ENCLOSURE 1

M210133

Revised Responses to Request for Additional Information (eRAI)
9859

Licensing Topical Report
NEDO-33914, Revision 0,
BWRX-300 Advanced Civil Construction and Design Approach

Non-Proprietary Information

SRP Review Section: 02.05.04 - Stability of Subsurface Materials and Foundations

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02.05.04-01 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Sections: TR NEDO-33914 Sections 3.1.1, 3.1.2, 3.1.3, and 4.3.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

Issue:

Figure 4-2 shows the rheological model of an interface to be used in the Foundation Interface Analysis (FIA) with several parameters, such as, k_n, σ_t, τ_{max}, k_s, C, C_r, φ. These parameters determine whether the interface slides (shear failure) or dilates (tensile failure) under the imposed loads including the load from the safe shutdown earthquake (SSE). The response of both soil and rock media surrounding the Reactor Building (RB) shaft to the imposed loads significantly affects the loads imposed on the RB walls. In addition, the loads imposed on the RB wall may not be symmetric around the shaft walls, especially in the rock medium.

Section 4.3.1.2, Fault or Joint Planes or Interfaces Between Bedding Units in a Geologic Formation, states that the nonlinearity and behavior of the joints are analyzed throughout the life stages of a reactor and the same interface model would be used in modeling the joints, bedding planes, and faults in the rock mass as part of the FIA model. The properties assigned to the interface elements along a rock discontinuity are to be obtained from laboratory or field testing (Sections 3.1.1 and 3.1.2). In addition, Section 4.3.1.2 states that the parameters representing slip of the interface model may be estimated based on properties of the weakest interface materials.

It is not clear from the discussions given in Site Investigation Program (Section 3.1.1) and Laboratory Testing Program (Section 3.1.2) whether a specific program would be developed to collect the necessary samples at the site and conduct specific tests at the laboratory to determine the parameters of the FIA model, as shown in Figure 4-2, or any other model to be used to represent the interfaces. It is also not clear how the weakest plane (interface) would be identified at a given site with its strength properties.

Request:

The staff requests GEH to identify the sample collection and testing programs that would be used to determine the parameters necessary to model the behavior of all interfaces (RB Wall/Soil, RB Wall/Rock, Soil/Rock, and Rock/Rock for joints/bedding planes), as appropriate. Modify the TR as necessary.

GEH Response to NRC Question 02.05.04-01

The sample collection and testing program discussed in Section 3.1 of NEDO-33914 will include samples of soil and rock materials that will be adjacent to the interfaces as well as samples of discontinuities that form rock/rock interfaces. Strength tests will be performed to characterize the shear strengths of the Reactor Building (RB) wall/rock and rock/rock interface. Shear strengths for other interfaces will be based on the strength properties of adjacent soil or rock materials. The strength testing program may also be used to measure interface stiffness parameters.

Figure 4-2 of NEDO-33914 provides an example model to simulate interactions at the RB wall/soil, RB wall/rock, soil/rock, and rock/rock interfaces. The model consists of two sets of elastic-perfectly plastic springs to simulate potential sliding and gapping at the interfaces. The properties for the interface model can be divided into strength properties, such as f_t, τ_{max}, c, c_r, and ϕ, and elastic stiffness properties, such as k_n and k_s. The strength properties are important because they determine the plastic deformations caused by either shear or tensile failures at the interface.

The stiffness properties determine the elastic deformations that are small compared to the plastic deformations and should have a minimal effect on the overall response of the nonlinear Foundation Interface Analysis (FIA). Most commercial software suitable for the nonlinear FIA have guidance for setting the k_s and k_n values (References 01-1 and 01-2). The values of the k_s and k_n are typically set in accordance with the guidance for the selected software. This guidance typically includes the use of interface stiffness values based on a value larger than adjacent materials, measured stiffness from laboratory strength tests, or other appropriate methods (References 01-1 and 01-2).

The strength properties control whether the shear failure (sliding) or tensile failure (gapping) occur along the interface under the proposed loading. The strength properties can be determined from direct shear (e.g., References 01-3 and 01-4) and/or triaxial (e.g., Reference 01-5) tests on recovered rock cores with natural discontinuities from the field investigation and artificial interfaces. If samples from specific rock discontinuities are needed, additional sampling focused on those rock discontinuities may be required. The lowest measured strength properties or the range of properties from the strength tests on representative rock discontinuities may be used to simulate movement along rock interfaces or evaluate the sensitivity of the results.

If the example interface model in Figure 4-2 of NEDO-33914 is not used, the site investigation and laboratory testing programs shall be modified to determine the parameters for the selected interface model.

References

01-1. Bentley, PLAXIS 3D - Reference Manual, March 4, 2021 <https://communities.bentley.com/cfs-file/__key/communityserver-wikis-components-files/00-00-00-05-58/PLAXIS3DCE_2D00_V21.01 _2D00_02_2D00_Reference.pdf>.

01-2. Itasca, FLAC3D Manual – Theory and Background, 2019 (updated 10/01/2021) <http://docs. itascacg.com/flac3d700/flac3d/docproject/source/flac3dhome.html?node1877>.

01-3. American Society for Testing and Materials ASTM D5607, "Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force," 2016.

01-4. U.S. Army Corps of Engineers, "Method of Test for Direct Shear Strength of Rock Core Specimens," RTH 203-80, Waterways Experiment Station, Vicksburg, MS, 1993.

01-5. U.S. Army Corps of Engineers, "Standard Method of Test for Multistage Triaxial Strength of Undrained Rock Core Specimens Without Pore Pressure Measurements," RTH 204-80, Waterways Experiment Station, Vicksburg, MS, 1993.

Proposed Changes to NEDO-33914 Revision 0

Section 3.1.2 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to include direct shear and triaxial strength tests for natural and artificial discontinuities. Direct shear tests are added to the minimum laboratory tests required for rock materials.

Section 3.1.3 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to identify direct shear and triaxial compressive tests as laboratory tests on recovered samples of discontinuities.

Section 4.3.1.1 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to state that the interface parameters are from adjacent soil/rock elements or strength test on natural and artificial discontinuities developed to be consistent with the selected nonlinear FIA software and interface model. Uncertainties in these interface parameters may require sensitivity analyses that adjust the spring stiffness and shear strength using strength reduction factors. Removed text discussing the potential boundary scenarios.

Section 4.3.1.2 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to indicate that the weakest strength parameters from multiple tests on rock discontinuities may be used for interface elements and that strength reduction factors may be used to modify the interface values for strength and stiffness.

Section 8.0 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to add ASTM D5607, RTH 203-80, RTH 204-80, RG 1.132 and RG 1.138 to the list of references.

02.05.04-02 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Sections: TR NEDO-33914 Sections 3.1.1, 3.1.3, 3.2.1, 4.2.2, and 5.2.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 2, describes methods acceptable to the NRC staff for conducting field investigations to acquire the geological and engineering characteristics of the site and provides recommendations for developing site-specific guidance for conducting subsurface investigations.

RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Revision 3, describes laboratory investigations and testing practices for determining soil and rock properties and characteristics needed for engineering analysis and design of foundations and earthworks for nuclear power plants.

Issue:

It is not clear from the discussion given in Section 3.1.3, Characterization of Rock Mass Properties, whether the geological characterization of the rock unit(s) would be adequate to represent the rock mass in the FIA analyses. Discussions on fracture network characterization of the rock mass is mostly limited to collecting 1D information through boreholes. However, rock fractures are 3D in nature and occur in sets (joint sets). Multiple sets of rock joints can be present in a rock mass creating individual rock blocks. Additionally, the rock mass may be a bedded deposit comprising of multiple rock beds. No discussion is given in Section 3.1.3 how the rock mass fracture network, which can significantly influence the rock pressure of the RB walls, would be characterized.

Additionally, Section 3.1.3, Characterization of Rock Mass Properties, discusses the use of rock mass classification systems (e.g., the Rock Mass Rating (RMR) system, the Geological Strength Index (GSI) system) to develop an estimate of the stress-strain behavior of rock (Section 4.2.2, Rock Constitutive Model) and rock mass stiffness properties (Section 5.2.1.2, Rock Mass

Equivalent Linear Properties). The RMR system specifically requires information of the rock discontinuity spacing, orientation, and conditions. The GSI system requires information on at least J_r (joint roughness number) and J_a (joint alteration number) parameters to determine the specific GSI value of the rock mass. It is not clear how these parameters would be determined based on discussion given in Section 3.1.1, Site Investigation Program. Additionally, it is not clear what inspection and verification programs would be used during the Construction Phase (Section 3.2.1, Excavation and Foundation Inspections and Testing) to verify the assumptions made about the rock mass (e.g., rock fracture network, joint strength, etc.) before the excavation commences.

Request:

The staff requests GEH to identify the plan(s) and program(s) for characterizing the rock fracture network and determining the necessary parameters for the rock mass classification system used to determine the rock mass stress-strain behavior. The staff is also requesting GEH to identify the program(s) to verify the assumptions made of the rock and soil media surrounding the RB shaft as the excavation progresses. Modify the TR, as necessary.

GEH Response to NRC Question 02.05.04-02

The program for characterizing the rock fracture network and determining the necessary parameters for the rock mass classification system at depths for engineering purposes (see the GEH Response to NRC Question 02.05.04-08) will include four primary data collection components (Reference 02-1):

- geologic mapping prior to the field investigation;
- intrusive boreholes during the field investigation;
- laboratory testing of recovered rock cores; and
- geologic mapping of the excavation during construction.

The geologic mapping, field investigation, and laboratory testing data are used to estimate parameters for design and analysis. The excavation mapping data collection is intended to confirm the rock conditions were realistically estimated for analysis and design when bedrock is at or above the basemat level of the Reactor Building (RB) shaft (Reference 02-1).

Following a review of the available geologic data, surface mapping of identified rock outcrops and surface geologic features will be completed. At a minimum the mapping is intended to:

- identify the rock structure;
- the orientation, spacing and persistence of principal joint sets; and
- characterize discontinuities, shear zones, faults, and other potentially weak planes in the bedrock units.

Based on the results of the surface mapping, the recommended field investigation plan provided in Section 3.1.1 of NEDO-33914 may be supplemented to include:

- inclined borings at orientations to better intersect the anticipated discontinuities;
- additional borings to investigate specific structural features; or
- larger diameter samples to recover natural discontinuities.

The geotechnical borings will provide recovered cores, televiewer measurements, seismic measurements, access for water-pressure tests in bedrock, and allow installation of piezometers. This data would be used to supplement the surface mapping and better characterizing the rock mass. Surface geophysical measurements between the borings will also be completed to aid in mapping variations in the bedrock units as indicated in Table 3-1 of NEDO-33914.

The laboratory investigation described in Section 3.1.2 of NEDO-33914 includes testing of recovered rock core samples to characterize the rock mass. These rock cores will be from the borings in the field investigation. The exact testing of the recovered rock cores would be based on the selected rock mass classification systems, but tests on recovered rock cores would potentially include:

- Uniaxial compressive and triaxial strength testing of intact rock cores (Reference 02-2).
- Tensile strength testing of intact rock cores and natural discontinuities (Reference 02-3).
- Direct shear and/or triaxial testing of natural or artificial discontinuities (References 02-4, 02-5, and 02-6).

As described in Section 3.2.1 of NEDO-33914, the walls and floors of the rock excavation will be mapped during and at the completion of the excavation when bedrock is present at or above the basemat level of the RB shaft. This excavation mapping is to verify the rock mass characteristics estimated during design and analysis are appropriate and will be completed in accordance with Appendices A and B of Reference 02-7. If the rock characteristics observed during the excavation do not conform to those estimated for the analysis and design, sensitivity evaluations will be performed to assess their effect on the design.

References

02-1. RG1.132, “Site Investigations for Foundations of Nuclear Power Plants,” Revision 2, October 2003.

02-2. American Society for Testing and Materials ASTM D7012, “Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures,” 2014.

02-3. American Society for Testing and Materials ASTM D2936, “Standard Test Method for Direct Tensile Strength of Intact Rock Core Specimens,” 2020.

02-4. American Society for Testing and Materials ASTM D5607, “Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force,” 2016.

02-5. U.S. Army Corps of Engineers, “Method of Test for Direct Shear Strength of Rock Core Specimens,” RTH 203-80, Waterways Experiment Station, Vicksburg, MS, 1993.

02-6. U.S. Army Corps of Engineers, “Standard Method of Test for Multistage Triaxial Strength of Undrained Rock Core Specimens Without Pore Pressure Measurements,” RTH 204-80, Waterways Experiment Station, Vicksburg, MS, 1993.

02-7. U.S. Nuclear Regulatory Commission, “Field Investigations for Foundations of Nuclear Power Facilities,” NUREG/CR-5738, ADAMS Accession No. ML003726925, November 1999. .

Proposed Changes to NEDO-33914 Revision 0

Section 3.1.1 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to identify the need for geologic mapping of outcrops to improve the field investigation program and the rock characterization when bedrock is encountered at depths for engineering purposes.

Table 3-1 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to add “characterize rock mass and discontinuities” to test purposes for geotechnical borings and the borehole televiewer.

Section 3.1.3 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to identify the investigation locations and methods, including geologic mapping, intended to characterize the rock and rock mass parameters.

02.05.04-03 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Sections: TR NEDO-33914 Sections 3.2, 3.3, 3.4, and 4.1

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 2, describes methods acceptable to the NRC staff for conducting field investigations to acquire the geological and engineering characteristics of the site and provides recommendations for developing site-specific guidance for conducting subsurface investigations.

RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Revision 3, describes laboratory investigations and testing practices for determining soil and rock properties and characteristics needed for engineering analysis and design of foundations and earthworks for nuclear power plants.

Issue:

Section 4.1, Foundation Interface Analysis Model, states that a numerical model of the interfaces would be developed that examines the response of the BWRX-300 and its surrounding media due to alterations of in-situ subgrade conditions. The responses would be monitored, both through the FIA model response and field measurements. The numerical FIA model will also be calibrated using the field measurements to predict future response of the structure. It is not clear from the discussions in Sections 3.2, 3.3, and 3.4 how the predicted interface behavior would be compared against physical observations from the monitoring programs. Sections 3.2, 3.3, and 3.4 do not discuss any plan or program to monitor the shear and normal displacements along an interface, as shown in Figure 4-1.

Request:

The staff requests GEH to identify the plan(s) or program(s) to monitor the response of the BWRX-300 and its surrounding media and comparing them with predictions using the FIA model for calibrating the numerical FIA model. Additionally, this process should verify that the structural and site responses are within the design bounds. Modify the TR as necessary.

GEH Response to NRC Question 02.05.04-03

As discussed in Section 3.4 of NEDO-33914, a field instrumentation plan will be developed to monitor deformations, groundwater pressures and soil and rock pressures during excavation, construction, loading and operation. Specific locations will be determined based on the subsurface conditions and areas identified in the design where deformation and pore pressures are anticipated along the perimeter of the Reactor Building (RB) shaft. The specific locations may be inside and outside of the RB shaft. These measurements can be benchmarked against design estimates and used to calibrate the nonlinear Foundation Interface Analysis (FIA) model by modifying select parameters.

During construction and in-service operation, the nonlinear FIA model will be calibrated based on actual properties of RB structures and the measured response of soil and rock surrounding the RB shaft. The RB structure properties can be updated based on the as-built measurements and testing results described in Section 3.2.2 of NEDO-33914. The properties of soil and rock models will be calibrated in the nonlinear FIA based on measured deformations of the soil and rock as well as measured pore water pressure from piezometers. Select inputs or parameters of the soil, rock and rock/rock interfaces associated with the difference between modeled and measured results will be modified. If a Hoek-Brown material model is used for the rock mass that is producing less deformation than measured, then an example would be modifications to Geologic Strength Index (GSI), disturbance factor (D), or intact rock modulus (E_{ri}) used to estimate the rock mass modulus (E_{st}) or direct modification of E_{st} to better match the measured deformations.

The earth pressure from the calibrated nonlinear FIA will be compared with that from the initial nonlinear FIA and the design Soil-Structure Interaction (SSI) analysis as described in Section 5.1.3 of NEDO-33914 to ensure the pressures are within the design bound with an adequate margin. The adequacy of the margins is evaluated based on the levels of uncertainty in the subgrade conditions. The design SSI analysis is the 1-g static SASSI (a system for analyses of soil structure interaction) analysis described in Section 5.1 of NEDO-33914.

Proposed Changes to NEDO-33914 Revision 0

Section 3.4 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to indicate that the specific locations of sensor may be inside and outside of the RB shaft.

Section 4.2 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to include a description of the calibration process using parameters for the selected soil and rock constitutive models.

Section 5.1 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to clarify that the one-step approach is implemented using a linear elastic SASSI analysis approach.

02.05.04-04 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Section: TR NEDO-33914 Section 5.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

In Section 5.1.2, Soil-Structure Interaction Modeling Assumptions, the rock mass is assumed to be continuous, and the presence of cavities, fracture zones, joints, bedding planes, discontinuities, and other weak zones is neglected. It is not clear from the discussion whether their effects on the rock mass properties (e.g., rock mass modulus, strength) would be incorporated through equivalent rock mass properties so that the calculated loads on the RB walls are realistic. It is also not clear whether an isotropic assumption of the equivalent material properties would be made. Rock fractures have specific orientations in the 3D space and make the rock mass properties anisotropic.

Request:

The staff requests GEH to provide a discussion in the TR how the effects of rock fractures etc. would be incorporated in the SSI modeling.

GEH Response to NRC Question 02.05.04-04

A continuous model is anticipated to be used for the nonlinear Foundation Interface Analysis (FIA), as described in Section 4.0 of NEDO-33914, to simulate the Reactor Building (RB) structure and subgrade conditions for the excavation, construction, loading, startup and operation stages. Mohr-Coulomb or Hoek-Brown material models will typically be used to represent massive rock units and jointed or fractured rock units that approximate a continuum. Highly anisotropic features like bedding planes and select discontinuities may be incorporated into the continuous model using rock/rock interfaces described in the GEH response to NRC Question 02.05.04-01. The use of discontinuous models is not anticipated for most sites because the excavation would be reinforced for unstable rock masses during excavation and construction, and the RB shaft would be present after construction. A continuous model is typically appropriate because the rock reinforcement and the RB structure would constrain the rock mass and limit the deformations.

Possible fracture zones, joints, bedding planes, discontinuities and cavities in the rock are not explicitly included in the design Soil-Structure Interaction (SSI) analyses providing demands for the RB structures that are described in Section 5.0 of NEDO-33914. The design demands are obtained from SASSI analyses based on the principles of continuum mechanics using isotropic and linear elastic constitutive models for all materials, including the rock materials.

The design of deeply embedded RB structure must consider different environmental and plant operating loads that are combined in different design load combinations per the governing design codes. The superposition principle, which is applicable only for linear elastic analyses, is essential for the design because it allows the results of the different dynamic, static and thermal stress analyses to be combined in different load combinations. The linear elastic assumption also allows the one-step design SSI analyses in Section 5.1 of NEDO-33914 to be performed on a refined RB structural model with many degrees of freedom and eliminates the need for defining initial conditions for each design load combination to calculate the structural design demands.

Sections 5.1.3 of NEDO-33914 describes the approach used to ensure the RB design bounds the subgrade conditions with adequate margins through comparisons of the results of:

- the linear-elastic 1-g SASSI analysis that provides static earth pressure demands used for the design of RB structure, and
- the nonlinear FIA that are performed following the guidelines in Section 4.0 of NEDO-33914.

The nonlinear FIA provides more realistic estimates of the earth pressures on the RB shaft by using models that better represent the response of fracture zones, joints, bedding planes, discontinuities or cavities in the rock.

Additional design analyses may be performed where earth pressure loads are applied to the below grade exterior walls of the refined RB structural model to account for:

- the effects on the RB design of anisotropic or heterogenous rock responses that cannot be directly modeled by the isotropic-elastic SASSI model; or

- potential pressures from unstable blocks of rock mass.

The magnitude and distribution of these additional earth pressure loads are determined from the results of nonlinear FIA or other estimates of earth pressures from unstable blocks of rock mass calculated as described in the GEH response to NRC Question 02.05.04-05 and in Sections 5.1.3 and 5.1.4 of NEDO-33914. The structural design demands obtained from the additional earth pressure analysis are combined with the results of the one-step design SSI analysis, as described in Section 5.1 of NEDO-33914, to ensure the RB structural design adequately addresses the effects of anisotropic and heterogenous rock behavior and accounts for potential unstable rock mass loads.

Proposed Changes to NEDO-33914 Revision 0

Assumption (1) in Section 5.1.2 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to clarify that the properties of subgrade materials for the design SSI analyses performed using the SASSI methodology are assumed isotropic.

Section 5.1.2 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to describe the approach used to account in the design for the effects of anisotropic or heterogenous rock response including potential pressures from unstable blocks of rock mass.

02.05.04-05 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Section: TR NEDO-33914 Section 5.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

Section 5.1.2, Soil-Structure Instruction Modeling Assumptions, states that "Strong rock without disadvantageous fracture zones, joints, bedding planes, discontinuities and other zones of weakness will frequently be self-supporting even if some reinforcement is required to ensure a safe excavation." It is not clear what is meant by disadvantageous fracture zones, joints, bedding planes, discontinuities, and other zones of weakness, and how they will be identified at a site.

It is further stated that "Joints and other weak planes may create isolated blocks that are unstable; however, these blocks are not typically large relative to the area of the structure and would be unlikely to produce significant loads on the exterior of the structure compared to other loads (e.g., hydrostatic). These blocks would also not be able to create a cascading failure once the structure is in place." It is not clear what are the basis for the assumption that unstable blocks would be isolated. It is also not clear why the unstable blocks would not produce significant loads on the RB structure. The unstable blocks could impose concentrated load(s) with significantly higher magnitude than the hydrostatic load on the RB walls (e.g., the scenario shown in Figure 5-1). It is also not clear from the discussion how the design of the RB structure would account for such large rock mass failure.

Request:

The staff requests GEH to provide an approach to identify the disadvantageous fracture zones, joints, bedding planes, discontinuities, and other zones of weakness at a site. The staff also requests GEH to provide rationale why the unstable blocks would not produce significant loads on the RB structure and explain how the design of the RB structure would account for such load. Modify the TR as necessary.

GEH Response to NRC Question 02.05.04-05

The text describing the smaller loads on the Reactor Building (RB) structures from isolated blocks will be removed from Section 5.1.2 of NEDO-33914. The text is misleading because the load from blocks and wedges would be estimated. Blocks and wedges smaller than the maximum size would likely not be as significant on the RB structures, but these loads could be estimated.

The general approach for identifying fracture zones, joints, bedding planes, discontinuities, and other zones of weakness at a site are provided in the GEH response to NRC Question 02.05.04-02 concerning characterization of the rock fracture network. As stated in the GEH response to NRC Question 02.05.04-02, characterization of the rock fracture network may include additional or inclined borings to investigate specific discontinuities, structural features, and recover rock cores with natural discontinuities.

Discontinuities identified through mapping, field investigation and laboratory testing may form unstable blocks or wedges that could potentially move towards the excavation without reinforcement (Reference 05-1). Therefore, identification of these blocks and wedges is important for identifying potentially unstable excavations that require reinforcement. For the BWRX-300, a stable excavation would either have no unstable blocks and wedges or would be stabilized by reinforcement. A stabilized excavation would potentially result in earth pressures on the RB shaft after degradation of the reinforcement as discussed in the GEH response to NRC Question 02.05.04-06 and in Section 5.1.2 of NEDO-33914.

Identification of unstable blocks and wedges will typically use a graphical method or computer program to implement block theory (References 05-1 and 05-2). Block theory is used to identify potential blocks and wedges that may form at the perimeter of the excavation (Reference 05-2). This process evaluates the orientation data of discontinuities from mapping and borehole measurements to determine the number of principal joint sets in the bedrock units. The average orientation as well as the variation in the average orientation (e.g., Fisher constant) is determined for the strike and dip of each set (Reference 05-3). A graphical method or computer program can then determine if the different joint sets form finite and removable blocks that are potentially unstable (References 05-1 and 05-2). The maximum unstable block (key block) can be determined once the excavation dimensions are considered, and the maximum block size can be further refined when data on the spacing of the discontinuities is incorporated (Reference 05-2).

Estimates of earth pressures on the RB shaft from the maximum unstable block size can be obtained from:

- Nonlinear Foundation Interface Analysis (FIA) that includes rock/rock discontinuities represented by interface models as described in Section 4.3.1.2 of NEDO-33914 and in the GEH response to NRC Questions 02.05.04-01 and 02.05.04-04; and/or
- Force equilibrium analyses described in Section 5.1.4 of NEDO-33914.

The primary focus in estimating the earth pressure will be on the maximum block sizes and unstable blocks that could produce larger loads. If the load from specific blocks or wedges is large, alternative mitigation measures may be considered, such as overexcavating and backfilling or the use of degradation resistant reinforcement.

References

05-1. Hoek, E., Practical Rock Engineering, RocScience < https://www.rocscience.com/assets/resources/learning/hoek/Practical-Rock-Engineering-Full-Text.pdf >, 2007.

05-2. Goodman, R.E., and Shi, G., Block Theory and its Application to Rock Engineering, Prentice-Hall, Inc, 1985.

05-3. Brady, B.H.G., and Brown, E.T., Rock Mechanics for Underground Mining, 3rd Edition, Kluwer Academic Publishers, 2004.

Proposed Changes to NEDO-33914 Revision 0

Section 5.1.2 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to remove the text stating isolated unstable blocks do not produce significant loads. The text is modified to indicate an appropriate method (e.g., block theory) should be used to identify potentially unstable blocks and wedges and that the nonlinear FIA may be used to estimate the potential loads of unstable blocks and wedges.

Section 5.1.3 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to include other mitigation methods like overexcavation and backfilling when the potential load from a block or wedge is large.

Section 8.0 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to include Goodman and Shi (1985) as a reference.

02.05.04-06 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Section: TR NEDO-33914 Section 5.1.2

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

Section 5.1.2, Soil-Structure Instruction Modeling Assumptions, assumes that the rock is self-supporting. It is not clear whether the BWRX-300 reactor system cannot be installed in a rock mass that is not self-supporting, e.g., rock mass with poor rock quality.

Request:

The staff requests GEH to clarify whether a site requiring significant permanent support system(s) to keep the surrounding media stable would be unsuitable for siting a BWRX-300 reactor. Modify the TR as necessary.

GEH Response to NRC Question 02.05.04-06

The BWRX-300 can be deployed at soil sites and sites having rock masses that require support during the excavation and construction of the deeply embedded Reactor Building (RB) shaft. The as-built site-specific subgrade conditions must ensure the stability of the BWRX-300 power block foundations by conforming to the regulatory requirements of NUREG 0800 Standard Review Plan

(SRP) 2.5.4, "Stability of Subsurface Materials and Foundations" (Reference 06-1). The stability of the surface mounted foundations of the surrounding Radwaste Building (RwB), Control Building (CB) and Turbine Building (TB) is crucial for the stability and structural integrity of the deeply embedded RB. Therefore, the SRP 2.5.4 requirements shall be satisfied not only for the Seismic Category 1 RB foundation but also for the surrounding surface mounted foundations.

Nonlinear Foundation Interface Analysis (FIA) are performed, as described in Section 4.0 of NEDO-33914, to evaluate the suitability of the site for deployment of BWRX-300 by assessing the stability of the supporting media, soil and/or rock, and RB, CB, TB and RwB foundations per SRP 2.5.4. The nonlinear FIA are performed for different life stages starting from the site characterization, excavation, construction, loading to start-up and operation. The results of the analysis of each stage are used to establish the initial conditions for the subsequent stage. The excavation support elements, such as rock reinforcement and soil support are included in the FIA model used for the analyses of the excavation, construction and loading stages.

The GEH response to NRC Question 02.05.04-05 describes the approach used to identify potentially unstable blocks and wedges in the rock mass that may require reinforcement. When a rock mass requires reinforcement, it is not considered stable over the life of the BWRX-300. The excavation support elements are considered temporary and are only included in the nonlinear FIA for the excavation, construction, and loading stages. The excavation support elements are removed from the nonlinear FIA for the startup and operation stage to calculate the earth pressures on the RB shaft. These earth pressure results can be compared with:

- the earth pressure loads considered for the conceptual generic design of the RB structure to obtain a general first-hand assessment of the suitability of the BWRX-300 generic design for the site-specific subgrade conditions; and,
- the earth pressure results of the site-specific design SSI analyses, as described in Section 5.1.3 of NEDO-33914, for the final assessment of the RB structural design suitability for the site.

For sites where the subsurface conditions may result in large loads to the RB shaft, the BWRX-300 may still be deployed with additional mitigation methods beyond a more robust design of the RB structure. As described in the GEH response to NRC Question 02.05.04-05, these mitigation methods to reduce the loads on the RB shaft may include overexcavation and backfilling, installation of degradation resistant rock reinforcement, or other methods.

Reference

06-1. NUREG-0800 Standard Review Plan (SRP) 2.5.4, "Stability of Subsurface Materials and Foundations," Revision 5 (Reference 06-1).

Proposed Changes to NEDO-33914 Revision 0

Assumption (4) in Section 5.1.2 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to clarify that the design analyses can only neglect the rock pressures due to the weight of rock masses that are not required to be laterally supported during the excavation and construction.

02.05.04-07 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Section: TR NEDO-33914 Section 4.3.3

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

Issue:

Section 4.3.3, Fluid-Soil Interaction, states that the 3D model of BWRX-300 may have hydraulic interface(s) to simulate the effects of pore water during excavation, construction, loading, and operation phases of the reactor. In rock, flow through the rock fracture network can be the dominant flow mechanism. It is not clear what approaches would be taken to deal with fracture flow if it is present.

Request:

The staff requests GEH to clarify the approach to account for fracture flow. Modify the TR as necessary.

GEH Response to NRC Question 02.05.04-07

Explicit simulation of fractured flow is not anticipated for the model outlined in Section 4.3.3 of NEDO-33914. The model of potential groundwater flow would be used to evaluate changes in the groundwater level from high and low water tables or dewatering activities. Therefore, simulating the rock as a continuum is considered adequate for most sites. The fractured flow of groundwater in rock will likely be affected or reduced by grouting and/or dewatering near the excavation for the Reactor Building (RB) shaft by construction activities as noted in Section 3.1.3 of NEDO-33914. Monitoring of the water pressure in the rock mass will be completed as part of the field instrumentation plan in Section 3.4 of NEDO-33914.

The influence of groundwater will be addressed following the recommendation of the selected rock mass characterization method. The Rock Mass Rating (RMR) system uses a groundwater parameter and rating value to account for the groundwater in the fractured rock mass (Reference 07-1). The RMR groundwater rating is based on (Reference 07-1):

- inflow per 10 meters of tunnel length;
- the stress ratio of water pressure in the joints to the major principal stress in the rock mass; and,
- general conditions (dry, damp, wet, dripping, flowing).

At most sites, the inflow measurement will be impractical until the shaft excavation begins, and when the shaft is present the inflow value may be altered by grouting or other modifications for construction groundwater control. Measurements of the groundwater pressure using piezometers installed as part of the field investigation and monitoring program may be used to measure the water pressure in discontinuities and the rock mass. These water pressure measurements could then be used with the in-situ stress measurements in the rock mass, described in the GEH response to NRC Question 02.05.04-08 to assign the groundwater rating for RMR based on the stress ratio. However, the RMR groundwater rating may also be based on the qualitative general conditions description that would include observations from the field investigation and conservative estimates of the appropriate rating (Reference 07-1).

The Geological Strength Index (GSI) characterization of rock mass incorporates the potential deterioration of shear strength along rock discontinuities in wet conditions by recommending a shift to lower values in rocks with fair to very poor discontinuity surface conditions (Reference 07-2). Water pressure does not modify the GSI value; however, it is included by effective stress analysis using an appropriate material model (e.g., Hoek-Brown, Mohr-Coulomb).

Other rock mass ratings for RMR and GSI (e.g., uniaxial compressive strength; rock quality designation; rock structure; and, spacing, condition and orientation of discontinuities) would be based on the fracture characterization and rock data described in the GEH response to NRC Question 02.05.04-02.

References

07-1. Brady, B.H.G., and Brown, E.T., Rock Mechanics for Underground Mining, 3rd Edition, Kluwer Academic Publishers, 2004.

07-2. Hoek, E., Brown, E.T., “The Hoek–Brown failure criterion and GSI – 2018 edition,” Journal of Rock Mechanics and Geotechnical Engineering, 11(3), pp. 445–463, 2019.

Proposed Changes to NEDO-33914 Revision 0

Section 3.1.3 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to state that the groundwater conditions shall be included according to the selected method in evaluating rock mass characterization.

02.05.04-08 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Section: TR NEDO-33914 Section 3.1.1

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

Issue:

The TR does not state whether there would be a program to measure the in-situ stress field at the site. In Section 3.1.1, Site Investigation Program, the maximum required drilling depth is set at 120 m because the expected change in stresses due to excavation of the shaft would be less than 10% from the original in-situ stress field. It is not clear how this can be set without knowing the in-situ stress field. The stress distribution around the RB shaft could be quite different if horizontal stresses are larger than the vertical stress affecting the loads on the RB shaft walls.

Request:

The staff requests GEH to clarify whether there will be process to measure the in-situ state of stresses at the site and incorporate the stress field in the analyses. Modify the TR as necessary.

GEH Response to NRC Question 02.05.04-08

There will be a process to identify the in-situ state of stresses at the site and, when necessary, measure and incorporate the in-situ state of stress into analyses. Identification of the in-situ state of stress shall begin with reviewing the state of stress in the crust as part of evaluating the tectonic framework and unrelieved stresses in bedrock near the site.

A review of regional and/or local references that evaluate the current state of stress in the crust and the potential for horizontal stresses from tectonic activity, residual strains, or topographic conditions shall be used to assess the likelihood for increased horizontal stress in the bedrock (NUREG/CR-5738, Reference 08-1). Based on the results of this review, in-situ tests will be considered to make site-specific measurements of the in-situ state of stress in bedrock formations as part of the geotechnical borings and televiewer tests shown in Table 3-1 of NEDO-33914.

Overcoring and hydraulic fracturing are identified in Table 3-1 of NEDO-33914 as potential methods for estimating the in-situ stress; however, other methods including the identification of the principal stress directions and relative magnitudes from those identified in RG 1.132 (Reference 08-2) and breakouts recorded by borehole televiewer may be used (e.g., Reference 08-3). The appropriate tests for measurement of in-situ stress will be selected based on the likelihood for increased horizontal stresses and the type of subsurface materials at the site. NEDO-33914 does not list all tests for measuring in-situ stress because the selection of the appropriate tests is specific to each site.

When the in-situ state of stress is different than lithostatic in bedrock units, this difference will be incorporated into the initial conditions of the nonlinear Foundation Interface Analysis (FIA) model. The nonlinear FIA model and the potential key blocks described in the GEH response to NRC Question 02.05.04-05 may then be used to evaluate potential loads from an excavation with the in-situ stress field. These loads will be included in the design as described in the GEH response to NRC Question 02.05.04-04.

Consistent with Appendix D of RG 1.132 (Reference 08-2), the maximum required drilling depth for engineering purposes (d_{max}) of 120 m is based on a change in the vertical stress.

References

08-1. U.S. Nuclear Regulatory Commission, “Field Investigations for Foundations of Nuclear Power Facilities,” NUREG/CR-5738, ADAMS Accession No. ML003726925, November 1999.

08-2. RG 1.132, “Site Characterization Investigations for Nuclear Power Plants,” Revision 2, October 2003.

08-3. Science Applications International Corporation (SAIC), “Final Report – In Situ Stress Measurements in the NPR Hole,” Report Submitted to Westinghouse Savannah River Company, ADAMS Accession No. ML013190312, July 1992.

Proposed Changes to NEDO-33914 Revision 0

Section 3.1.1 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to define d_{max} based on the vertical stress and as the depth for engineering purposes.

Table 3-1 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to correct “in-site stress” to “in-situ stress” for the test purpose of geotechnical borings and borehole televiewer.

Section 3.1.3 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to include a discussion on reviewing the current knowledge of the state of stress in the bedrock and, as needed, measurements of the in-situ stress state.

Section 4.3.4.1 of NEDO-33914 is being revised as shown in the Enclosure 2 markups to state the initial stress conditions include the influence of groundwater and measured horizontal stresses for the nonlinear FIA.

02.05.04-09 (eRAI 9859)
Date of eRAI Issue: 07/30/2021
LTR Application Section: TR NEDO-33914 Section 5.1.4

Requirements:

General Design Criterion (GDC) 2 requires that structures, systems, and components (SSCs) important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function. GDC 2 also specifies that the design bases for these SSCs shall reflect the importance of the safety functions to be performed.

10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology. 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.

Standard Review Plan (SRP) NUREG-0800, Section 2.5.4, provides regulatory guidance for the investigation and reporting site-specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.1, provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories.

Standard Review Plan (SRP) NUREG-0800, Section 3.7.2, states for the seismic design of nuclear power plants, it is customary to specify earthquake design ground motions that are exerted on the plant structures and used in soil-structure interaction (SSI) analyses.

Issue:

Section 5.1.4, Probabilistic Earth Pressure Analyses, presents an approach as an example to account for the uncertainties in the estimated value of the load on the RB shaft walls in a soil medium. It is not clear whether similar approaches would be used to account for uncertainties in at least important parameters significant to the reactor design; for example, the estimated rock mass modulus estimated using various empirical equations from different measured and inferred parameters (indirect estimation).

Request:

The staff requests GEH to clarify whether there will be a plan to account for the uncertainties in other site-related parameters with potential to significantly affect the reactor design. Modify the TR as necessary.

GEH Response to NRC Question 02.05.04-09

The design accounts for uncertainties in all site-related parameters that can potentially have a significant effect on the stability of the BWRX-300. The uncertainties in the site-related parameters can be addressed deterministically by considering conservative values, performing sensitivity analyses for multiple values, or probabilistically based on results of statistical analyses.

Conservative site-related design parameters are developed, as described in Section 5.2 of NEDO-33914, considering the natural randomness of subgrade materials and errors in measurement of the subgrade material properties. Uncertainties related to the methods or empirical relationships used for development of site-related design parameters are also addressed by considering different models. For example, uncertainties in the estimated rock mass modulus may consider different models as the ones shown in Equations 5-17 to 5-22 of NEDO-33914. The uncertainties in the measured and estimated parameters used in these models, such as Rock Mass Rating (RMR), Geological Strength Index (GSI), disturbance factor, modulus ratio, Uniaxial Compressive (UC) strength, intact rock modulus, are also considered either deterministically or probabilistically.

Using the same approach implemented for probabilistic analyses in Section 5.1.4 of NEDO-33914, the statistical analyses performed to develop the site parameters may consider:

- probabilistic distributions, usually normal or log-normal, to address the aleatory variability of the measured parameters; and
- discrete probabilistic distribution combined using appropriate weight factors to address epistemic uncertainties related to the use of different measuring techniques or methods for development of the site parameters.

When the results of the deterministic analyses show the site-related parameters are sensitive to the input values or indicate limited margin in the design, a probabilistic analysis will be completed to demonstrate that the design adequately addresses uncertainties in the site-related parameters with potential to significantly affect the Reactor Building (RB) design. Section 5.1.4 of NEDO-33914 presents a probabilistic approach used to ensure the design adequately addresses the uncertainty in the estimated soil and rock pressures that are the most important site-related load affecting the stability of the deeply embedded RB structure. However, the same probabilistic approach can be used to address uncertainties in other important site-related design parameters.

Proposed Changes to NEDO-33914 Revision 0

Section 5.1.4 of NEDO-33914 is being revised as shown in the Enclosure 2 mark-ups to explain that the probabilistic earth pressure evaluations also consider uncertainties in the methods or empirical relationships used for development of site related parameters following an approach similar to the approach used to account for modelling uncertainties.

Table 5-1 of NEDO-33914 is being revised as shown in the Enclosure 2 mark-ups to indicate that the models for probabilistic analyses consider the natural and measurement uncertainties in rock mass properties.