Dynamic site characterisation of the Waikato Basin using H/V spectral ratios and surface wave methods

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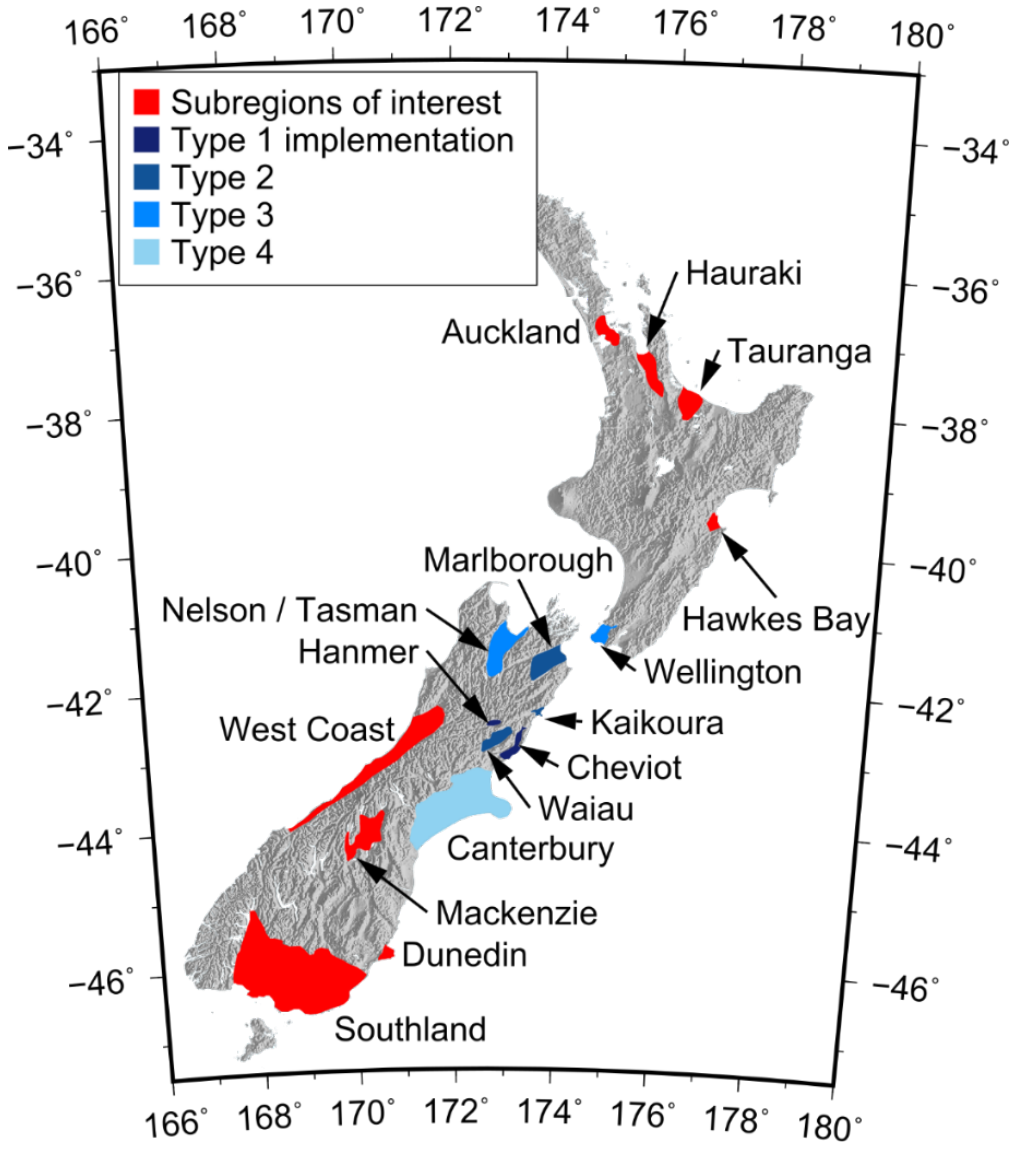
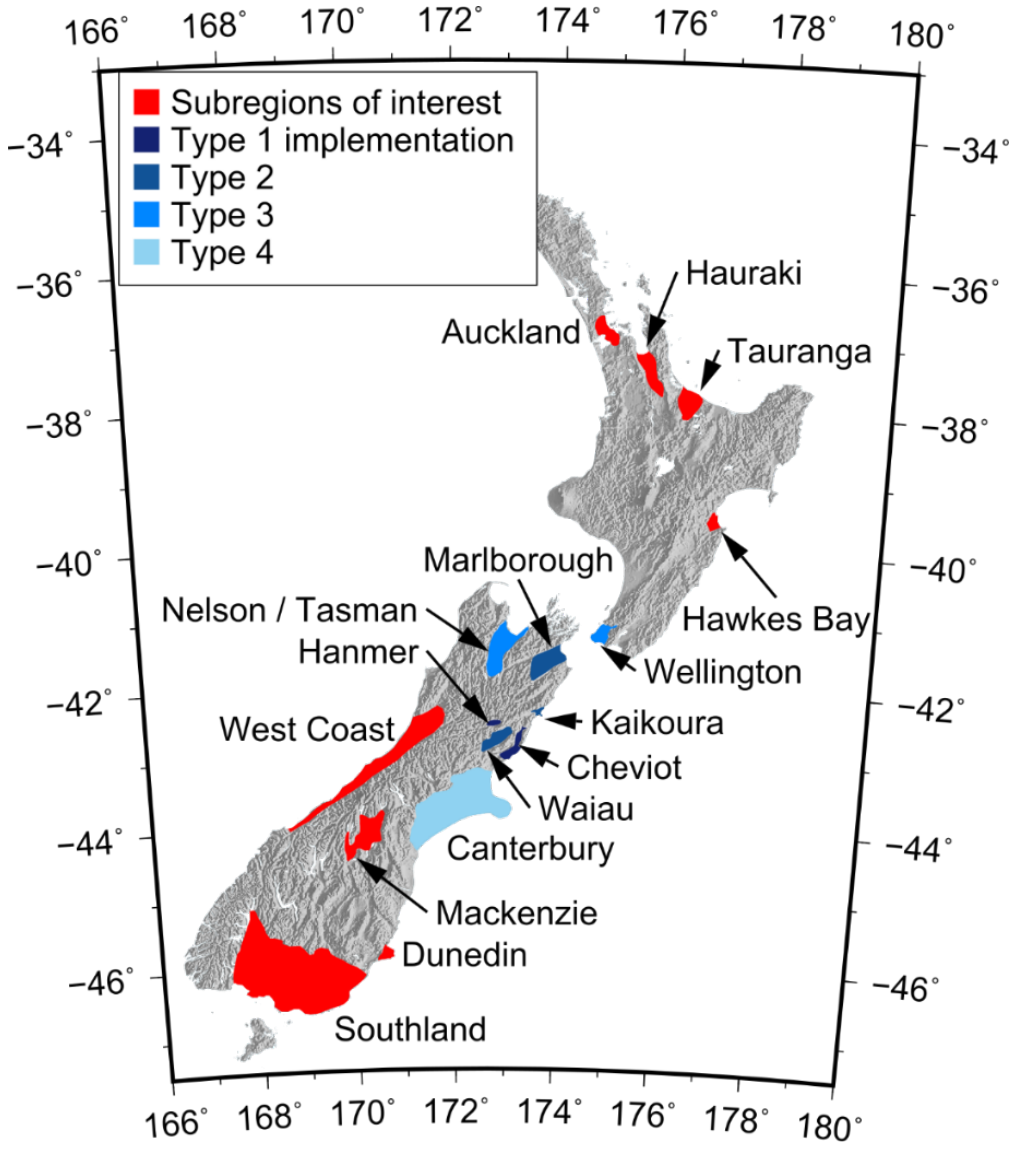
Introduction

NZ basin models



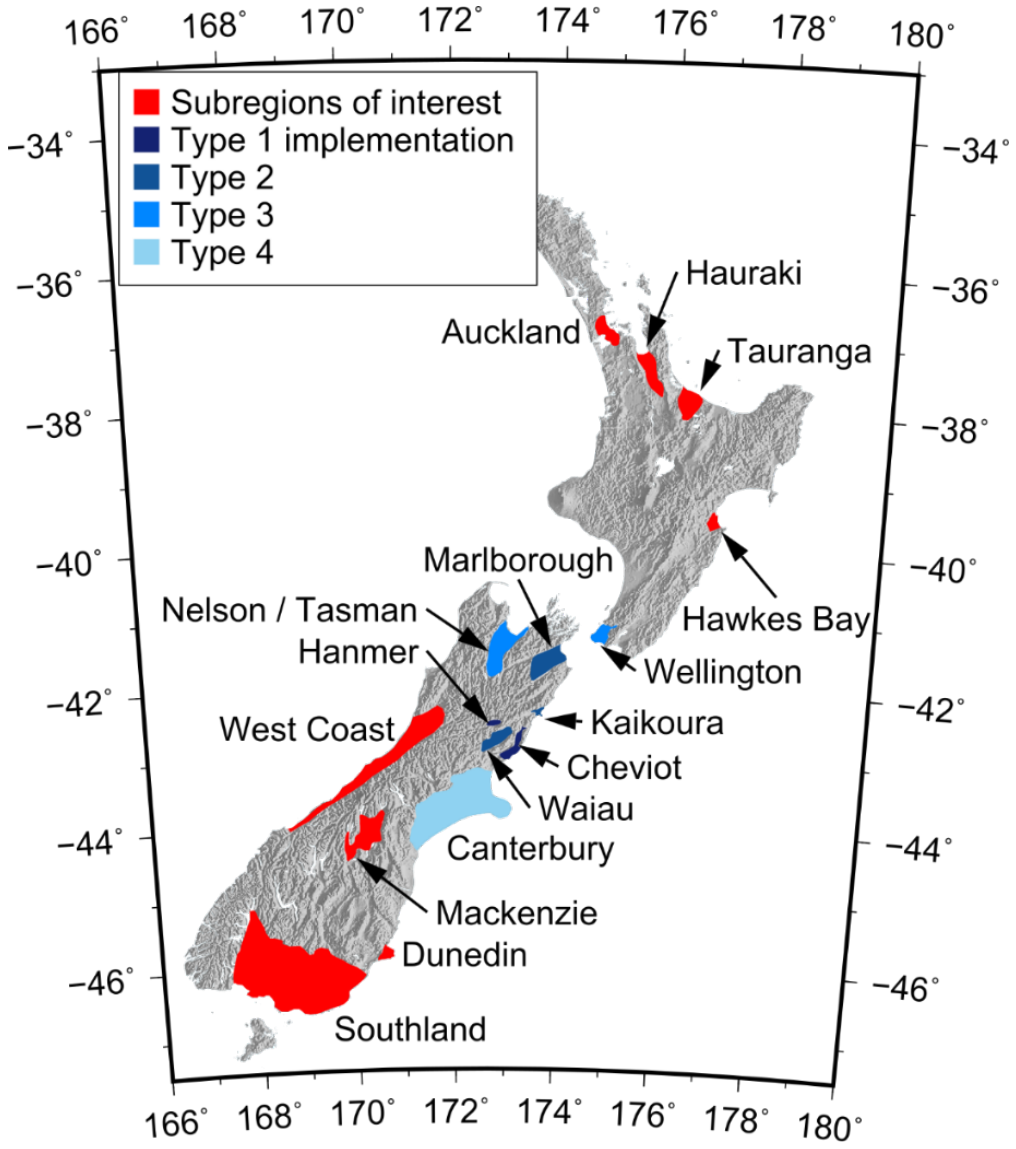
- Soft sedimentary basins amplify and extend the duration of ground motions by:
  - The impedance contrast, and
  - The trapping of waves within the basin

NZ basin models



- Initial basin models
  - Topography
  - Geologic maps
- Refinement of models through field testing:
  - H/V → Site Period
  - Surface wave testing → V_S

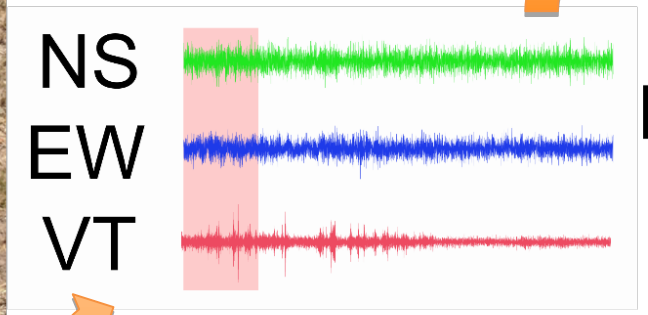
NZ basin models



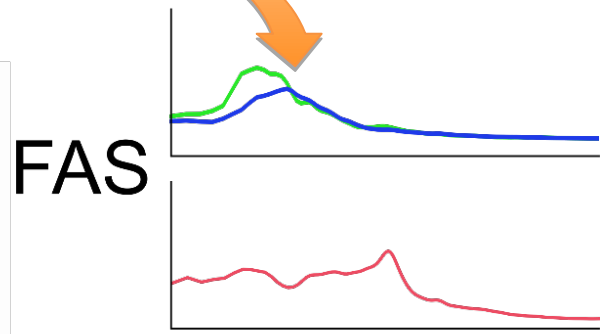
- Recent field testing
  - Waikato
  - Hawkes Bay
  - Hauraki Plains
  - Auckland
  - Tauranga/BoP

Site period from H/V ratio

Record Ambient Signal

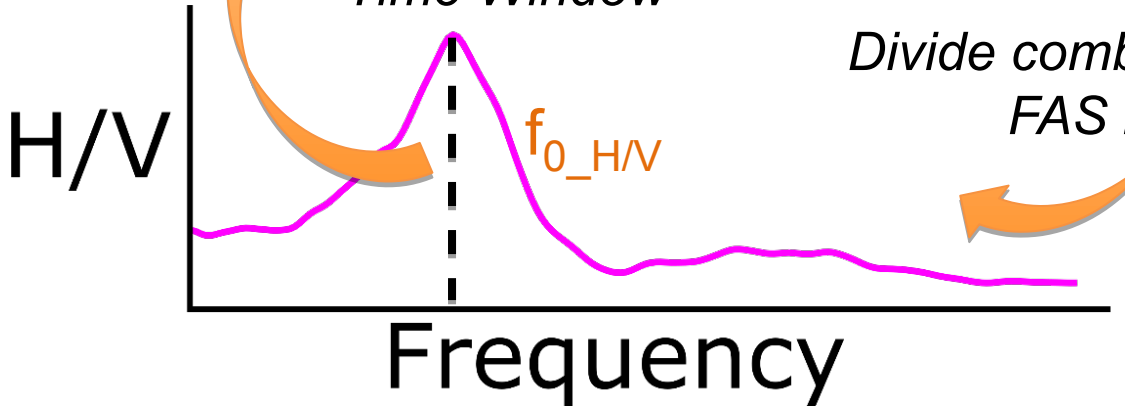


Fourier Transform & Smoothing



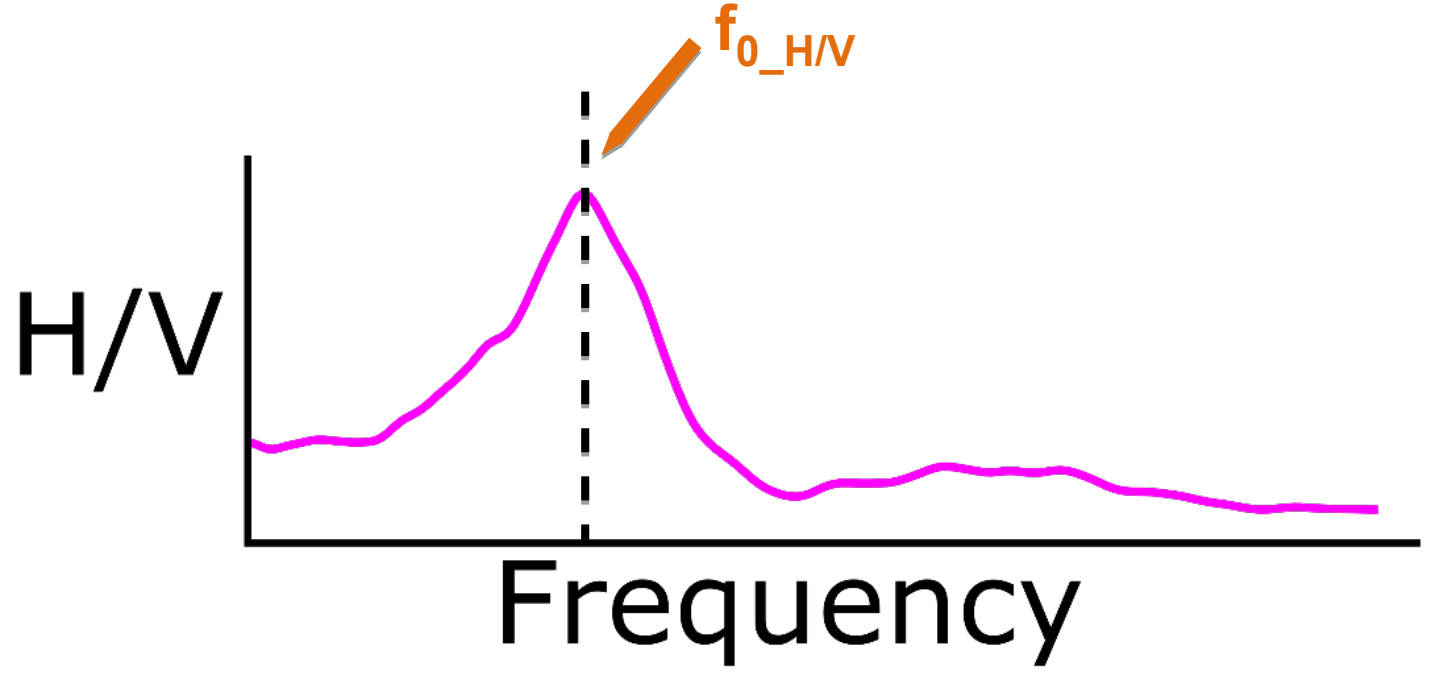
Repeat for each Time Window

Divide combined NS and EW FAS by VT FAS



Site period from H/V ratio

- Originally proposed by Nakamura (1989) as an estimate of 1D transfer function.
- A clear peak in the H/V curve closely approximates the site fundamental resonant frequency.
- H/V, HVSR, Nakamura ratio, etc



H/V spectral ratio method: the theoretical basis

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- Why does H/V ratio resembles the 1D transfer function?
- Many different theories about the composition of microtremors:
  - Rayleigh wave elipticity (Lermo & Chavez-Garcia 1994; Malischewsky & Sherbaum 2004)
  - Dominance of body waves around the H/V peak (Nakamura 2000; Bonnefoy-Claudet et al. 2008)
  - Diffuse field concept (Sanchez-Sesma et al. 2011)

Motivations

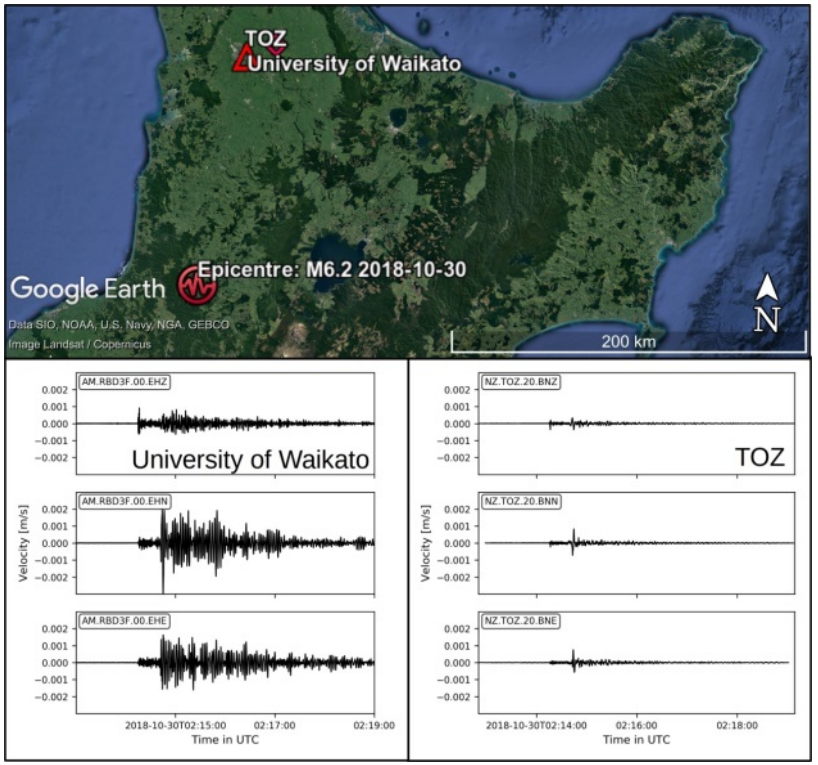
- “Low” seismic hazard in Waikato; but what will be the impact like?

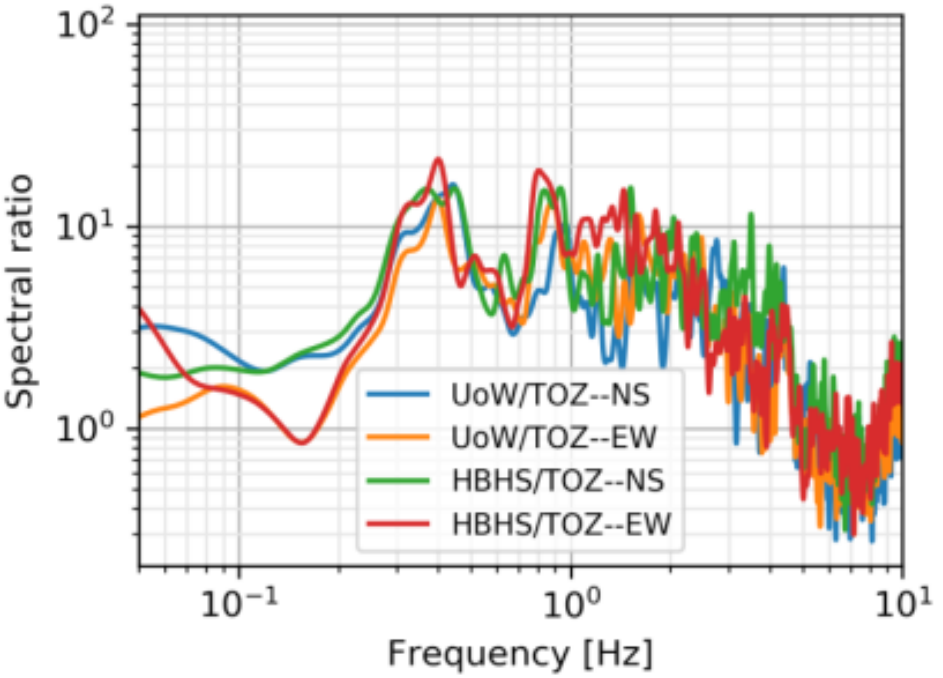
- Kerepehi fault ~40km away from Hamilton; Hikurangi subduction zone

- Lack of quantitative site characterisation data

Observed site effect in Waikato

- Observed soft basin effect in the 2018 M6.2 Taumarunui EQ; high intensity, long period shaking of long durations
- Empirical TF demonstrates large amplification





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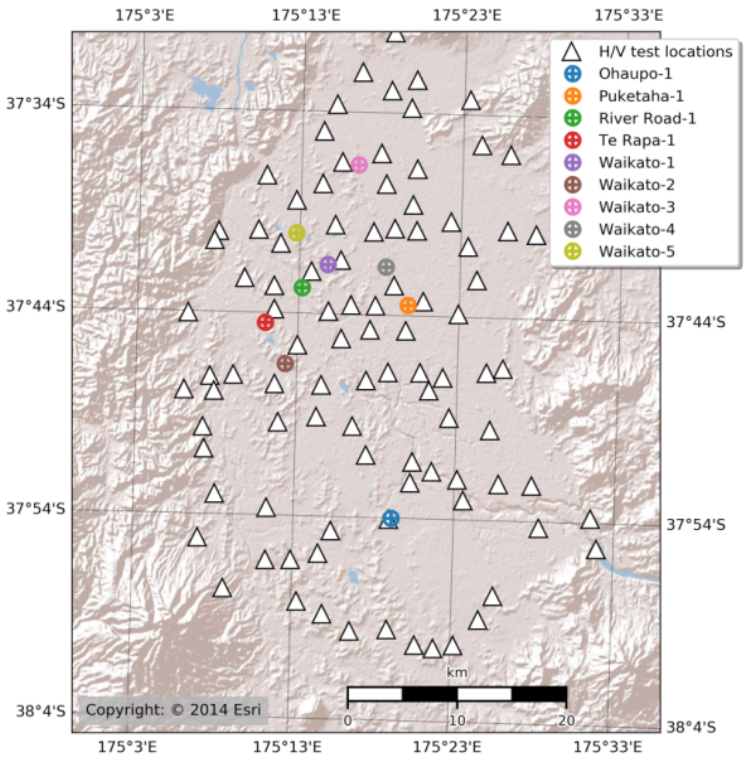
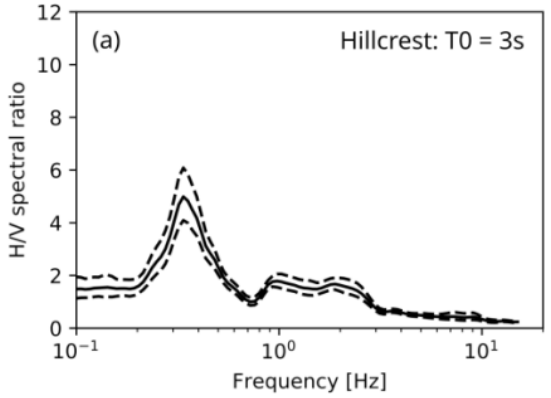
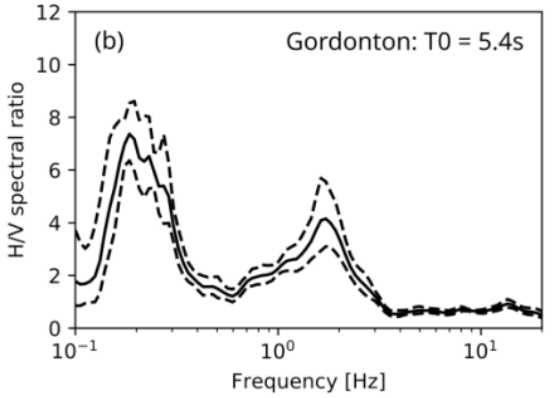
H/V testing in Waikato

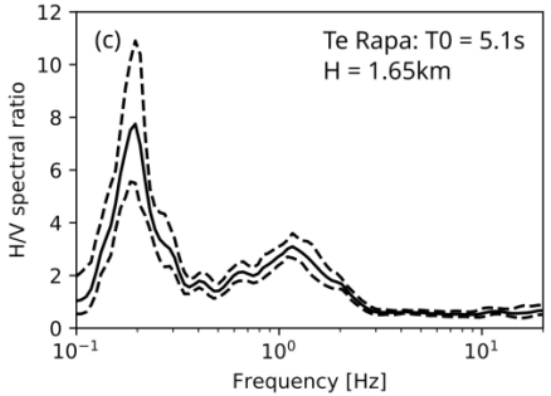
H/V spectral ratios in Waikato

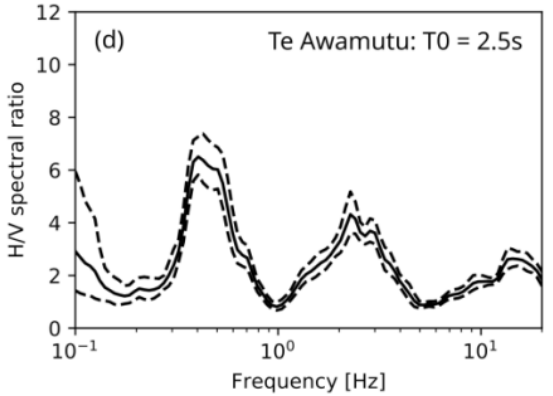
- H/V spectral ratios at over 100 sites to obtain the fundamental period, T_0
- H/V spectral ratios in Waikato suggest soft basin overlying hard rock
- Many sites have a long site period indicative of deep, soft basin



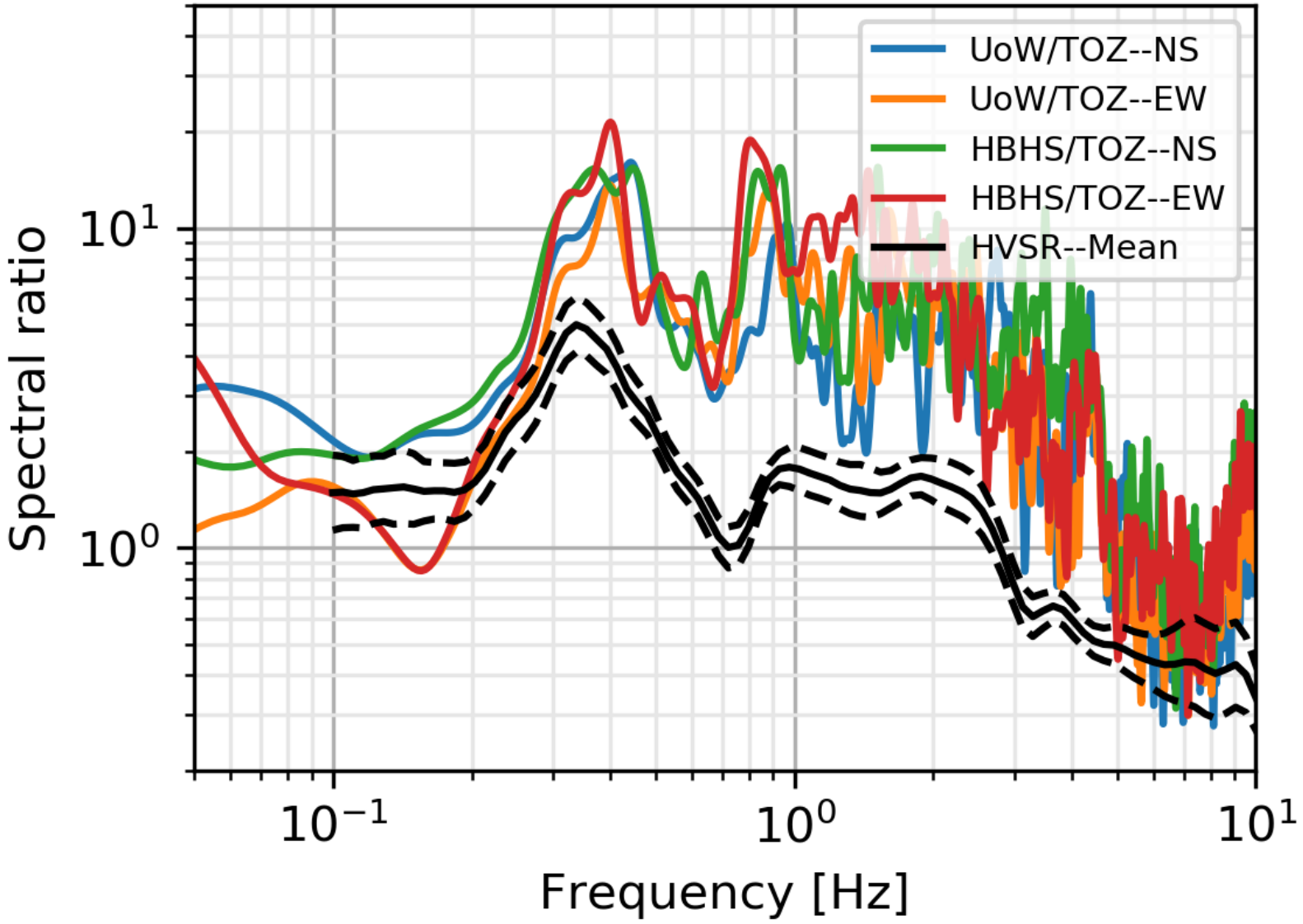








HVSR vs Empirical TF in Hillcrest



Site periods and site classes

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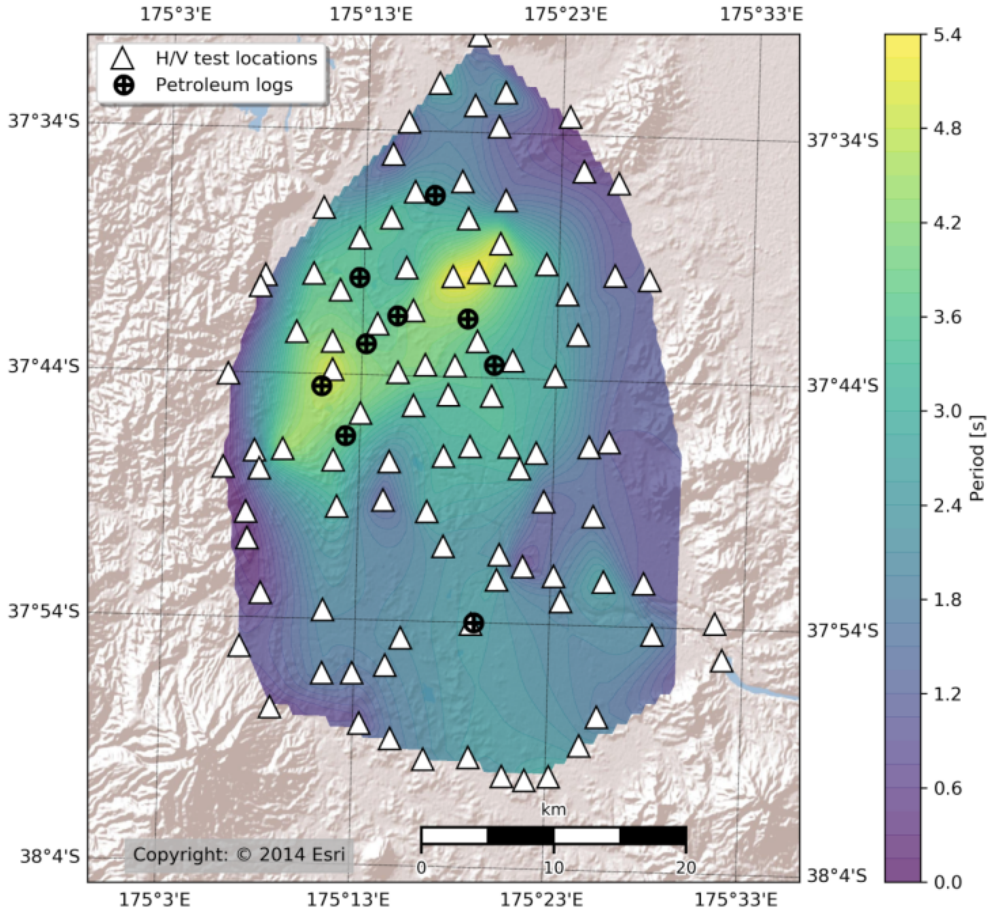
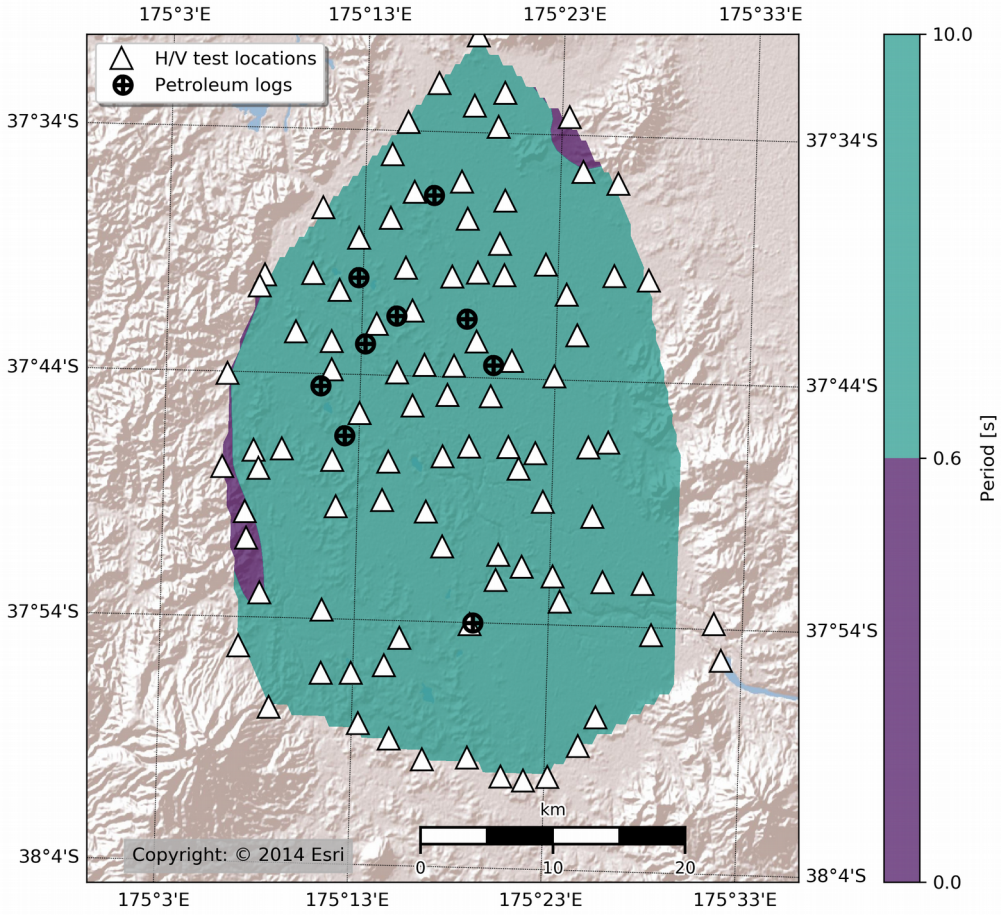
T_0 map by spatial interpolation

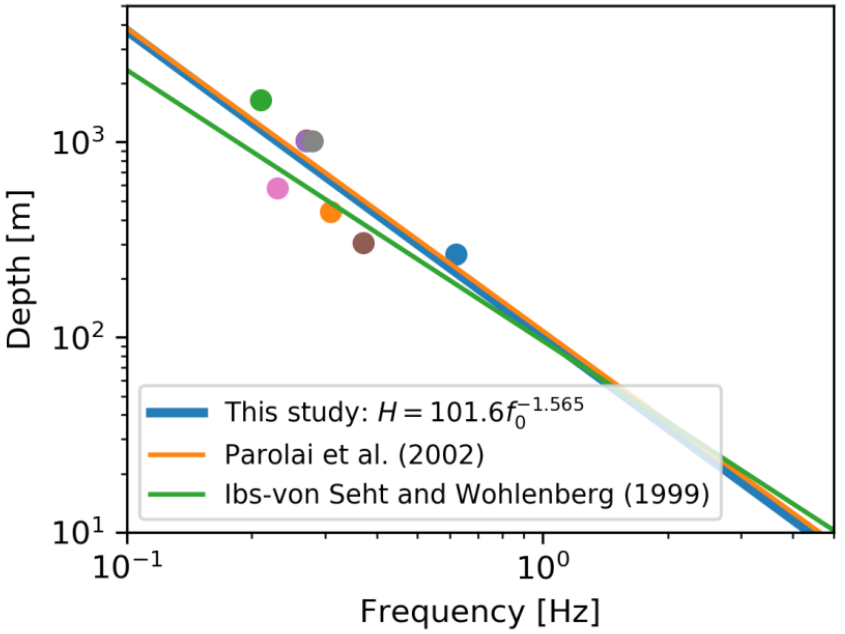


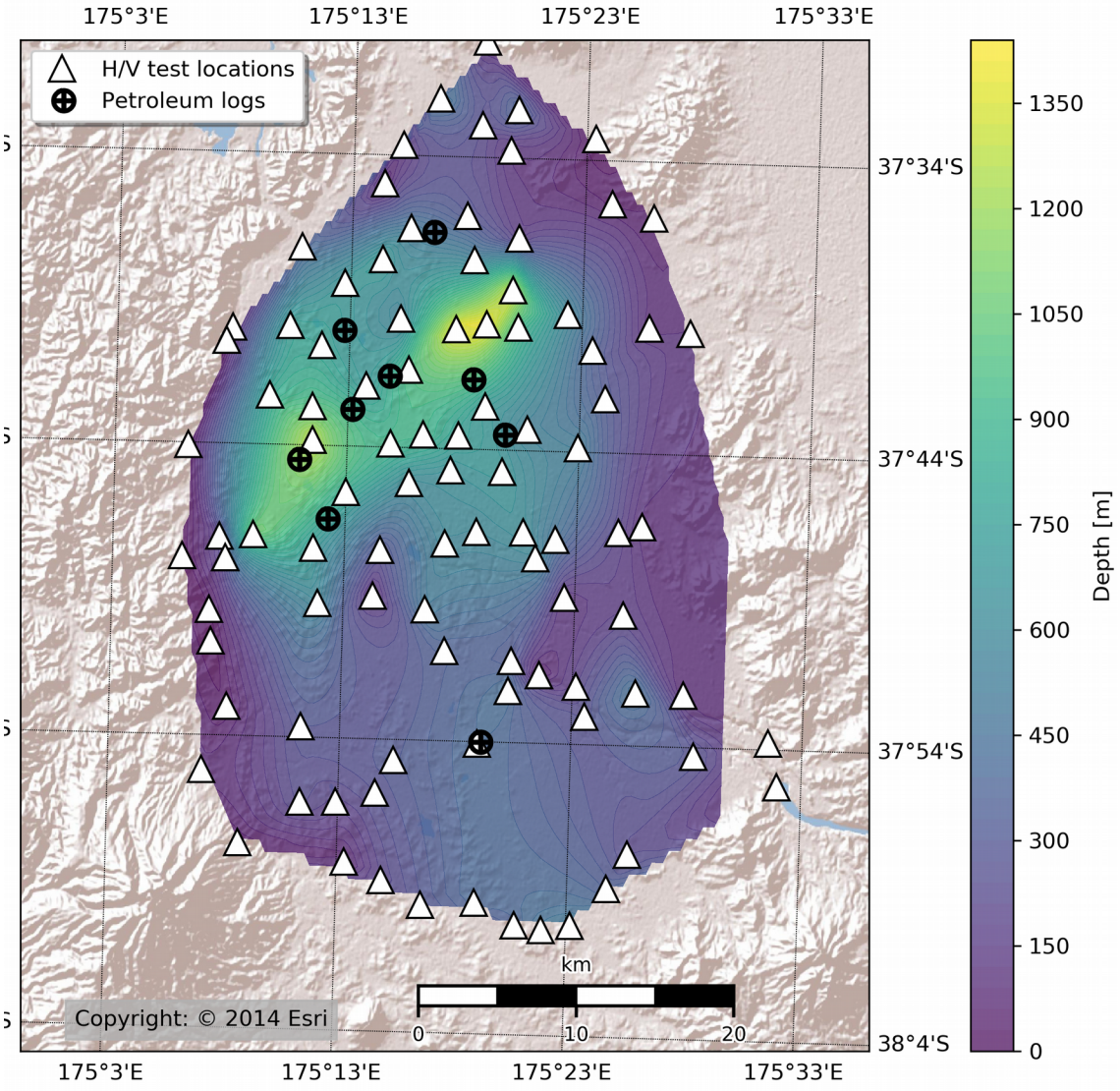
Mostly class D sites



Depth to the bedrock

- Depths to the basement from the petroleum log data (Edbrooke *et al.*, 2009)
- A power-law relationship between H and f_0





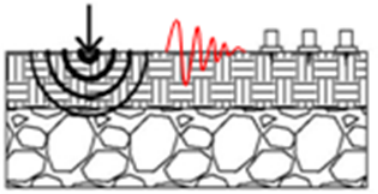
Surface wave testing

Surface Wave Testing

- Obtain the V_s profiles compatible with the observed dispersive characteristics of surface waves

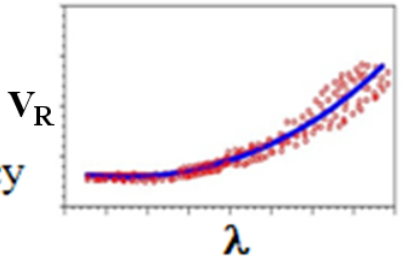
Acquisition

Field Data Collection:
Measurement of stress waves at the ground surface



Processing

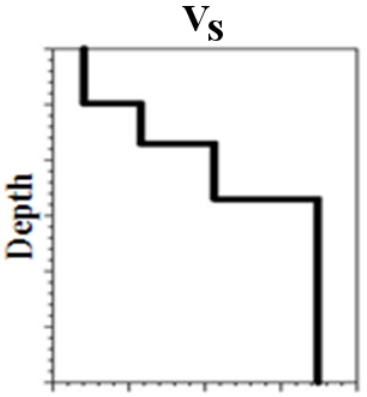
Dispersion Curve:
Rayleigh Wave Phase Velocity vs. Wavelength/Frequency



Inversion

Shear Wave Velocity Profile:
Variation of Small Strain Shear Modulus vs. Depth

$$G_{max} = \rho V_S^2$$



Active (MASW) & Passive (MAM) Methods

Active:
FK &FDBF in MATLAB
Passive:
MSPAC & HFK in Geopsy

Dinver and MATLAB
Layering Ratio method to constrain parameters

Surface wave testing for V_s profiles

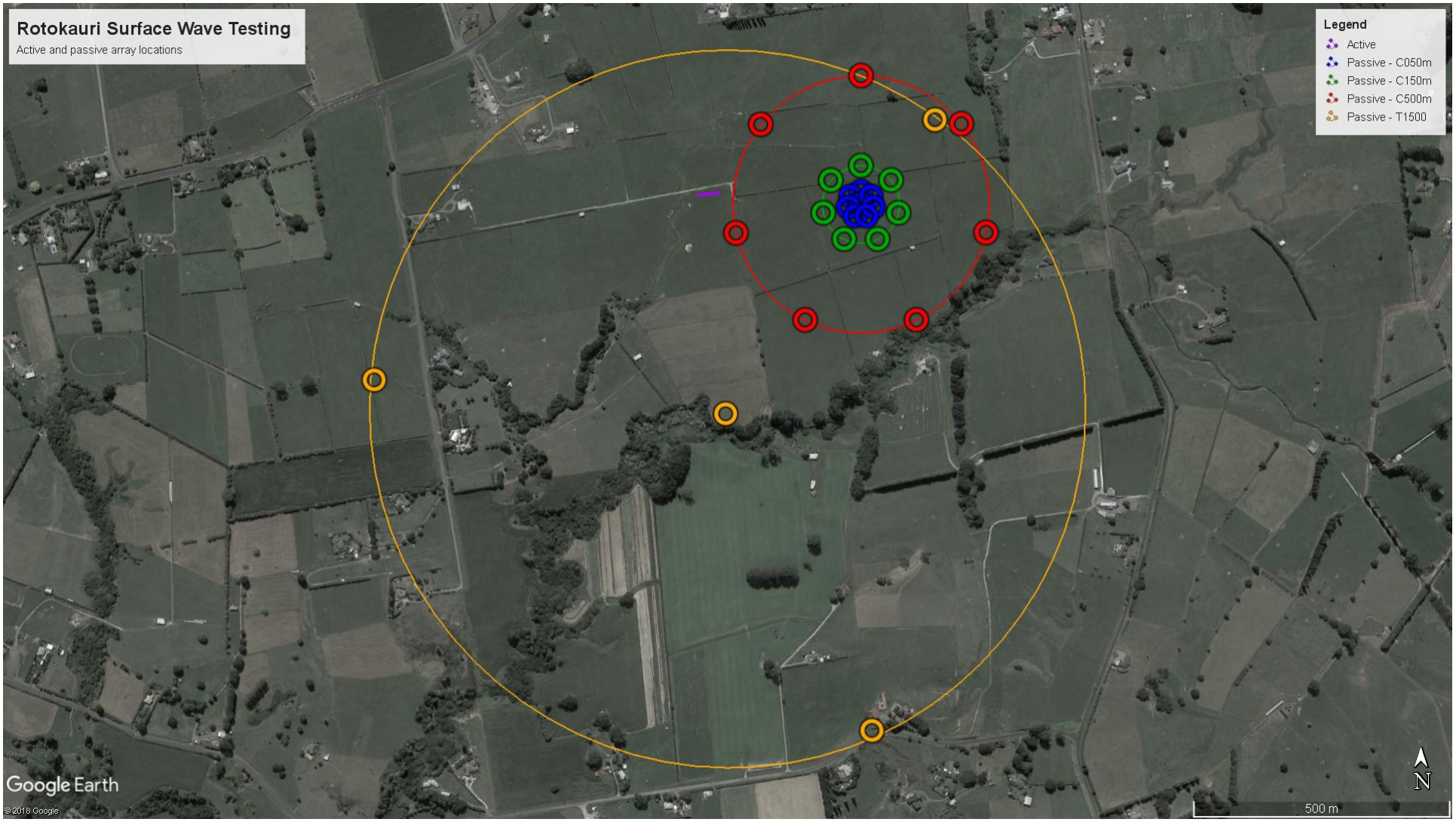
- V_s profiles are used for seismic hazard analysis, liquefaction susceptibility analysis, etc.
- Two sites done, one at Rotokauri and another at Ruakura
- Over 10 sites planned to be completed by September 2020
- V_s profiles all the way down to the Greywacke basement

Rotokauri Site

- Active Testing (MASW)
  - 24x vertical 4.5 Hz geophones
  - 2 m geophone spacing
  - Source offsets:
    - Both ends of the array
    - 5 m, 10 m, 20 m

- Passive Testing (MAM)
  - Nanometrics Broadband Seismometers
  - Circular Arrays:
    - 50 m, 150 m, 500 m diameters
  - Triangular Array:
    - 1500 m diameter

Rotokauri Site



Rotokauri Dispersion Curves

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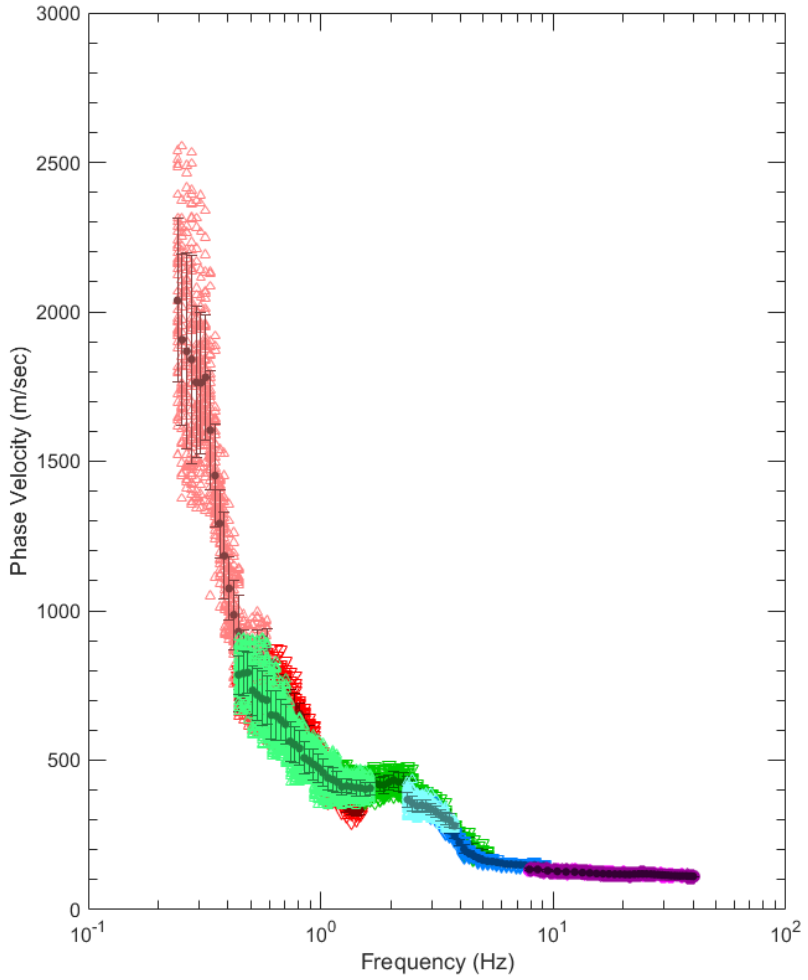
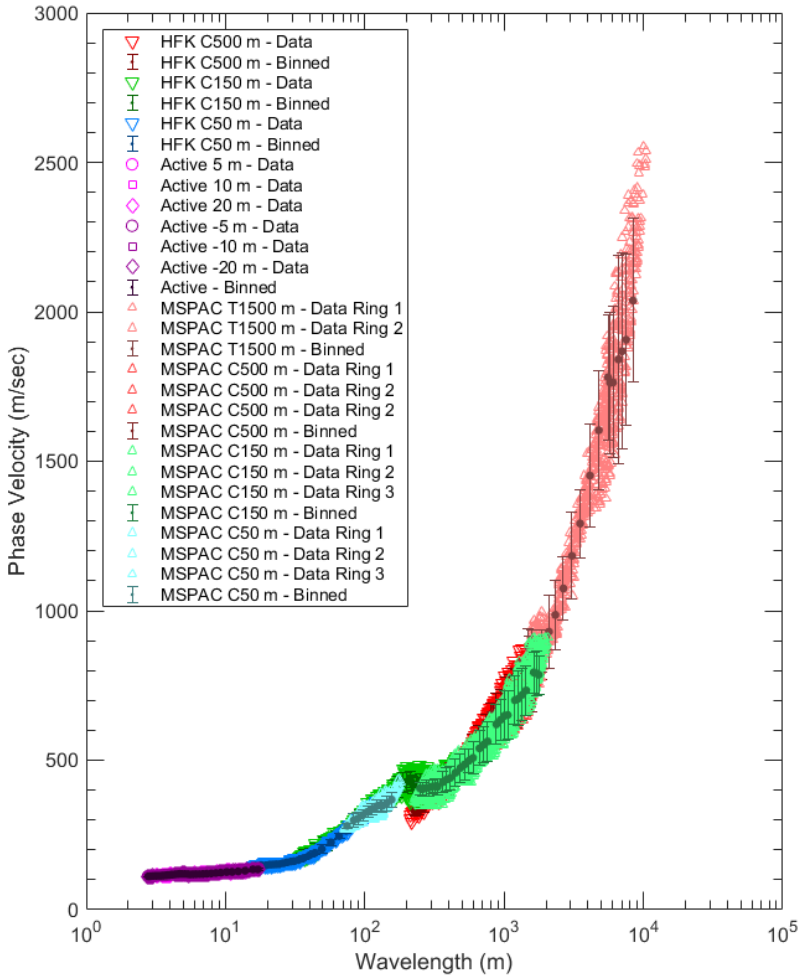
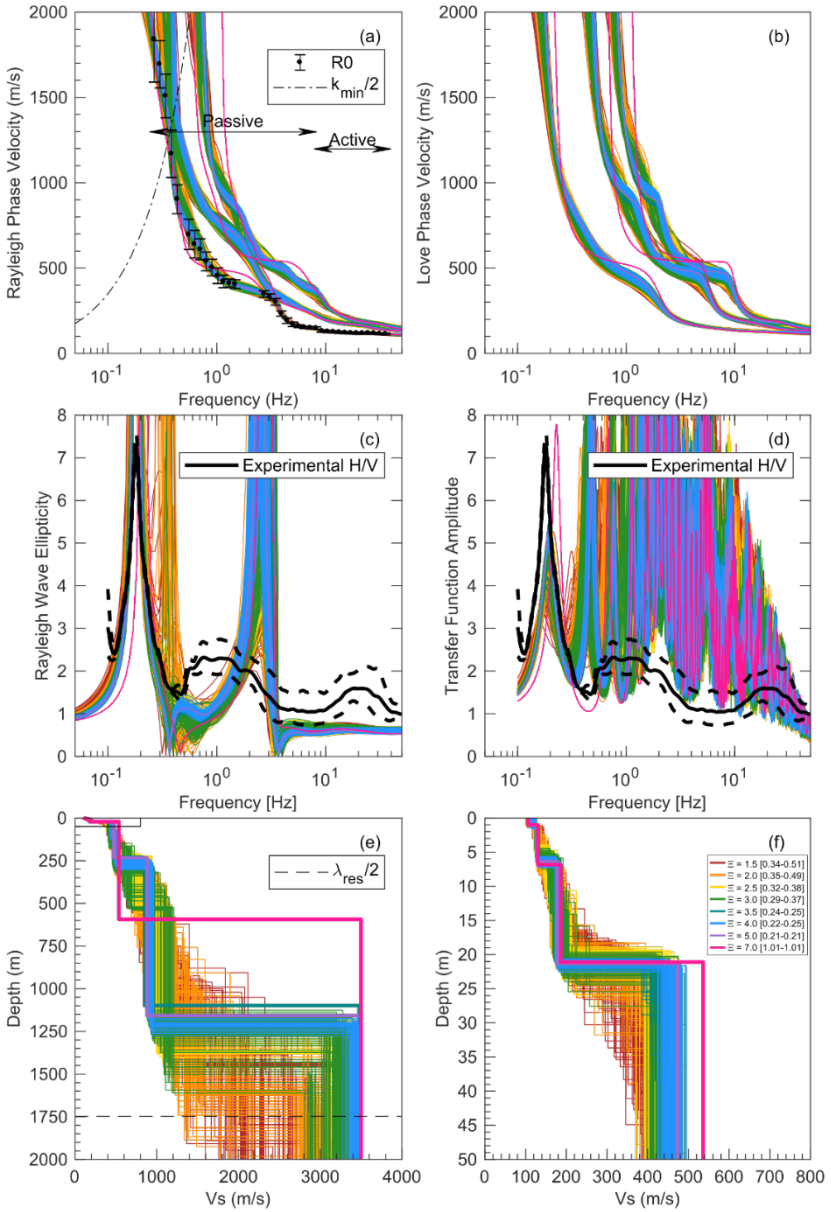




Rotokauri Initial Results

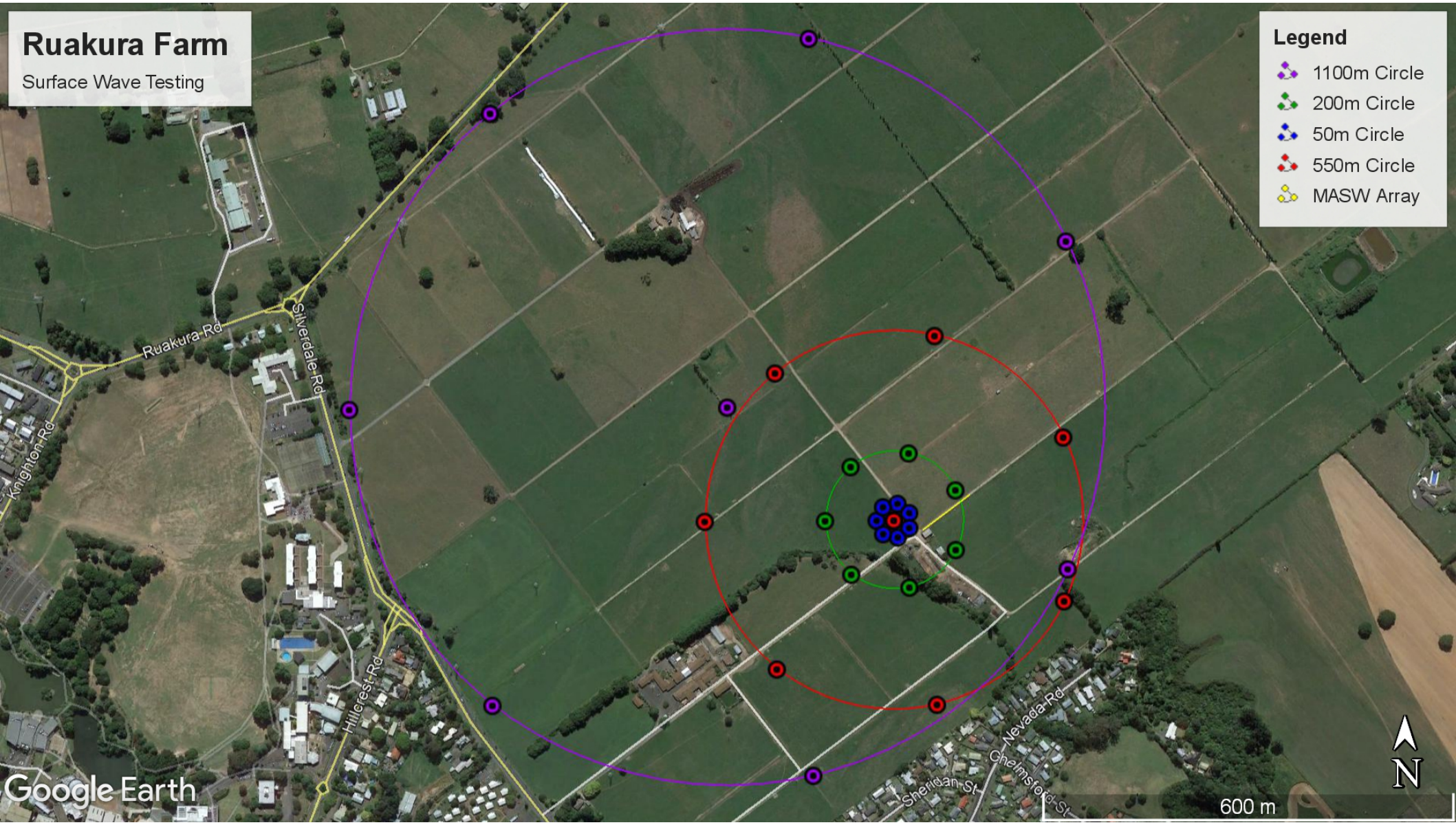


- Inversion Targets
  - R0 DC (w=0.7)
  - Ellipticity Peak 0.18 Hz (w=0.3)
- Layering Ratios:
  - Cox and Teague 2016
  - 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, and 7.0
- Inversions
  - Software: Dinver
    - Neighbourhood Algorithm (Wathelet et al. 2004)
  - For each LR:
    - 310,000 trial profiles
    - Keep 1000 best profiles
    - 100 profiles shown here

Ruakura Site

- Active Testing (MASW)
  - 24x vertical 4.5 Hz geophones
  - 2 m geophone spacing
  - Source offsets:
    - Both ends of the array
    - 5 m, 10 m, 20 m
- Passive Testing (MAM)
  - Nanometrics Broadband Seismometers
  - Circular Arrays:
    - 50 m, 200 m, 550 m, 1100 m diameters

Ruakura Site



Conclusions

- The 2018 M6.2 Taumarunui EQ demonstrated large amplification and duration-lengthening of ground motions in Waikato.

- The site class should be “D” in most places in the Waikato basin, according to the NZS1170.5: 2004. Class “E” sites may be identified in the future.

- We developed a preliminary empirical model for the bedrock depth, as a function of f_0.

- Surface wave testing is currently underway to develop V_s profiles and refine the basin model in Waikato

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Recent alined projects

Alined projects: Tauranga/BoP

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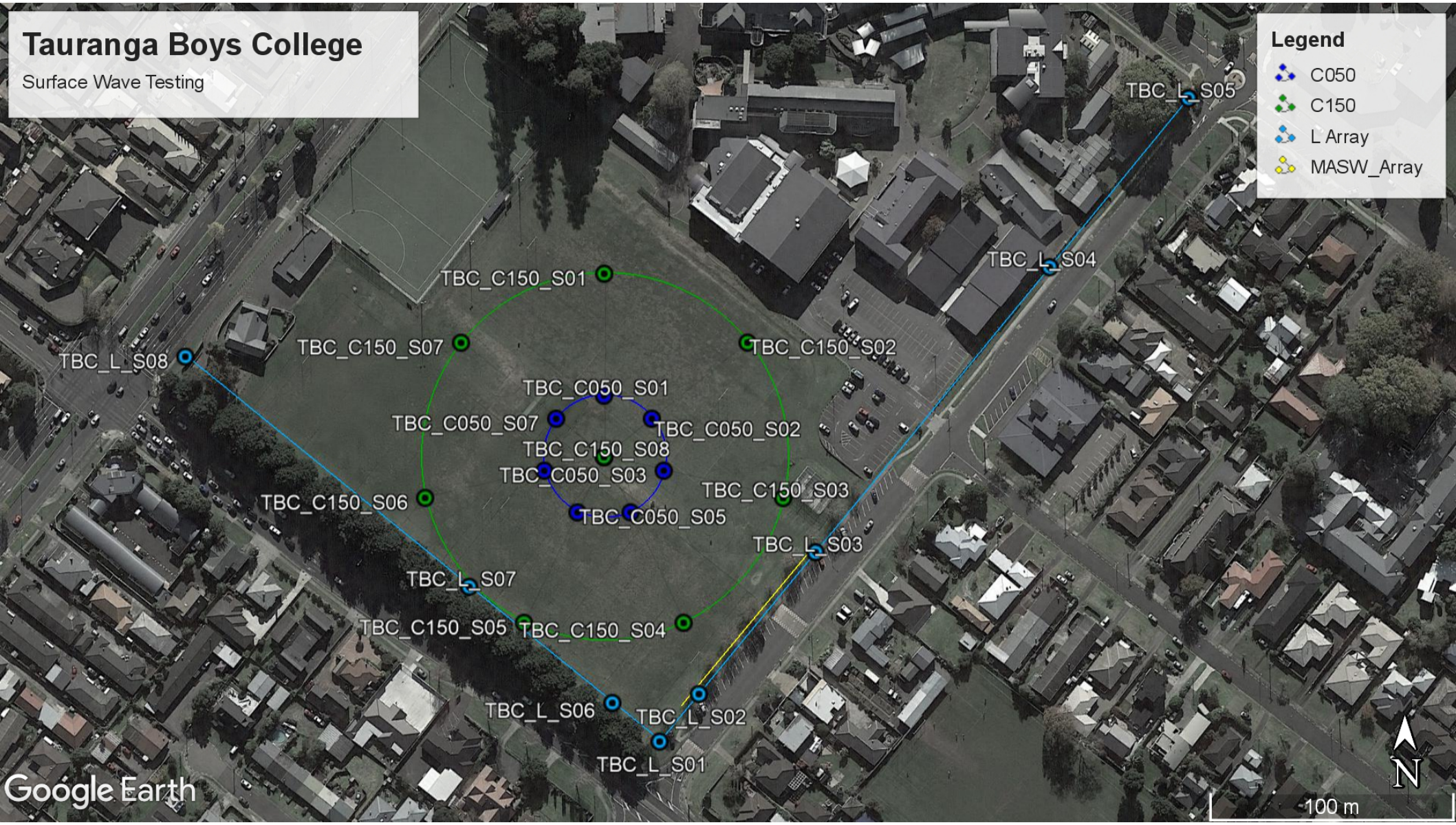
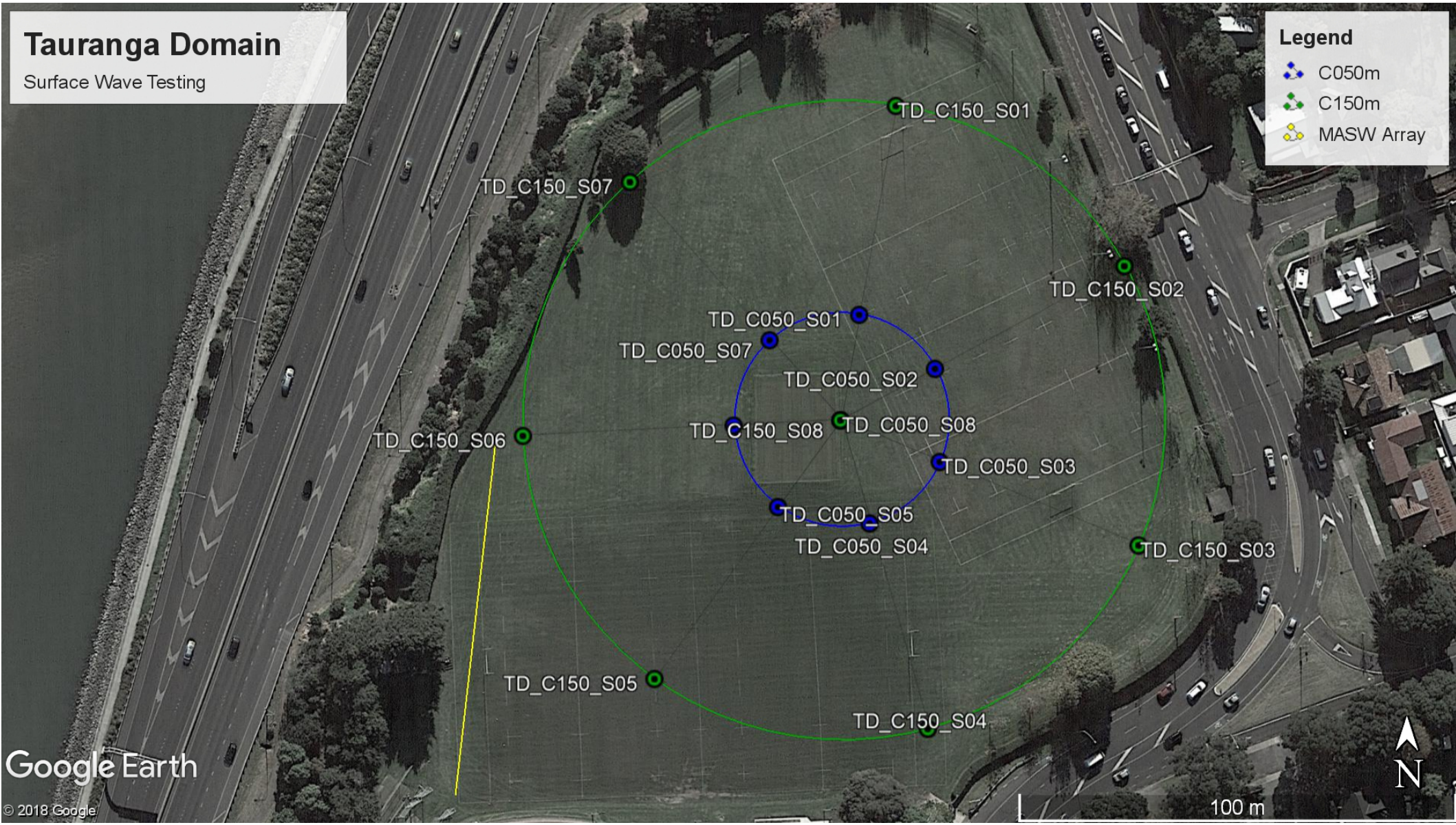


Alined projects: Tauranga/BoP



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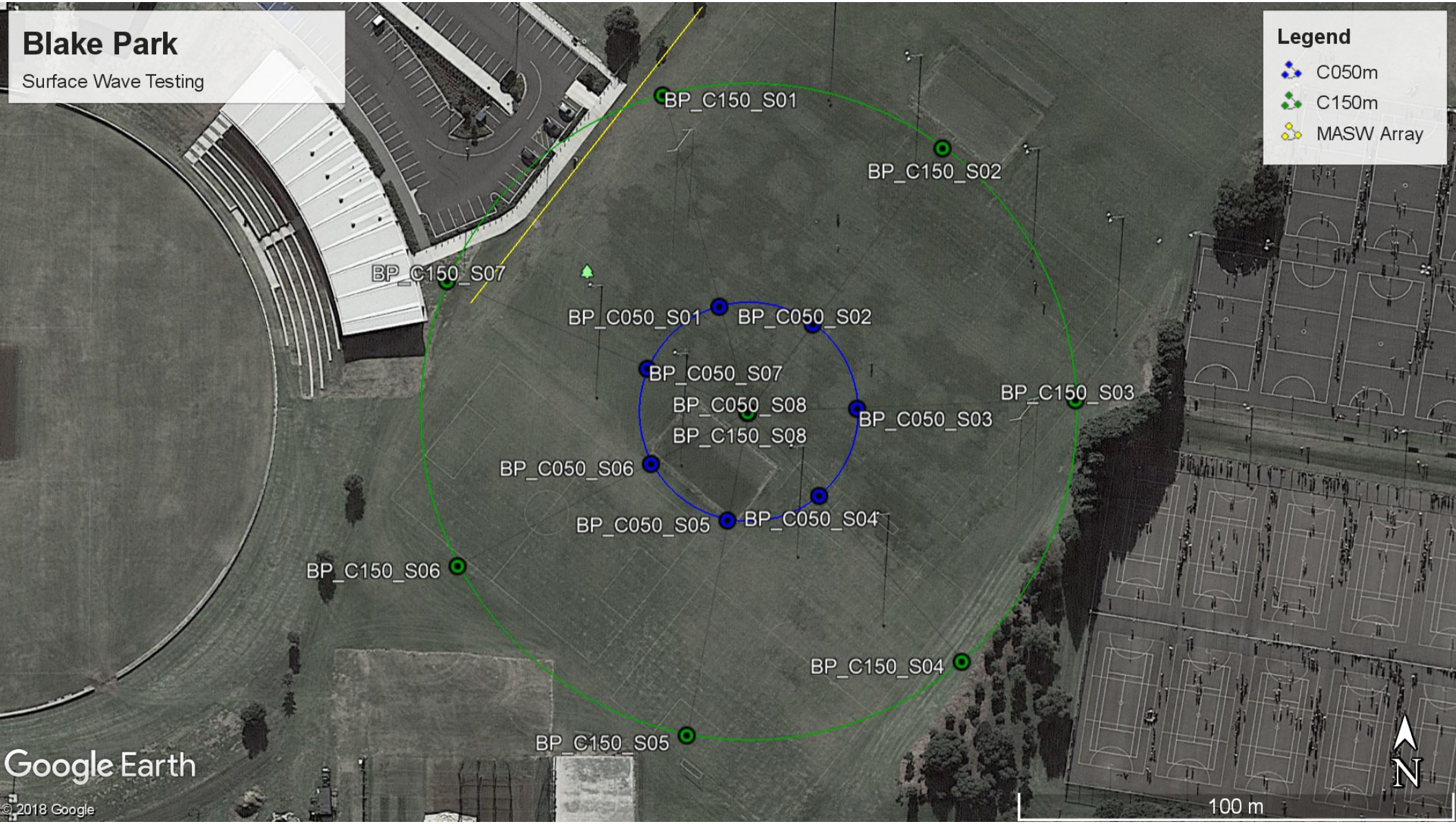
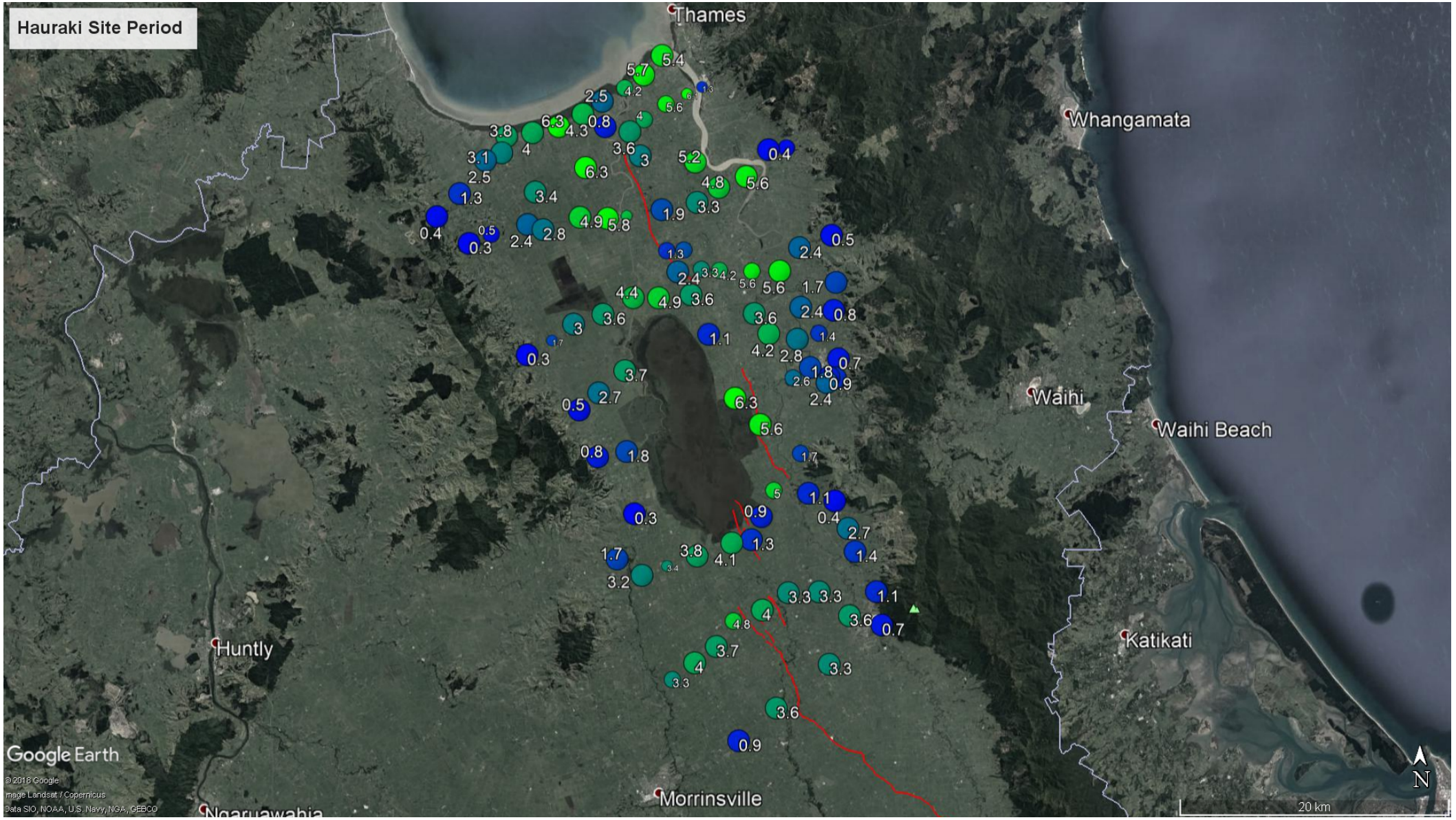
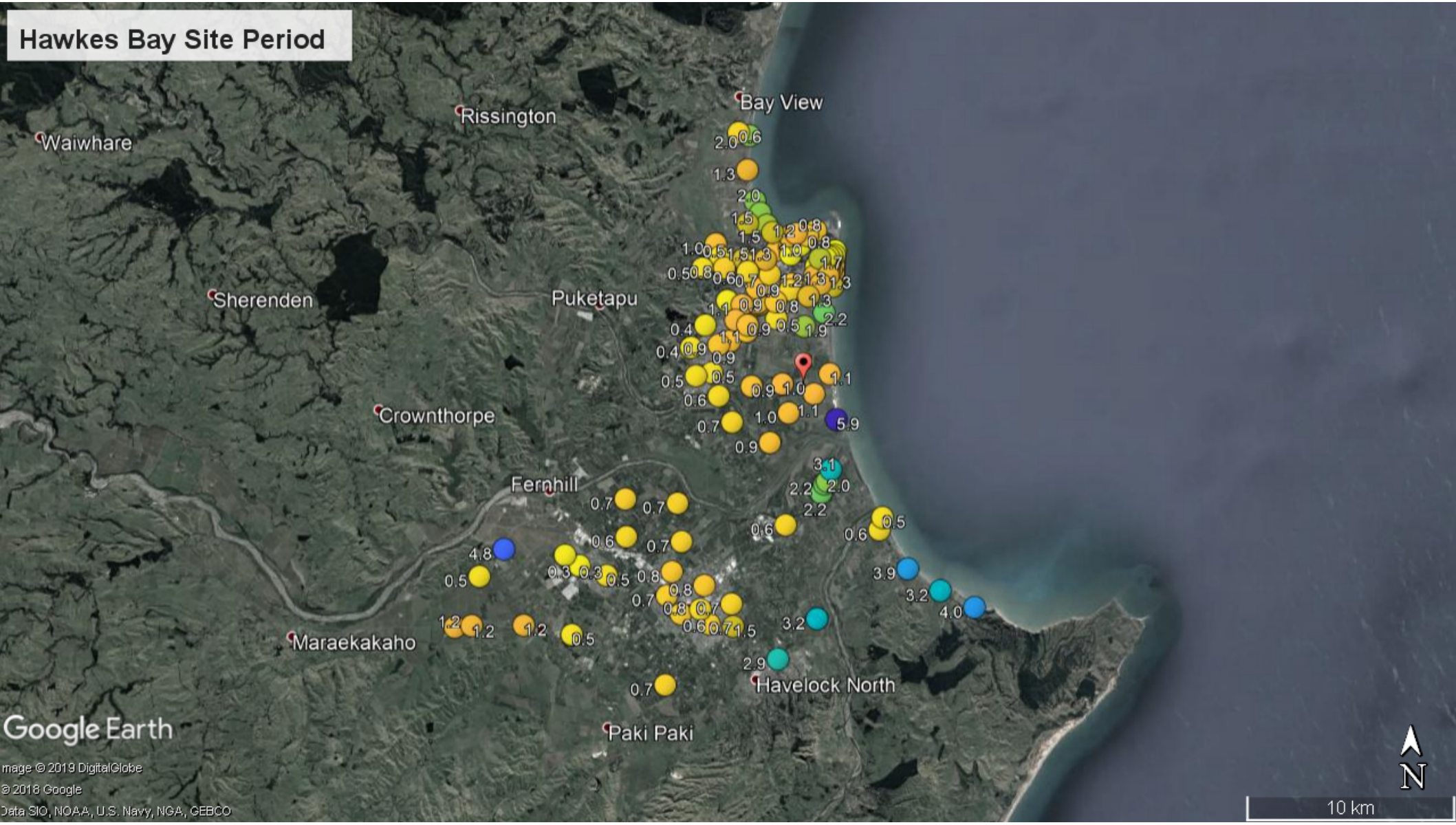


Alined projects: Hauraki Plains



Aligned projects: Hawkes Bay



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Thank you!