STATUS UPDATE

THE POINT LEPREAU NUCLEAR GENERATING STATION SEISMIC HAZARDS SUMMARY UPDATE

April 2016

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The methodology to assess a nuclear station response to an earthquake event has evolved over time.

External events and seismic risk will continue to be an important safety priority for the Point Lepreau Nuclear Generating Station (PLNGS).

PLNGS has a robust seismic design. The plant was designed taking into account the type of ground level acceleration that was expected to be produced from an earthquake that would have a return frequency of about one in a thousand years. Over time NB Power has developed an improved understanding of the plant response to events that go beyond its design basis resulting in further improvements for responding to beyond design basis events.

PLNGS operated as a safe plant leading into refurbishment. Safety was enhanced as a result of the activities performed associated with the refurbishment outage along with additional improvements performed in response to the Canadian Nuclear Safety Commission's Fukushima action plan.

To support life extension activities performed as part of refurbishment project planning, NB Power undertook studies which examined the response to events well beyond those considered in the original design of the plant.

To address the topic of large potential seismic events, a Probabilistic Safety Assessment (PSA) based seismic margin assessment was performed. This assessment evaluates plant robustness and identifies areas where improvements can be made to increase the likelihood of avoiding core damage and large radioactive releases from containment caused by a very rare, large earthquake. The insights gained from this study were used to perform a number of seismic upgrades at the plant during the refurbishment outage.

As a result of the accident at Fukushima Daiichi in March of 2011, the nuclear industry improved the methodology that had been used to assess external events and seismic events in particular. As the seismic margin assessment does not specifically evaluate risk, NB Power performed a preliminary evaluation to better understand the rough order of magnitude of the current seismic risk at the time. International Atomic Energy Agency (IAEA) guidance indicated that either median or mean could be used as a central value as the intent it to present risk as a best estimate value. As the seismic hazard curve available at that time was based on median data, the median value approach was selected. NB Power had the risk estimate and calculations independently reviewed by a seismic expert.

As part of the Canadian Nuclear Safety Commission decision for 2012 license renewal, the CNSC requested NB Power to update a site specific seismic hazard assessment and make the results public. The concept of "hazard" differs from that of "risk" in that a hazard assessment provides the likelihood of earthquakes occurring of various sizes, and the determination of risk evaluates the potential impact, or consequences, those earthquakes may have on the plant.

A summary of the results of the comprehensive hazard assessment was made available to the public in December of 2014 in parallel with it undergoing a third party expert review. As this study was to lay the foundation for performing a more detailed risk assessment, hazard curves were presented for both the mean and median values and for other percentiles. The study identified the following:

Design basis - When comparing the hazard at a 1000 year return period to our design, the response spectra was significantly lower than the design spectra at frequencies lower than 10 Hz. That is to say it is bounded by the existing design, indicating that design margins have increased in the area of interest. The design spectra was however slightly exceeded at higher frequencies, but based on industry knowledge, high frequency aspects of an earthquake do not damage plant structures and equipment because their natural frequencies are lower, tending to be more in the range of 2-8 Hz and 1-10 Hz respectively. NB Power also committed to follow and report on the findings of an Electric Power Research Institute's Program looking further into the impact of high frequencies. This is discussed further in section four below.

Beyond design basis - Although the hazard assessment showed that the earthquake magnitudes for more frequent earthquakes that might occur over the lifetime of the Station is lower than previously predicted, the magnitudes of very rare earthquakes that are unlikely to occur over the lifetime of the plant are larger than historically regarded as credible. To assess this finding, an interim seismic risk assessment, using a similar methodology that was used in the Canadian nuclear industry, was also included in the December of 2014 posting. The interim seismic risk estimate replaced the 2011 preliminary seismic risk assessment, and as the mean hazard curve was then available, the mean hazard curve was used in the interim seismic assessment report. The interim results demonstrated that plant risk due to seismic events was acceptably low. To provide a greater level of assurance, NB Power indicated in the 2014 posting, that we will perform a full seismic PSA.

The third party experts have completed their review of the PLNGS seismic hazard assessment, which resulted in a slight reduction of the overall hazard as reported in 2014, and the final hazard assessment was submitted to the Canadian Nuclear Safety Commission at the end of June 2015. Seismic experts at Natural Resources Canada have completed their review and the CNSC has accepted the seismic hazard assessment for use at PLNGS.

As a result of the assessed reduction in the final earthquake hazard, the conclusions reported in our December 2014 posting that the safety case for the plant continues to be strong and that the plant is operating safely under our current understanding of possible earthquake hazards remain valid.

In keeping with the industry trend of continuing to refine the potential risk from seismic events and to improve the understanding of any potential plant vulnerabilities, NB Power undertook to perform a Seismic PSA. This uses the updated completed seismic hazard curves which allows for the use of the mean hazard curves, which is appropriate for this type of analysis as per the latest nuclear industry guidance. If this new work identifies potential vulnerabilities at the plant to withstand seismic events that might challenge our safety objectives, those vulnerabilities will be addressed to ensure that the safety case remains strong.

Status Update on Seismic-Related Work

In its December 2014, posting, NB Power identified the following work in the spirit of continuous improvement going forward:

1. ***Completing the third party review of the draft site-specific seismic hazard assessment and issue the report***

   The third party review of the seismic hazard assessment has been completed and submitted to the Canadian Nuclear Safety Commission. The numerical results in Table 1 and Table 2 in tabular form and in Figure 1 and Figure 2, the hazard curves for peak ground acceleration, and a comparison to prior work are included at the end of this summary.

2. ***Updating the PSA-based Seismic Margin Assessment methodology to reflect the new seismic hazard information***

   This work is in progress. An update to the PSA-based Seismic Margin Assessment is scheduled for completion by the end of year 2016.

3. ***Continuing to refine seismic capacity estimates for structures and equipment***

   The strength of structures and equipment to withstand earthquakes is determined by estimating their seismic capacity. As the work to evaluate the implications of the updated seismic hazard assessment has progressed, NB Power's external experts have been performing a site seismic response analysis and refining the seismic capacity estimates for certain structures and equipment.

   A site seismic response analysis raises the vibrations from an expected earthquake upwards through the different rock and soil layers to determine what the foundations of key buildings will "feel" taking into account soil-structure interaction. Given that the objectives of the seismic PSA is to provide risk estimates for an earthquake magnitude that might occur with a mean return period of about 10,000 years, only the expected vibration for an earthquake of that magnitude has been propagated upwards.

   Utilizing the seismic response at the foundations as an input, the seismic vibrations have been moved further upwards into key safety-related buildings to identify what building floors will "feel" at various heights above ground level. To produce meaningful results, detailed 3D modeling and structural response analysis has been performed for those key safety-related buildings. The results are then used as an input to refine calculations of how strong structures and equipment are to withstand earthquakes.

4. ***Following the Electric Power Research Institute's High Frequency Program***

   New assessments of seismic hazard are performed for nuclear power plants around the world from time to time. In some cases, updated information has led to an assessment that the seismic hazard is higher than had been previous understood in certain frequency ranges, especially in the

high frequency range. As a result, the Electric Power Research Institute has been developing and providing guidance to the nuclear industry regarding the seismic capabilities of a diverse set of typical nuclear plant control components. In general, that work has shown that the higher frequency component of earthquakes does not pose concern to nuclear power plant equipment.

NB Power has continued to follow the Electric Power Research Institute's High Frequency Program. The test program results and guidance for applying those results to support plant-specific analyses of potential high frequency effects has been provided to our expert contractors to ensure that the seismic PSA includes the latest industry insights and guidance.

5. Developing full seismic PSA methodology reflecting industry practice

The seismic PSA methodology, reflecting latest best practice and industry guidance, was completed and issued to the Canadian Nuclear Safety Commission in August 2015.

6. Performing a full seismic PSA

The development of the full seismic PSA is well underway. All contracts are in place with experts who are performing the work. NB Power is keeping the Canadian Nuclear Safety Commission apprised of our progress and the seismic PSA is currently expected to be completed in the summer of 2016. The seismic PSA will be submitted to the Canadian Nuclear Safety Commission when complete.

7. Updating the off-site consequence assessment to aggregate seismic risks to confirm no adverse impact on public health risk

As mentioned in in our last posting, NB Power exceeded the requirements of the Canadian Nuclear Safety Commission for probabilistic safety assessment by going a step further and assessing the potential off-site consequences of a highly improbable severe accident, which is well beyond the plant design basis. This assessment evaluated risk to the public in the highly unlikely event of an accident that progressed to the point of a large radiological release following a severe accident. The assessment showed that the risk to public health was quite small. In lieu of a full seismic PSA being completed at that time, NB Power hired experts to provide their opinion or judgment as to what impact aggregating seismic risks may have on public health risk. Our experts have indicated that no significant impact is anticipated; however, NB Power in exercising its due diligence has included within the overall scope of work an update to the off-site consequence assessment to ensure that the results of the final seismic PSA are fully considered in terms of public health risk.

NB Power's highest priority is the safety of the public and our workers. Expert evaluation of the latest results of the site-specific seismic hazard assessment demonstrated the capability of the plant to withstand very rare, large earthquakes. Point Lepreau Nuclear Generating Station is a safe facility. It is operated daily to the highest nuclear safety standards and is held to rigorous requirements by the national nuclear regulator. Our current understanding of the seismic hazard for the Point Lepreau region does not reveal any tangible challenge to the plant to safely shut down and protect the public and our workers.

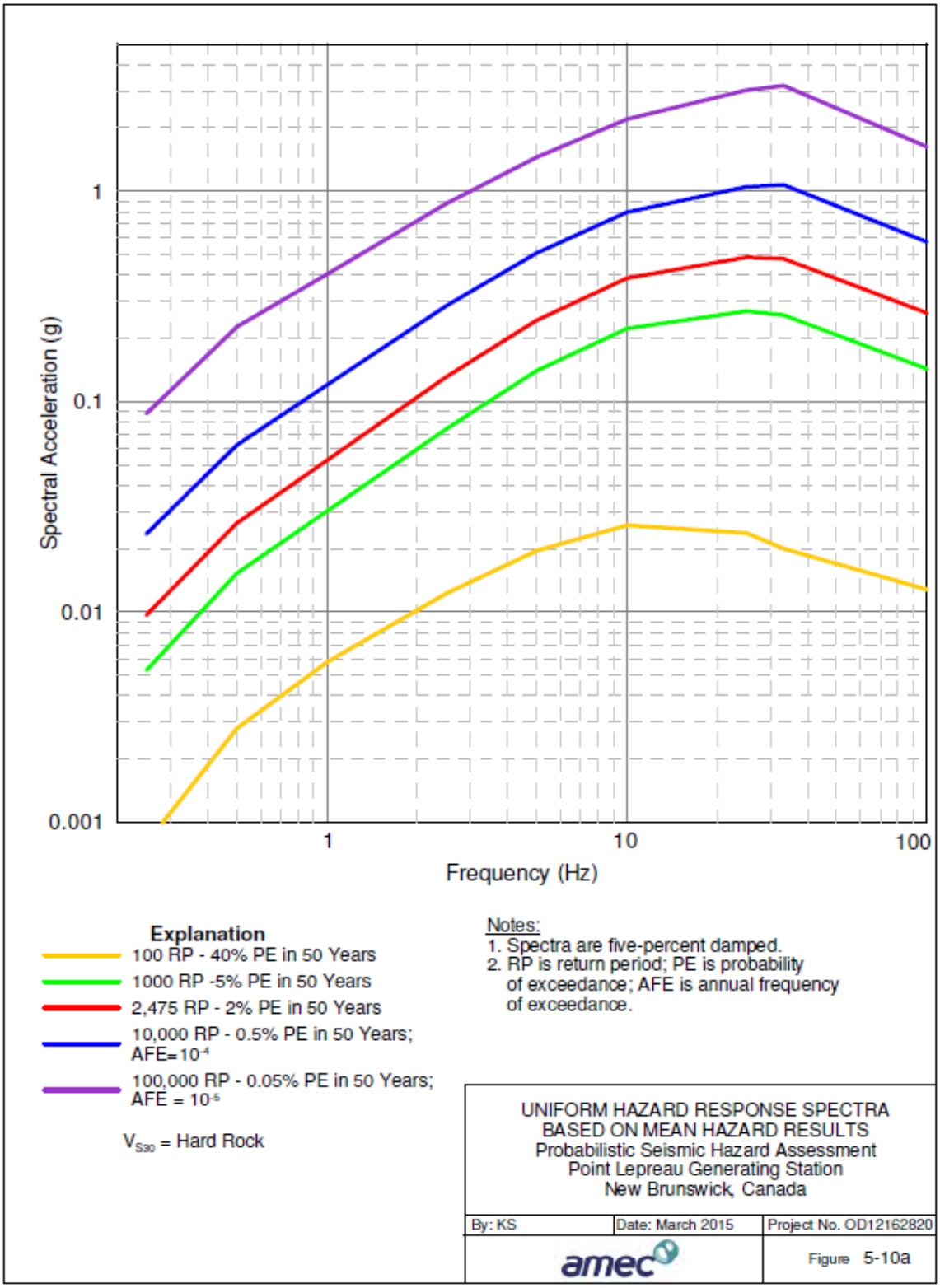
Results of the Seismic Hazard Assessment – TABLE 1

HORIZONTAL UNIFORM HAZARD RESPONSE SPECTRA
Point Lepreau Generating Station
New Brunswick, Canada

Spectral Frequency (Hz)	Spectral Acceleration (g) at 5% Damping for Return Period (yr)				
	475	1,000	2,475	10,000	100,000
Mean hazard					
100	0.078	0.143	0.264	0.575	1.628
40	0.140	0.258	0.479	1.073	3.175
25	0.151	0.270	0.486	1.048	3.024
10	0.129	0.223	0.387	0.796	2.205
5	0.083	0.141	0.244	0.508	1.452
2.5	0.044	0.074	0.131	0.286	0.876
1	0.019	0.030	0.053	0.120	0.403
0.5	0.010	0.015	0.027	0.062	0.227
0.25	0.003	0.005	0.010	0.024	0.088
50^{th} Percentile hazard					
100	0.052	0.088	0.157	0.343	0.982
40	0.096	0.171	0.310	0.675	1.946
25	0.107	0.185	0.322	0.677	1.862
10	0.094	0.157	0.263	0.527	1.366
5	0.064	0.103	0.171	0.336	0.861
2.5	0.035	0.056	0.092	0.182	0.474
1	0.015	0.023	0.038	0.073	0.191
0.5	0.007	0.011	0.018	0.035	0.089
0.25	0.002	0.004	0.007	0.013	0.037
84^{th} Percentile hazard					
100	0.127	0.212	0.362	0.747	1.921
40	0.229	0.387	0.685	1.438	3.727
25	0.241	0.400	0.677	1.388	3.520
10	0.199	0.321	0.527	1.032	2.543
5	0.126	0.203	0.332	0.652	1.671
2.5	0.067	0.107	0.182	0.373	1.009
1	0.027	0.042	0.072	0.154	0.446
0.5	0.014	0.022	0.037	0.079	0.232
0.25	0.005	0.008	0.014	0.031	0.092

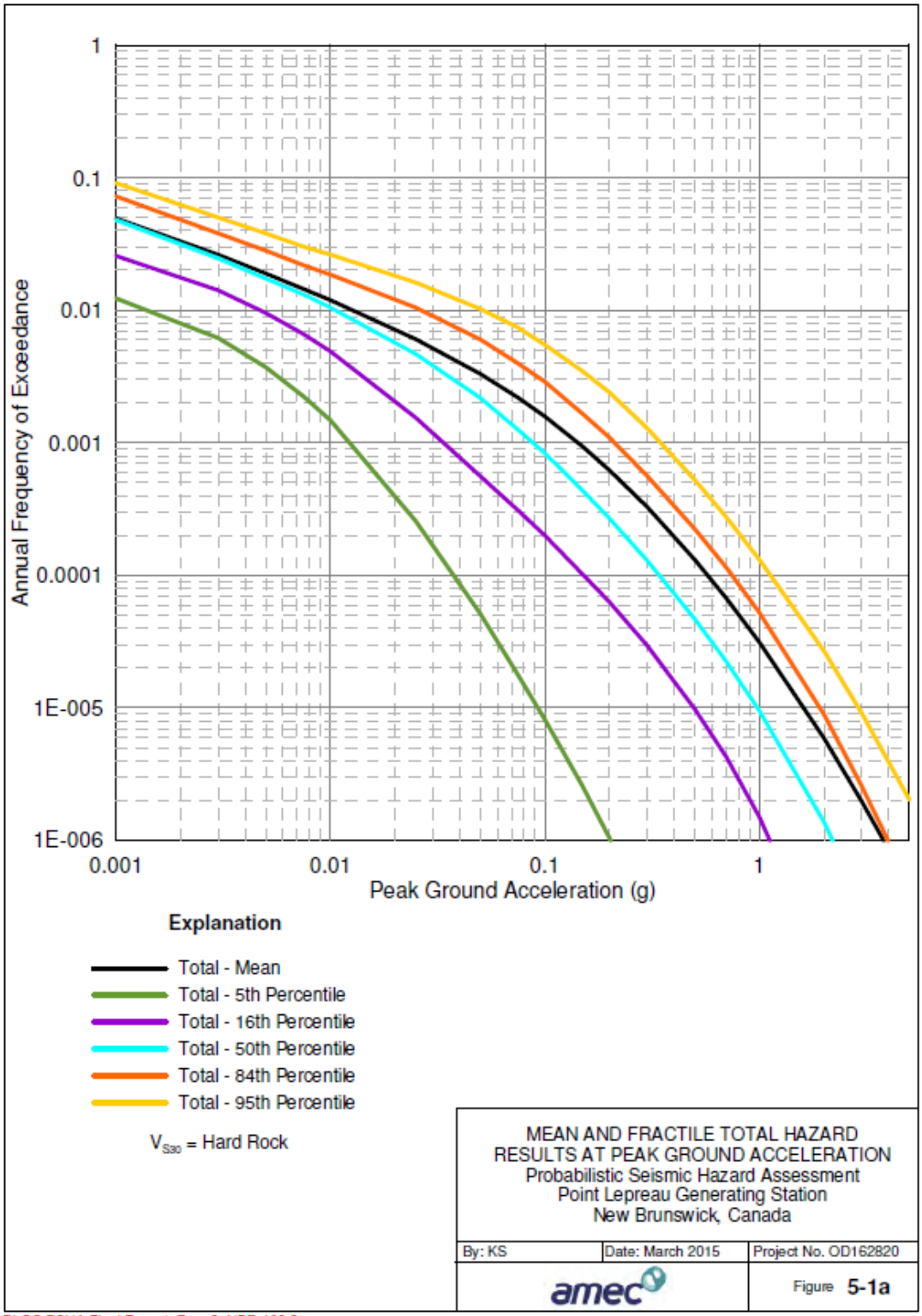
Results of the Seismic Hazard Assessment – FIGURE 1

UNIFORM HAZARD RESPONSE SPECTRA BASED ON MEAN HAZARD RESULTS



Results of the Seismic Hazard Assessment – FIGURE 2

MEAN AND FRACTILE TOTAL HAZARD RESULTS AT PEAK GROUND ACCELERATION



Results of the Seismic Hazard Assessment – TABLE 2

COMPARATIVE SUMMARY OF PROBABILISTIC SEISMIC HAZARD ANALYSIS (PSHA) RESULTS

Probabilistic Seismic Hazard Assessment
Point Lepreau Generating Station
New Brunswick, Canada

Probability of Exceedance [Equivalent Return Period]	Structural Frequency, f (Hz)	Spectral Acceleration, S_a (g)[1]				
		This Study [Mean]	This Study [Median]	2010 NBCC [Median][2]	2010 NBCC Adjusted to Hard Rock[2,3] [Median]	AECL and Maritime Nuclear (1984)[4] [Median]
PE = 10% in 50 Years [475 years]	PGA	0.078	0.052	0.074	0.053	0.09-0.12
	5	0.083	0.064	0.162	0.084	---
	2.5	0.044	0.035	0.089 (T=0.5 sec)	0.037 (T=0.5 sec)	---
	1	0.019	0.015	0.043	0.017	---
	0.5	0.010	0.007	0.015	0.005	---
PE = 2% in 50 Years [2,475 years]	PGA	0.264	0.157	0.199	0.143	0.17-0.25
	5	0.244	0.171	0.387	0.200	---
	2.5	0.131	0.092	0.209 (T=0.5 sec)	0.088 (T=0.5 sec)	---
	1	0.053	0.038	0.101	0.039	---
	0.5	0.027	0.018	0.032	0.011	---
AFE = 10^{-4} [10,000 years]	PGA	0.575	0.343	0.460	0.331	0.25-0.43
	5	0.508	0.336	0.800	0.412	---
	2.5	0.286	0.182	0.44 (T=0.5 sec)	0.185 (T=0.5 sec)	---
	1	0.120	0.073	0.210	0.081	---
	0.5	0.062	0.035	0.060	0.021	---

Notes:

1. All spectral ordinates are given as spectral acceleration (S_a) relative to gravity acceleration (g).
2. Values for AFE = 10^{-4} have been estimated by extrapolation of a straight line projection connecting the 10% in 50 and 2% in 50 years exceedance probability values reported by GSC, as suggested by the 2010 NBCC National Seismic Hazard Maps.
3. Median 2010 NBCC values have been adjusted from Site Class C (soil) to "rock or stiff soil" using the Reference Ground Condition factors defined by Adams et al. (1996).
4. Values cited are based on the full range of results reported for probabilistic seismic hazard analyses of three assumed seismic source models and parametric variations on the source model parameters; no combined single hazard curve was presented.