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NZ Centre for Earthquake Resilience

A Vs30 map for New Zealand based on geology, topography slope and direct measurements

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Motivation

Vs30 (the time-averaged shear wave velocity in the uppermost 30 metres of a given location) is an important engineering parameter used in research and practice. Vs30 is not straightforward or inexpensive to measure directly. Mapping Vs30 as a continuous quantity falls within the realm of geostatistical problems – where a limited set of observations in limited locations are used to attempt to understand the situation elsewhere. These observation points are often geographically and geologically clustered, *viz.*: more measurements are collected in the built environment (in or near cities and towns), and cities & towns are often located in places with specific geologic characteristics (such as near alluvial deposits and water sources, for their ease of construction and transportation, among other considerations).

This study represents a second proxy Vs30 mapping (Figure 1) for New Zealand after Perrin *et al*. (2015). Similar work has been carried out for other regions, e.g. North America. Most approaches to Vs30 mapping share some common characteristics: using a limited set of observed Vs30 values for a region, and finding correlations with readily available proxy data (geology & topography) to constrain estimated values of Vs30. This work aims to add to the knowledge of Vs30 mapping for New Zealand including, e.g., interpolation to resolve local discrepancies with available data (Figure 2) and developing a continuous estimate of model uncertainty. The resulting Vs30 and uncertainty maps will be valuable as a first-order resource for classifying uncharacterised sites, and as inputs to ground motion simulation research.

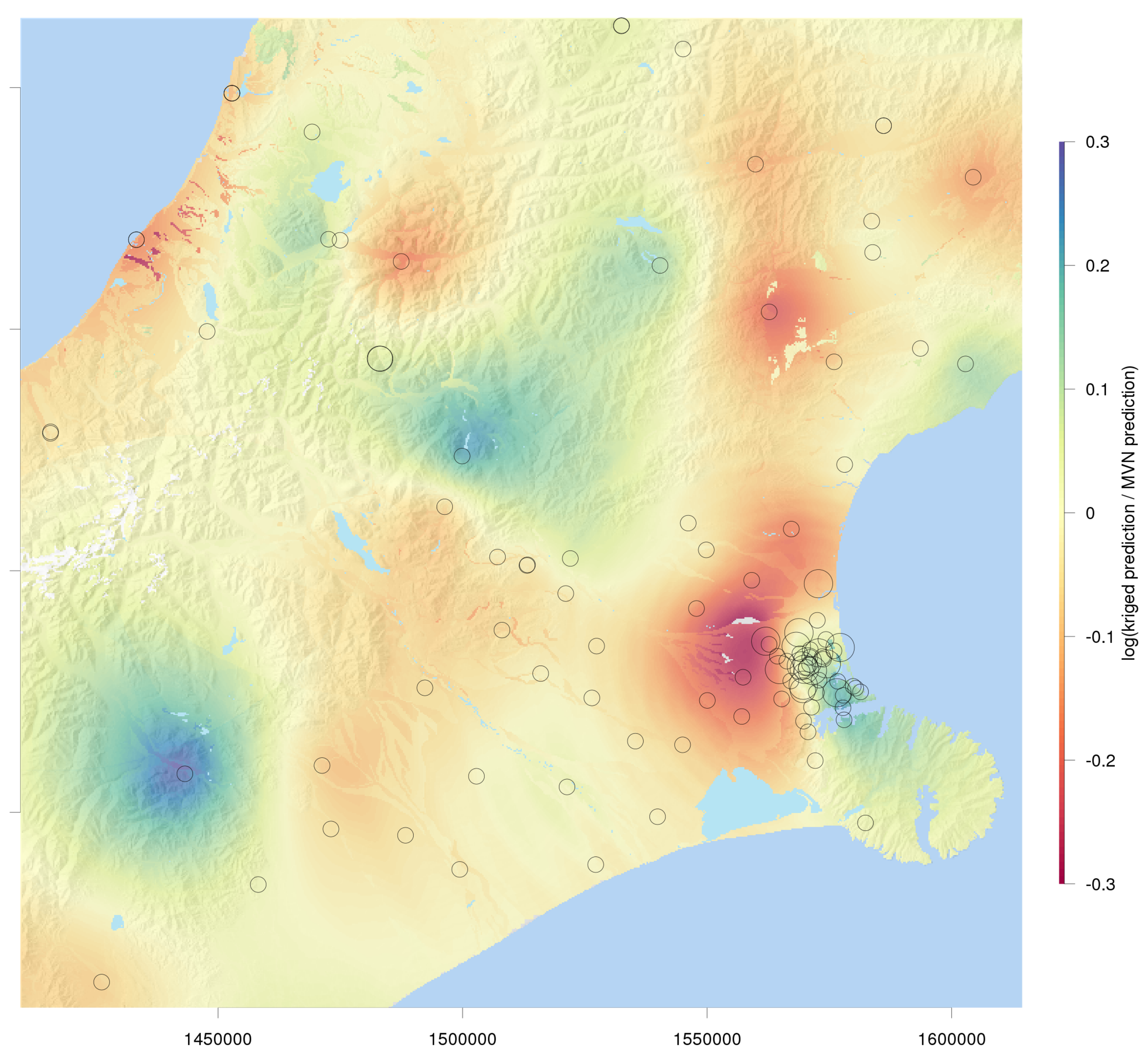

Figure 2: Comparing the performance of two interpolation methods applied in the final stage of mapping to bring map into local agreement with discrete Vs30 measurements. The conventional approach, Kriging, assumes the same uncertainty at all points. The "MVN method" (Worden *et al.*, in review) allows different measurement uncertainty to be assumed for different points. Map coloration is based on the ratio of MVN mean prediction to Kriging mean prediction. Data locations are overlaid with circle diameter indicating data quality (Q1, Q2 and Q3). Larger circles indicate higher precision. The difference in model predictions arises from the manner in which imprecise data are handled by the MVN approach.

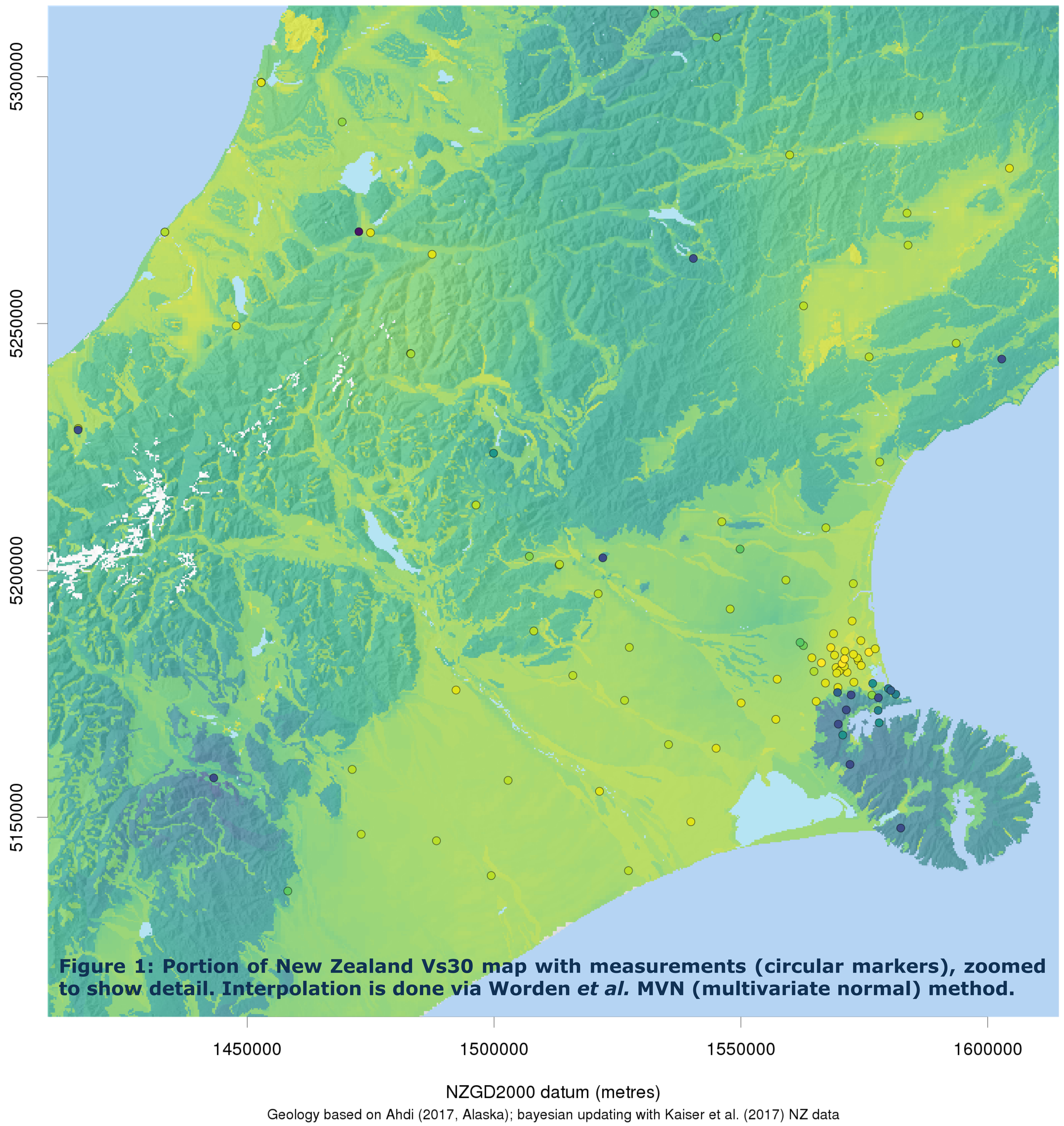

Figure 1: Portion of New Zealand Vs30 map with measurements (circular markers), zoomed to show detail. Interpolation is done via Worden *et al.* MVN (multivariate normal) method.

Methodology

We employ a rigorous statistical methodology that expands on similar previous work in a few important ways. Because Vs30 data is geologically clustered (Figure 3), we take a Bayesian approach to estimating log-mean Vs30 and standard deviation for various geology subgroups. Bayesian priors are borrowed directly from another study (Ahdi, 2017: Alaska). The Bayesian updating allows reasonable Vs30 estimates to be applied for geology that is underrepresented in the NZ data. A "hybrid" map is then generated by applying corrections based on the correlation between topographic slope and Vs30 (Figure 4). A pointwise comparison of geology-based model estimates between this work and Perrin *et al*. is presented in Figure 5.

The Vs30 estimate map uses a geostatistical interpolation scheme (Worden et al., in review) that offers some advantages over the conventional regression kriging approach. The method is computationally intensive for continuous mapping but has the significant advantages of (a) directly accounting for subgroup standard deviation and (b) allowing for "fuzzy" measurements and/or estimates. Judgment-based assumptions of the precision of measurements are used to represent epistemic uncertainty, allowing the interpolation to constrain the model locally without introducing abrupt "spikes and dips" in the mean, and without conveying a misleadingly low standard deviation in the vicinity of imprecise data.

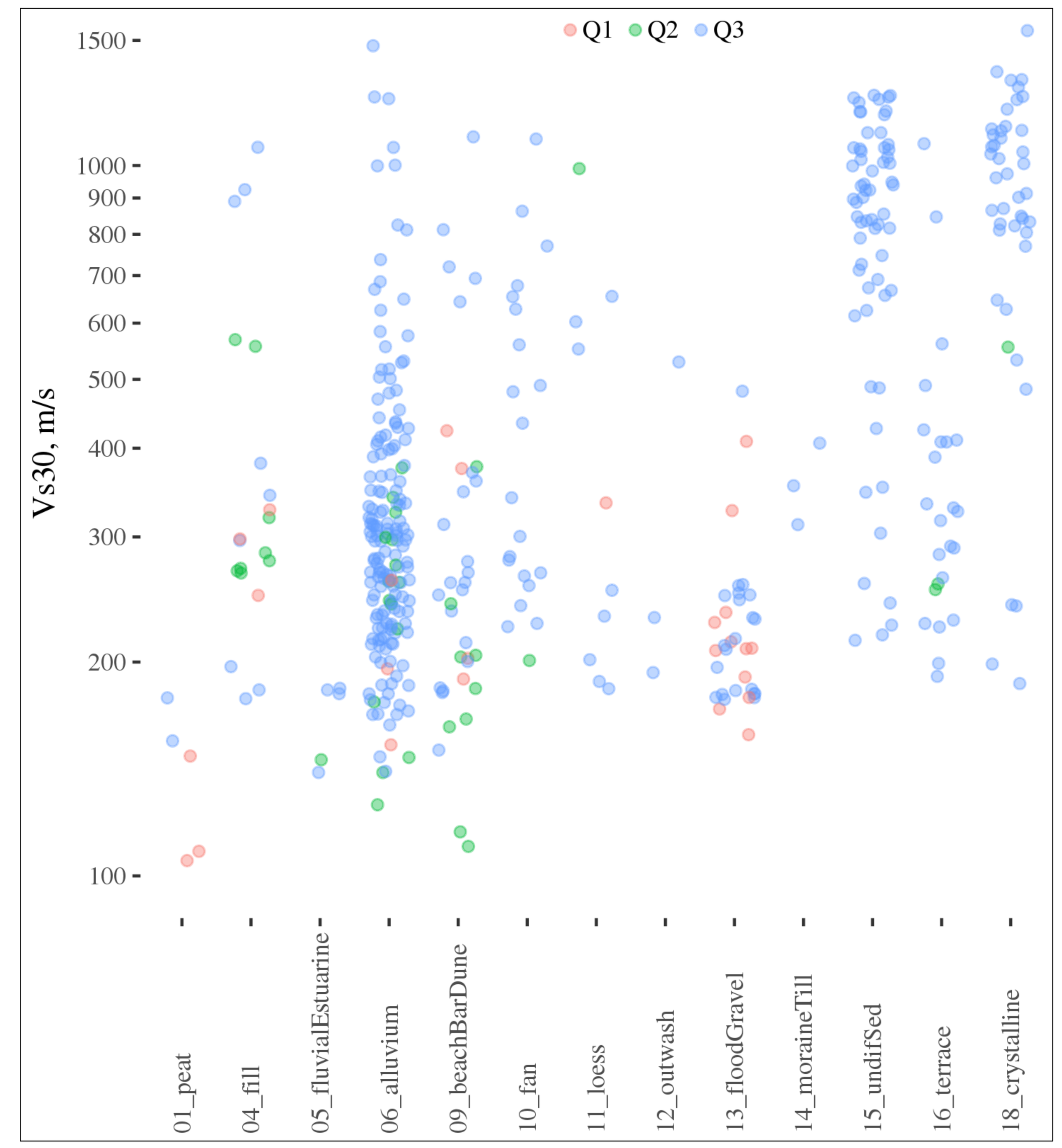

Figure 3: Vs30 measurements from Kaiser *et al.*, grouped by the geology classifications of Ahdi. Coloration indicates the Kaiser *et al.* assessment of data quality (Q1, red: highest quality ranking). The high-quality data are outnumbered by lower quality data or estimates (some based on previous mapping work by Perrin *et al.*). Some geology groups are sparsely populated.

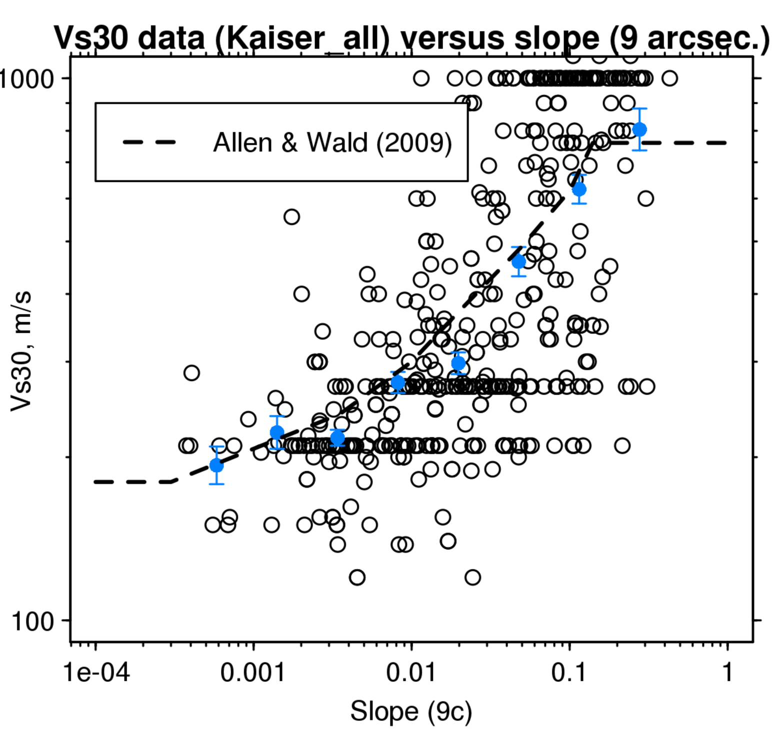

Figure 4: Vs30 plotted against slope for the Kaiser dataset. This plot shows uncategorised data; the trend is most prevalent in alluvial soil units. The slope-based correction in the mapping is applied on a per-geology-group basis.

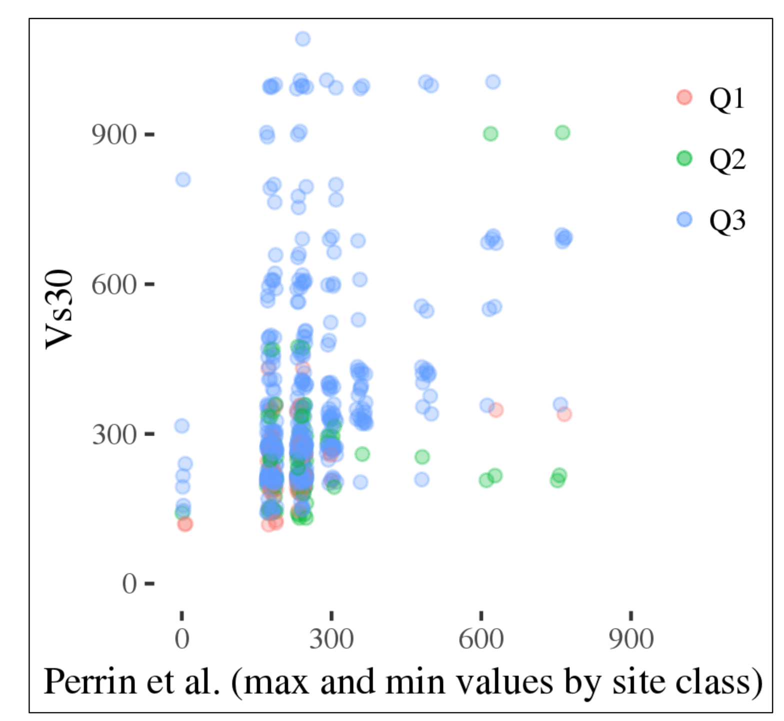

Figure 5: For points in the Kaiser dataset, Vs30 values (vertical axis) and minimum & maximum values from Perrin *et al.* map are compared. Color indicates quality ranking (Q1 = best). (Note that some Q3 Kaiser values are based on Perrin *et al.*)