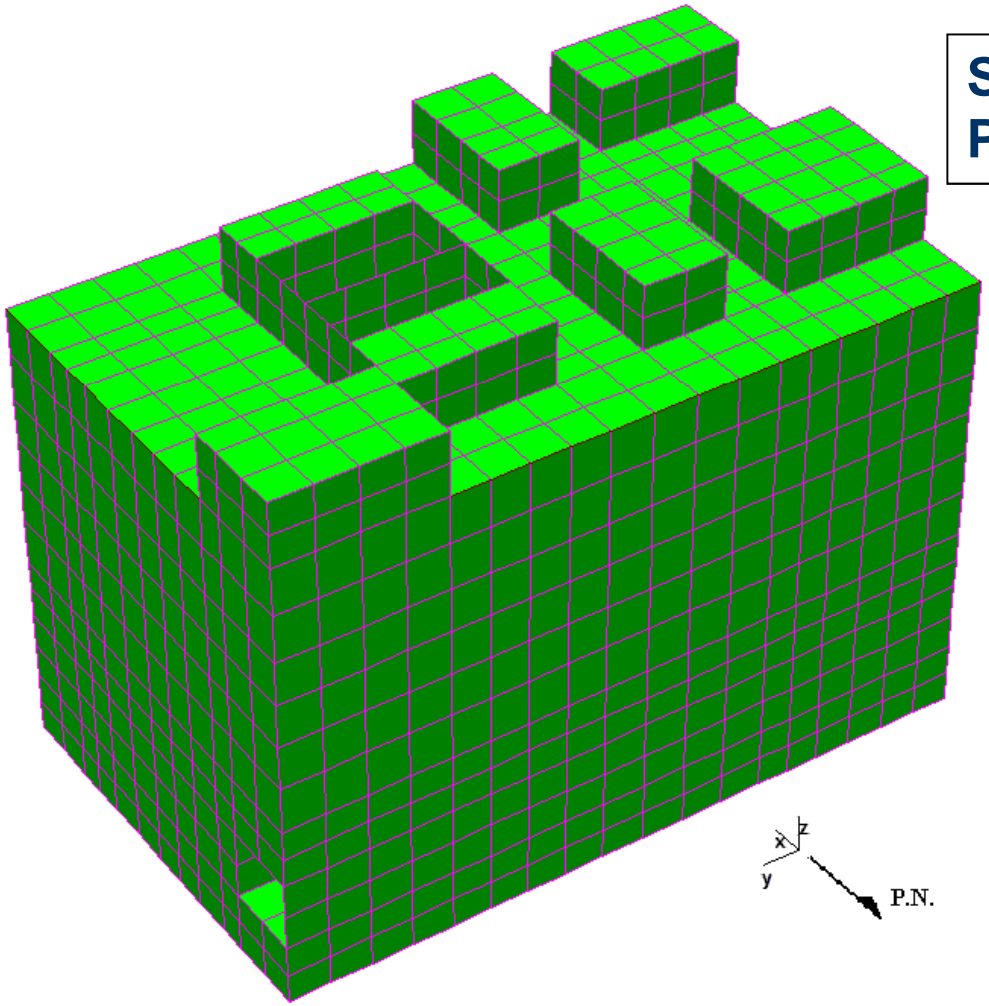
Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

SASSI Structural Model of Reactor Building Complex



Site-Specific SSI Analyses of Standard Plant Category I Structures



SASSI Structural Model of Power Source Building

Site-Specific SSI Analyses of Standard Plant Category I Structures

Types of site specific SSI analyses

Model	Ground Motion	ISRS
Surface Founded	Coherent	Coherent ISRS represent envelope of surface and embedded model responses
Embedded (*)		
Surface Founded	Incoherent	Incoherent ISRS adjusted to include embedment amplifications

(*) Embedded foundation analysis considers basement of building fully embedded and in full contact with soil

Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

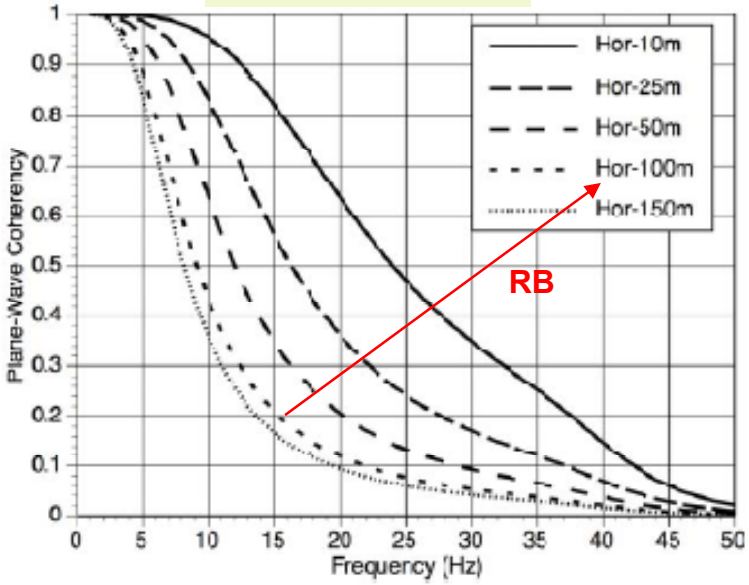
- **Incoherency Model**
  - US NRC ISG-01, May 2008
  - 2007 Abrahamson “hard-rock” plane-wave coherency functions (EPRI TR-1015110, Dec ‘07)
  - Stochastic simulation approach applied to compute incoherent ISRS and incoherent structural forces and moments
  - Responses obtained as mean average of results of 10 stochastic simulations using as input random field realizations of incoherent free-field motion (EPRI TR-1015111, Nov ‘07)

Dominion

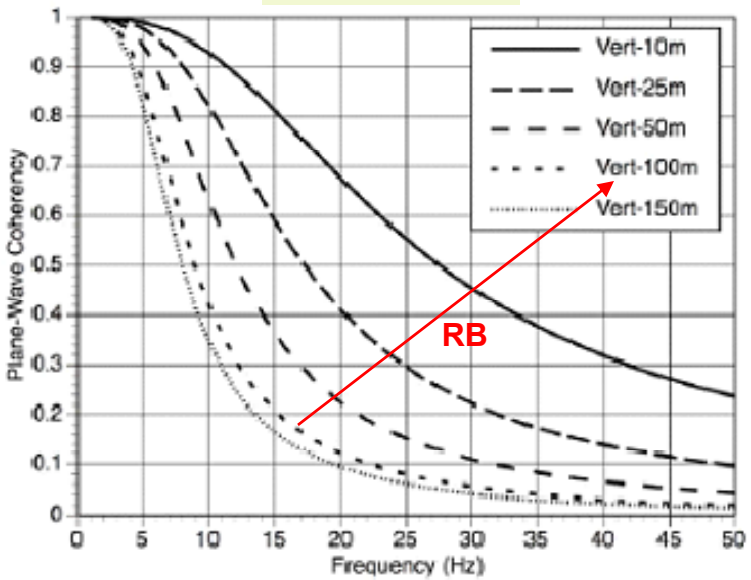
Site-Specific SSI Analyses of Standard Plant Category I Structures

2007 Abrahamson Coherence Functions for Rock Sites

HORIZONTAL



VERTICAL



Site-Specific SSI Analyses of Standard Plant Category I Structures

- **Computation of Incoherent ISRS Using Simulation**
  1. Compute free-field coherency matrix at interaction nodes
  2. Perform spectral factorization of coherency matrix and check its accuracy
  3. Generate random samples of incoherent input motion field using Monte Carlo method
  4. Apply interpolation smoothing to improve complex TF and adjust TF phases to avoid eventual canceling effects
  5. Perform convolution of the complex TFs with input motion FFT
  6. Compute acceleration time histories at selected locations by inverse FFT
  7. Compute ISRS from acceleration time histories for each simulation
  8. Compute mean incoherent ISRS by statistical averaging

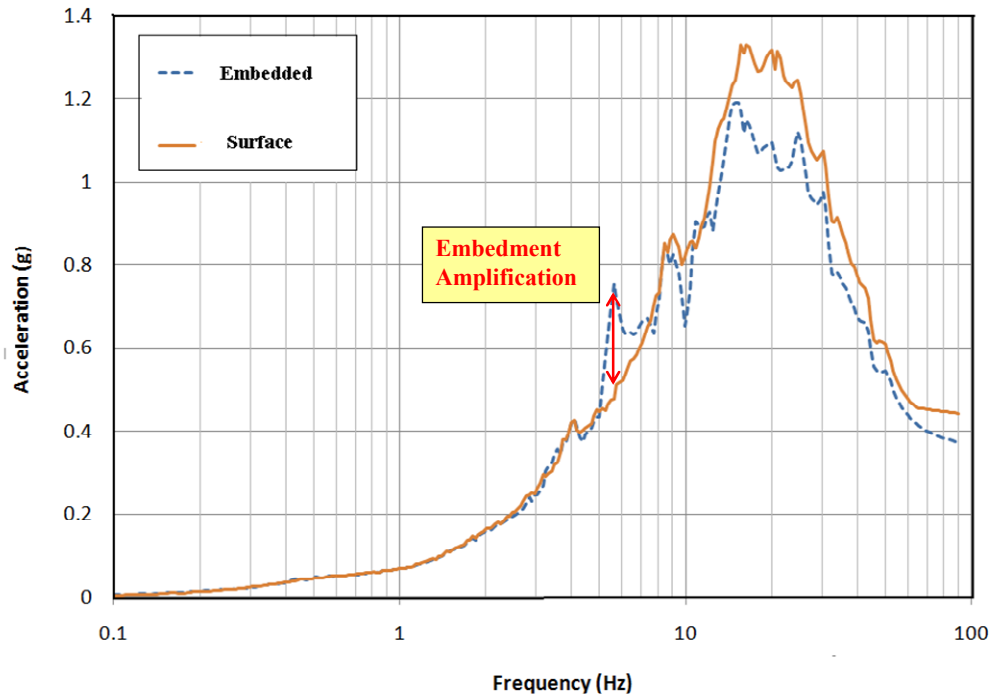
Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

Embedment Effects

US-APWR buildings are founded on stiff rock subgrade and are partially embedded in much softer backfill soil.

Embedment amplifies response at low frequencies close to backfill column frequency where effects of ground motion incoherency are insignificant.



$$FA_{EMB} = \frac{\text{Coherent Sa (envelope embedded \& surface)}}{\text{Coherent Sa (surface)}}$$

Embedment Amplification Factor

Site-Specific SSI Analyses of Standard Plant Category I Structures

- **Development of Unit 3 Site-Specific ISRS for each Standard Plant Structure**
  1. Develop ISRS enveloping responses from different soil cases to include variations of site properties using coherent surface, coherent embedded and incoherent surface SSI analyses
  2. Develop a new coherent envelope ISRS as envelope of surface model and embedded model ISRS
  3. Adjust the incoherent envelope ISRS for amplifications due to embedment effects by using embedment amplification factors
  4. Group the adjusted incoherent envelope ISRS at different locations within each floor and then perform 15% broadening to address structural modeling uncertainties
  5. Compare final broadened incoherent ISRS with coherent ISRS to assess effects of incoherency
  6. Compare final incoherent ISRS with DCD ISRS to identify high frequency exceedances

Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

- R/B Complex Response
  - Site-specific ground motion has small intensity at frequencies near natural frequencies of R/B complex structures
  - 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 ground motion incoherency effects

Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

- 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

Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

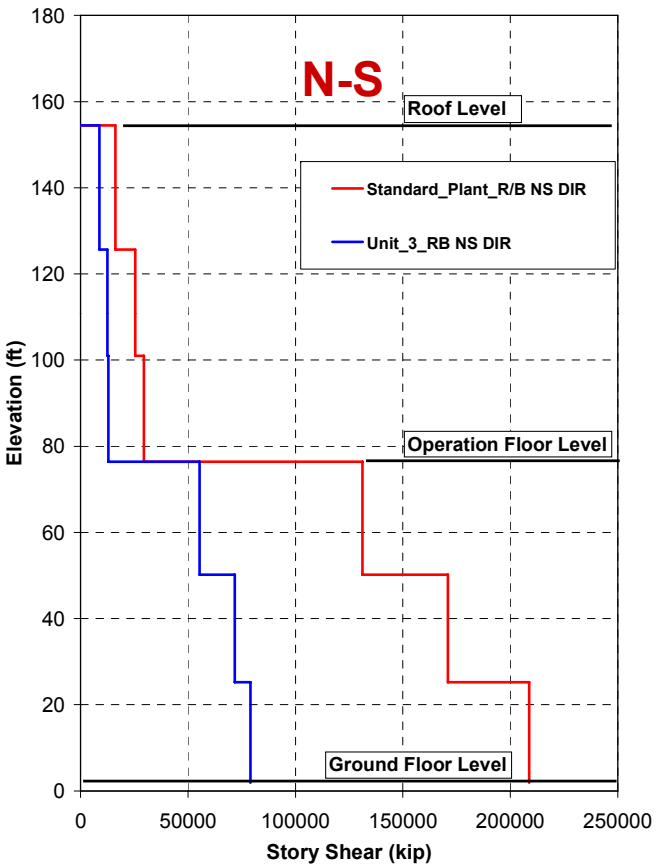
Structure	Max. Seismic Displacements with respect to Free Field Control Motion	
	Site Independent	Unit 3 Site Dependent
Prestressed Concrete Containment Structure	2.10 in.	0.44 in.
Containment Internal Structure	1.57 in.	0.56 in.
Reactor Building	1.50 in.	0.33 in.
Power Source Building	0.41 in.	0.12 in.

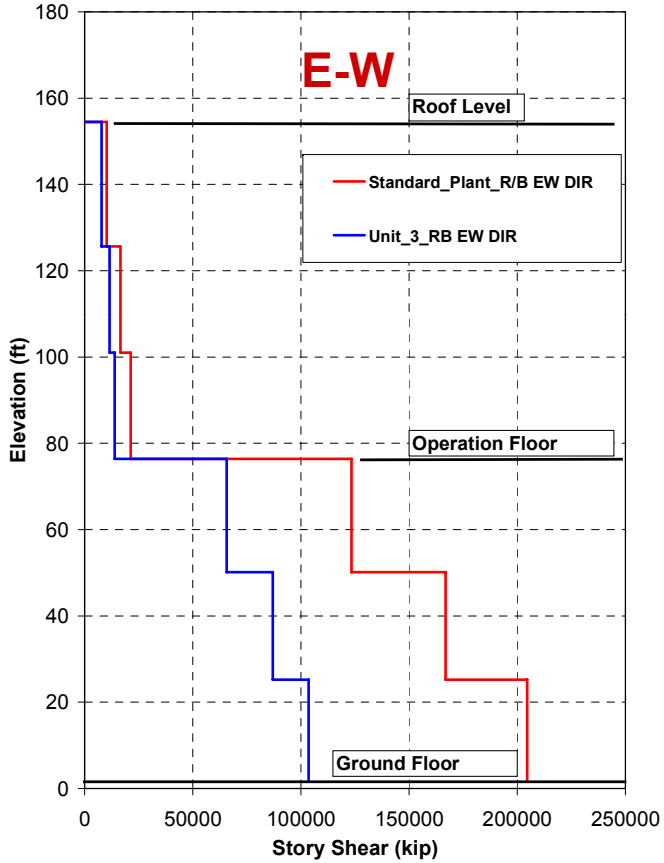
Nominal minimum gap size between adjacent buildings is 4 in.

Dominion

Site-Specific SSI Analyses of Standard Plant Category I Structures

R/B SSE Loads Shear Force Diagrams

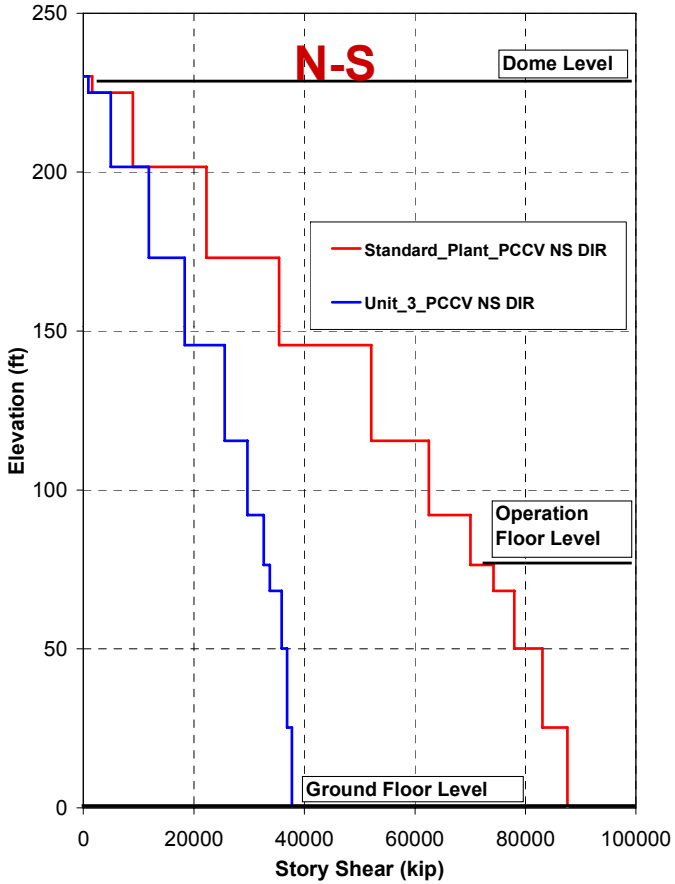


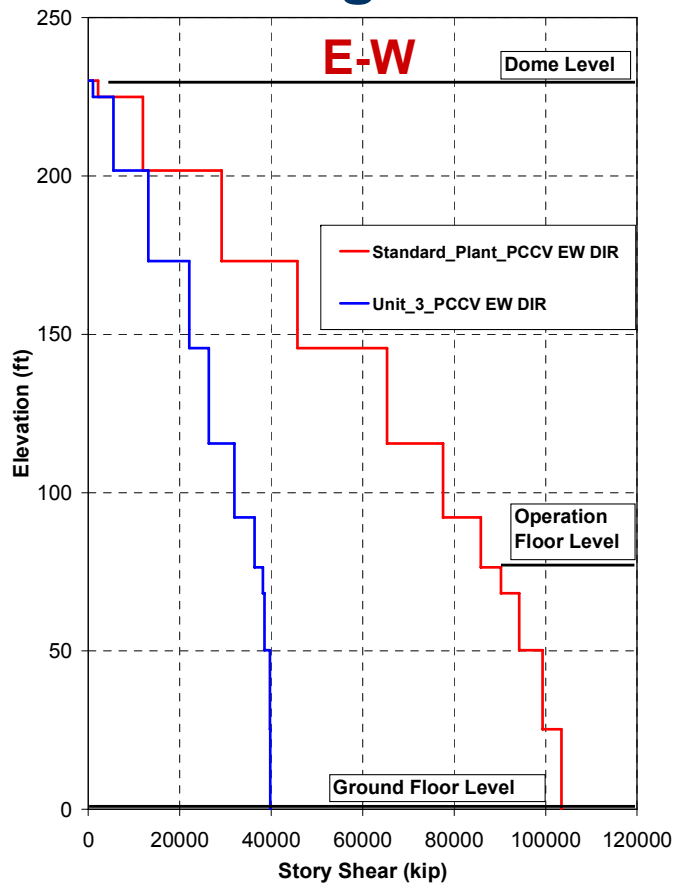


Loads developed from SSI analyses results for stick member forces and moments

Site-Specific SSI Analyses of Standard Plant Category I Structures

PCCV SSE Loads Shear Force Diagrams

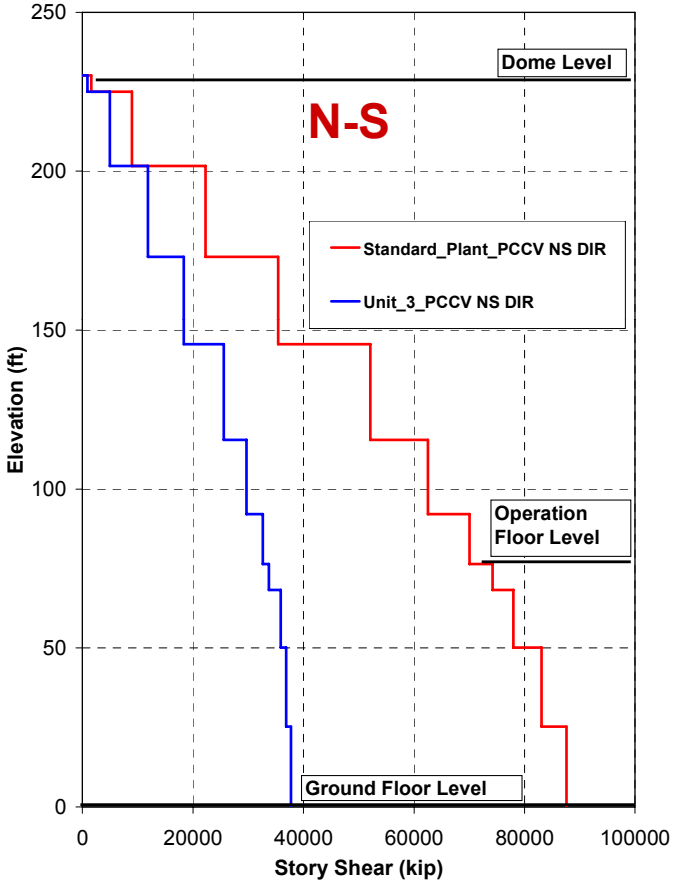


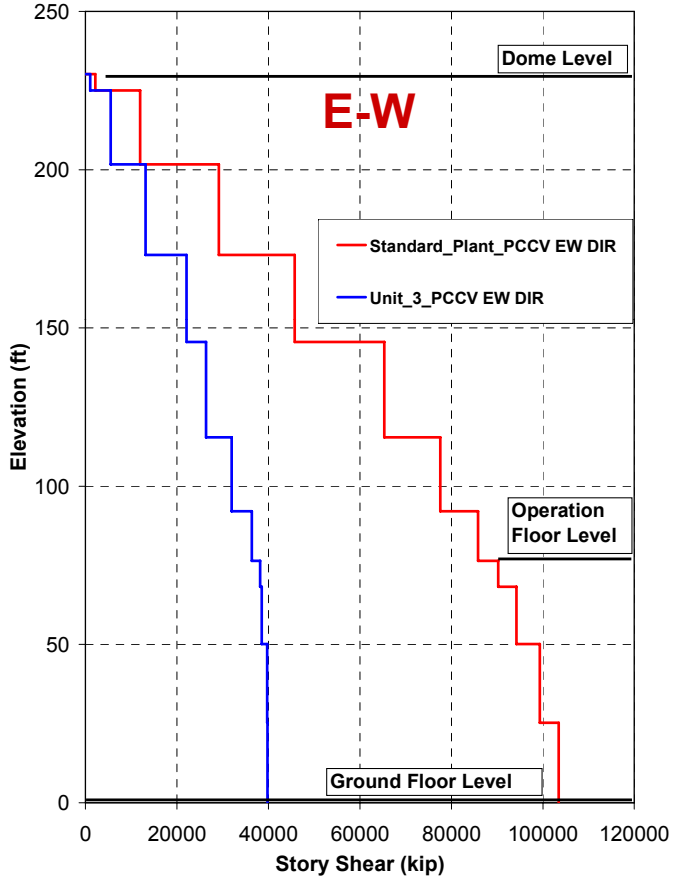


Loads developed from SSI analyses results for stick member forces and moments

Site-Specific SSI Analyses of Standard Plant Category I Structures

CIS SSE Loads Shear Force Diagrams

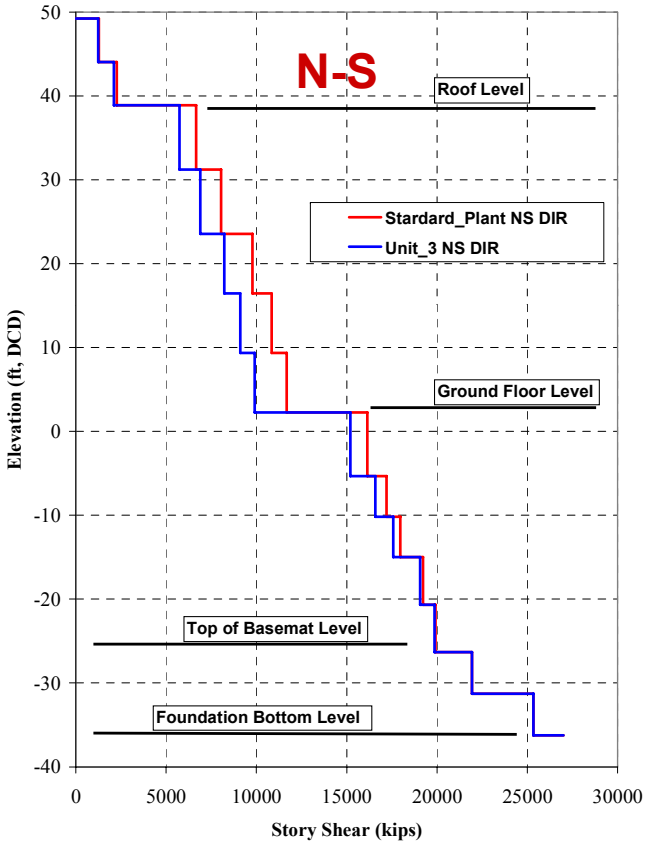


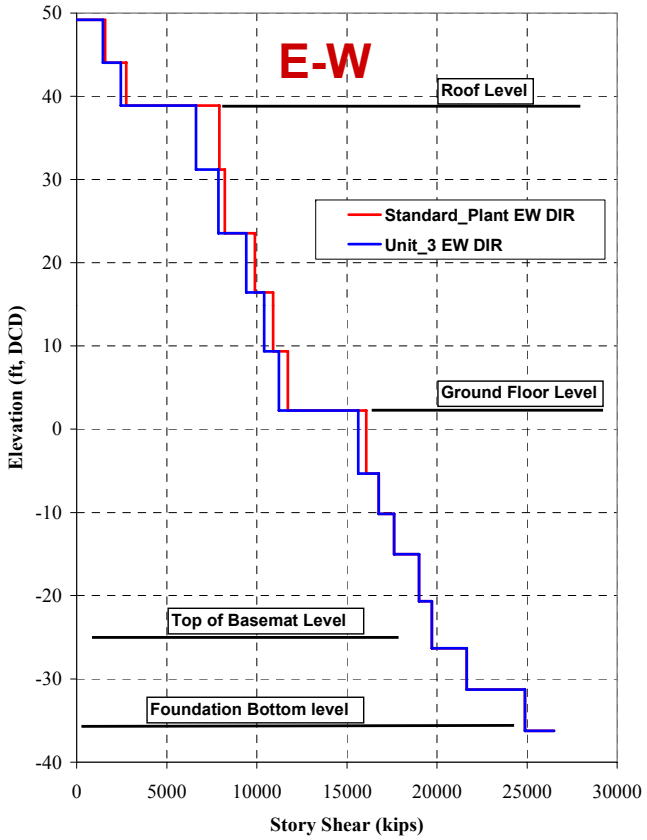


Loads developed from SSI analyses results for stick member forces and moments

Site-Specific SSI Analyses of Standard Plant Category I Structures

PS/B SSE Loads Shear Force Diagrams

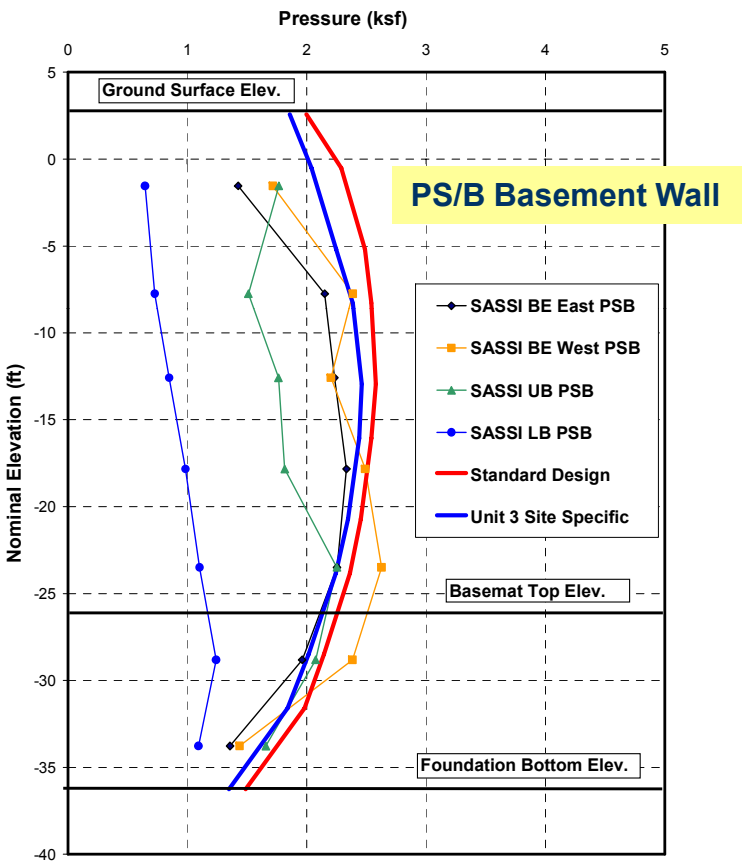




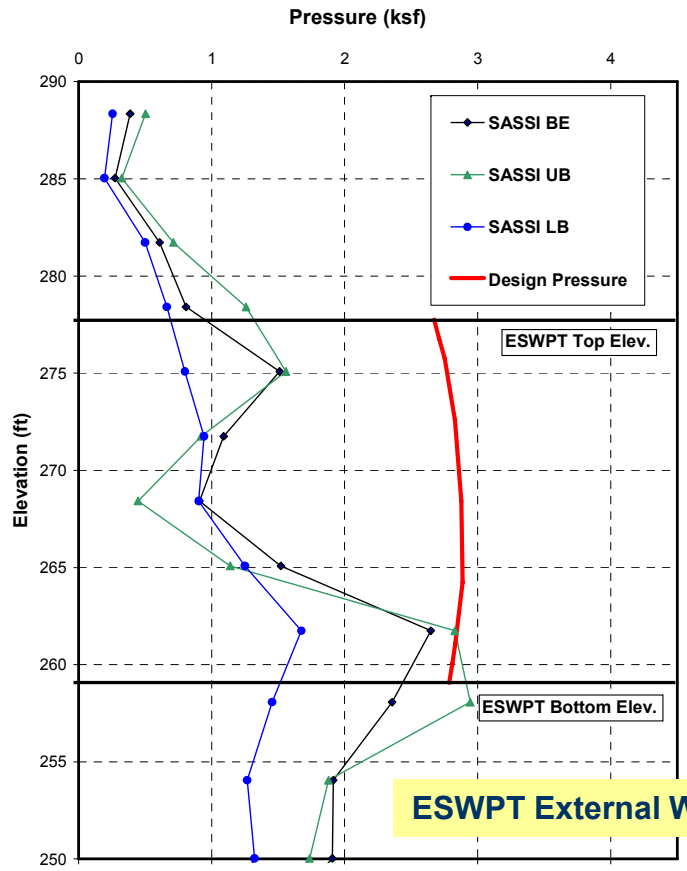
Loads developed from SSI analyses results for maximum nodal accelerations

Site-Specific SSI Analyses of Standard Plant Category I Structures

Dynamic Earth Pressure Results

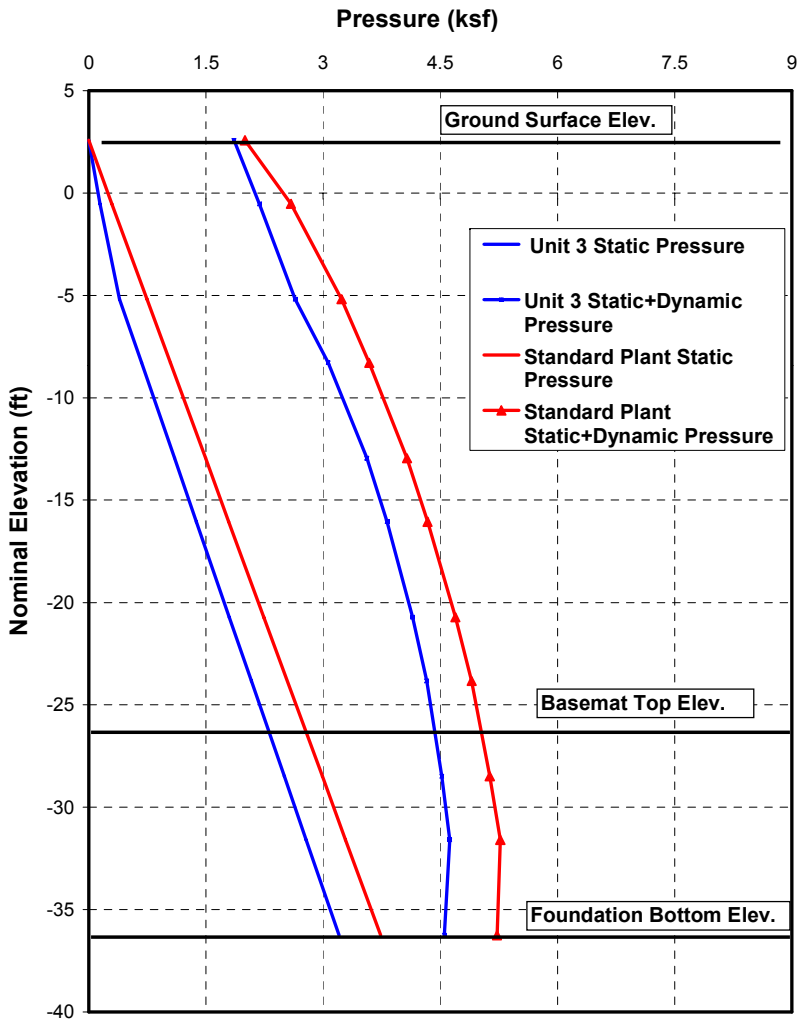


PS/B Basement Wall



ESWPT External Wall

Reconciliation of Standard Plant Seismic Design for Unit 3



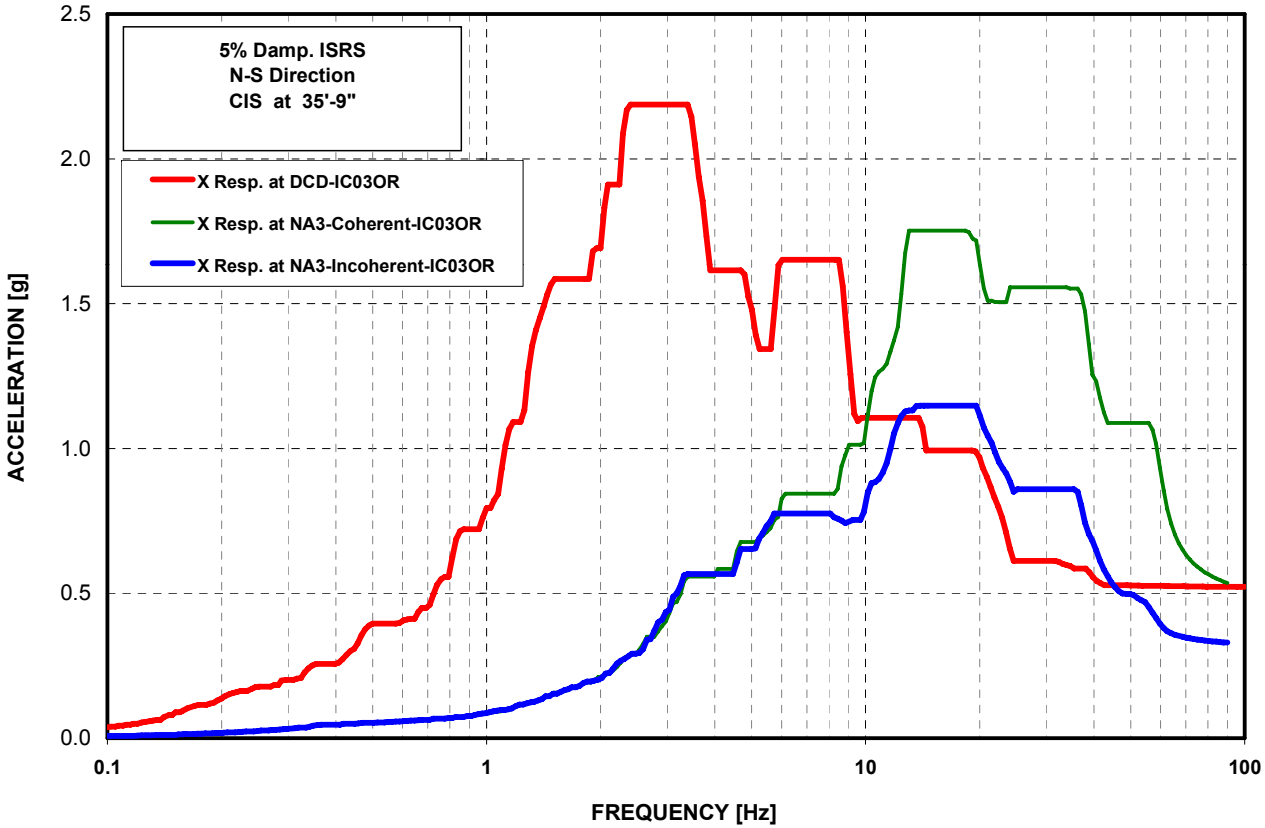
Standard Design Earth Pressure Loads

vs.

Unit 3 Site-Specific Earth Pressure Demands

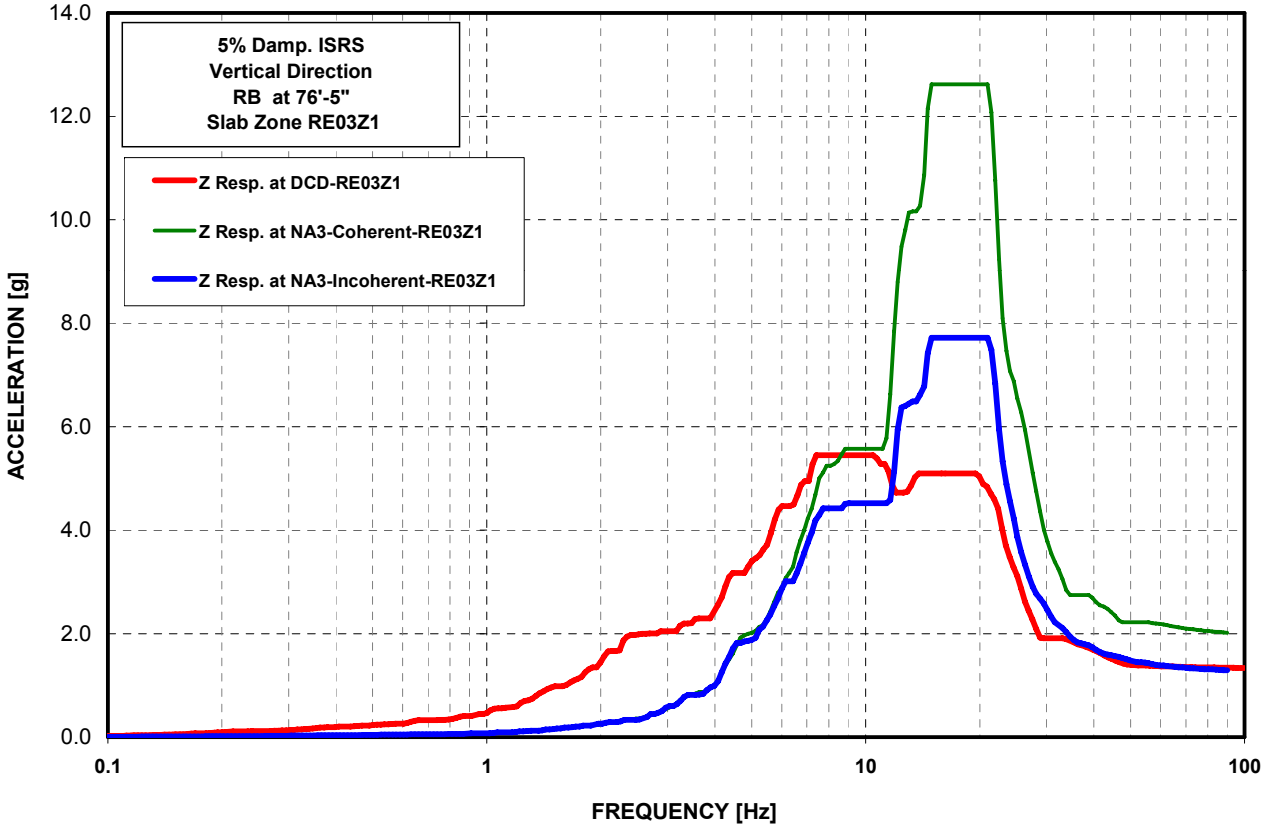
Site-Specific ISRS for Standard Plant Category I Structures

Horizontal ISRS at Reactor Vessel Support



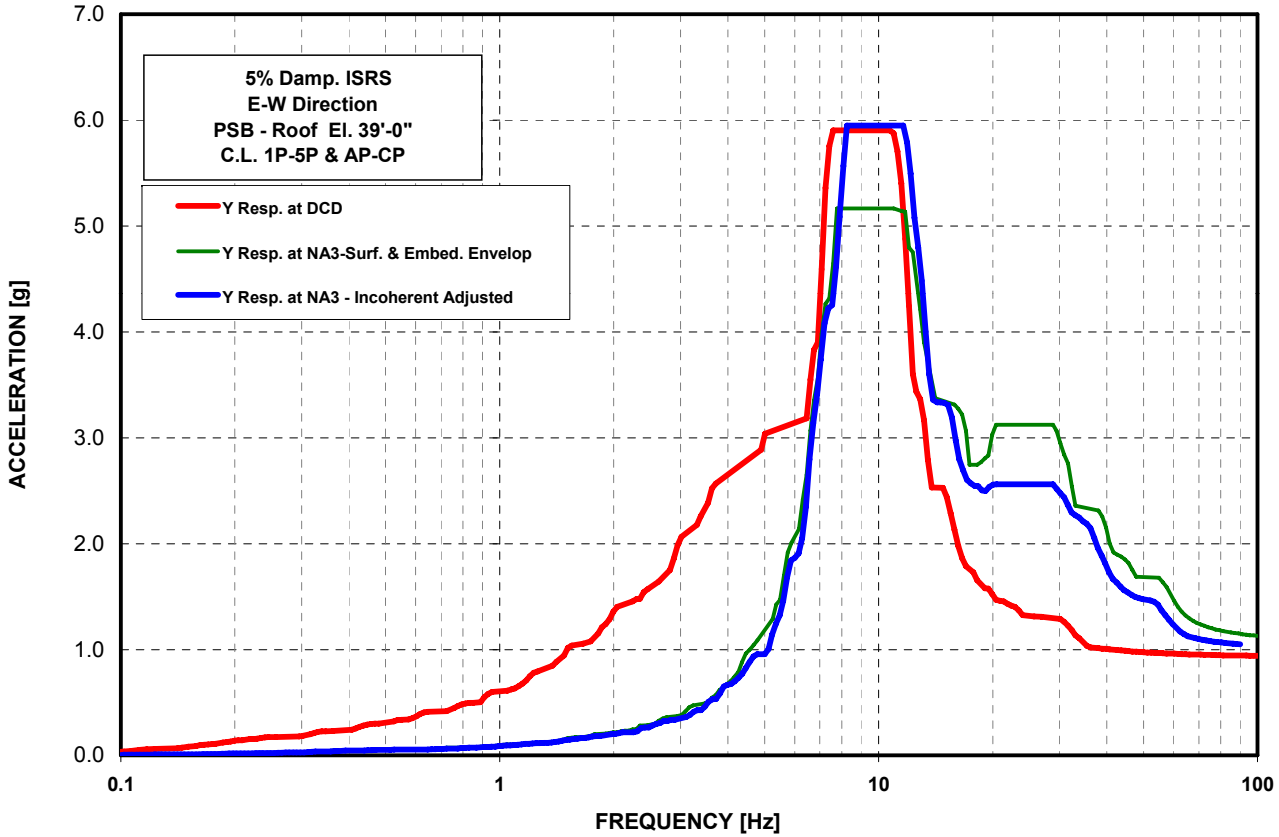
Site-Specific ISRS for Standard Plant Category I Structures

ISRS at R/B Operating Floor considering Slab Flexibility



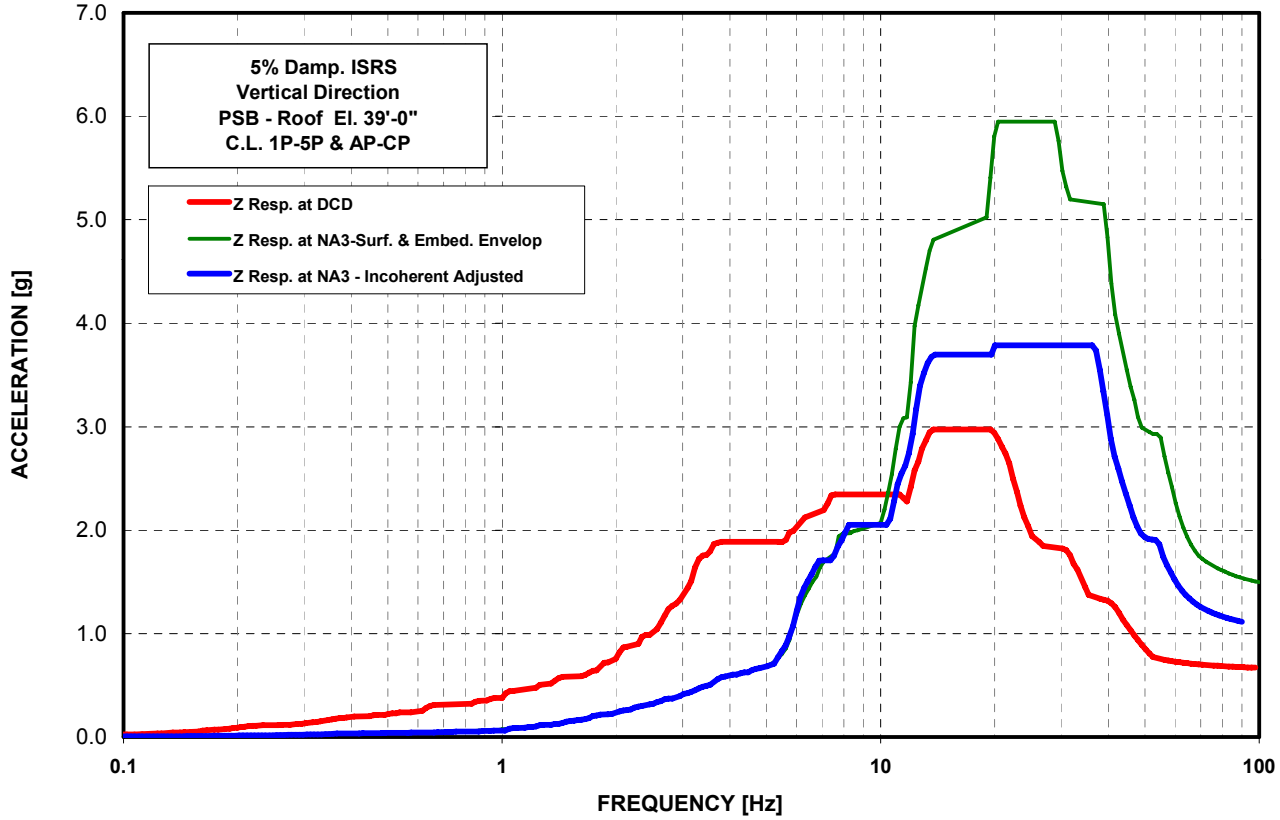
Site-Specific ISRS for Standard Plant Category I Structures

Horizontal ISRS for PS/B Roof



Site-Specific ISRS for Standard Plant Category I Structures

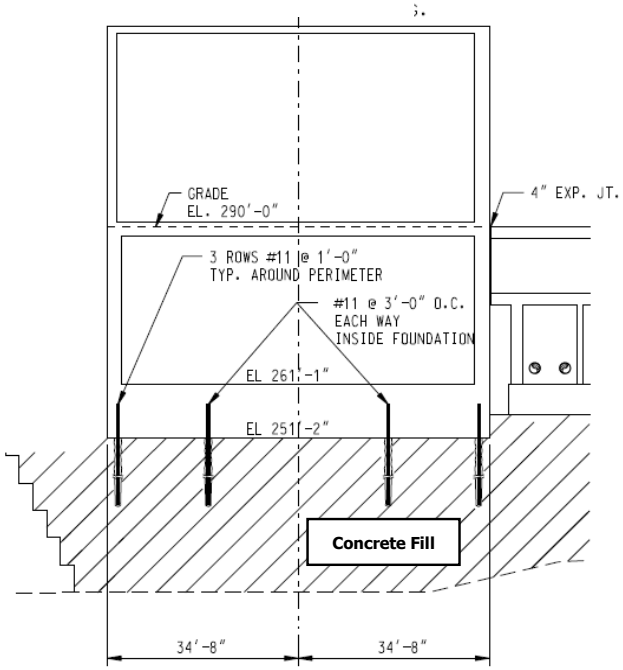
Vertical ISRS for PS/B Generator

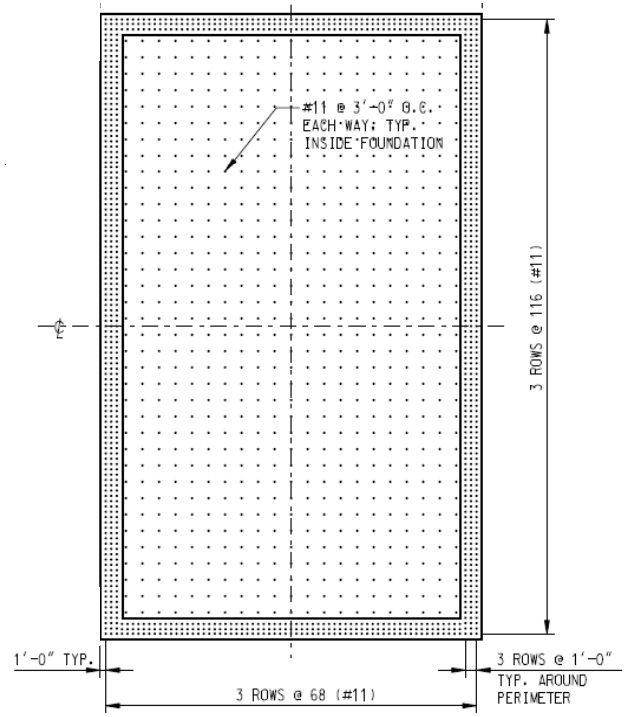


Reconciliation of Standard Plant Seismic Design for Unit 3

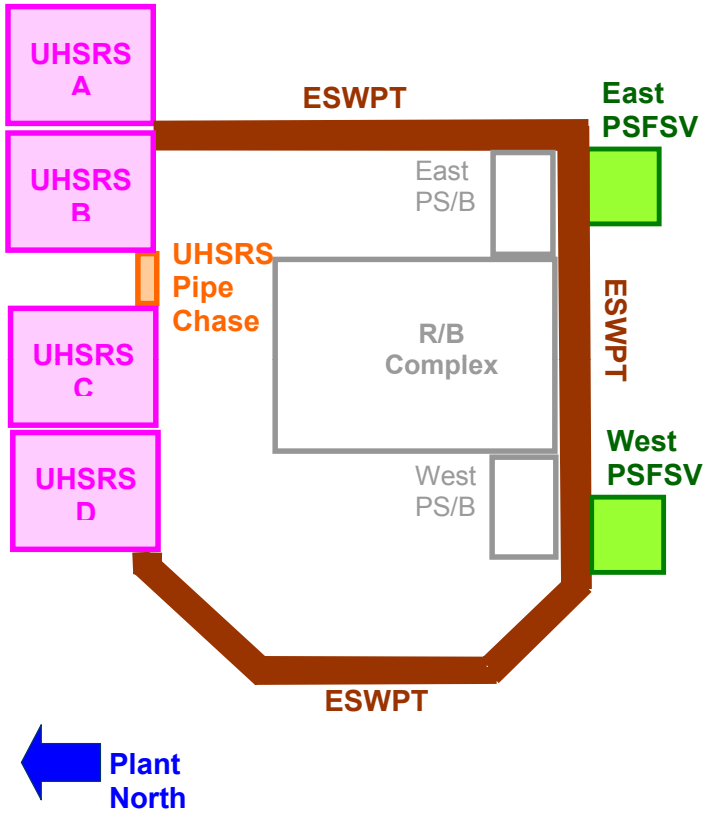
S-COLA DEP 3.7(1)

Standard design of PS/Bs foundation reinforcement added to meet Unit 3 sliding stability resistance demands





Seismic Analysis of Unit 3 US-APWR Site Specific Category I Structures



- Unit 3 Seismic Category I Structures designed on site specific basis:
  - East and West PSFSV
  - ESWPT
  - UHSRS A, B, C, and D
  - UHSRS Pipe Chase
- Part 11 presents SSI analyses and seismic design of Unit 3 site-specific Category I structures

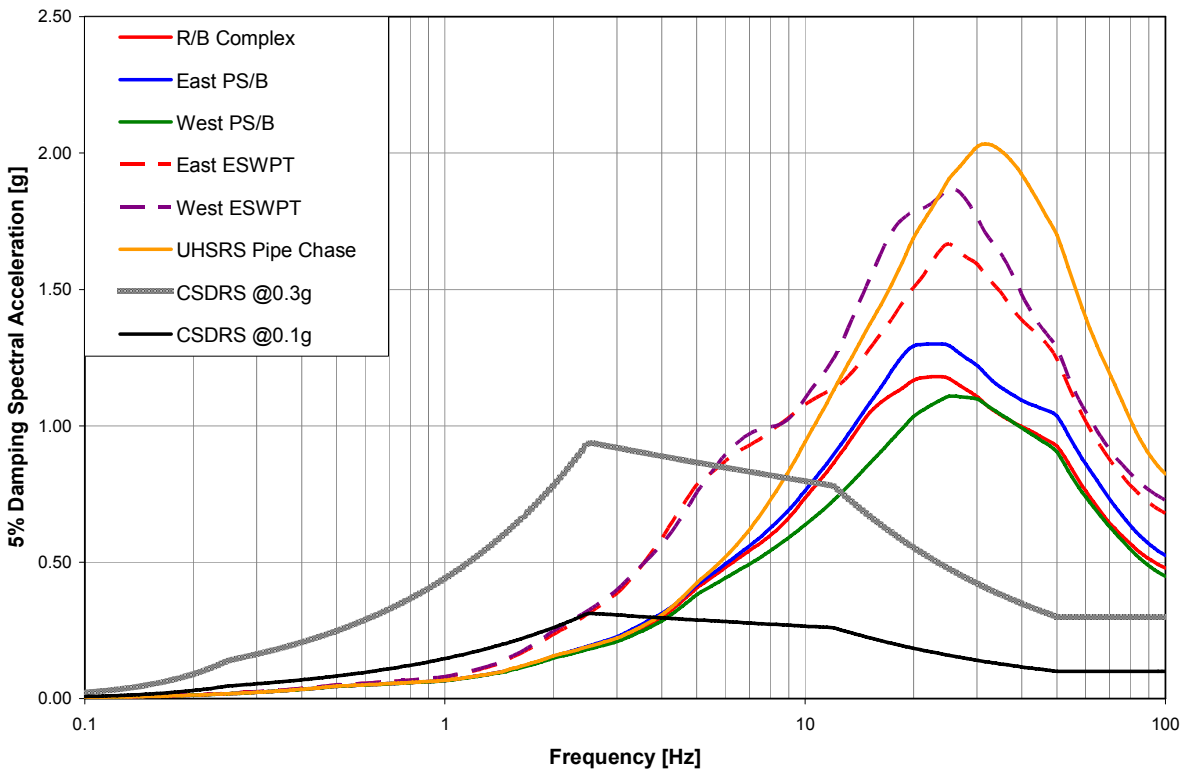
SSI Analyses of Unit 3 Site-Specific Category I Structures

- SASSI analysis methodology employed using dynamic FE models
- Strain compatible soil properties are obtained from site response analysis
- Effects of ground motion incoherency deemed insignificant due to small size of foundations and are neglected
- SSI analyses provide design ISRS and input SSE loading for structural design

Dominion

SSI Analyses of Unit 3 Site-Specific Category I Structures

SSI analyses envelop site-specific ground motions and required minimum design earthquake (1/3 CSDRS)



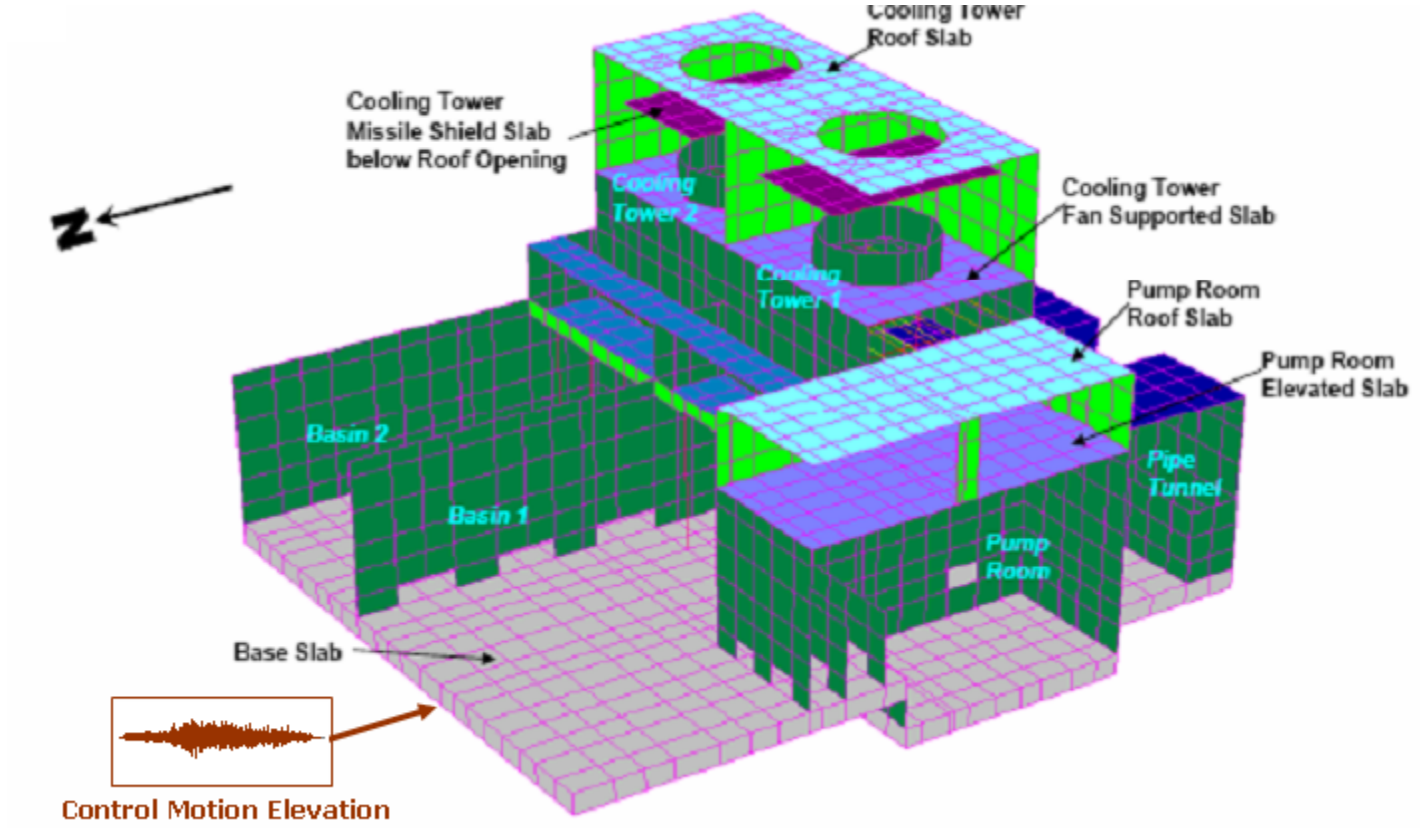
SSI Analyses of Unit 3 Site-Specific Category I Structures (UHSRS)

- UHSRS responses obtained from SSI analyses of 7 site profiles enveloped to address site variations in subgrade dynamic properties and layering at UHSRS A, B, C and D
- Portion of UHSRS pump house sump below basemat bottom elevation 277 ft considered embedded
- Effects of 13 ft foundation embedment above UHSRS main basemat bottom elevation neglected (this embedment depth represents less than 15% of UHSRS overall height)
- UHSRS seismic analyses use input ground motion that envelopes both 1/3 of CSDRS and site specific ground motion design spectra

Dominion

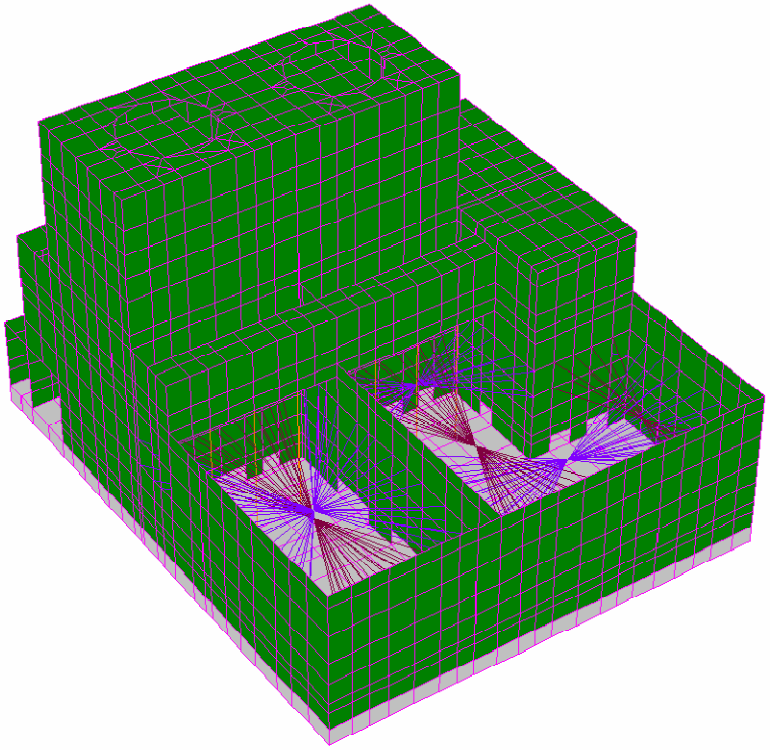
SSI Analyses of Unit 3 Site-Specific Category I Structures (UHSRS)

UHSRS SASSI Model



SSI Analyses of Unit 3 Site-Specific Category I Structures (UHSRS)

SASSI Modeling of Hydrodynamic Effects



- Mass of water in UHSRS basins, cooling towers, and pump house sump separated in five regions
- 5 lumped masses and 10 sets of springs model horizontal response of sloshing water
- Horizontal impulsive water mass lumped at basins walls nodes
- Vertical impulsive water mass lumped at basemat nodes

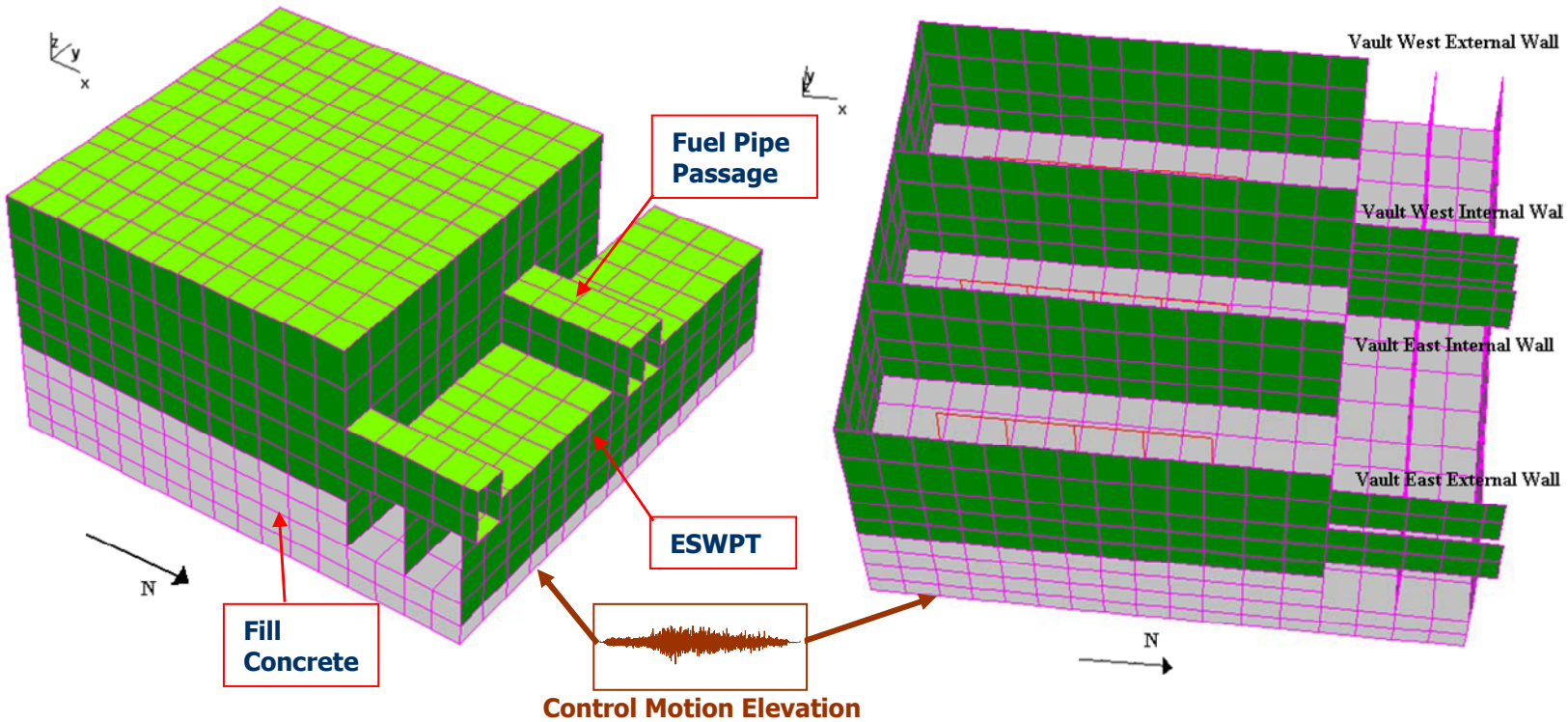
SSI Analyses of Unit 3 Site-Specific Category I Structures (PSFSV)

- SSI analyses of PSFSV use site profiles identical to those used as input for SSI analyses of PS/Bs
- Set of 8 SSI analyses of PSFSV model (4 surface foundation + 4 embedded foundation) provide envelope response of East and West PSFSVs and include amplifications due to embedment soil response
- SSI analyses of PSFSV as surface foundation use two sets of acceleration time histories:
  - Time histories compatible to site-specific design ground motion spectra
  - Time histories compatible to 1/3 of CSDRS (minimum design earthquake)
- ISRS envelope responses of site-specific design ground motion and minimum design earthquake motion

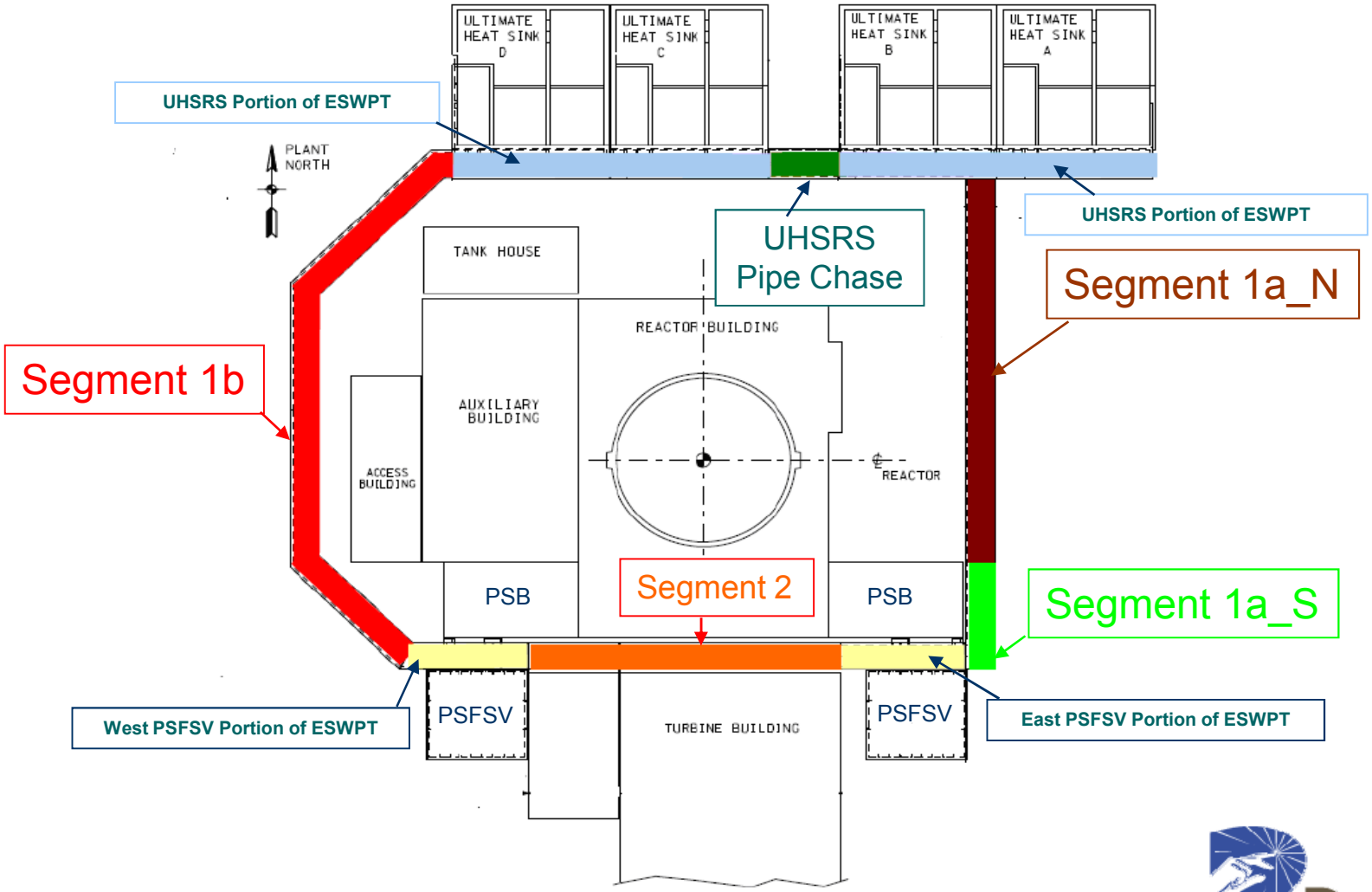
Dominion

SSI Analyses of Unit 3 Site-Specific Category I Structures (PSFSV)

PSFSV SASSI Model



SSI Analyses of Unit 3 Site-Specific Category I Structures (ESWPT)



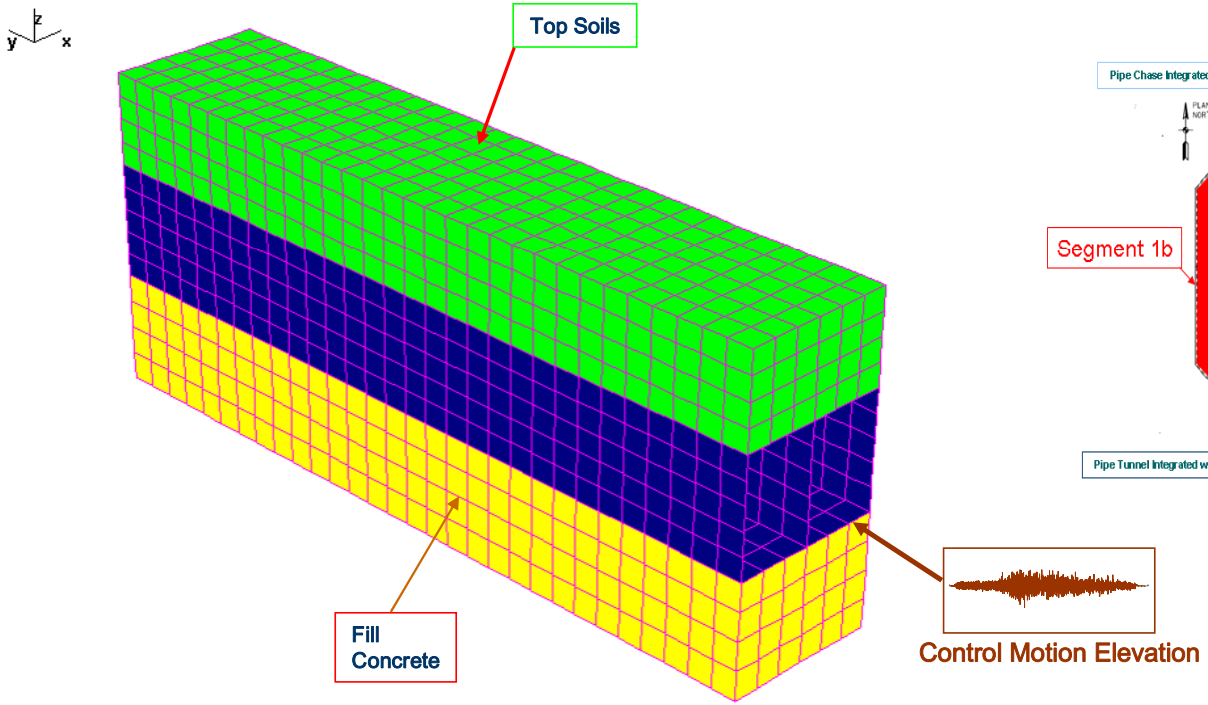
Matrix of ESWPT and UHSRS Pipe Chase Seismic Analysis

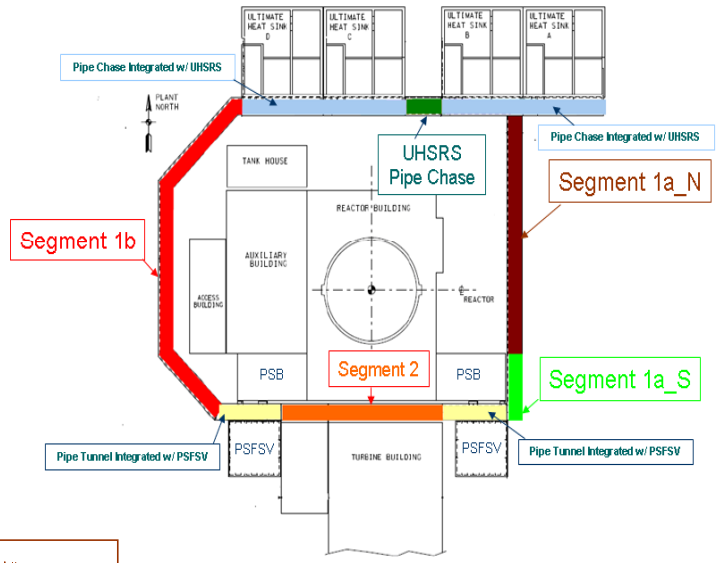
Segment	Soil Profile	Model	Foundation Type	SASSI Results	Structural Design	Input Motion
ESWPT Segment 1a-N	LB -Entire ESWPT	Fully Embedded Model	Base Slab on Fill Concrete	ISRS Group 2	Quasi-Static	Envelope Site Specific ground motion and 1/3 of CSDRS
	BE - East of R/B					
	UB -Entire ESWPT					
ESWPT Segment 1b	LB -Entire ESWPT	Fully Embedded Model	Base Slab on Fill Concrete	ISRS Group 2	Quasi-Static	
	BE - West of R/B Complex					
	UB -Entire ESWPT					
UHSRS Pipe Chase	LB - Pipe Chase	Embedded Foundation	Base Slab on Fill Concrete	ISRS Group1	RSA	
	BE- Pipe Chase					
	UB- Pipe Chase					
ESWPT Segment 1a-S	LB -West and East PS/B	Surface Foundation	Basemat on Concrete fill or Rock III/IV	ISRS Group 3	Quasi-Static	
	BE - West PS/B					
	BE - East PS/B					
	UB - West and East PS/B					
ESWPT Segment 2	LB -West and East PS/B	Surface Foundation	Basemat on Concrete fill or Rock III/IV	ISRS Group 2	RSA	
	BE - West PS/B					
	BE - East PS/B					
	UB - West and East PS/B					

Dominion

Seismic Analyses of Unit 3 Site-Specific Category I Structures (ESWPT)

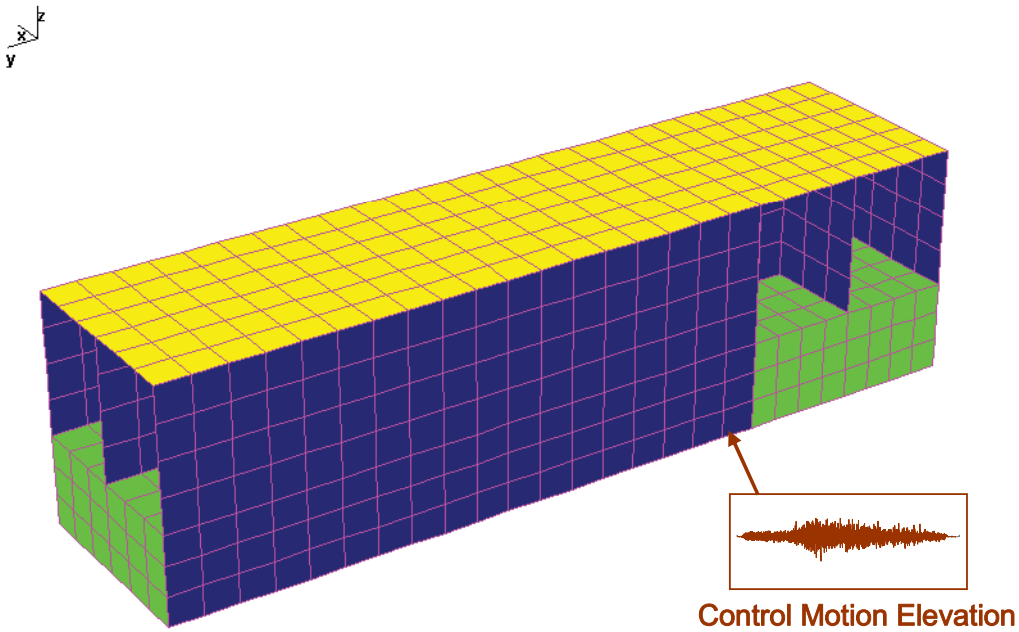
Segment 1a-N SASSI Model

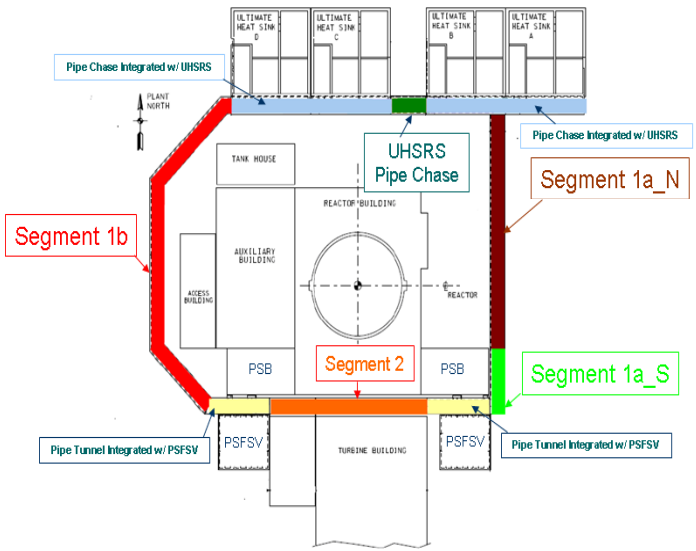




Seismic Analyses of Unit 3 Site-Specific Category I Structures (ESWPT)

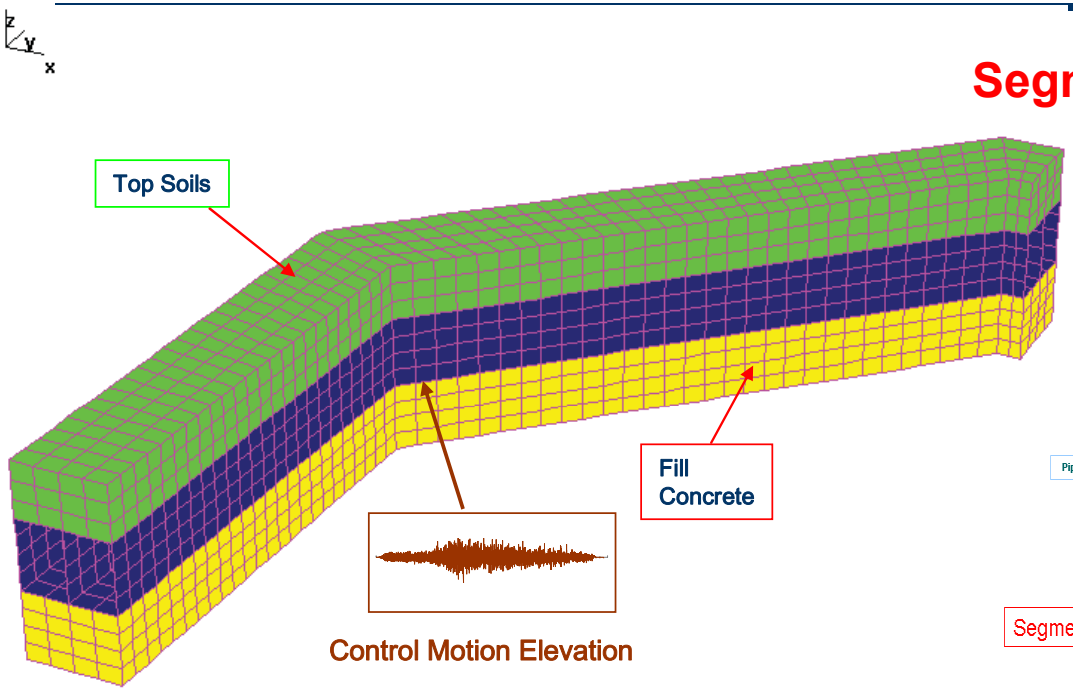
Segment 1a-S SASSI Model

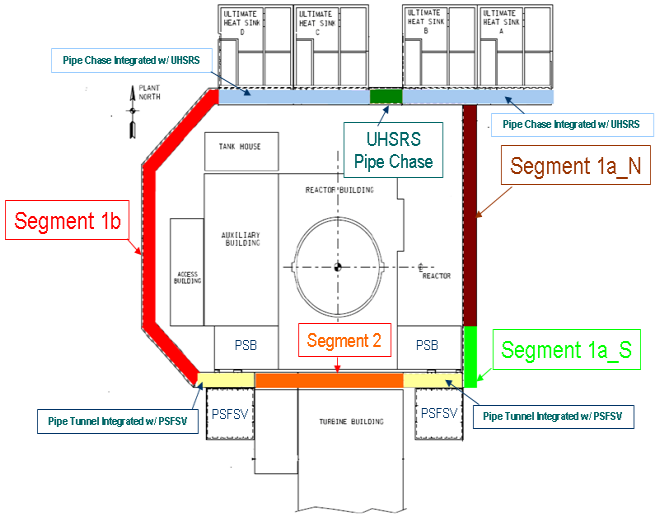




Seismic Analyses of Unit 3 Site-Specific Category I Structures (ESWPT)

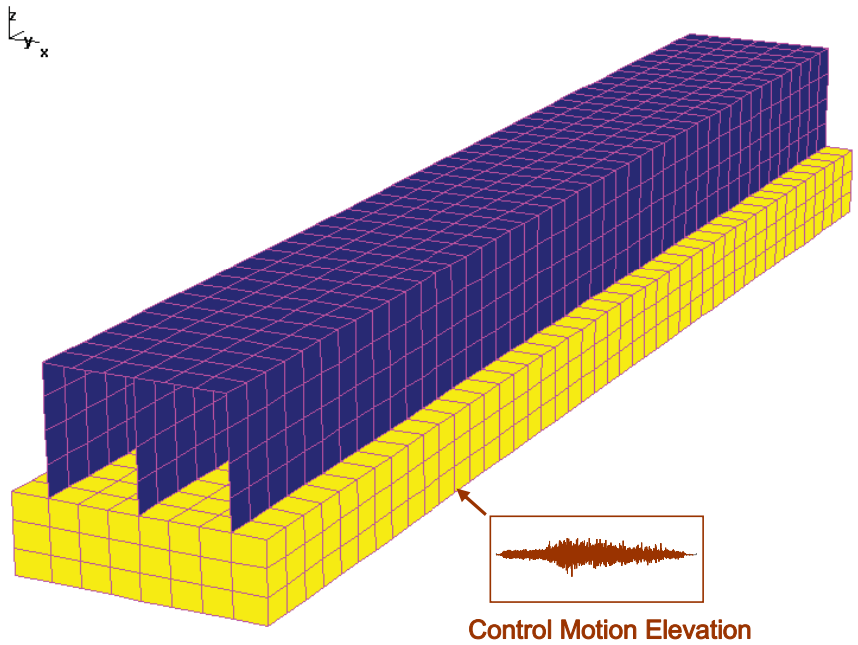
Segment 1b SASSI Model

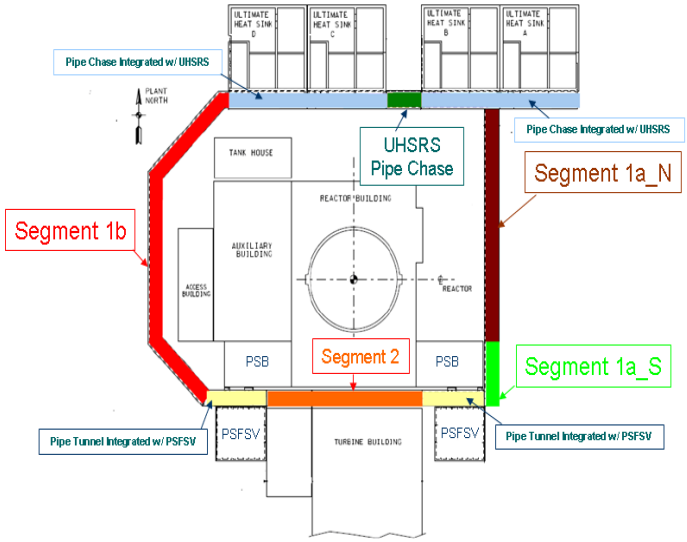




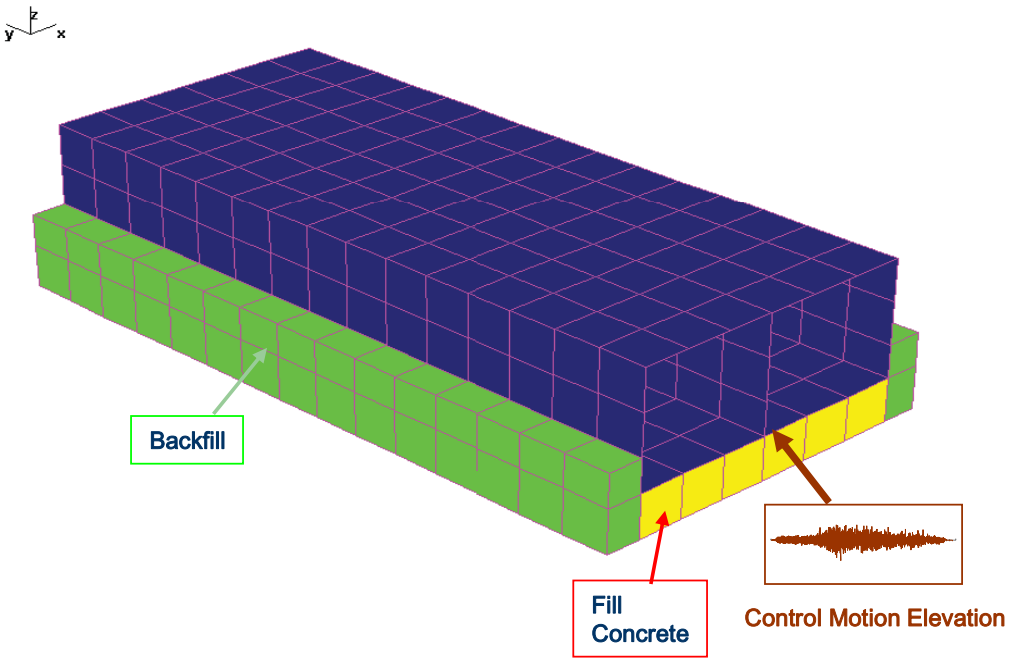
Seismic Analyses of Unit 3 Site-Specific Category I Structures (ESWPT)

Segment 2 SASSI Model

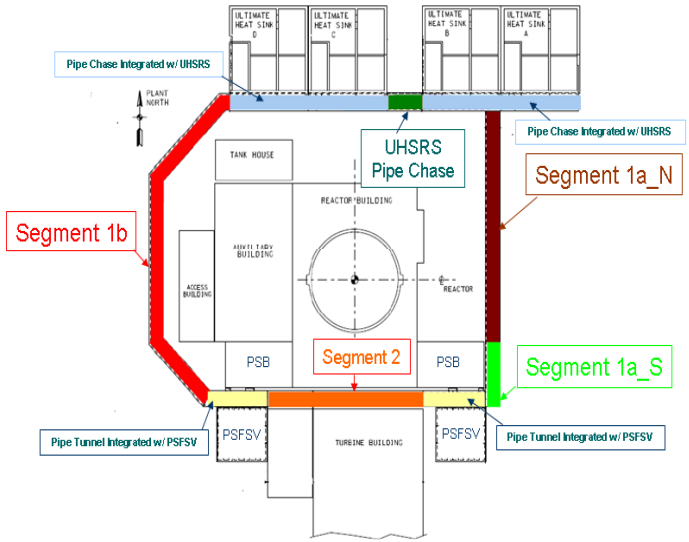




Seismic Analyses of Unit 3 Site-Specific Category I Structures (ESWPT)



Pipe Chase SASSI Model



Basic Design of Unit 3 Site-Specific Category I Structures

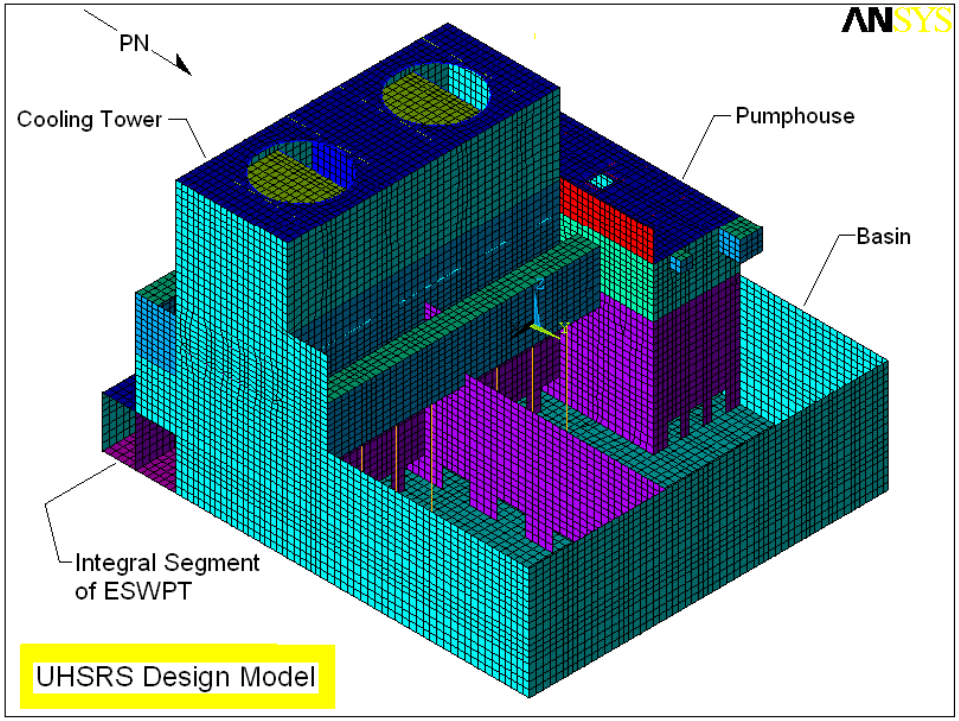
Overview of Basic Design Process

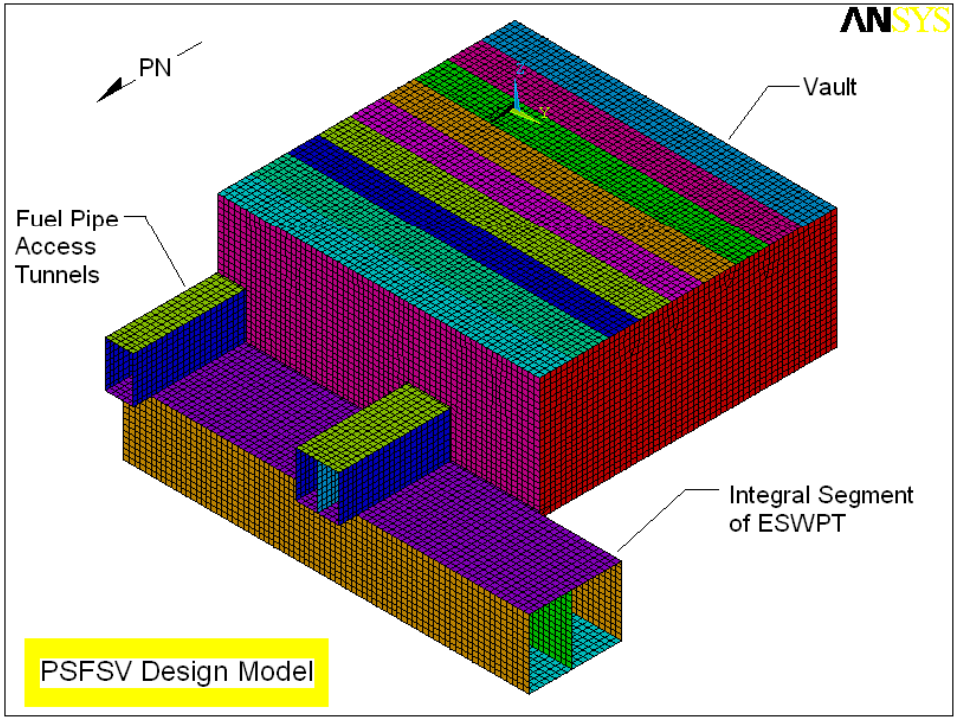
- Detailed FE models of UHS, PSFSV, and ESWPT generated in ANSYS
- Analyses performed for all basic and site-specific loading conditions
  - Criteria for loading: DCD, ASCE 7-05, ASCE 4-98
  - Lateral soil pressures: COLA Section 2.5
  - Site response and SSI analyses provide SSE loading:
    - → Max. accelerations for quasi-static analysis
    - → 5% damped free field design ground motion spectra for RSA
- Basic design of reinforced concrete prepared in accordance with ACI 349-01

Dominion

Design of Unit 3 Site-Specific Category I Structures

Detailed ANSYS Design Models for UHSRS and PSFSV





Basic Design of Unit 3 Site-Specific Category I Structures

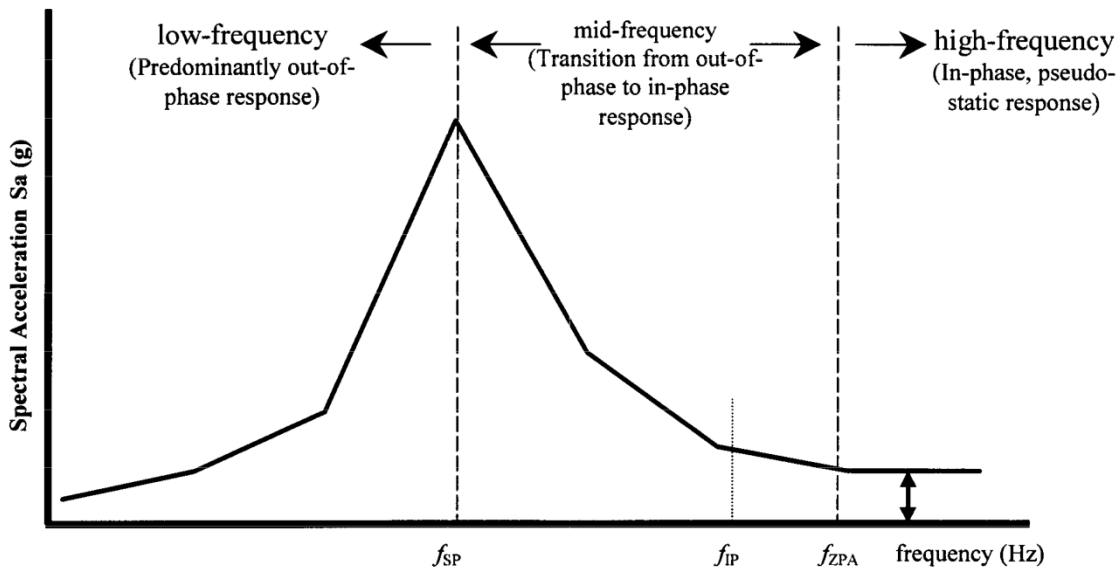
Types of SSE loads considered:

- Self Inertia
  - Response Spectrum Analysis using Lindley-Yow Method (UHSRS, UHSRS Pipe Chase, PSFSV, ESWPT Segment 2)
  - Quasi-static analysis (ESWPT Segment 1)
- Hydrodynamic response of UHSRS basin water
  - Modified Housner Method
- Dynamic soil pressures
  - ASCE 4-98 Elastic Solution (Wood) that envelops dynamic earth pressure results from SSI analyses
- Accidental Torsion
  - Angular Acceleration = (Torque due to 5% eccentricity) / I_{zz}

Dominion

Basic Design of Unit 3 Site-Specific Category I Structures

- **Lindley-Yow Response Spectrum Analysis (RSA) Method**
  - Specified in Reg. Guide 1.92
- Three directional responses combined by SRSS



Basic Design of Unit 3 Site-Specific Category I Structures (UHSRS)

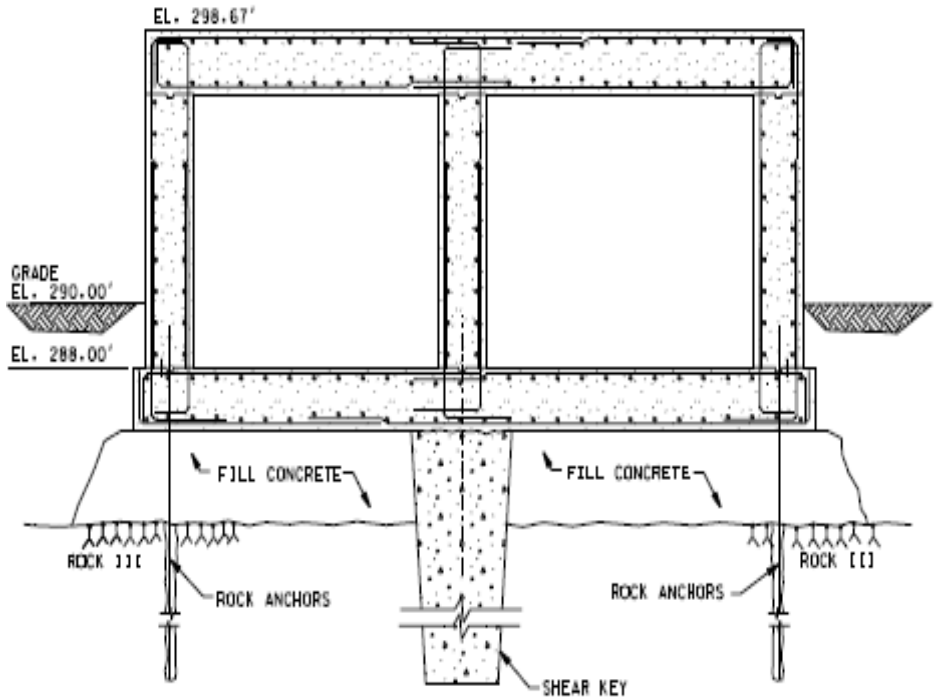
Hydrodynamic SSE Loads

- Applied Modified Housner Method referenced in:
  - *"Fluid/Structure Interaction During Seismic Excitation"*, ASCE Committee on Nuclear Structures and Materials, 1984
  - "Dynamic Pressures on Fluid Containers", Chapter 6, TID-7024, U.S. Atomic Energy Commission, 1963
- Modeling of hydrodynamic effects in detailed ANSYS model:
  - Impulsive Effects: uni-directional impulsive masses added to nodes of walls and mat
  - Convective (Sloshing) Effects: applied pressures on walls and mat
  - Response to Vertical Acceleration: applied lateral pressures on walls based on vertical response spectrum analysis of individual chambers

Dominion

Basic Design of Unit 3 Site-Specific Category I Structures

ESWPT and UHSRS Pipe Chase Stability Evaluation



Section: UHSRS Pipe Chase (Typ.)

Stability of UHSRS Pipe Chase and ESWPT Segment 2 provided by

- Shear Key into Rock III/Concrete Fill providing shear resistance
- Force Couple formed by tension in rock anchors and compressive bearing stress resisting overturning moment

Seismic Qualification of Equipment

MUAP-08015 is used for seismic qualification of equipment in compliance with industry standards and guidance, including:

- IEEE Std. 344-2004
- ASME QME-1-2007
- NRC Regulatory Guide 1.100 Rev. 3, September 2009
- NRC Interim Staff Guidance ISG-01, May 2008

Dominion

High Frequency Response: Equipment Qualification

Program summarized in Technical Report MUAP-08015(R1)

- Guidance for frequency sensitive components 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

Dominion

High Frequency Response: Equipment Qualification

- US-APWR EQ program seismic qualification methods, including direction to address HF ground motion, are described in MHI Technical Report, MUAP-08015, R1, Appendix B, Sections B.10-B.14
- Seismic qualification for site-specific equipment housed in site-specific structures must be adequate for spectra obtained from the site-specific SSI analyses of those structures
- Standard plant equipment seismic qualifications must be reviewed, and re-performed, if appropriate, considering effects of any exceedances of standard plant broadened ISRS that are identified by the site-specific SSI analyses:
  - For SSCs not sensitive to HF with spectral exceedances below 50 Hz from DCD-based ISRS, structural integrity and functional evaluations will be performed via appropriate testing/analysis pursuant to guidance in ISG-1, Section 3.2.2
  - For SSCs sensitive to HF, qualification is based on guidance in ISG-1, Section 4.1. Screening shall be performed to identify sensitive equipment affected by ISRS exceedances and if needed, additional testing shall be performed

Dominion

Potentially HF Sensitive Equipment (Not a Complete List)

- Electro-Mechanical Relays (e.g., Control, Time Delay and Protective Relays)
- Electro-Mechanical Contactors including Motor Control Center Starters
- Circuit Breakers
- Auxiliary Contacts (e.g., Molded Case Circuit Breakers, Fused Disconnects, and Contactors/Starters)
- Switches including Control Transfer and Process Switches
- Sensors (e.g., Pressure, Differential Pressure, Temperature, Level, Limit/Position and Flow Sensors)
- Potentiometers
- Digital/Solid-State Devices (e.g., Solid-State Relays and Microprocessor-Based Components
- High Frequency Sensitive Mechanical Components

Dominion

Analysis of Piping Systems and Components

- Piping systems are addressed in Section 3.12 of FSAR
- Components are addressed in Section 3.9 of FSAR
- For standard plant piping systems and components, design margins introduced in standard design are expected to envelop Unit 3 seismic demands

Dominion

Seismic Margin Analysis (ISG-20)

- DCD
  - Implemented PRA-based seismic margin analysis (SMA) using CSDRS and URD. HCLPFs of plant and accident sequences will meet ISG-20 criteria, i.e., 1.67 times SSE (0.3g PGA)
  - Analyses and tests that comply with ISG-20 are planned to be performed
- S-COLA
  - NA3 SSE is greater than CSDRS in high frequency range. PRA or PRA-based SMA will be performed to show that Unit 3 meets ISG-20 using the site specific ISRS

Dominion

Summary and Conclusions

- Containment location for the US-APWR is same as that of ESBWR
- Additional site subsurface data are consistent with ESBWR R-COLA
- GMRS in S-COLA is same as ESPA hard rock SSE
- Site seismic analysis approach is consistent with ESPA SSE analysis and the methodology of ESBWR R-COLA
- Development of S-COLA FIRS incorporates ISG-017 recommendations
- Site-specific SSI analysis demonstrated applicability of standard structural design for Unit 3 and provided site specific ISRS
- Equipment seismic qualification program follows industry standards and NRC guidance

Dominion