TOWARDS AN EARTHQUAKE SAFER AND RESILIENT SOCIETY

14th IWSMRR

Mexico City, October 23-24, 2025

Seismic Site Characterization of Eastern Metro Vancouver

Benjamin Fordjour, Natalia Gomez Jaramillo, Charlotte Motuzas, Sheri Molnar

Department of Earth Sciences, University of Western Ontario, London, Canada, **bfordjou@uwo.ca**, smolnar8@uwo.ca

Western Science

BRITISH COLUMBIA — Ministry of Emergency Management and Climate Readiness

Institute for Catastrophic Loss Reduction — Building resilient communities

1. Introduction

Seismic microzonation necessitates robust, site-specific characterization of near-surface shear-wave velocity (Vs) and resonance properties, as local sedimentary conditions strongly control ground motion amplification. Presenting findings from the 2024 field campaign throughout eastern Metro Vancouver (Langley, Maple Ridge, Pitt Meadows), this study advances the Metro Vancouver microzonation effort. We obtain fundamental frequencies (f_{0HV}), amplification spectra, and resolved Vs(z) profiles by combining 42 multi-seismic method (AVA, MASW & MHVSR) surveys with 433 microtremor horizontal-to-vertical spectral ratios (MHVSR). This study advances the nearly decade-long Metro Vancouver seismic microzonation mapping project (**www.metrovanmicromap.ca**) by presenting seismic site characterization results for eastern Metro Vancouver, including the cities of Langley, Maple Ridge, and Pitt Meadows, as well as the Township of Langley.

2. Geological Setting

- Eastern Metro Vancouver is dominated by Quaternary deposits whose composition and thickness vary regionally due to glacial and post-glacial processes.
- Key units include the Fort Langley Formation (thinly bedded glaciomarine silty sands and clays), Sumas Drift (deltaic sands and gravels), Capilano sediments, and thick Fraser River deltaic sediments in the lowlands.
- These units produce strong lateral contrasts in Vs: typical Vs ranges are ~150–250 m/s for Fraser River deposits, ~200–400 m/s for Fort Langley–type sediments, and >700 m/s for pre-Tertiary granitic bedrock exposures (Maple Ridge area).

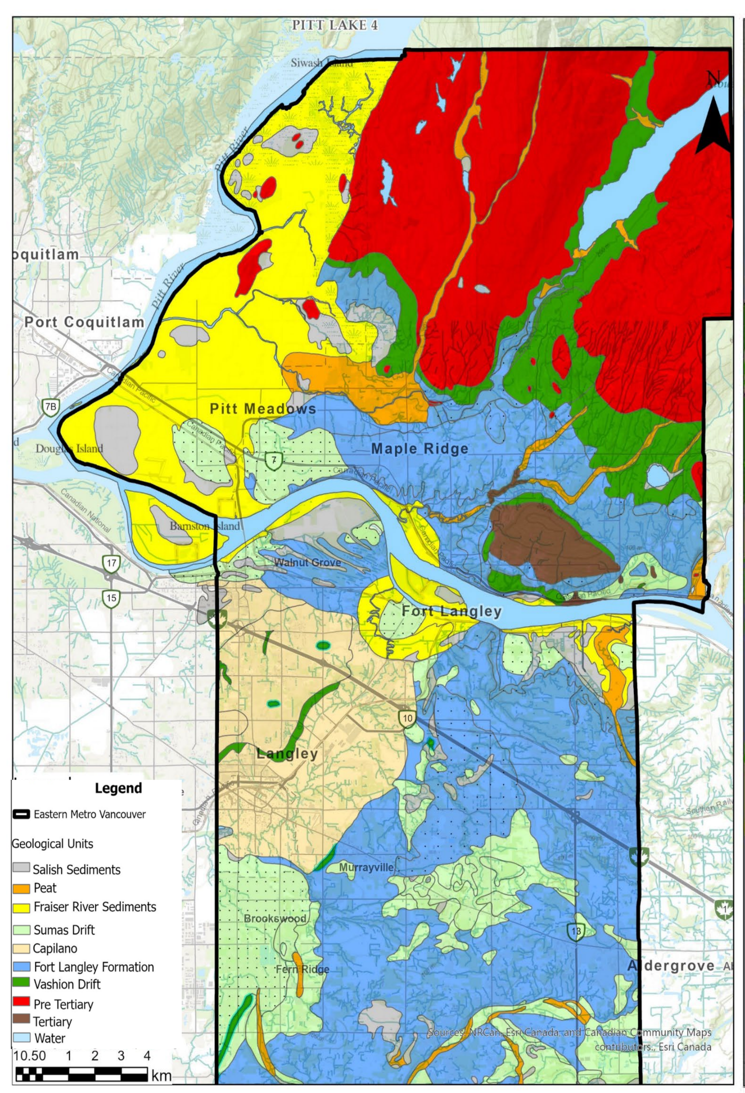

Figure 1: Surficial geology map of the Eastern Metro Vancouver study region (Armstrong and Hicock, 1979 & 1980).

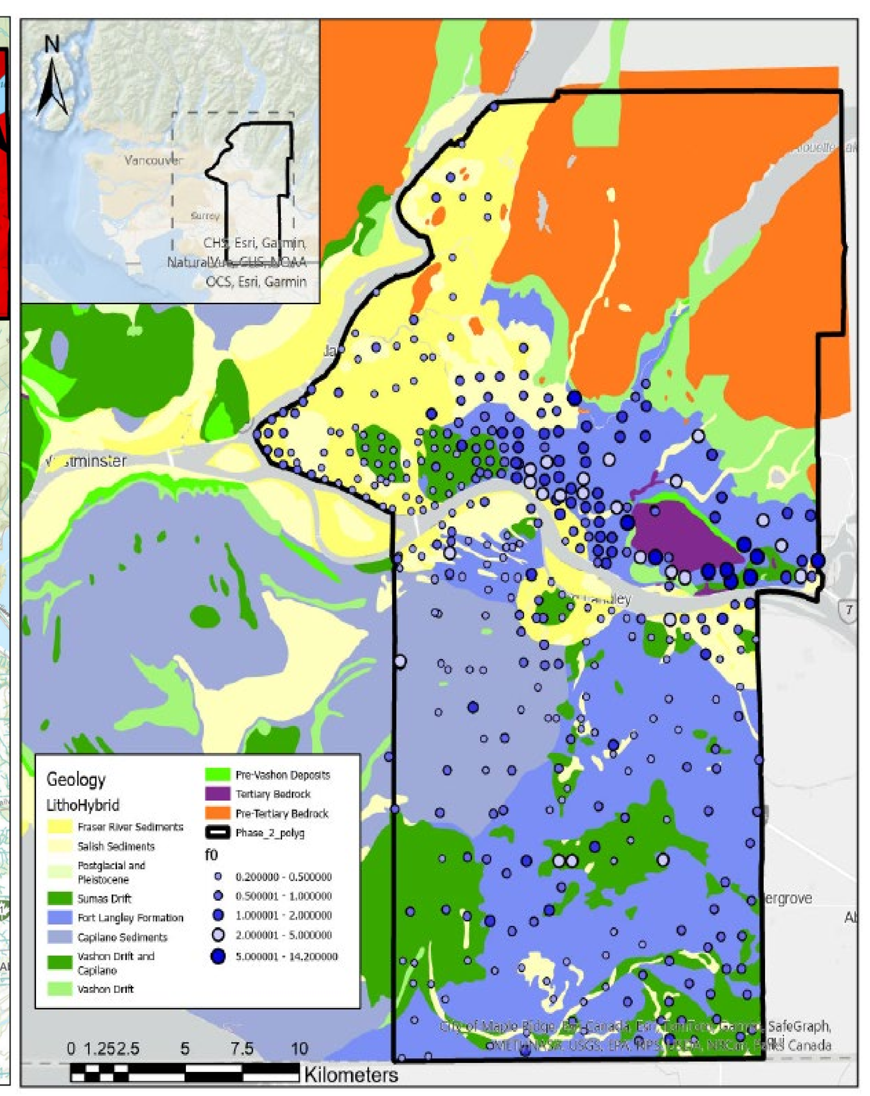

Figure 2: Comparison of MHVSR peak frequency (sized circles) at 442 sites with the regional surficial geology.

- The diverse post-glacial and multiple-glaciation Quaternary stratigraphy necessitates a tailored, multi-method seismic surveying approach for site characterization in microzonation studies.
- Spatial variation of these deposits explains observed differences in resonance and amplification across the study area.

3. Site Period Classification

- 433 MHVSR measurements were performed across Eastern Metro Vancouver at a ~600 m spacing. The median f_{0HV} is ~0.56 Hz.
- These MHVSRs are classified according to their site period (Di Alessandro et al., 2012).

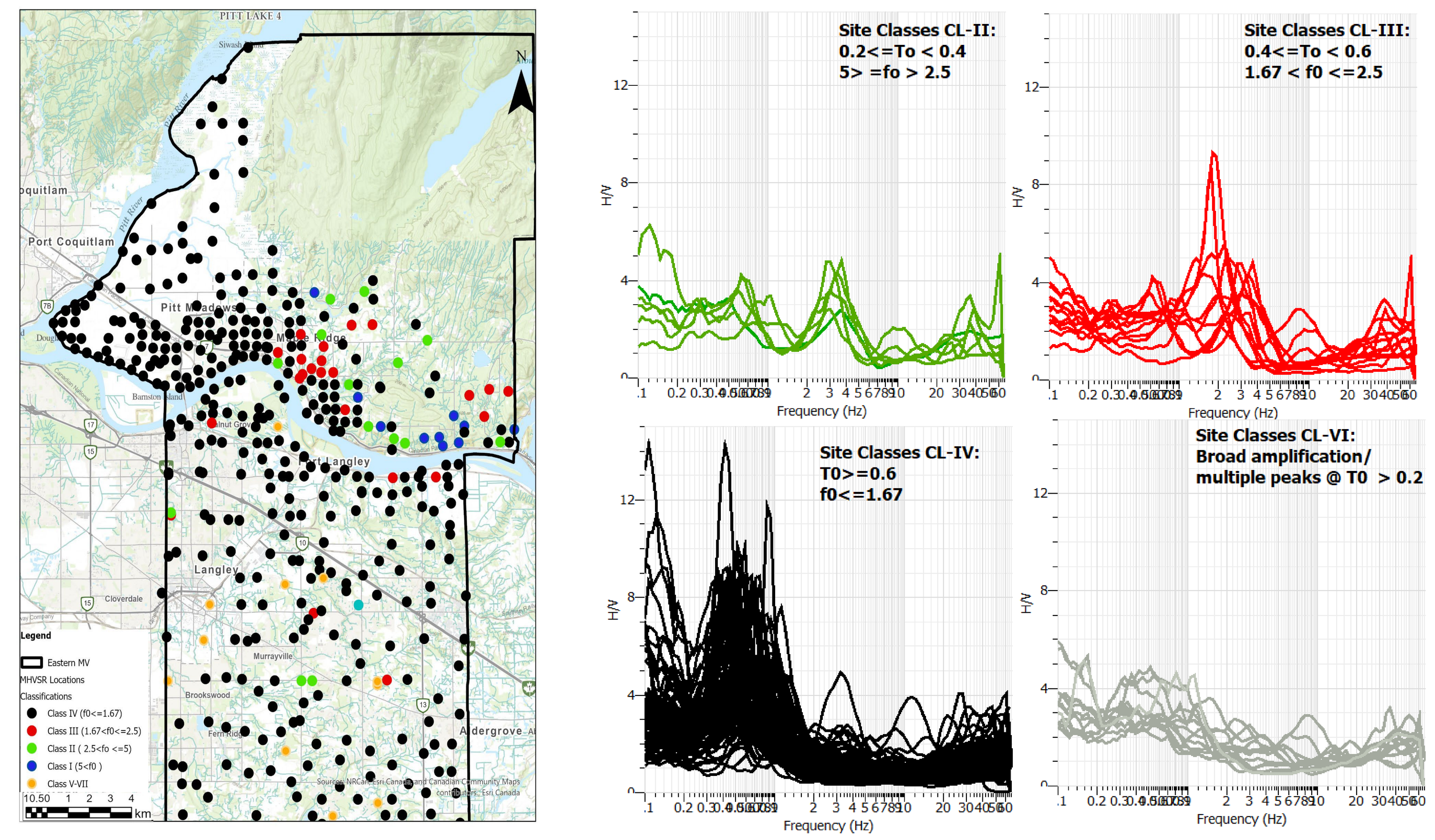

Figure 3: (left) Spatial distribution of f0HV grouped according to Di Alessandro et al. (2012) site-period-based classification (Classes I to VII). (right) Associated MHVSR curves of the site-period-based classifications.

- The most dominant site period classification is Class IV with $f_0 \leq 1.67$ Hz.
- Class II (f_0 2.5 to 5.0 Hz) occurs the least.
- About 30% of MHVSR sites show multi-peak or broad amplification < 5 Hz.
- Multi-peak MHVSR response, characterized by plateaued and/or spectral 'bumps' or 'shoulders,' is observed throughout the southern study area, were multi-glacial Quaternary sediments are present.

4. Vs_{30} Site Classification

- At 42 sites, we conducted multi-method seismic field surveys to obtain fundamental-mode AVA & MASW combined dispersion estimates and MHVSR peak frequencies that are jointly inverted to resolve shear-wave velocity (Vs) depth profiles.

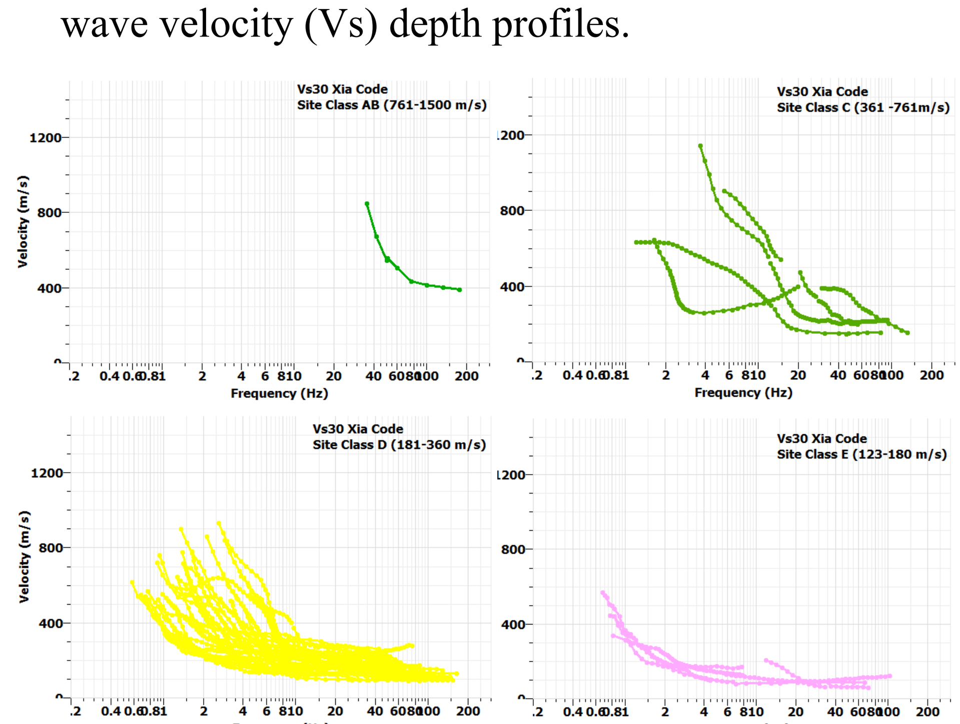

Figure 4: Dispersion curves grouped and coloured according to Vs30-based site class.

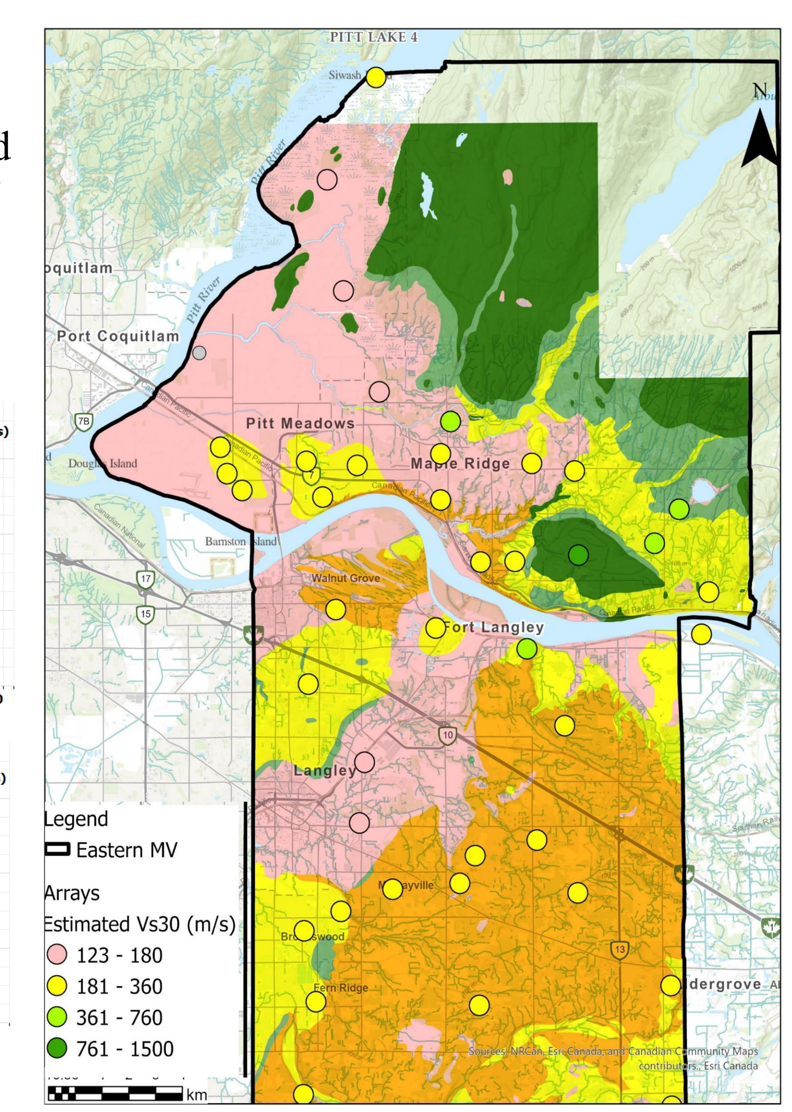

Figure 5: Map comparing Vs30 determined at the 42 multi-seismic method sites (circles) compared to pre-existing Vs30-based class mapping by Monahan (2005).

- A layering-ratio approach to the model parameterizations of the joint inversions was developed. See poster of N. Gomez Jaramillo.
- The majority (73%) of sites correspond to site class D (and are equally divided in DE and DC subclasses).

5. Vs - Depth Trends

- The inverted Vs profiles of the 42 array sites are compiled into Di Alessandro et al. (2012) site period classification groupings to analyze Vs-z trends.

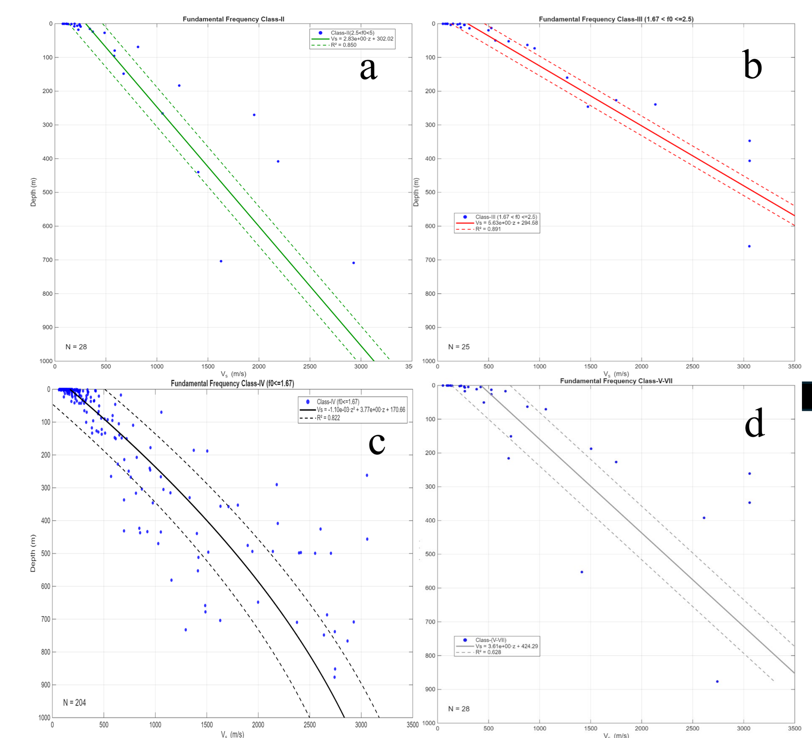

Figure 6: Inverted Vs results for site-period-based (a) Class II, (b) Class III, (c) Class IV, and (d) Classes V-VII.

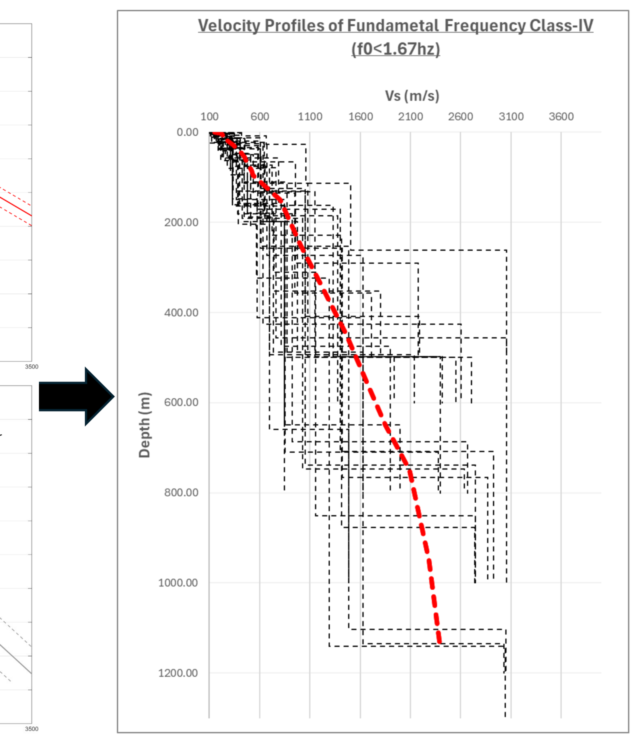

Figure 7: Inverted Vs results for the Class IV (f_{0HV} < 1.67 Hz) grouping.

- An exponential trend best fits the Class IV data (Fig. 6), whereas the remaining classes follow linear relationships with strong correlations ($R^2 > 0.8$, except Class VI).
- This behavior aligns with the averaged clustered Vs profiles (Fig. 7), which also display an exponential increase with depth, suggesting similar subsurface stiffness progression.
- The exponential trend in the clustered Vs profiles strongly supports the modeled relationships, particularly the Class IV exponential behavior.

6. Concluding Remarks and Future Work

- The 2024 datasets yield a first comprehensive Vs_{30} and f_{0HV} characterization for eastern Metro Vancouver, dominantly Vs_{30}-based site class D and site-period-based class IV, revealing wide areas of soft, amplifying sediments and clear spatial trends linked to Quaternary geology.
- Joint inversion at 42 sites produced resolved Vs(z) profiles suitable for input to 1D site response modeling, and for improving site-specific hazard assessments.
- **Next steps:** Explore further refine potential zonation by refining Vs_{30} and site period classifications in the corresponding 180-360 m/s and < 1.67 Hz ranges.

7. Acknowledgements

Project funding provided by the Institute of Catastrophic Loss Reduction with support from the BC Ministry of Emergency Management and Climate Readiness.

Datasets are communicated at the project's website (https://metrovanmicromap.ca/products/) and published in an online project data repository at https://borealisdata.ca/dataverse/MVSMMP.

8. References

- Adhikari, S. R., & Molnar, S. (2024). Development and comparison of 3D seismic geology and shear-wave velocity models of Metro Vancouver. Seismica, 3(2), 1-16.
- Armstrong, J. E., & Hicock, S. R. (1979). Surficial geology, Vancouver, British Columbia. Geological Survey of Canada, "A" Series Map 1486A.
- Armstrong, J. E., & Hicock, S. R. (1980). Surficial geology, New Westminster, West of Sixth Meridian, British Columbia. Geological Survey of Canada, "A" Series Map 1484A.
- Assaf, J., Molnar, S., El Naggar, M. H., & Sirohey, A. (2022). Seismic site characterization in Fraser River Delta in Metropolitan Vancouver. Soil Dynamics and Earthquake Engineering, 161, 107384.
- Assaf, J., Molnar, S., & El Naggar, M. H. (2023). CPT-Vs correlations for post-glacial sediments in Metropolitan Vancouver. Soil Dynamics and Earthquake Engineering, 165, 107693.
- Di Alessandro et al. (2012). Predominant-period site classification for response spectra prediction equations in Italy. BSSA, 102, 680–695. doi:10.1785/0120110084.
- Molnar, S., Assaf, J., Sirohey, A., & Adhikari, S. R. (2020). Overview of local site effects and seismic microzonation mapping in Metropolitan Vancouver, British Columbia, Canada. Engineering Geology, 270, 105568.
- Molnar, S., Bilson Darko, A., Ghofrani, H., Adhikari, S., & Salsabili, M. (2023). The Metro Vancouver Seismic Microzonation Mapping Project: Overview and multi-method approach to regional geodatabase development. Joint Canadian and Pacific Conference on Earthquake Engineering, Vancouver, BC, Paper 258, 8 p.
- Monahan, P. (2005). Soil hazard map of the Lower Mainland of British Columbia for assessing the earthquake hazard due to lateral ground shaking, in Seismic Retrofit Guidelines (3rd edition), APEGBC, UBC, BC Ministry of Education, June 2017, Volume 9, Part III, 1 sheet.