

OVERVIEW OF TS 1170.5:2025 AND CHANGES FROM NZS 1170.5:2004

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ABSTRACT

This paper provides the background and overview of the development of Technical Specification (TS) 1170.5, released for public comment in February 2024 and published in 2025. The paper also serves as an introduction to the second of two special issues of the Bulletin of the New Zealand Society for Earthquake Engineering, including a total of eight papers providing supporting technical background for changes to NZS 1170.5:2004 and other considerations during the development of TS1170.5:2025. This is the first major update to NZS 1170.5 since 2004. These special issues are expected to be of interest to practicing engineers and researchers wanting an in depth understanding of the basis for the changes found in TS 1170.5 and future standards development committees. The paper concludes with a brief introduction to ongoing efforts under Stage 2 of the Seismic Risk Work Programme.

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INTRODUCTION

In February 2024, Standards New Zealand (SNZ) released Draft Technical Specification (TS) DZ TS1170.5 [1] for public consultation. After a thorough review of the public comments and suitable modifications by TS Committee P1170.5., TS1170.5:2025 [2] is expected to be published in mid-2025. The TS provides updated engineering guidance to determine earthquake loadings when designing new buildings. The TS was developed based on the currently cited standard, NZS 1170.5:2004 [3], with review of aspects from NZS 1170.5:2004 Amendment 1 [4] considered valid to include. The TS was principally developed at this time to respond to the new knowledge about seismic hazard in New Zealand resulting from the publication of the 2022 National Seismic Hazard Model (NSHM). The TS also includes an update to the provisions for parts and components, as well as new provisions for rocking foundations for simple structures. Furthermore, geotechnical considerations are now referenced in performance requirements and geotechnical loading parameters are provided.

This paper serves as an introduction to a special issue of the Bulletin of the New Zealand Society for Earthquake Engineering on the changes to NZS 1170.5:2004 in TS 1170.5:2025. The papers of this special issue, in addition to a prior special issue in March 2025, provide detailed technical background for each of the key proposed changes, including insights on options considered during the development of the TS. The purpose of these papers is to provide engineers with

the technical basis for the provisions of the TS beyond that which can be readily included in a Commentary to the TS. The papers may also be of value to the authors of future design standards on earthquake actions, as the continued evolution of our understanding of earthquakes and the performance of buildings is inevitably going to require updating of earthquake loading standards in the future.

The topics covered in papers in this issue include:

1. Shape of the elastic design spectrum [5],
2. Modification of PGA to account for nonlinear site response [6],
3. Consideration of near-fault effects [7],
4. Assessment of life-safety risk [8], and
5. Modification of elastic spectrum for inelastic response [9].

Further papers related to the development of the TS were published in March 2025 issue of NZSEE Bulletin, covering the following topics:

1. Site classification [10],
2. Rocking foundations for simple structures [11],
3. Seismic design of parts and components [12], and
4. Consideration of deterministic limits on earthquake loading used in design [13].

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REGULATORY CONTEXT

NZS 1170.5:2004 remains the referenced standard used to show compliance with the New Zealand Building Code, even after publication of the TS. Changing of this reference is not being considered at this time. Use of the TS, once published, for new building design will only be allowed by an alternative solutions compliance pathway. Experience from use of the TS via alternative solutions will inform an impact analysis required prior to further public consultation on possible citing of the TS in future.

Publishing of the TS will not change the requirements of the earthquake-prone building (EPB) system in New Zealand. All seismic assessments, including voluntary seismic assessments for non-EPB purposes, should follow the same approach as for the national earthquake-prone building system and use the cited standard NZS 1170.5:2004.

Risk Settings

It is critical to recognise that all of the changes in TS1170.5 are independent of the risk settings of the Building Code and Verification Method B1/VM1 [14]. Performance objectives are defined in Clause B1 Structure of the Building Code [14], while the risk settings for seismic design are effectively set by the specification of Annual Probabilities of Exceedance (APoE) for different Importance Levels (IL) in Section 3 of AS/NZS 1170.0. For example, it was assumed that ULS would continue to be assessed for APoE of 1/500, 1/1000, and 1/2500 for IL2, IL3, and IL4 buildings, respectively, as specified in AS/NZS 1170.0 [15]. Changes to these risk settings would require further policy considerations, public consultation, and the development of a regulatory impact assessment. Nevertheless, as summarised in paper [8], risk assessment tools were used in the development of the TS to assess if the fatality risk resulting from designing to 1/500 APoE for IL2 buildings lined up with typical fatality risk thresholds.

SEISMIC HAZARD MODELS AND DESIGN STANDARDS

A key output of any National Seismic Hazard Model (NSHM) is the estimation of a Uniform Hazard Spectrum (UHS). All spectral ordinates on a UHS have an equal probability of being exceeded. A commonly used UHS for the design of buildings is that corresponding to a 10% probability of being exceeded in 50 years. Expressed as an annual probability of exceedance (APoE), this is equivalent to an APoE of 1/475, which is often rounded to 1/500.

The elastic seismic design spectrum used for structural design in New Zealand has been based on a UHS since NZS 4203:1992 [16]. For the ultimate limit state (ULS), NZS 4203:1992 adopted the UHS derived by Seismic Risk Subcommittee of Standards Association of New Zealand (summarised in Matuschka et al (1985) [17]) with an APoE of 1/450.

In 1998, Stirling et al [18] released a revised NSHM for New Zealand. Improvements over the 1985 study included the use of a modern ground motion model [19] and the use of an earthquake geology constrained fault-based source model which included the Hikurangi and Puysegur subduction zones. An update to the source modelling, led to a new NSHM in 2002 [20].

NZS 1170.5:2004, the standard currently cited in the New Zealand Building Code verification method to determine earthquake actions on buildings, includes elastic design spectra derived based on the UHS from the 2002 NSHM. The APoE for the UHS are specified in AS/NZS 1170.0:2002 based on the Importance Level (IL) of the building. For typical IL2 buildings, an APoE of 1/500 is used for ULS.

A further update to the NSHM was completed in 2010 [21]. This included an update to the data used for the rupture modelling and methodological change for the approach to distributed seismicity, however, for most locations the 2002 and 2010 models give similar results [21].

While the elastic design spectra are based on the results of the corresponding NSHM, some simplifications from the UHS directly from the NSHM are typically made in the development of the design spectra. Figure 1 illustrates such differences between the 2010 NSHM and NZS 1170.5:2004 for two sites in Wellington. For Site Class C, the 1170.5 design spectrum provides a close approximation of the NSHM UHS except for the cutoff at short periods and a conservative estimation of demands at long periods. The cutoff at short periods is generally felt to be appropriate for design given the high uncertainty in the estimation of building period – a similar cutoff has been adopted in the TS1170.5. The conservative estimate of demands at long periods was adopted in NZS 1170.5:2004 to provide an envelope of all UHS across New Zealand in one simplified spectral shape coefficient [22]. The Site Class D comparison in Figure 1 indicates 2010 NSHM UHS varied considerably from NZS 1170.5:2004.

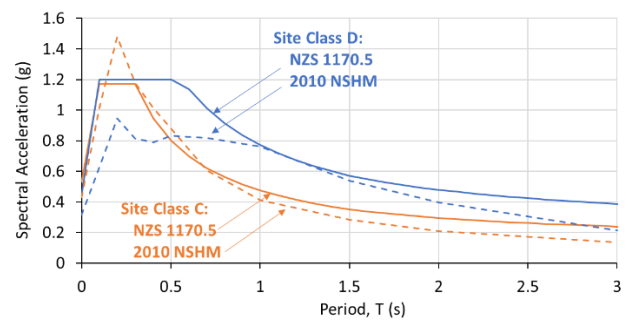


Figure 1: Comparison of UHS from 2010 NSHM and NZS1170.5:2004 for Wellington and APoE of 1/500.

2022 NATIONAL SEISMIC HAZARD MODEL

Following the release of the 2010 NSHM, significant advances were made by the seismological community in their ability to: 1) model fault ruptures, including complex multi-fault ruptures as seen in both the 2010 Mw 7.2 Darfield earthquake [23] and the 2016 Mw 7.8 Kaikoura earthquake [24]; 2) model ground shaking from large earthquakes, including subduction interface events; and 3) understand and model uncertainty in seismic hazard forecasts. These improvements were driven by both the New Zealand and the global hazard community through the occurrence of many large events around the world. Prior to the initiation of the 2022 NSHM revision, preliminary results and site-specific studies indicated an expectation of large increases in hazard for much of the country through the use of latest science; this initial expectation was based on improvements in understanding of ground shaking alone.

Based on the awareness of these advances and the likelihood for significant changes in the forecast hazard, a revision of the NSHM was jointly commissioned by the Ministry of Business Innovation and Employment (MBIE) and the Earthquake Commission (EQC) in 2020. The NSHM project placed an important focus on the science decision making and review process. The science team involved approximately 60 scientists and engineers and used a structure to minimise bias and to encourage a full understanding of knowledge of earthquake occurrence and shaking. The team came from across New Zealand universities and Crown Research Institutes and from around the globe. The NSHM project involved significant collaboration with the United States Geological Survey and the Global Earthquake Model foundation.

The review process involved three components. The first was a participatory peer review (PPR) process similar to recommendations from the nuclear industry [25]. The PPR included a 17-member team who were involved in the project from its inception. The team was about half international hazard modelling scientists and half technical users from the engineering and insurance industries. The technical users included representatives from MBIE, the New Zealand Society for Earthquake Engineering, the Structural Engineering Society of New Zealand and the New Zealand Geotechnical Society. The PPR was actively involved and tasked with providing detailed reviews and recommendations while the science was developed and implemented. This task also included reviewing of more than 40 technical reports. A second review process was commissioned by MBIE. This review brought in an international panel to review the decision and review processes used by the NSHM team with favourable conclusions [26]. The final review component was international journal peer review of approximately 40 publications (for a summary see [27]).

Every component of the model, from the base data sets to the hazard modelling software, was revised. Here we highlight some of the most significant changes. First was a philosophical change to include modelling of epistemic uncertainty, which is uncertainty in knowledge of earthquake occurrence and shaking. This is typically considered using multiple alternative models. Importantly, not only does this give confidence bounds on the forecast, but it: 1) often impacts the mean hazard (as used in NZS1170.5 and TS1170.5); and 2) creates a more thorough understanding of the hazard for both users of the model and for future revisions of the NSHM. In previous versions of the NSHM, no epistemic uncertainty was considered. Another overall change was to adopt a 100-year forecast as opposed to a nominally time-independent forecast in previous NSHMs. Important changes to the source model involved: the development of complex multi-fault ruptures; improvements to the Hikurangi and Puysegur Subduction interfaces; new models specifically for lower seismicity regions; and new understanding of the variability in earthquake occurrence rates over time. Previous NSHMs had simplified fault models where faults were only capable of rupturing a single geometrical fault extent and magnitude. They also did not allow more than one fault to rupture in a single earthquake, which is something observed in most historical New Zealand earthquakes [28]. The 2022 model relaxes this constraint and allows multiple magnitudes to occur on a fault and for multiple faults to rupture in a single earthquake. The subduction interfaces represent some of the most important sources of hazard and risk for New Zealand with updates to both the modelling techniques and the data used to constrain the magnitudes and occurrence rates. For lower seismicity regions, previous NSHMs have applied the same modelling techniques that were used in the rest of the country without considering the paucity of data in these regions. In the 2022 NSHM, new models were applied that account for the reduced number of observations and result in increases in hazard in these regions. Finally, a significant improvement in the ability to model variations in the mean rate through time was implemented in the 2022 NSHM; this was most impactful for understanding the range of potential hazard and also influenced the mean hazard.

For the more seismically active parts of New Zealand, the largest changes in hazard are driven by changes to the ground motion models (GMMs; [29] and [30]). At a high level these changes are driven by the additional 25 years of global

observations since the previous GMM change ([18] and [19]), and by the use of multiple GMMs that were developed using modern methods. The additional data constraints and modelling methods have resulted in impactful changes to predicted spectral shapes and in the uncertainty associated with the predicted ground-shaking for individual rupture scenarios. Despite the additional 25 years of shaking data, observations from near source and for large earthquakes are limited. It is for this reasons that the use of multiple models has become standard practice internationally ([31] and [32]). For the 2022 NSHM, a collection of global models from the Next Generation Attenuation (NGA)-West 2 project [33] and NGA-Subduction [34] were used. The global models were supplemented by three models that were scaled to fit New Zealand observations ([35] [36] and [37])). Changes in predicted ground motions for both crustal and subduction earthquakes resulted in increased hazard. Finally, to enable the use of internationally developed models and data, the 2022 NSHM is based on the time-average shear wave velocity to 30m depth (V_{s30}).

Almost ubiquitously, the forecast hazard has increased across New Zealand relative to the 2010 NSHM. Figure 2 shows the mean forecast for the spectral acceleration for a period of 1 second, $SA(1s)$, with a 10% probability of exceedance in 50 years for $V_{s30} = 250\text{m/s}$. All of the changes introduced in the preceding paragraphs, plus others not mentioned, have influenced both the mean hazard and the forecast range from the epistemic uncertainty. Overall, the ground motion models dominate the increases in hazard in high seismicity regions and the source model dominates in lower seismicity regions.

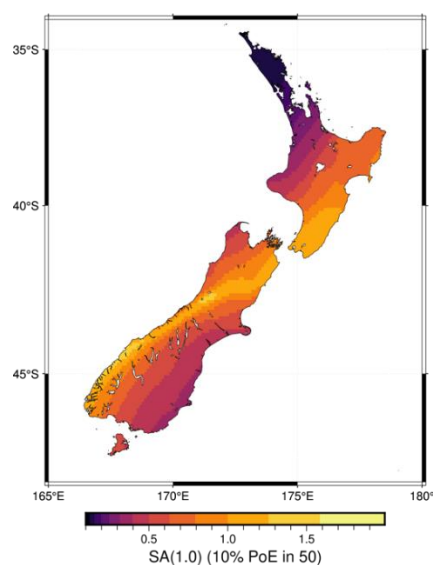


Figure 2: $SA(1s)$ with a 10% probability of exceedance in 50 years for $V_{s30} = 250\text{ m/s}$.

Figure 3 shows the hazard curve for Wellington for $SA(1s)$ for $V_{s30} = 250\text{m/s}$. This figure also presents the full hazard forecast via the 80% and 95% confidence bounds. These bounds show the range of possible futures given the models and uncertainty within the NSHM. Figure 4 show the Wellington uniform hazard spectra (UHS) for 10% probability of exceedance in 50 years with uncertainty bounds, also for $V_{s30} = 250\text{ m/s}$. Comprehensive maps, hazard curves, and UHS can be found using the NSHM webtools at <https://nshm.gns.cri.nz>

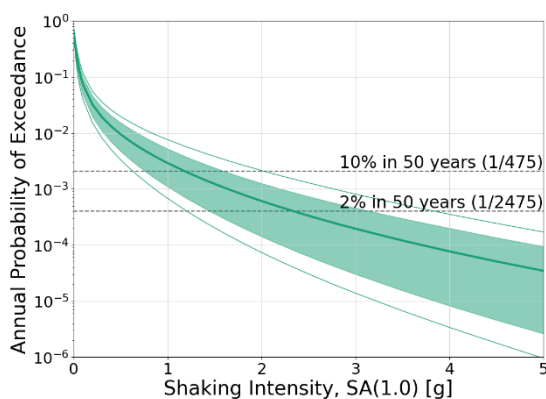


Figure 3: Wellington hazard curve for $SA(1s)$ and $V_{s30} = 250$ m/s. The bold green line indicates mean hazard curve. Shaded region highlights the 80% confidence interval and non-bold green lines indicate the 95% confidence bounds.

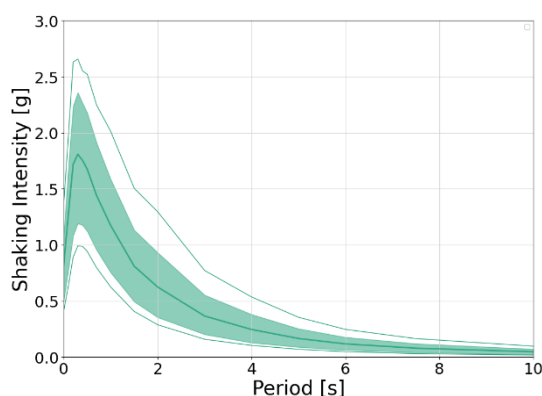


Figure 4: Wellington ($V_{s30} = 250$ m/s) UHS for 10% probability of exceedance in 50 years, corresponding to dashed line in Figure 3. The mean forecast (bold green line) and the 80% (shaded region) and 95% (non-bold green line) confidence bounds are shown.

DEVELOPMENT OF TS 1170.5:2025

The Seismic Risk Working Group (SRWG) was established by MBIE and convened by Engineering New Zealand to provide advice on how the updated NSHM could be applied within the Building Code system to support the design and construction of future buildings. The SRWG identified five principals guiding the development of seismic design provisions [38]:

1. be as simple as possible,
2. deliver consistent and acceptable performance,
3. consider and reflect the uncertain nature of earthquakes and building response,
4. be set at the appropriate level in the building control system e.g. Act, Code or Verification Method, and
5. be stable but adaptable to maintain consistency in design but allow flexibility for future advances in understanding of hazard or building performance.

In 2022, the SRWG was commissioned by MBIE to undertake the Seismic Risk Work Programme in two stages. Stage 1, completed in mid-2023, focused on immediate work required to enable the output of the NSHM to be integrated into the existing design framework, as soon as and in the simplest way possible. Stage 2, initiated in late 2023 and running for approximately two and a half years, will lead to an update of the design and analysis approaches to deliver more consistent and acceptable

building performance, while ensuring the seismic design process is easy for professionals to follow.

These special issues report on studies conducted during Stage 1 to support the development of changes to NZS 1170.5:2004. All changes from NZS 1170.5:2004 in Amendment 1 were also considered by the SRWG prior to inclusion. Two specific Amendment 1 modifications were not included in the TS content: analysis for buildings susceptible to ratcheting and SLS2 considerations for IL2 and IL3 buildings. Both topics were considered by SRWG to require further research and development prior to being included in a design standard. These topics will be considered further in Stage 2.

All changes from NZS 1170.5:2004 were formally balloted by the SRWG. For each change proposal, a background statement was prepared summarising the rational for the change, options considered, and supporting research. All negative votes on a change proposal were resolved by one of the following three methods:

1. Change to proposal to address the negative.
2. Removal of negative with further discussion.
3. Voting the negative non-persuasive.

Changes successfully balloted through the SRWG were provided to SNZ for consideration and approval by TS Committee P1170.5.

The decision to develop a Technical Specification rather than a new Standard was driven by the need to get the new knowledge from the NSHM in a form which can be used by engineers for the design of buildings as quickly as possible. A Technical Specification differs from a Standard in that it should be reviewed at least every three years to decide if it should be converted into a Standard, confirmed for a further 3 years as a TS (with or without revisions), or withdrawn.

SUMMARY OF CHANGES FROM NZS 1170.5:2004

Key changes in TS 1170.5:2025 include (with special issue papers providing background for these changes identified in parentheses):

- a. Limitations on the extent of reduction in seismic demand parameters available from special studies,
- b. Inclusion of new site demand parameter tables as a result of the 2022 NSHM [5] [6] [8] and [13],
- c. Revision of formulation for the site spectra [5],
- d. Revision to site class determination and consideration of uncertainty in estimation of $V_{s(30)}$ [10],
- e. Removal of the near-fault factor [7],
- f. Changes to site spectra for vertical loading for near-fault locations,
- g. Specific inclusion of geotechnical considerations in performance requirements and setting appropriate geotechnical loading parameters,
- h. Changes to the derivation of the horizontal design action coefficient for short-period structures [9],
- i. Addition of a simplified design for shallow foundations [11],
- j. Acceptance of sliding under ultimate limit state (ULS) actions [11], and
- k. Changes to the derivation of design actions for parts and components [12].

The following sections provide brief summaries of considerations and changes not covered in detail in the special issue papers.

Geotechnical Considerations

The seismic performance of a building is fundamentally linked to the strength, stiffness and stability of the ground supporting the building foundations; however, NZS 1170.5:2004 does not provide direction or guidance on how geotechnical matters (i.e., the performance of the ground and the interaction of the ground with the foundations) are to be incorporated into seismic designs of buildings, either with respect to intended philosophy or how verification of the limit states might be achieved. NZS 1170.5:2004 also did not directly provide seismic loading parameters appropriate for geotechnical analysis and design.

Given the general complexity and uncertainties associated with earthquake geotechnical engineering problems, as well as the large variety of ground conditions encountered, it is not considered feasible to develop Verification Methods or Acceptable Solutions which adequately address the complex issues requiring engineering evaluation and judgement (apart from some simple, low-risk and limited situations). However, the complete absence of geotechnical requirements / guidance within NZS 1170.5:2004 has resulted in inconsistent application of geotechnical considerations in the design process.

Given that it is completely new material, for the TS, a “soft” introduction of geotechnical considerations was adopted. Section 2 (Verification) of the TS contains relatively broad minimum requirements for consideration of geotechnical issues (e.g., “deformation of the ground supporting foundations must be considered”), and the supporting commentary highlights and discusses key issues, and references Section 175 guidance (i.e., the MBIE / NZGS Earthquake Geotechnical Engineering Practice modules) and select technical references.

The table of site demand parameters in TS1170.5 provides seismic hazard parameters for geotechnical analysis and design: peak ground acceleration (PGA) and magnitude (M) values for the new site classes and various annual probabilities of exceedance. These parameters were determined based on the output of the 2022 NSHM, and the values are different from those provided in NZGS Module 1 (2021) [39]. A revised version of NZGS Module 1 that refers to the seismic hazard parameters in TS1170.5 will be published concurrently with the final version of TS1170.5.

Site Demand Parameters, Locations, and Maps

Site demand parameters are provided in tabular form in TS 1170.5 based on city or rural settlement name. Constant values of site demand parameters are used within the city/settlement boundaries. Outside these cities/settlements, the site demand parameters are tabulated by 0.1x0.1 degree latitude/longitude (approximately 10 km x 10 km) grid point.

The city/settlement boundaries are sourced from StatsNZs ‘Urban Rural 2022’ geospatial layer [40]. All urban areas (Major Urban Area, Medium Urban Area, Small Urban Area), as well as ‘rural settlement’ areas that match locations from NZS1170.5, are used to define the city/settlement boundaries (polygons). This results in 214 named locations. The design intensity for each location is calculated at the centroid of the polygon, though the location is adjusted to the central business district for Auckland, Hamilton, Tauranga, Napier, New Plymouth, Wellington, Lower Hutt, Upper Hutt, Nelson, Christchurch, Dunedin, and Invercargill.

For 198 of the 214 city/settlement areas there is less than 1% variation of design intensities from grid points within the boundary. Christchurch, Hamilton, New Plymouth, and Dunedin have variations of 2%, 3%, 3%, and 5%, respectively.

Eight locations listed in NZS 1170.5:2004 are not included in the ‘Urban Rural 2022’ geospatial layer. Table 1 explains how the site demand parameters were determined for these locations.

Figure 5 provides contour maps of the spectral acceleration at short periods and at 1 sec for Site Class IV based on TS 1170.5. City/settlement boundaries can be seen in the Lower North Island close-up, with spectral acceleration values given for some key urban areas.

Table 1: NZS 1170.5:2004 legacy locations.

NZS1170.5 legacy locations	Definition of polygon and site demand parameters
Wellington CBD	Falls within the Wellington polygon, assigned the same values
Eastbourne, Wainuiomata	Fall within the Lower Hutt polygon, assigned the same values
Manukau City	Falls within the Auckland polygon, assigned the same values
Mount Maunganui	Falls within the Tauranga polygon, assigned the same values
Springs Junction, Otira, Milford Sound	New polygon is created with a buffer of 0.5 km applied around the reference location

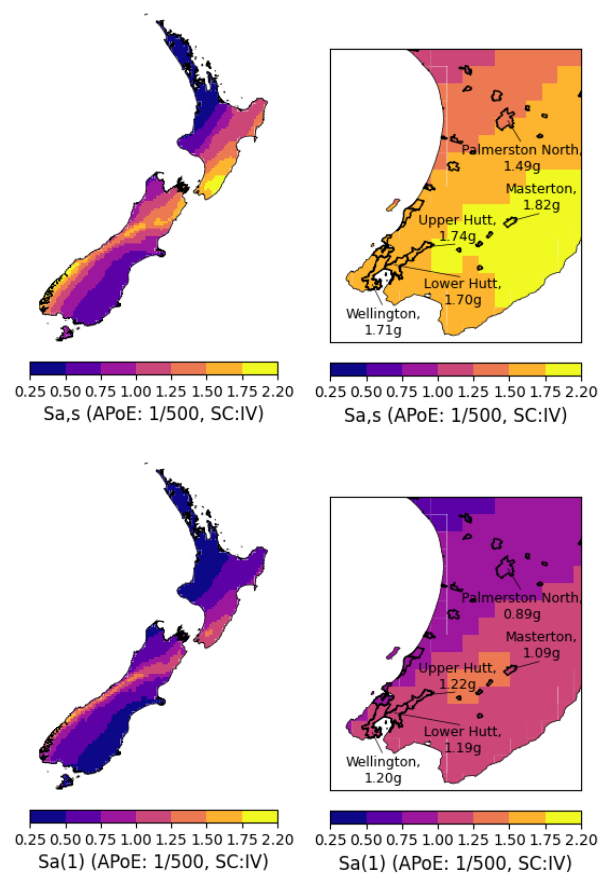


Figure 5: Maps of short-period spectral acceleration, $S_{a,s}$, and $S_{a(1)}$ for site class IV for APoE 1/500 from Draft TS 1170.5 (close-up of Lower North Island shows city/settlement boundaries with S_a values for selected urban regions).

Lower Bound Hazard

Consistent with NZS 1170.5:2004, a lower bound hazard, controlling in lower hazard regions such as Auckland and Northland, is included in the tabulated site demand parameters in TS1170.5. However, the basis for this lower bound hazard has changed.

The lower bound hazard in NZS 1170.5:2004 was set as the 84th percentile ground motion from a M6.5 earthquake at 20 km. It was assumed that this magnitude was the largest earthquake that could occur on a previously unidentified fault. However, this assumption is no longer considered valid and the 2022 NSHM has incorporated a maximum magnitude of M8.0 in areas away from known faults. A M8.0 at 20 km distance would result in extreme ground motions, not appropriate as a “lower bound”. Further, the 84th percentile ground motion, has been exceeded in both the 2011 Christchurch and 2016 Kaikōura earthquakes. These two points suggests the logic behind selecting the floor level in NZS 1170.5:2004 is no longer valid based on new science and observations from earthquakes in New Zealand.

For TS1170.5, the lower bound hazard is set based on a percentile of the hazard for Auckland. This lower bound ensures a minimum level of earthquake shaking anywhere in New Zealand, as a safeguard against overconfidence in regions where the infrequency of earthquake events reduces our ability to constrain the mean hazard and its uncertainty. While the minimum earthquake shaking for design and Auckland’s aggregated risk can be considered as separate but parallel issues, the mitigation measures are similar. Therefore, a single lower bound is used to address both concerns. The 90th percentile uniform hazard spectrum (from the epistemic uncertainty in the 2022 NSHM) for Auckland’s Central Business District is selected to: 1) increase confidence that the uncertainty in the mean is accounted for in the seismic design level in low hazard zones; and 2) provide additional confidence in outcomes via reduction of the potential for large consequences for Auckland, and indeed New Zealand as a whole, from future earthquakes affecting the Auckland region. The increase from Auckland’s mean uniform hazard spectrum to the 90th percentile is shown in Figure 6 for Site Class V and an APoE of 1/500. This earthquake shaking can be approximately represented by the expected (mean) shaking for a magnitude 7.5 earthquake 30 km away or a magnitude 6.5 event 15 km away.

Within our confidence of estimated seismic hazard in lower seismic zones, the SRWG did not consider there to be strong justification to decrease the design hazard for Northland compared to Auckland as done in NZS 1170.5:2004. Hence, TS 1170.5 applies the same lower bound hazard across all of New Zealand.

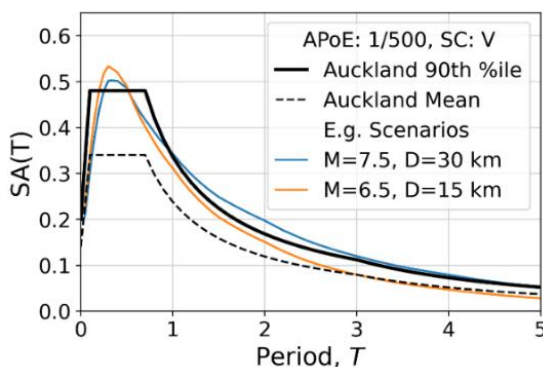


Figure 6: Lower bound hazard (defined by Auckland’s 90th percentile UHS) compared to Auckland’s mean spectrum for APoE of 1/500, Site Class V. Mean spectra for a M7.5 at 30 km and M6.5 at 15 km are included for comparison.

For Auckland, the proposed 90th percentile floor results in a 15 – 50 % increase over the mean uniform hazard spectra, depending on the annual probability of exceedance and the site class. This is similar to the 30% increase between the NZS 1170.5:2004 design floor ($Z=0.13$) and the 2002 NSHM for Auckland ($Z=0.1$).

The proposed lower bound has been estimated to provide significant reductions in societal risk for Auckland compared to not using a lower bound. Regional risk modelling using the design spectrum with and without the lower bound for a potential future building stock in Auckland, has estimated the proposed lower bound could result in a reduction of ~30 % in economic loss (direct damage) and a ~60 % reduction in life-safety risk (for a scenario earthquake ground motion with an APoE of 1 in 2500) compared to not using a lower bound. This was estimated by generating two future exposure models for all buildings in Auckland that would be constructed based on the proposed loading standards. The first exposure model assumed all buildings were designed with the design spectrum without a lower bound, and the second all buildings were designed with the lower bound. These two exposure models were then run through a regional risk model (RiskScape, [41]) to estimate the probabilistic losses in terms of economic (repair costs) and life-safety (fatality) risk. The model used a simplified vulnerability functions for economic loss based on the assumption that zero loss would occur up to the intensity of SLS and there would be 50% loss at the intensity of ULS [42]. To estimate life-safety (fatality) risk the model used a collapse fragility curve and a fatality rate given collapse of 0.1 as discussed in [8]. The results from using the two exposure models (with and without lower bound) were then compared to show the benefit of using a lower bound in reducing risk.

Vertical Spectra

Vertical acceleration spectra are traditionally specified for design as a ratio of the horizontal design spectra, often referred to as a V/H ratio. Data from the 2022 NSHM suggests that the mean V/H ratio tends to remain fairly constant (approximately 0.7) with period and site soil class. However, the 2022 NSHM data also suggests that vertical demands are greater for short site-source distance values, which broadly aligns with the findings of [43]. Consequently, the vertical demands have been set to 70% of the horizontal demands (in line with values specified in NZS 1170.5:2004) except for sites located within 10km of active faults.

For sites located within 10km of active faults, the vertical acceleration demands are prescribed as 100% of the horizontal shaking demands on an equivalent rock site. Reference to the rock site demands is made because near-source records from the Canterbury earthquakes suggested that at short distances, site class has little impact on the vertical acceleration demands. Conversely, near-source soft soil sites substantially reduce horizontal spectral accelerations at low periods due to highly nonlinear response (i.e., loss of high-frequency content due to large damping in soils) resulting in a substantial increase in the V/H ratios, in such cases.

NZS 1170.5:2004 Amendment 1 had recommended a more complex model for vertical spectra based on [43]. The above simplified approach for vertical demands has been adopted in the TS 1170.5 because vertical demands are not expected to be critical for the seismic design of most structures.

Near Fault Provisions

While the Draft TS released for public comment included a near-fault adjustment to the design spectrum, further study, summarised in [7] and considered by the TS Committee P1170.5, has indicated that the previous form of the near-fault

factor in NZS 1170.5:2004 was not compatible with the hazard determined based on 2022 NSHM. Continuing to use the near-fault factor would significantly over-estimate the mean hazard at near-fault sites, and hence has been removed in the published version of TS 1170.5:2025.

Although the near-fault factor has been removed, the distance to fault is still used in the new vertical spectra provisions as noted above. NZS 1170.5:2004 includes a list of eleven major faults that require near-fault factors to be considered. As part of the 2022 NSHM, a significant amount of work has been done to develop a NZ Community Fault Model (CFM) that defines the geometry and slip rates for active faults in New Zealand [44]. The CFM forms the basis for the proposed change in the values for the distance term (D).

Major faults are defined as those within the CFM that have a slip rate of 5mm/year or greater. This criterion includes the major faults from NZS 1170.5:2004 and includes additional fault segments that have been found to have high activity rates. By setting the cut off at 5mm/year, faults or fault segments with either high long term slip rates, or high conditional probabilities over the short-medium term are included. By considering fault segments, the CFM and TS reflect a more refined view of the spatial distribution of fault activity than the previous NZS 1170.5:2004 list of faults.

The distance term, D, is calculated as the shortest distance between the location of interest and the nearest major fault. This can be calculated ‘on-the-fly’ through a web-based portal [45]. Alternatively, D values given in TS tables are conservatively given as the shortest distance between the city/settlement

polygon and the nearest major fault (or from grid point to the nearest major fault). If a fault passes through the polygon, then D is listed as zero.

As a result of using the CFM, two sites listed in NZS 1170.5:2004 as requiring near-fault considerations, Picton (previously $D = 16$ km) and Dannevirke (previously $D = 10$ km), are no longer within 20 km of a major fault. This is because the Wairau and Mohaka faults, which were previously the closest faults to these locations, do not meet the new criteria for a major fault (≥ 5 mm/yr slip rate).

INTERNATIONAL COMPARATORS

The SRWG reviewed seismic design provisions from other countries with high seismic hazard to identify how the proposed provisions compared. Since each standard takes a slightly different approach to developing the design spectra, it is challenging to compare clause by clause. However, it is useful to compare the APoE of the hazard used in design as a proxy for risk settings, as shown in Table 2.

It is also useful to compare the final design spectra after all force reduction factors (e.g. S_p , k_u , R) are applied. Examples for ductile shear walls, two different site classes, and several cities generally known for having high seismicity are shown in Figure 7. Force reduction factors and site classification used for each design spectra in Figure 7 are given in Table 3. While certainly not an exhaustive study, examples shown indicate that the proposed design values for Wellington are within the range of design values for other cities with high seismicity.

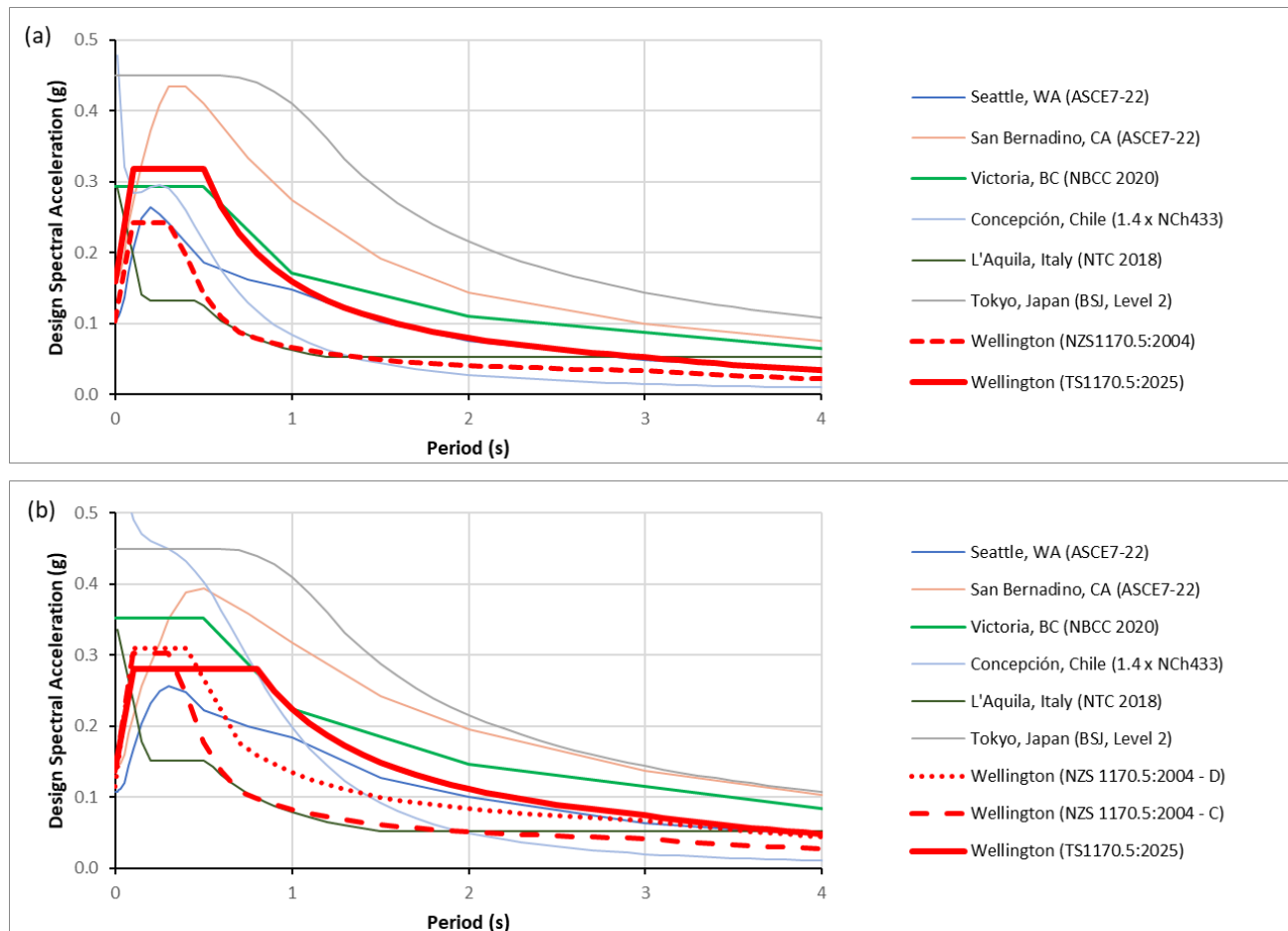


Figure 7: Example inelastic design spectra for ductile concrete shear wall buildings (IL2)
 (a) for site with $V_{s30} = 375$ m/s (b) for site with $V_{s30} = 225$ m/s.

Table 2: APoE used in international seismic design standards.

Country	Standard	SLS	ULS
NZ	AS/NZS 1170.0:2002 [15]	1/25	1/500
USA	ASCE 7-22 [46]	N/A	Note 1
Canada	NBCC 2020 [47]	N/A	1/2500
Europe	EC8: EN1998-1:2004 [48]	1/95	1/475
Chile	NCh433 (mod 2012) [49]	N/A	1/475
Japan	BSL 2016 [50]	1/43 ²	1/475 ²

1: ASCE 7-22 uses risk-targeted spectra except where controlled by deterministic ground motions near active faults – i.e. no single APoE.

2: BSL not based directly on probabilistic seismic hazard model but effective APoE estimated as shown.

NEXT STEPS

The previous sections, and the papers in March and June 2025 issues of the *Bulletin of the New Zealand Society for Earthquake Engineering*, describe work done in Stage 1 of the Seismic Risk Work Programme. While Stage 1 was largely

focused on the seismic hazard used for design, Stage 2 will take a broader look at the seismic design provisions in New Zealand to seek to provide better outcomes for society from our built environment in earthquakes, recognising cost and sustainability. Key issues with the current seismic design approach to be addressed in Stage 2 include:

- Design process does not facilitate a focus on controlling damage in buildings.
- Importance Level structure confuses amenity and life safety performance objectives.
- Critical role of irregularities in driving building damage is not fully recognised.
- Analysis provisions are out of date leading to uncertainty in estimated local demands and global response.
- Inconsistent alignment between NZS1170.5 and external standards, including capacity design requirements.
- Compliance framework does not adequately address geotechnical considerations.

Stage 2 is expected to lead to further proposed updates to TS 1170.5:2025 and a report on other recommendations beyond the scope of TS 1170.5.

Table 3: Force reduction factors and site classes used in Figure 7.

Country	Standard	System	Force Reduction Factor	Site class for $V_{s(30)} = 375\text{m/s}$	Site class for $V_{s(30)} = 225\text{m/s}$
New Zealand	NZS 1170.5:2004 Draft TS1170.5	Ductile RC shear wall	$k_u/S_p = 5.7$ ¹	B III	C or D ² V
USA	ASCE 7-22	Special RC shear wall	$R = 5$ ³	CD	D
Canada	NBCC 2020	Ductile RC shear wall	$R_d R_o = 5.6$	C ⁴	D ⁴
Europe/Italy	EC8: EN 1998-1:2004	Ductility Class High / Classe di Duttività Alta	$q = 5.4$	B	C
Chile	NCh433 (mod 2012)	Hormigón armado	$R^* = 1$ to 11 ⁵	C	D
Japan	BSL 2016	RC Shear Wall	$1/D_s = 2.2$	II	II

1: For NZS 1170.5:2004, k_u is reduced for $0.7 \text{ sec} > T > 0.4 \text{ sec}$

2: NZS 1170.5:2004 does not distinguish between site classes C and D based on $V_{s(30)}$

3: ASCE 7-22 $R = 5$ for Bearing Wall Systems. $R = 6$ for Building Frame Systems.

4: NBCC 2020 allows for UHS to be customised to the specific V_{s30} values for the site, hence site classification is not required. Figure 7 shows the customised spectra for the specified V_{s30} values.

5: NCh433 R^* varies based on site class and period.

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