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Introduction

The Geological Survey of Canada (GSC), a part of Natural Resources Canada, has mandated responsibilities to monitor, investigate, and report on natural geological hazards such as earthquakes, landslides, and tsunamis that occur in, or have the potential to negatively impact Canada. The GSC's findings are used to inform decisions by land-use planners, regulatory agencies, and standards organizations to mitigate the impacts these types of events may have on communities, critical infrastructure, and the environment. The GSC is undertaking geoscience studies in the BC north coast (BCNC) to improve the capacity to assess such geohazards and conduct research on the most effective options for their mitigation. This initiative includes targeted mapping, monitoring, and modelling of selected marine and coastal geohazards.

Post-earthquake analyses have shown that the level of ground shaking, and thus the amount of potential damage in an area, not only depends on the size and location of the earthquake, but also on the topography, underlying geology, and sediment thickness of the near surface. Earthquake-induced ground shaking is often amplified in areas with significant impedance contrasts, such as soft, low-velocity sediments overlying stiff bedrock. In this setting, the impedance contrast causes a shortening of shear wave wavelengths and an increase in shear wave amplitudes (Shearer and Orcutt, 1987; Hunter and Crow, 2012). This amplification can be escalated in the presence of large impedances causing shear waves to become trapped in the low-velocity soil zone and 'ring' at the fundamental (resonant) frequency (f_0) and subsequent harmonics until the energy eventually dissipates. The f_0 can be approximated by $f_0 = (V_S/4H)$ where V_S is the average shear wave velocity of the host material and H is the thickness of this layer (Hunter and Crow, 2012; Kramer, 1996). Additional refining relationships for soft sediments following the work of Dobry (1976) are given by Hunter et al. (2010). Further 2- and 3-dimensional amplification effects can occur when soft sediments overlie bedrock with topographic lows (Hunter and Crow, 2012; Bard and Bouchon, 1985; Molnar et al., 2014).

The horizontal-to-vertical spectral ratio (HVSR) of ambient noise (or microtremors) can be analysed to provide a site specific f_0 (Nakamura, 1989). Studies and experience have shown that HVSR amplitudes provide the lower bound to broadband amplification of ground motion caused by seismic events (Hunter et al., 2010). Using instrumentation designed specifically for ambient noise HVSR measurements (Micromed Tromino electro-dynamic 3-component sensor and data acquisition system); a preliminary microtremor survey was conducted at 27 locations in Kitimat, BC.

Summary of Work

Data were recorded using a Micromed Tromino for 30 minutes at all sites, with the exception of sites KIT-15 and KIT-16 where wind testing was conducted. Data were downloaded and processed using Micromed's Grilla software. Resulting spectrograms were visually inspected; windows exhibiting the highest energy in the estimated resonance frequency band (0.5 - 5.0 Hz for this area) were selected for HVSR analyses. Windows containing high energy at frequencies lower than 0.5 Hz and greater than 5.0 Hz were rejected for analysis. Specific processing parameters are shown in Table 1. Resulting horizontal-to-vertical (H/V) curves were inspected and considered good quality if they passed the statistical tests outlined in Sesame H/V User Guidelines (2005).

Processing window	30 seconds
Spectral Filtering	Konno-Omachi Algorithm b = 40
Editing	Manual selection of windows with arithmetic averaging
Spectral Windows	0.2 Hz to 20 Hz

Table 1 –Parameters used in the processing of ambient noise recordings.

According to the Sesame H/V User Guidelines (2005), good quality ambient noise measurements were recorded at 16 locations in the vicinity of Kitimat, BC. HVSR analysis of the collected data found f_0 ranging from 0.5 to 1.38 Hz (± 0.01-1.46), which corresponds to fundamental periods (T_0) of 0.72-2.0 s (Table 2, Figure 1). Assuming a V_S of the soft sediments of 200 m/s (Agra Health and Environmental Limited, 1998), this suggests sediment thickness in the study area ranges from 36 – 100 m. HVSR peak amplitudes range from 4.0 - 7.5. Although ambient noise HVSR measurements do not represent absolute amplification, they do suggest relative amplification within a local study, shown by the size of the circles in Figure 1.

Previous studies have shown that HVSRs with peak amplitudes greater than 4.0 correlate to significant broadband amplification of earthquake-induced ground motions (Hunter et al., 2010). In general, results from this survey show significant soil resonance, likely due to thick layers of soft sediments such as clays, silts and sands overlying bedrock. At present, good quality data have been collected at 16 sites. Although no definite conclusions can be drawn regarding the soft sediment thickness or amplification trends observed in this survey, additional geotechnical data (e.g. V_S profiling, more densely spaced ambient noise surveys) are planned for 2015 in the Kitimat area to complete a more thorough investigation of seismic resonance.

Site	**Latitude (°N)**	**Longitude (°W)**	**f_0 (Hz)**	**f_0 Error (Hz)**	**T_0 (s)**	**Peak Amplitude Ratio**
KIT-1	53.991	-128.696	NR			
KIT-2	54.045	-128.686	NR			
KIT-3	54.045	-128.652	NR			
KIT-4	54.040	-128.647	1.38	0.44	0.72	6.0
KIT-5	54.045	-128.646	NR			
KIT-6	54.039	-128.622	0.91	0.02	1.10	7.5
KIT-7	54.035	-128.643	0.91	0.005	1.10	6.0
KIT-8	54.037	-128.632	1.19	1.46	0.84	4.7
KIT-9	54.078	-128.649	1.16	0.05	0.86	4.1
KIT-10	54.070	-128.644	1.28	0.03	0.78	5.5
KIT-11	54.071	-128.645	1.22	0.02	0.82	7.0
KIT-12	54.049	-128.650	NR			
KIT-13	54.049	-128.650	0.81	0.01	1.23	5.5
KIT-14	54.049	-128.650	0.81	0.01	1.23	4.3
KIT-15	54.049	-128.650	0.75	0.005	1.33	5.8
KIT-16	54.049	-128.650	0.78	0.05	1.28	5.0
KIT-17	54.035	-128.624	NR			
KIT-18	54.035	-128.624	NR			
KIT-19	54.035	-128.624	0.91	0.13	1.10	4.0
KIT-20	54.045	-128.624	1.22	0.03	0.82	4.6
KIT-21	54.037	-128.625	1.38	0.03	0.72	5.2
KIT-22	54.039	-128.626	0.97	0.01	1.03	5.9
KIT-23	54.031	-128.696	0.50	0.01	2.00	5.3
KIT-24	54.045	-128.686	3.06	0.03	0.33	3.0
KIT-25	54.052	-128.673	0.84	0.01	1.19	7.5
KIT-26	54.042	-128.671	0.66	0.05	1.52	4.1
KIT-27	54.037	-128.660	0.88	0.01	1.14	5.5
		min	0.50	0.01	0.72	4.0
		max	1.38	1.46	2.00	7.5
		mean	0.98	0.13	1.10	5.4

Table 2 – Locations and preliminary HVSR analysis results of March 2014 microtremor (Tromino) survey. NR – indicates record was of poor quality.

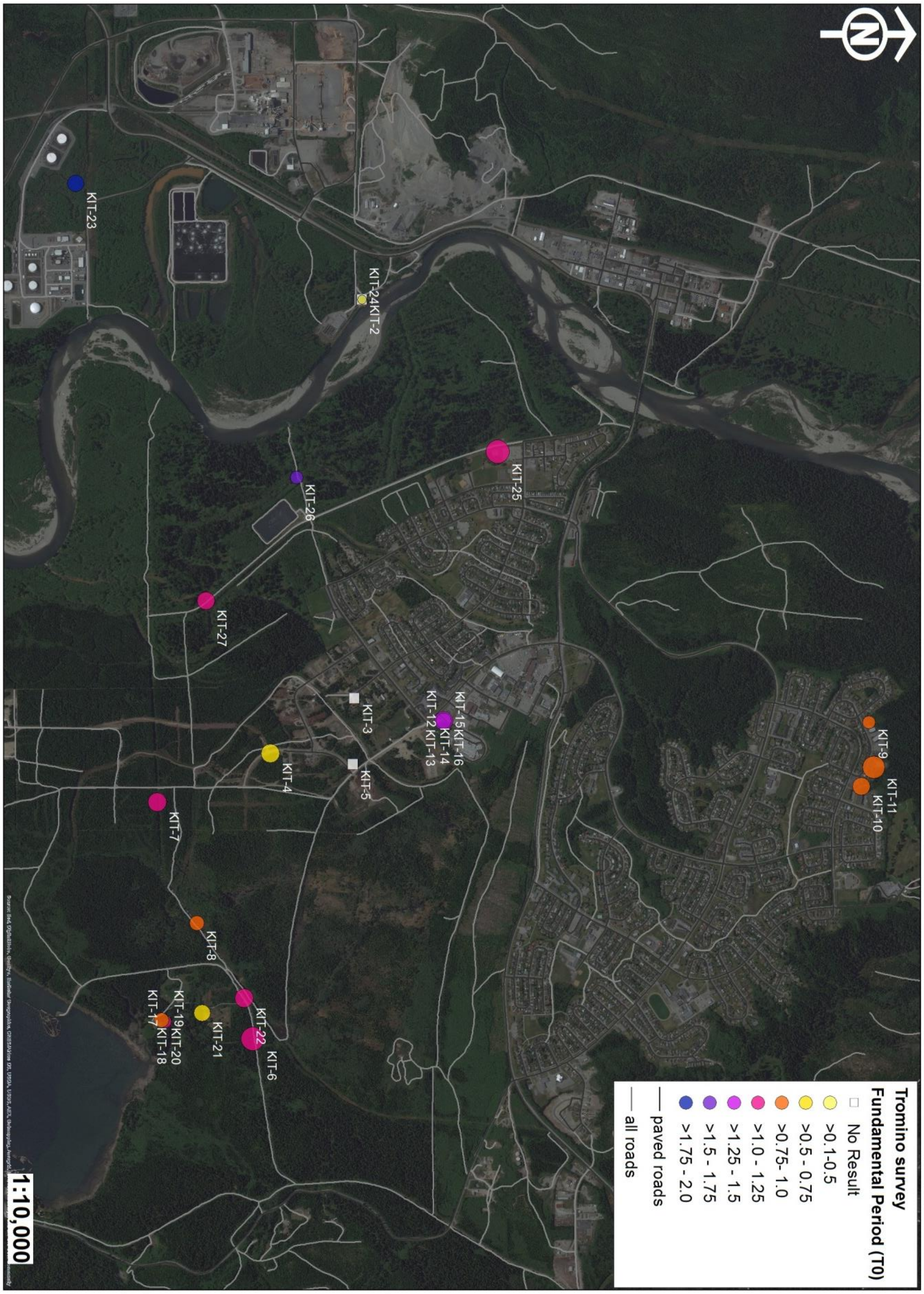

Figure 1 - Locations of microtremor measurements during March 2014 survey. Station labels correspond to those in table 2. Colors indicate peak resonant period as shown in the legend. The size of the symbol indicates HVSR peak amplitude relative to other stations in this survey. Note: KIT-1 is south of the area shown in this figure.

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