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Method on Seismic Hazard Assessment

FOR

New Nuclear Unit Site

Content

1. General Provisions

The document specify the acceptable methods for conducting geological, geophysical, seismological, and geotechnical investigations, identifying and characterizing seismic sources and conducting a probabilistic seismic hazard assessment for the new nuclear plant site and specific design ground motion determination. The requirements are applied at review of the seismic hazard evaluation reports for the Armenian new nuclear unit site submitted by an applicant in line with the licensing procedure.

Review, expert technical assessment, document and process verification of the Armenian new nuclear unit (NNU) site seismic hazard evaluation is required by the regulatory authority prior to design terms of reference.

The method cover the evaluation of applied approaches and methods used for geological, geophysical, seismological and geotechnical investigations; for identification and characterization of seismic sources; for PSHA implementation, determination of characteristics of seismic waves transmission, and for determination of ground motion response spectra.

The NNU site seismic hazard evaluation may require additional or repeated reviews connected with submission of additional, updated or corrected materials.

Based on the seismic hazard evaluation results, the regulatory authority shall prepare a document with summary expert conclusion on the ANPP site seismic hazard assessment.

After the review process completion and regulatory approvment, applicant should develop relevant design requirements and the correspondent Terms of Reference for deisgn.

The conclusions of the review of the ANPP site seismic hazard assessment evaluation developed by the regulatory authority are binding for the applicant, contractors, design and other involved organizations.

2. Procedure of Evaluation

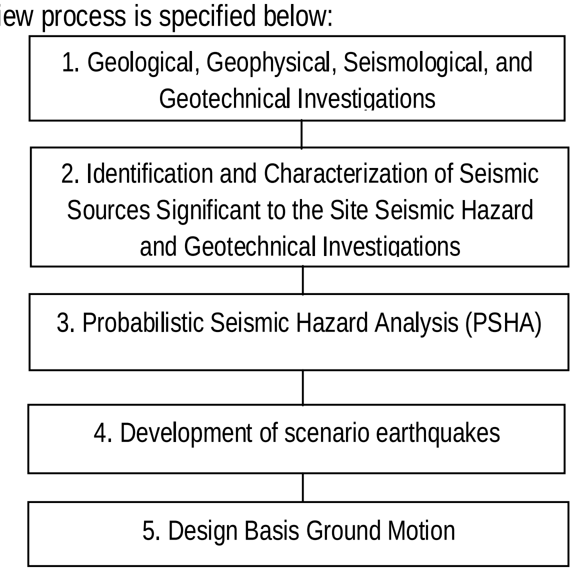
2.1. The conclusions resulting from expert assessments which are the basis for regulatory decisions shall include the following topics:

- Characteristics of the site, initial data used in the assessments, design characteristics and parameters of the site;
- Description of applied methodology and procedures for investigation and documentation requirements set forth in the TOR;
- Adherence to the methodology and requirements set forth in the regulatory documents and standards listed in References;
- Findings on relevance of content and format of the submittals;
- Recommendations on the acceptance (when there are no serious comments or identified issues requiring repeated review or change in evaluation) or the lack of acceptance of results contained in the submitted documents.

2.2. A list of documentation to be included in PSHA reports subject to review and expert assessment is provided in Chapter 10.

2.3. An entity making the evaluation on behalf of the regulatory authority may request through the regulatory authority that the applicant submits additional information or materials necessary for the review of issues within the jurisdiction of the regulatory authority.

2.4. A Flow Chart of review process is specified below:



3. Investigations and Data Collection

3.1. Geological, Geophysical and Geotechnical Database

The regulatory authority shall review and verify geological, geophysical and geotechnical information submitted by applicant. The geological, geophysical and geotechnical information should be obtained as a result of new site-specific field surface and near surface site survey and laboratory investigations, as well as results of investigations conducted at the site previously for ANPP unit 2 seismic safety re-evaluation purposes. The new evaluations shall form the basis of NNU site PSHA.

Detailed geological, geophysical and geotechnical investigations should be carried out both in the region and at the site for the purpose of developing an up-to-date site-specific database that supports site characterization and a PSHA. The available scientific and technical information should be reevaluated and updated, also taking into account the Unit 1 and 2 site related data and assessments. Results of new investigations and interpretation of the complete set of obtained data should be adequately implemented in the PSHA databases and in the seismic source characterization model.

Pre-instrumental earthquakes are to be used for determining an appropriate magnitude-frequency relationships, particularly for rare, large magnitude earthquakes. Thus, effort should be put to identify and investigate these through paleoseismic investigations, including geomorphology and paleoliquefaction studies. Paleoseismic studies should be performed for the following purposes:

- Identification of relevant seismogenic structures based on the recognition of topographic and geophysical effects of past earthquakes in the region;
- Improvement of the completeness of large events in the earthquake catalogues and reduction of event uncertainty through identification and characterization of historic earthquakes. As an example, trenching across identified capable faults may be useful in estimating the amount of displacement during large events and the rate of occurrence of such events;
- Estimation of the maximum seismic potential of a given seismogenic structure, typically on the basis of the displacement per event (trenching) as well as of the cumulative effect (landscape geomorphology);

3.2. Seismological database

The data collected shall include information on all earthquakes in the region that were recorded or can be identified from historical records. Data from archeological investigations should be also reviewed.

3.2.1 Historical earthquakes

All ‘pre-instrumental’ historical earthquake data (that is, early events for which no instrumental recording was possible) should be collected, extending as far back in time as possible. Palaeoseismic and archaeological information on historical and pre-historical earthquakes should also be taken into account. To the extent possible, the information on each earthquake shall include the following information:

- Date and time of event,

- Location of macroseismic epicentral area,
- Assessment of focal depth,
- Assessment of magnitude, type of magnitude and description of methodology applied to determine magnitude from macroseismic intensity,
- Maximum intensity, intensity in macroseismic epicentral region with description of local conditions,
- Isoseismic contours,
- Earthquake intensity together with soil data appropriate for determining site response,
- Assessment of uncertainty of all mentioned parameters,
- Assessment of quality and quantity of data on which the evaluation of above mentioned parameters were estimated and estimation of uncertainties to the extent possible.

A region-specific intensity scale catalogue should be developed. Assessment of the likely magnitude and depth of each earthquake should be based on a region-specific empirical correlation between instrumental data and macroseismic information that is developed based on the assembled database.

3.2.2 Instrumental Earthquakes

All available data from instrumentally recorded earthquakes should be collected. For each event the following information should be collected:

- Date and time of event;
- Coordinates of epicenter, and full characterization of rupture plane, if possible;
- Focal depth;
- All magnitude estimates, including those on different scales, and any information on seismic moment;
- Dimensions and geometry of the fore-shock and aftershock zones;
- Magnitude and seismic moment;
- Sizes and geometry to shock and aftershock zones;
- Other information that can be useful for understanding the seismotectonic regime, focal mechanism, seismic moment, stress drop, rupture in the stress field and any other parameters related to location or rupture properties, asperity location and size;
- Assessment of uncertainty of all above parameters.

An assessment of the completeness and reliability of available information should be carried out. In particular, a review of the macroseismic intensity, magnitude, date, location, depth of hypocenter should be made after the catalogues of historic and instrumental earthquakes have been compiled. An assessment of completeness of the catalogues should be made using relevant and state-of-the-art methods. For each event in the instrumental catalogue, an estimation of a consistent magnitude scale (e.g. moment magnitude) should be determined. Information should be provided on the methods used to covert data between magnitude scales for the earthquakes for which this is required. Prior to determining appropriate magnitude-frequency relationships for seismic sources, the catalogues should be reviewed for:

- Selection and relevance of uniform magnitude scale;
- Definition of magnitude of each event;
- Identification of main shocks;
- Assessment of completeness of catalogues as a function of magnitude, regional location and time frame;
- Assessment of the quality of the data with an estimation of uncertainties of all parameters.

The selection and determination of relevant attenuation relationships for ground motion prediction (i.e. ground motion prediction equations) and the development of site-specific response spectra are based, in part, on the seismological database. It is necessary to collect and document a complete set of accumulated records of regional and local earthquakes to the extent possible.

3.2.3 Specific Instrumental Data

In order to obtain as much detailed information about potential seismic sources as possible, it is necessary to also use data from sensitive seismographs that are part of local (including telemetric) and national networks that record microearthquakes. Recorded earthquakes should be studied in detail and used in the identification of seismogemnic structures near the site. The potential of these faults to be capable should be investigated using other data as described in Section 8. Seismicity that cannot reasonable be associated with a seismogenic structure should be included as diffuse seismicity, typically defined by area sources in the seismic source model.

3.3 Seismogenic structures

3.3.1. Identification

All seismogenic structures that have the potential to contribute to ground motion and fault displacement hazard at the site should be included in the seismotectonic model. Seismogenic structures may be identified through assessment of the geological, geophysical and seismological databases. These databases may provide direct or indirect evidence of the seismic sources in tectonic regime. In particular, earthquakes may have a greater likelihood of originating where there is a correlation between historic and instrumental earthquakes records and geological structures.

All seismogenic structures whose location and earthquake potential are capable of affecting the seismic hazard of the site in the range of spectral frequencies of interest should be specifically studied and included in the ground motion hazard assessment.

When assessing hazard associated with fault displacement and direct rupture, the focus should be placed on seismogenic structures closest to the site that have a potential to cause displacement at or near the ground surface that would affect the safety of NPP structures, systems and components.

Uncertainties in earthquake hypocenter location, stress state, and distribution of shock and after shock data shall also be used for review of the consistency between the seismogenic structures and the seismologic data. The combination of seismogenic structures within the seismotectonic model should be reasonably justified by available data and the associated combination of uncertainties in identification of these structures should be provided.

Assessments of uncertainty should be provided for all assumptions and estimates in the model that link earthquake properties with geological and geophysical properties. In cases where data on geological and geophysical properties are limited, the assessment of uncertainty shall reflect the lack of data.

3.3.2. Characteristics of Seismogenic Structure

The following characteristics and information should be determined for the identified seismogenic structures that affect the seismic hazard:

- Dimensions of structure (length, down-dip width);
- Orientation (strike, dip);
- Amount and direction of displacement;
- Maximum historical intensity and maximum historical magnitude;
- Geological properties (segmentation, branching, structural relationships);
- Data on earthquakes compared with identical ones for which historical data are available.
- Paleoseismic data;

Geometry or dimensions of the fault plane should be determined from definition of maximum potential magnitude if available geologic or geophysical data are not sufficient., Potential sources should be provided in the form of a function of fault plane sizes and possible stress drops, in addition to magnitude. The potential stress drop range for a region can be assessed with available published investigations of such tectonic media.

Different approaches or combinations of approaches may be applied to define the maximum potential magnitude Mmax, for each source. The range of values determined for each source, and the associated uncertainties, should be consistent with geological and geomorphological data. In addition to Mmax, magnitude-frequency relationships should be evaluated for each seismogenic structure included in the seismotectonic model to determine the rate of earthquake activity, the appropriate magnitude-frequency relationship or relationships to include in the model (e.g., characteristic or exponential), and the uncertainty in this relationship and its parameters.

3.4 Zones of Diffuse Seismicity

3.4.1 Identification

Zones of diffuse seismicity in seismotectonic areas are defined as regions with similar seismic potential within their areas. Zones can also be separated if they have different assessments of Mmax. A geographically non-uniform distribution of diffuse seismicity can also be used provided that the available data support this assumption and appropriate characterization techniques (e.g. smoothed seismicity) are used. In addition, significant differences in focal depths (crustal versus sub-crustal), focal mechanisms, state of stress, tectonic characteristics and Gutenberg-Richter b-values may all be used to differentiate between provinces or zones.

Diffuse seismicity zones are defined and characterized based on the seismological database. When assessing the maximum depth of earthquakes associated with a zone, one shall take into account that earthquakes may occur within brittle or brittle to ductile transition areas of the Earth. .

3.4.2 Characteristics of diffuse seismicity zone

The maximum potential magnitude of earthquakes not associated with identified seismogenic structures should be evaluated on the basis of historical data and the seismotectonic characteristics of the zone. Attention should be paid to earthquakes that have occurred in tectonically analogous regions found internationally. Estimates of the maximum depth of earthquakes within a zone can be made on the basis of the recognized fact that earthquakes originate within or above the brittle to ductile transition zone of the Earth's crust.

Significant differences in focal depths (for example, between crustal and sub-crustal), focal mechanisms, stress states, tectonic characteristics, and Gutenberg-Richter b-value are used to differentiate between provinces or zones. Regardless of the approach used to determine the b-value of the magnitude-frequency relationship, uncertainty in the parameter should be appropriately assessed and incorporated into the seismic hazard analysis.

3.5 Investigations

Investigations should be carried out for four areas defined by radii from the site boundaries: of for regional investifgation 320km, for near regional investigation not less than 25km, for site vicinity investigation - not less than 5 km, and for site area, including entire area of ANPP and NNU site. These dimensions should be adjusted to reflect the local conditions. The areas closest to the NNU site and the territory of NPP site should be investigated in increasing detail. Seismotectonic investigations covering the territory of neighboring countries should be carried out with the goal of providing a uniform database for the whole region. Investigations shall provide data at four levels of detail based on the following characteristics:

- Distance from the site
- Nature of the Quaternary tectonic regime
- Geological complexities of the site and region
- Existence of potential seismic sources or structures
- Potential for surface faulting or deformations

3.5.1 Regional investigations. These investigations cover the area within a radius of 320km and are carried out with the purpose of determining and assessing the geodynamic situation and tectonic regime of the region and to identify potential seismic sources within the region. Regional investigations are carried out with maps in 1: 500 000 scale or better with relevant cross sections and using appropriate geological and geophysical methods. The most relevant among those geological features are structures that show potential for displacement and/or deformation at or near the ground surface (i.e. capable faults). However, all seismic sources or tectonic structures that may contribute to ground shaking hazard at the site should be identified, investigated, and appropriately characterized for incorporation into the PSHA. It may be appropriate to further investigate identified seismic sources using the techniques described for the site vicinity investigation.

3. 5.2 Near Regional investigations cover the area with a radii not less than 25 km from the site and is carried out based on comprehensive and detailed surveys. The purpose of detailed investigations is:

1. The near regional seismotectonic characteristics more detailed database shall be used than obtained from the regional study;
2. To determine geologically recent motions that have occurred on faults of interest through additional field explorations;
3. To determine the amount and nature of displacements, rates of activity and evidence of segmentation of faults.

The geological structure and tectonic history of the region should be developed based on the current tectonic regime and specific investigations. The tectonic regime around the site and the time period of current and past tectonic activity should be thoroughly investigated.

Various sources of information should be used, in addition to field surveys. For example, methods of geophysical investigations (e.g., reflection method, refraction, gravimetric, electrical and magnetic waves) are used for identification of spatial characteristics of faults and for associated parameters, such as geometry, maximum magnitude, and level of tectonic activity.

Data based on surface expressions can be derived from studies of Quaternary formations or landforms, such as terrace analysis and sedimentological studies. Aerial and satellite photographs and/or images are among the data that should be used for this task.

The current degree and type of deformations should be investigated with the use of advanced technologies, such as GPS data and interferometry, and also through deformation measurement-related data.

Investigation of the site is carried out by maps with 1:50000 scale or better with relevant cross sections.

3.5.3 Site Vicinity Investigations. Site vicinity investigations cover the geographic area within a radius of 5 km from the site and include more detailed studies of neotectonic properties of faults, as well as further identification of potential of fault displacement levels and conditions of origination of geological instability of the site.

Site investigation results shall include geomorphological and geological surveys, geophysical prospecting, geotechnical field testing, and soil samples obtained from boreholes with the purpose of developing the following data and information with acceptable certainty:

- Geologic map with cross sections,
- Age, type, value and level of displacement and deformations of all faults at the site,

- Detection and characterization of potential hazards resulting from natural phenomena (for instance collapse due to karstic formations, subsidence, slope instability) and human actions such as excessive mining.

Data should be provided on maps with a 1:5000 scale or better with relevant cross sections.

3.5.4 Investigation of NNU Site Area

The site area investigations shall cover the area occupied by the NNU. The objective of these investigations is the development of a very detailed study of geological, geophysical and geotechnical properties to assess soil and rock geometry, characteristics, and dynamic behavior. Data are developed through field and laboratory investigation and testing. Static and dynamic properties of geologic materials at the site should be determined for use in site response analysis.

Site investigation should be carried out by geological, geophysical, seismological and geotechnical methods, as discussed below.

1) *Geological and geotechnical investigations*. Investigations including field in-situ, field testing of soil/rock samples, geophysical methods, and laboratory testing should be carried out for the purpose of determining thickness, depth, slope, and static and dynamic properties of the different geological layers that underlie the site. These investigations are necessary to define parameters such as the Poisson's ratio, Young's modulus, shear modulus, non-elastic and non-linear small-strain properties , strain-dependent shear modulus and damping curves, density, relative density, characteristics of consolidation and swelling, and the granular size distribution of the soil. The soil model used for site response analyses is developed based on data resulting from the geological, geophysical and geotechnical investigations.

2) *Hydrogeological investigations* are necessary to determine ground water levels and the hydrologic characteristics of water-saturated layers and aquifers, including the nature of their interactions. The investigations are also necessary to define the geometry, physical and chemical properties, hydraulic conductivity and permeability, and the degree of water saturation of each layer.

3) *Additional investigations.* Dynamic properties of geologic layers underlying a site can be assessed through instrumental measurements, and also through analysis of information obtained from experimental investigations undertaken.

Investigations should be aimed to obtain all data necessary to carry out analysis of dynamic soil-structure interaction.

Data should be provided on maps with a 1:500 scale or better and with relevant cross sections.

3.5.5. Specifics Detected During Site Preparation and Construction

During the course of site preparation and construction, in particular during excavation activities, previously unknown faults may be detected. Before submission of the application for the operational license, it is necessary to demonstrate that faults detected during excavations do not threaten the installation. Detected formations should be identified, analyzed, characterized; and the impact of these formations on ground motion should be assessed and sufficiently documented in the safety analysis report. If a geologic feature that may be a fault is detected in an excavation, the regulatory agency should be informed and should be provided an opportunity to view the feature.

4. Development of Regional Seismotectonic Model

4.1 Basics

A regional seismotectonic model is developed through analyses that consider and coherently merge the information from all the regional databases available. In order to gain increased long-term regulatory stability, the model shall not try to identify the single best explanation, but rather account for all scientifically valid alternate hypotheses and appropriately weight the alternatives and uncertainties. In the construction of such a model, all existing interpretations of the seismotectonics of the region that may be found in the available literature should be identified, considered, and included in the documentation submitted. All alternate interpretations should be taken into account (e.g. through a logic tree framework) with determination of the weighting of alternate hypotheses based in part on the scientific consistency of each of the interpretations with the various databases collected. The use of formal and established methods of incorporating expert opinion into the study should be incorporated into the PSHA program. The goal during construction of the seismotectonic model and in developing the suite of ground motion prediction equations (which jointly form the PSHA input model) is to create a robust PSHA model.

The seismogenic structures identified may not explain all the observed earthquake activity. This is because seismogenic structures may exist without recognized surface or subsurface manifestations and because of the timescales involved; for example, fault displacements may have long recurrence intervals with respect to seismological observation periods.

Seismogenic structures can exist without observable surface or near surface expression in the time frames of interest. The seismotectonic model developed shall include two types of seismic sources:

- Structures that are revealed and characterized with the existing database;
- Sources that account for diffuse seismicity (consisting usually, but not always, of small to moderate earthquakes) which is not attributable to specific structures identified by using the available database.

The assessment and characteristics of these two types of seismogenic sources have associated uncertainties, especially in the case of diffuse seismicity because the structure of these sources are not well understood. In developing sources describing diffuse seismicity, alternate approaches to smoothing of seismicity or area source development can be considered. The final seismic hazard assessment shall include a review of all alternative models and approaches and shall provide relevant weights for each of the alternative models. An assessment of epistemic uncertainties shall include all input assumptions, starting with seismic source characterizations and including all parameters up to frequencies of earthquakes.

As part of the seismic source characterization, the seismic potential of each source should be evaluated. Typically, characterization of the seismic potential consists of four equally important elements:

1. selection of a model for the spatial distribution of earthquakes in a source;
2. selection of a model for the temporal distribution of earthquakes in a source;
3. selection of a model for the relative frequency of earthquakes of various magnitudes including an estimate of the largest earthquake that could occur in the source under the current tectonic regime;
4. a complete description of the uncertainty.

For example, truncated exponential and characteristic earthquake models are often used for the distribution of magnitudes. A stationary Poisson process can be used to model the spatial and temporal occurrences of earthquakes in a source.

4.2 Assessment of Magnitude-Frequency Correlation

The magnitude scale used in the hazard evaluation shall correspond to the magnitude scale of the ground motion attenuation relationship to be used in the PSHA. However, for the purposes of determining magnitude-frequency relationships, the moment magnitude M_w scale is beneficial in the range of considered magnitudes because it varies linearly and is not susceptible to magnitude saturation effects. If a different scale is used, attention should be paid to assessing and addressing any saturation effect issues.

A magnitude-frequency relationship should be developed for each seismic source and shall contain:

- Frequency of occurrence for each earthquake magnitude ,
- The maximum magnitude that the source is capable of producing

To account for uncertainty, the magnitude-frequency relationship is defined as a distribution with regard to correlation between parameters.

Maximum potential magnitude (Mmax) is defined for each seismic source. In probabilistic seismic hazard analysis Mmax values are used as upper integration limits and as the upper bound of the magnitude-frequency relationships.

To account for uncertainty, Mmax values should be described by a discrete or continuous distribution of probability. The sensitivity of the resulting hazard to the choice of the Mmax distributions should be tested.

5. Assessment of Ground Motion

5.1 Basics

The site-specific ground motion response spectra are defined based on seismologic, geologic, geophysical and geotechnical database. Based on PSHA they will represent the SL-2 or the Safe Shutdown Earthquake (SSE) of the NNU.

Site-specific ground motion response spectra are defined as response spectra of horizontal and vertical free field ground motions at a specific reference point. During development of site-specific ground motion response spectra it is necessary to take into account regional and local geology, regional and local tectonics, and the site specific geotechnical characteristics of subsurface materials of the site. Realistic assessments of all uncertainties should be clearly and appropriately incorporated in PSHA calculations. Epistemic uncertainties are incorporated into the PSHA through alternate branches of the logic tree formulation. Aleatory variability is included in the PSHA through the use of probability distributions on properties. Conservatism in definition of site-specific ground motion response spectra is taken into account through the choice of appropriate confidence level of annual frequency of exceedance that corresponds to mean frequency of exceedance.

5.2 Characteristics of Ground Motion

Ground motion is characterized by response spectra that define spectral acceleration, velocity and displacement for each spectral frequency of interest. Other parameters of interest are peak ground acceleration values, peak ground velocity, peak ground displacement, the averaged spectral values over a specified spectral frequency range, A Fourier amplitude spectrum and power spectral density can also be used to characterize a given earthquake or structural response waveform. Because earthquakes cause three-dimensional motions, various methods of expressing ground motion spatially are used. The ground motion components are most frequently expressed by using the largest horizontal component, the geometric mean of the two horizontal components, the random horizontal component or the vector sum of the two horizontal components. The vertical should be considered separately.

The selection of the ground motion parameters and components should be consistent with the requirements of the users of the seismic hazard analysis.

5.2.1. Ground Motion Prediction Equations

Ground motion prediction equations (GMPEs), formerly known as attenuation laws, shall define ground motion as a function of relevant parameters using empirically or theoretically developed relations in the form:

$$GM = g(m,r,c_i) + \varepsilon_{gm} + \varepsilon_c$$

where, *GM* – average assessment of ground motion parameter; g() - mathematical function, m-earthquake magnitude, *r* – distance from source to site, c_i – coupled parameters, ε_{gm} – aleatory uncertainty, ε_c- component-to-component variability, the variability between the two horizontal components shall the random horizontal component of ground motion be used in the seismic hazard analysis.

In certain cases, aleatory uncertainty is divided into components among events (ε_τ) and inter events (ε_σ) (i.e. intra - and inter - event terms). Furthermore, for a given site (like the ANPP) it may be appropriate to use single station standard deviation of the GMPE which will be less than the total standard deviation.

The definition of magnitude, distance and other input parameters vary between GMPEs and are based on the definitions used in the original databases used for GMPE development. In the PSHA, these parameters should be defined in such a way as to be consistent with the definition of the applied parameters required by each GMPE. In cases where different sets parameters are needed for the GMPEs, each of the parameters should be developed either through direct assessment of the parameter or by known empirical correlations.

The GMPEs should be compatible with the reference site condition and the regional tectonic environment. If these conditions are not the same and sufficient appropriate GMPEs are not available, an adjustment should be made using appropriate empirical or theoretical site-response factors or other corrections. In these cases, the corresponding uncertainty must be assessed. If for a given attenuation relationship the aleatory uncertainty is not partitioned into inter-event, intra-event and component-to-component elements, a separate aleatory model that accounts for this partitioning may be developed.

GMPEs should be selected such that they meet the following main criteria:

- Reflect modern approaches for assessing ground motions for given scenario events;
- Are appropriate for the seismic mechanisms anticipated for each source;
- Appropriately reflect seismic energy attenuation of the given region;
- Are appropriate for the tectonic environment of the considered region;
- Are developed based principally on data from recorded earthquakes.

Use of local earthquakes records for scaling or modifying existing GMPEs should be justified by demonstrating that scaling parameters of assumed values of magnitudes and distances correspond to earthquakes of considered range of magnitudes and distances. Caution should be exercised when comparing selected GMPEs with recorded ground motions from small, locally recorded earthquakes. The use of such recordings (e.g., in scaling the selected GMPEs) should be justified by showing that their inferred magnitude and distance scaling properties are appropriate for earthquakes within the ranges of magnitude and distance that are of greatest concern to the seismic safety of the nuclear installation. In addition, scaling or modification of existing GMPEs shall only be undertaken if there are a sufficient number of locally-recorded records to be statistically significant and if the locally-recorded records can be shown to fall outside the accepted levels of uncertainty for the GMPE, such that the site can be shown to be anomalous.

Empirical uncertainty should be assessed and addressed by including a range of GMPEs for each tectonic media considered in the PSHA. GMPEs should be selected in such a way as to cover the whole range of scientifically viable interpretations of seismic source model characteristics. Seismic intensity data may also be used to develop GMPEs in those regions of the world where strong motion recording instruments have not been in operation for a long enough period of time to provide sufficient instrumental data. However, care should be applied when undertaking this process as it does not allow for the combined use of historic and recorded data. It is more common to apply a process that first undertakes a study of historic earthquakes to determine event magnitudes and associated uncertainties; and then uses the historic magnitudes, combined with recorded data, to develop or assess GMPEs. It is recommended that an up-to-date list of attenuation relationships be assembled and that this list be used to select an appropriate set of relationships to use in the analysis is selected, especially the final versions of the NGA attenuation relationships. n order to adequately characterize epistemic uncertainty, it is recommended that at least three attenuation relationships be used in the analysis and that at least one of these relationships shall represent a more geographically diverse active tectonic regime, such as Europe and the Middle East.

The ground motion components and parameters in each of the attenuation relationships should be defined and that an explanation be provided describing how these parameters are evaluated for the specific seismic sources and plant site conditions.

5.2.2. Seismic Source Model

In seismically active regions where the structures of seismic sources are studied in detail, fault models and waves propagation paths should be developed. The model shall include the following parameters for each seismic structure or fault:

a. Fault geometry;

b. Macroparameters, including seismic moment, average dislocation, rupture velocity, and average stress drop,

c. Microparameters, including rise time, dislocation, and stress parameters for finite fault elements;

d. Crustal structure, such as shear wave velocity, density, and damping from wave propagation (i.e. the wave attenuation Q value).

6. Probabilistic seismic hazard assessment

6.1 Basics

PSHA assesses and incorporates all seismic source components of seismotectonic model; and transparently incorporates a quantitative assessment of the related uncertainties.

The PSHA procedure shall consist of the following steps:

a) Development of the seismotectonic model for the site region; including characterization of all of the defined seismic sources and the uncertainty in their boundaries and dimensions and characteristics;

b) For each seismic source, evaluation and characterization of the maximum potential magnitude, the rate of earthquake occurrence and the type of the magnitude-frequency relationship, together with the uncertainty associated with each evaluation;

c) Selection of the ground motion prediction equations for the site region and assessment of the uncertainty in both the mean and the variability of the ground motion as a function of earthquake magnitude and seismic source-to-site distance;

d) Performance of the PSHA for actual or assumed rock conditions with up-to-date interpretations of earthquake sources, earthquake recurrence, and strong ground motion estimation using original or updated sources;

The PSHA procedure and reporting shall include the following elements:

- CAV filtering can be used in place of a lower-bound magnitude cutoff;
- The hazard assessment should be conducted at a minimum of 20 frequencies, approximately equally spaced on a logarithmic frequency axis between 50 and 0.1Hz;
- The mean, 16th, 50th (median) and 84th fractile hazard curves are to be used to display the epistemic uncertainty for each measure of ground motion. The fractile hazard curves should be reported in tabular, as well as graphical format;
- The mean uniform hazard response spectra (UHRS) should be determined and reported for annual exceedance frequencies of 1E-04, 1E-05, and 1E-06 at a minimum of 20 structural frequencies approximately equally spaced on a logarithmic frequency axis between 50 and 0.1 Hz..

6.2 Range of Spectral Frequencies

The frequency range considered in the PSHA shall extend from a low frequency that can be reliably obtained from the current strong-motion data set. The use of an appropriately chosen and conservatively defined lower-bound magnitude cut off lower-bound magnitude cut-off level for earthquakes is acceptable in PSHA.

The frequency range shall extend from a low frequency that can be reliably determined from the database of strong earthquakes (which form the basis for GMPEs) to a high end frequency limit that allows the spectral acceleration to match the peak ground acceleration for hard rock sites.

6.3 Hazard Assessment

The amplitude of ground motion at a site corresponding to annual exceedance frequency of interest is assessed by integration of all related seismological inputs, as indicated below:

$$\lambda(A > a|t) = \sum_{i=1}^{S} \nu_i t \int_{r_{\min}}^{r_{\max}} \int_{d_{\min}}^{d_{\max}} \int_{m_{\min}}^{m_{\max}} P(A > a|m,r)\, f_{Di}(d|m)\, f_{Ri}(r|m,d)\, f_{Mi}(m) dr\, dd\, dm$$

where

λ(A > *a/t*) is the rate at which ground motion parameter *A* exceeds the value 'a' in time *t* at the site. Time *t* is usually taken as one year; *S* is the number of sources, m_{min}, *Mmax* are minimum and maximum magnitude of seismic source *i* ; d_{min}, d_{max} are minimum and maximum sizes of the seismic source *i*; r_{min}, r_{max} are minimum and maximum distance of seismic source *i* to the site; ν_i - is the expected frequency, per time period per seismic source area, of earthquakes of magnitudes equal to or greater than m_{min} of the seismic source *i*;

$f_{Mi}(m)$ is the probability density function of earthquake magnitude on seismic source *i;*

$f_{Di}(d/m)$ is the conditional probability density function of the dimensions of the rupture given an earthquake of magnitude m on seismic source *i*;

$f_{Ri}(r/m,d)$ is the conditional probability density function of distance from site to the given fault for a given earthquake magnitude *m* and dimension *d* and for seismic source *i;*

P(A>a/m,r) is the conditional probability that ground motion parameter A exceeds the value 'a' given an earthquake of magnitude 'm' on seismic source '" located at a distance 'r' from the site. This probability is typically defined as a lognormal probability distribution.

6.4 Development of scenario earthquakes

In order to assess characteristics of the ground motion, the fractional input of each seismic event (in terms of magnitude and distance) to the overall seismic hazard through a deaggregation process should be provided. Deaggregation should be undertaken as minimum for two spectral frequencies, with one each on the lower and upper limits of spectra. This allows identification of the magnitude-distance (*m-r)* combinations that are the biggest contributors to the ground motions hazard for certain spectral frequencies or annual frequency of exceedance values of interest.

Deaggregation procedures consist of the following steps ([3], RG1.208):

- For annual probabilities of 1 E^{-4}, 1 E^{-5} and 1 E^{-6}, spectral accelerations at spectral frequencies of 1, 2.5, 5 and 10 Hz are determined from the total mean hazard curves,
- Determine the linear average of the spectral acceleration ground motion values for 1 and 2.5 Hz; and for 5 and 10 Hz;
- Perform a deaggregation of the PSHA for each of the average spectral accelerations and annual probability levels and provide in a table, an example of which is shown below. A table should be produced for each of the cases (3 annual probabilities coupled with both of the average ground motion levels). A table of recommended magnitude and distance bins is provided below.

Moment Magnitude Range of Bins					
Distance Range of Bin (km)	5 - 5.5	5.5 - 6	6 - 6.5	6.5 - 7	> 7
0-15					
15-25					
25-50					
50-100					
100-200					
200-300					
>300					

If the deaggregated results for each of the 12 cases are not in terms of the fractional contribution to the total hazard then perform the steps as described below. Otherwise, average the low-frequency (1 and 2.5 Hz) and high-frequency (5 and 10 Hz) deaggregation results.

From the deaggregated results, the mean annual probability of exceeding the ground motion levels (spectral accelerations at 1, 2.5, 5, and 10 Hz) are determined for each mdf magnitude-distance bin. These values are denoted by H_{mdf}.

Using H_{mdf} values, the fractional contribution of each magnitude and distance bin to the total hazard for the average of 1 and 2.5 Hz, $P(m,d)_1$, is computed according to the following:

$$P(m,d)_1=[(\Sigma_{f=1,2}H_{mdf})/2]\div \Sigma_m\Sigma_d(\Sigma_{f=1,2}H_{mdf})/2]$$

where f = 1 and f = 2 represent the ground motion measure at 1 and 2.5 Hz, respectively.

The fractional contribution of each magnitude and distance bin to the total hazard for the average 2 of 5 and 10 Hz, $P(m,d)_2$, is computed according to the following:

$$P(m,d)_2=[(\Sigma_{f=1,2}H_{mdf})/2]\div \Sigma_m\Sigma_d(\Sigma_{f=1,2}H_{mdf})/2]$$

where f = 1 and f = 2 represent the ground motion measure at 5 and 10 Hz, respectively.

Deaggregation is undertaken as a way to better understand the earthquakes that contribute most to hazard at a site of interest and can be used to review and perform quality control checks on PSHA results. Controlling earthquakes can be used as the basis to determine the most appropriate response spectra to use as the basis for the selection of earthquake records for site response and soil-structure-interaction analyses.

A review of the PSHA model brings to light several areas that require additional information to perform a full review. These include the following:

Assignment of activity rates for area sources based on the seismicity database and seismotectonic models.

- Development and presentation in detail of the logic tree of the consistent with the characterization of all seismogenic sources and the weights given to various models.
- The development of Mmax values for both the seismogenic structures and the the area sources.

- The median and mean values of the pga resulting from the PSHA are the same over a large range of annual frequencies of exceedance.

7. Potential of fault displacement

7.1 Faults potential to displacement

On the basis of geological, geophysical, geodetic or seismological data, a fault should be considered capable if the following conditions apply:

a) If it shows evidence of past movement or movements (such as significant deformations and/or dislocations) of a recurring nature within such a period that it is reasonable to conclude that further movements at or near the surface may occur. In highly active areas, where both earthquake data and geological data consistently reveal short earthquake recurrence intervals, periods of the order of tens of thousands of years (e.g. Upper Pleistocene–Holocene, i.e. the present) may be appropriate for the assessment of capable faults. In less active areas, it is likely that much longer periods (e.g. Pliocene–Quaternary, i.e. the present) are appropriate.

b) If a structural relationship with a known capable fault has been demonstrated such that movement of the one fault may cause movement of the other at or near the surface.

c) If the maximum potential magnitude associated with a seismogenic structure is sufficiently large and at such a depth that it is reasonable to conclude that in the current tectonic setting, movement at or near the surface may occur.

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7.2. Investigations to Identify Fault Capability

a) Sufficient surface and subsurface related data should be obtained from the investigations in the region, near region, site vicinity and site area to show the absence of faulting at or near the site, or, if faults are present, to describe the direction, extent, history and rate of movements on these faults as well as the age of the most recent movement.

b) When faulting is known or suspected to be present, site vicinity scale investigations should be made that include very detailed geological and geomorphological mapping, topographical analyses, geophysical surveys (including geodesy, if necessary), trenching, boreholes, age dating of sediments or faulted rock, local seismological investigations and any other appropriate techniques to ascertain the amount and age of previous displacements.

c) Consideration should be given to the possibility that faults that have not demonstrated recent near surface movement may be reactivated by reservoir loading, fluid injection, fluid withdrawal or other such phenomena.

8. Design Basis Ground Motion

8.1. Design Basis Response Spectra

For the NNU seismic design purposes the site-specific ground motion response spectrum and eventually the Safe Shutdown Earthquake ground motion (SSE) and operating basis earthquake (OBE) should be determined. The ground motion response spectrum is defined as the free-field horizontal and vertical ground motion response spectra at the NNU site.

SSE represents the design earthquake ground motion at the site and is the vibratory ground motion for which certain safety related structures, systems, and components are designed to remain functional. For NNU seismic design purposes the SSE reference probability for the exceedance level it is acceptable to use a mean annual exceedance frequency $1E^{-04}$. Moreover, NNU safety related structures, systems and components should respond to a beyond SSE ground motion corresponding to a mean annual exceedance frequency $1E^{-05}$ without significant inelastic deformations. OBE is set at one-third of the SSE ground motion response spectra.

Both SSE and OBE levels should be defined by means of appropriate spectral representations and time histories. The ground motion for reference bedrock conditions should be given, provided that a good geotechnical database is available. Ground motions at the foundation level and at the surface can then be computed, with account taken of the transfer functions of the overlying soil layers. Consideration should be given to the appropriate interfacing of the defined reference ground motion and the site response analysis. Site response analysis should be compatible with the geotechnical and dynamic characteristics of the soil and rock layers beneath the site. This may also include incorporating site response into the calculations for seismic hazard analysis.

8.2 Time Histories

Time histories shall satisfactorily reflect all the prescribed ground motion parameters as embodied in the response spectra or other spectral representation with the addition of other parameters such as duration, phase and coherence. The number of time histories to be used in the detailed analyses and the procedure used in generating these time histories will depend on the type of analysis to be performed.

8.3 Ground motion duration

The duration of ground motion is determined by many factors, including the length and width of fault rupture, crustal parameters along the propagation path (generally characterized by distance), conditions beneath the site including, for example, the presence of a sedimentary basin. A consistent definition of duration should be used throughout the evaluation. Common definitions of duration include:

- The time interval between the onset of ground motion and the time at which the acceleration has declined to 5% of its peak value;
- The time interval between the 95th and 5th percentiles of the integral of the mean square value of the acceleration;
- The time interval for which the acceleration exceeds 5% of g.

In determining an appropriate duration for the time histories, due attention should be given to any empirical evidence provided by the regional database.

8.4 Methods of developing design time histories

Time histories should be compatible with the characteristics of the design earthquakes, the amplitude and spectral shape of the response spectra and the duration of the design ground motions.

Common methods for developing design time histories are as follows:

- Appropriately selected and scaled recorded time histories, for which the scaling factor is within the range 0.5–2.0;
- Appropriately selected recorded time histories modified using spectral matching techniques in which the phase characteristics of the ground motion are taken into account;
- Artificial time histories, usually having random phase;
- Simulated time histories based on numerical modelling methods.

In using response spectra to develop design time histories, it should be ensured that the time histories include the appropriate energy content represented by the design ground motions. This could be done by calculating the corresponding power spectral density functions.

8.5. Vertical ground motion

Vertical design ground motion is prescribed by the ratio between vertical and horizontal ground motions. The minimum acceptable vertical to horizontal ratio is 2/3.

9. Quality Assurance Plan

An adequate management system, that includes a quality assurance programme should be established and implemented to control the effectiveness of the execution, covering all activities relating to data collection, data processing and interpretation, field and laboratory investigations, numerical modelling and technical evaluations to ensure that the required quality of the work is achieved.

At each step in the hazard assessment, documentation should be provided to support the outcomes of the assessment in sufficient detail to permit an independent review. The documentation shall identify all sources of information used in the seismic hazard analysis, including information on where to find important citations that may be difficult to obtain. Unpublished data that are used in the analysis should be included in the documentation in an appropriately accessible and usable form.

The validity of the proposed seismic source model should be tested a posteriori against existing knowledge; for example, by comparing long term strain rates predicted by the model against geodetic and geological observations. Owing to the variety of investigations carried out (in field, laboratory and office) and the need for expert judgement in the decision making process, technical procedures that are specific to the project should be developed to facilitate the execution and verification of these tasks, and a peer review of the process should be conducted.

9.1 Output Specification

The output specification for the seismic hazard analysis describes all specific results necessary to fulfill the intended engineering uses and objectives of the study. The output specification is updated to accommodate additional results, to alter the prescription of the results. Elements that should be considered in the output specification include:

- *Ground motion parameters.* Specified ground motion parameters should be sufficient to develop the recommended results and any additional outputs required for engineering use.
- *Vibration frequencies.* The range and density of specified vibration frequencies for the uniform hazard spectra should be sufficient to adequately represent the input for all safety relevant structures, systems and components.
- *Damping.* Specified damping values should be sufficient to adequately represent input responses of all safety relevant structures, systems and components.
- *Ground motion components.* Provision for the output of both vertical and horizontal motions should be specified.
- *Control point.* The output specification should specify the control points (e.g. depths at the site) for which near surface hazard results are obtained. The specified control points should be sufficient to develop adequate input(s) for soil–structure interaction analyses.

9.2 Independent Peer Review

The peer reviewer(s) should not have been involved in other aspects of the probabilistic seismic hazard analysis and should not have a vested interest in the outcome. The peer review should address all parts of the seismic hazard analysis, including the process for the seismic hazard analysis, all technical elements (e.g. seismic source characterization, ground motion estimation), the method of seismic hazard analysis, and quantification and documentation. The peer review panel should include multidisciplinary expertise to address all technical and process related aspects of the analysis.

Two methods of peer review can be used:

- participatory peer review;
- late stage peer review.

A participatory peer review is carried out during the course of the study, allowing the reviewer(s) to resolve comments as the seismic hazard analysis proceeds and as technical issues arise. A late stage and follow-up peer review is carried out towards the end of the study. Participatory peer review will decrease the likelihood of the study being rejected at a late stage.

9.3 Output of Probabilistic Seismic Hazard Analyses

The seismic hazard analyses for the ANNU site should include the outputs described in the table below

	Output	Description	Format
1	Mean hazard curves	Mean annual frequency of exceedance for each ground motion level of interest associated with the suite of epistemic hazard curves generated in the probabilistic seismic hazard analysis.	Mean hazard curves should be reported for each ground motion parameter of interest in tabular as well as graphic format.
2	Fractile hazard curves	Fractile annual frequency of exceedance for each ground motion level of interest associated with the suite of epistemic hazard curves generated in the probabilistic seismic hazard analysis.	Fractile hazard curves should be reported for each ground motion parameter of interest in tabular as well as graphic format. Unless otherwise specified in the work plan, fractile levels of 0.05, 0.16, 0.50, 0.84 and 0.95 shouldshould be reported.
3	Uniform hazard response spectra	Response spectra whose ordinates have an equal probability of being exceeded, as derived from seismic hazard curves.	Mean and fractile uniform hazard response spectra shoul be reported in tabular as well as graphic format. Unless otherwise specified in the work plan, the uniform hazard response spectra should be reported for annual frequencies of exceedance of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} and for fractile levels of 0.05, 0.16 0.50, 0.84 and 0.95.
4	Magnitude–distance deaggregation	A magnitude–distance (M–D) deaggregation quantifies the relative contribution to the total mean hazard of earthquakes that occur in specified magnitude–distance ranges (i.e. bins).	The M–D deaggregation should be presented for ground motion levels corresponding to selected annual frequencies of exceedance for each ground motion parameter considered in the probabilistic seismic hazard analysis. The deaggregation should be performed for the mean hazard and for the annual frequencies of exceedance to be used in the evaluation or design.
5	Mean and modal magnitude and distance	The M–D deaggregation results provide the relative contribution to the site hazard of earthquakes of different sizes and at different distances. From these distributions, the mean and/or modal magnitudes and the mean and/or modal distances of earthquakes that contribute to the hazard can be determined.	The mean and modal magnitudes and distances should be reported for each ground motion parameter and level for which the M–D deaggregated hazard results are given. Unless otherwise specified in the work plan, these results should be reported for response spectral frequencies of 1, 2.5, 5 and 10 Hz.
6	Seismic source	The seismic hazard at a site is a combination of the hazard from individual seismic sources modelled in	The seismic source deaggregation should be reported for ground motion levels corresponding to each ground motion

	deaggregation	the probabilistic seismic hazard analysis. A deaggregation on the basis of seismic sources provides an insight into the possible location and type of future earthquake occurrences.	parameter considered in the probabilistic seismic hazard analysis. The deaggregation should be performed for the mean hazard and presented as a series of seismic hazard curves.
7	Aggregated hazard curves	In a probabilistic seismic hazard analysis, often thousands to millions of hazard curves are generated to account for epistemic uncertainty. For use in certain applications (e.g. a seismic probabilistic safety assessment), a smaller, more manageable set of curves is required. Aggregation methods are used to combine like curves that preserve the diversity in shape of the original curves as well as the essential properties of the original set (e.g. the mean hazard).	A group of aggregated discrete hazard curves, each with an assigned probability weight, should be reported in tabular as well as graphic format.
8	Earthquake time histories	For the purposes of engineering analysis, time histories may be required that are consistent with the results of the probabilistic seismic hazard analysis. The criteria for selecting and/or generating a time history may be specified in the workplan. Example criteria include the selection of time histories that are consistent with the mean and modal magnitudes and distances for a specified ground motion or annual frequency of exceedance.	The format for presenting earthquake time histories will generally be defined in the work plan.

References

1. IAEA Safety Standards Series No. SSG-9, Seismic Hazards in Site Evaluation for Nuclear Installations. Specific Safety Guide,
2. IAEA-TCR-05517 “Preliminary review of the seismic and volcanic hazard assessments for the new unit at the Armenian NPP site”, 2–6 August 2010,
3. US NRC Regulatory Guide 1.208, (March 2007). A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion.
4. US NRC Standard Review Plan, NUREG0-800: Section 2.5.2. Vibratory Ground Motion, Revision 4 - March 2007.
5. IAEA-RU-5270, “Seismic Safety (Site investigations) of Armenia NPP – 4th Follow-up of *SSRM*”, 28 May – 2 June 1995.
6. IAEA-TCR-03092, “Follow up Review of the Probabilistic Seismic Hazard Assessment of the Armenian NPP Site”, 17-21 July 2006.

Appendix A

Definitions

accelerogram. A recording of ground acceleration, usually in three orthogonal directions (i.e. components), two in the horizontal plane and one in the vertical plane.

aleatory uncertainty. Uncertainty inherent in a phenomenon. Aleatory uncertainty is taken into account by representing the phenomenon in terms of a probability distribution model.

capable fault. A fault that has a significant potential for displacement at or near the ground surface.

epicentre. The point on the Earth's surface directly above the focus (i.e. hypocentre) of an earthquake.

epistemic uncertainty. Uncertainty attributable to incomplete knowledge about a phenomenon, which affects the ability to model it. Epistemic uncertainty is reflected in a range of viable models, multiple expert interpretations and statistical confidence.

fault (geological). A planar or gently curved fracture surface or zone of the Earth across which there has been relative displacement.

free field ground motion. Motion that would occur at a given point on the ground owing to an earthquake if vibratory characteristics were not affected by structures and facilities.

frequency of exceedance. The frequency at which a specified level of seismic hazard will be exceeded at a site or in a region within a specified time interval. In probabilistic seismic hazard analysis (PSHA), generally a one year time interval (i.e. annual frequency) is assumed. When the frequency is very small and it cannot exceed unity (in the prescribed interval), this number approaches the probability of the same event when the random process is assumed to be Poissonian.

hypocentre. The point (focus) within the Earth at which an earthquake is initiated.

interplate. Of tectonic processes, at the interfaces between the Earth's tectonic plates.

intraplate. Of tectonic processes, within the Earth's tectonic plates.

magnitude (of an earthquake). Measure of the size of an earthquake relating to the energy released in the form of seismic waves. Seismic magnitude means the numerical value on a standardized scale such as, but not limited to, moment magnitude, surface wave magnitude, body wave magnitude, local magnitude or duration magnitude.

maximum potential magnitude. Reference value used in seismic hazard analysis characterizing the potential of a seismic source to generate earthquakes. The way in which it is calculated depends on the type of seismic source considered and the approach to be used in the seismic hazard analysis.

palaeoseismicity. The evidence of a prehistoric or historical earthquake manifested as displacement on a fault or secondary effects such as ground deformation (i.e. liquefaction, tsunami, landslides).

peak ground acceleration. The maximum absolute value of ground acceleration displayed on an accelerogram; the greatest ground acceleration produced by an earthquake at a site.

response spectrum. A curve calculated from an accelerogram that gives the value of peak response in terms of the acceleration, velocity or displacement of a damped single-degree-of-freedom linear oscillator (with a given damping ratio) as a function of its natural frequency or period of vibration.

Safe Shutdown Earthquake (SSE) - the vibratory ground motion for which certain structures, systems, and components are to remain functional. The SSE for the site is characterized by both horizontal and vertical free-field ground motion response spectra at the free ground surface.

seismogenic structure. A structure that displays earthquake activity or that manifests historical surface rupture or the effects of palaeoseismicity, and that is considered likely to generate macro-earthquakes within a time period of concern.

seismotectonic model. The model that defines the characterization of seismic sources in the region around a site of interest, including the aleatory and epistemic uncertainties in the seismic source characteristics.

site response. The behaviour of a rock or soil column at a site under a prescribed ground motion load

surface faulting. Permanent offsetting or tearing of the ground surface by differential movement across a fault in an earthquake.

uniform hazard response spectrum. Response spectrum with an equal probability of exceedance for each of its spectral ordinates.

Appendix B

Abbreviations

A - peak ground acceleration

ANPP - Armenian Nuclear Power Plant

D - distance

IAEA - International Atomic Energy Agency

M - magnitude

mdf - magnitude-distance frequency in bin.

NNU – New nuclear unit

NRC - U.S. Nuclear Regulatory Commission

OBE – Operating Basis Eartquake

PGA - peak ground acceleration

PGV - peak ground velocity

PSHA - probabilistic seismic hazard analysis

SRP - Standard Review Plan (NUREG-0800)

SSCs - structures, systems, and components

SSE - safe shutdown earthquake ground motion

UHRS - uniform hazard response spectrum

V - velocity

V/H ratio of vertical to horizontal spectral accelerations

Vs - shear wave velocity

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ՂԵԿԱՎԱՐԻ ՏԵՂԱԿԱԼ Տ. ԳԵՎՈՐԳՅԱՆ