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Mr. Matthew Firestone
Project Manager
Landric Homes
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Subject: **Shear Wave Velocity Sounding for the Site Class Determination**
6001 – 6005 Renaud Rd, Ottawa (ON)

Dear Sir,

Geophysics GPR International inc. has been mandated by Landric Renaud Property inc. to carry out seismic shear wave surveys at 6001 – 6005 Renaud Road, in Ottawa (ON). The geophysical investigation used the Multi-channel Analysis of Surface Waves (MASW) and the Spatial AutoCorrelation (SPAC). From the subsequent results, the seismic shear wave velocity values were calculated for the soils, to determine the Site Class.

The surveys were carried out on November 5th, 2021, by Ms. Karyne Faguy, B.Sc. and Mr. Dominic Déraps, tech. Figure 1 shows the regional location of the site and Figure 2 illustrates the location of the seismic spreads. Both figures are presented in the Appendix.

The following paragraphs briefly describe the survey design, the principles of the testing methods, and the results presented in tables and graphs.

MASW PRINCIPLE

The *Multi-channel Analysis of Surface Waves* (MASW) and the *SPatial AutoCorrelation* (SPAC or MAM for *Microtremors Array Method*) are seismic methods used to evaluate the shear wave velocities of subsurface materials through the analysis of the dispersion properties of the Rayleigh surface waves ("ground roll"). The MASW is considered an "active" method, as the seismic signal is induced at known location and time in the geophones' spread axis. Conversely, the SPAC is considered a "passive" method, using the low frequency “signals” produced far away. The method can also be used with "active" seismic source records. The dispersion properties are expressed as a change of phase velocities with respect to frequencies. Surface wave energy will decay exponentially with depth. Lower frequency surface waves will travel deeper and thus be more influenced by deeper velocity layering than the shallow higher frequency waves. The inversion of the Rayleigh wave dispersion curve yields a shear wave (V_S) velocity depth profile (sounding). Figure 3 schematically outlines the basic operating procedure for the MASW method.

Figure 4 illustrates an example of one of the MASW/SPAC records, the corresponding spectrogram analysis and resulting 1D V_S model. The SPAC method generally allows deeper Vs soundings. Its dispersion curve can then be merged with the one of MASW results to calculate a more complete inversion.

INTERPRETATION

The main processing sequence involved data inspection and edition when required; spectral analysis ("phase shift" for MASW, and "cross-correlation" for SPAC); picking the fundamental mode; and 1D inversion of the MASW and SPAC shot records using the SeisImagerSW™ software. The data inversions used a nonlinear least squares algorithm.

In theory, all the shot records for a given seismic spread should produce a similar shear-wave velocity profile. In practice, however, differences can arise due to energy dissipation, local surface seismic velocities variations, and/or dipping of overburden layers or rock. In general, the precision of the calculated seismic shear wave velocities (V_S) is of the order of 15% or better.

More detailed descriptions of these methods are presented in *Shear Wave Velocity Measurement Guidelines for Canadian Seismic Site Characterization in Soil and Rock*, Hunter, J.A., Crow, H.L., et al., Geological Surveys of Canada, General Information Product 110, 2015.

SURVEY DESIGN

The seismic geophones' sets were spread out on a grass strip, along Ziegler Street (Figure 2). The main seismic spread used 24 geophones, spaced 3.0 metres apart. A second seismic spread, with 1.0 metre geophone spacing, was dedicated to the shallow materials.

The seismic records counted 4096 data, sampled at 1000 µs for the MASW surveys, and 40 µs for the seismic refraction. The records included a pre-trigged portion of 10 ms. A stacking procedure was also used to improve the Signal / Noise ratio for the seismic records.

The seismic records were produced with a seismograph Terraloc Pro 2 (from ABEM Instrument), and the geophones were 4.5 Hz. A 9 kg sledgehammer was used as the energy source with impacts being recorded off both ends of the seismic lines.

The shear wave depth sounding can be considered as the average of the bulk area within the geophone spread, especially for its central half-length.

RESULTS

From seismic resonance (using V_P), the rock was calculated between 30 and 34 metres deep.

The MASW calculated V_S results are illustrated at Figure 5. It must be noted that some very low to low seismic velocities were calculated from the surface to approximately 4 metres deep.

The $\overline{V}_{S30}$ value results from the harmonic mean of the shear wave velocities, from the surface to 30 metres deep. It is calculated by dividing the total depth of interest (30 metres) by the sum of the time spent in each velocity layer from the surface down to 30 metres, as:

$$\bar{V}_{S30} = \frac{\sum_{i=1}^{N} H_i}{\sum_{i=1}^{N} H_i / V_i} \quad | \quad \sum_{i=1}^{N} H_i = 30 \text{ m}$$

(N: number of layers; H_i : thickness of layer "i" ; V_i : Vs of layer "i")

Thus, the $\overline{V}_{S30}$ value represents the seismic shear wave velocity of an equivalent homogeneous single layer response, between the surface and 30 metres deep.

The calculated $\overline{V}_{S30}$ value for the actual site is presented at Table 1. It is 262.1 m/s, corresponding to the Site Class "D".

CONCLUSION

Geophysical surveys were carried out for the 6001 – 6005 Renaud Road, in Ottawa (ON), to identify the Site Class. The seismic surveys used the MASW and the SPAC analysis, and the seismic resonance method, to calculate the $\overline{V}_{S30}$ value. This calculation is presented at Table 1.

The $\overline{V}_{S30}$ value of the actual site is 262 m/s, corresponding to the Site Class "D" (180 < $\overline{V}_{S30}$ ≤ 360 m/s), as determined through the MASW and the SPAC analysis, Table 4.1.8.4.A of the NBC, and the Building Code, O. Reg. 332/12.

It must be noted that some very low to low seismic velocities were calculated from the surface approximately 4 metres deep. A geotechnical assessment of the corresponding materials could be required.

It must also be noted that other geotechnical information gleaned on site; including the presence of liquefiable soils, very soft clays, high moisture content etc. (cf. Table 4.1.8.4.A of the NBC) can supersede the Site Classification provided in this report based on the $\overline{V}_{S30}$ value.

The V_S values calculated are representative of the in situ materials and are not corrected for the total and effective stresses.

Hoping the whole to your satisfaction, we remain yours truly.

P.Eng.

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Senior Project Manager

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Figure 1: Regional location of the Site
(source: *OpenStreetMap©*)

Figure 2: Location of the Seismic Lines
(source: *GeoOttawa*)

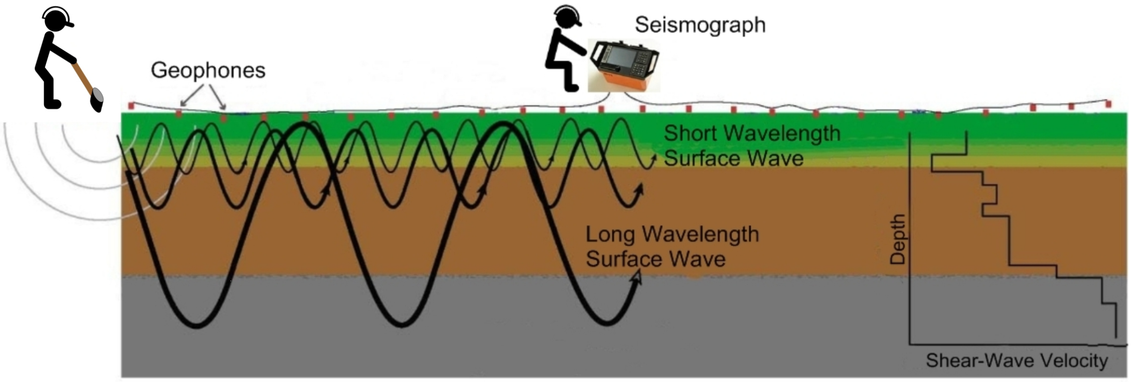

Figure 3: MASW Operating Principle

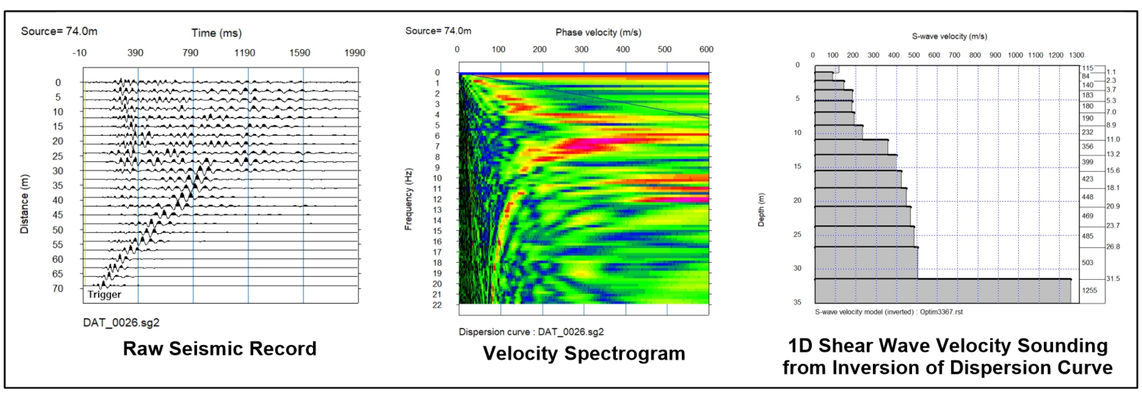

Figure 4: Example of a MASW/SPAC record, Rayleigh wave Velocity - Frequency Dispersion Curve and resulting 1D Shear Wave Velocity

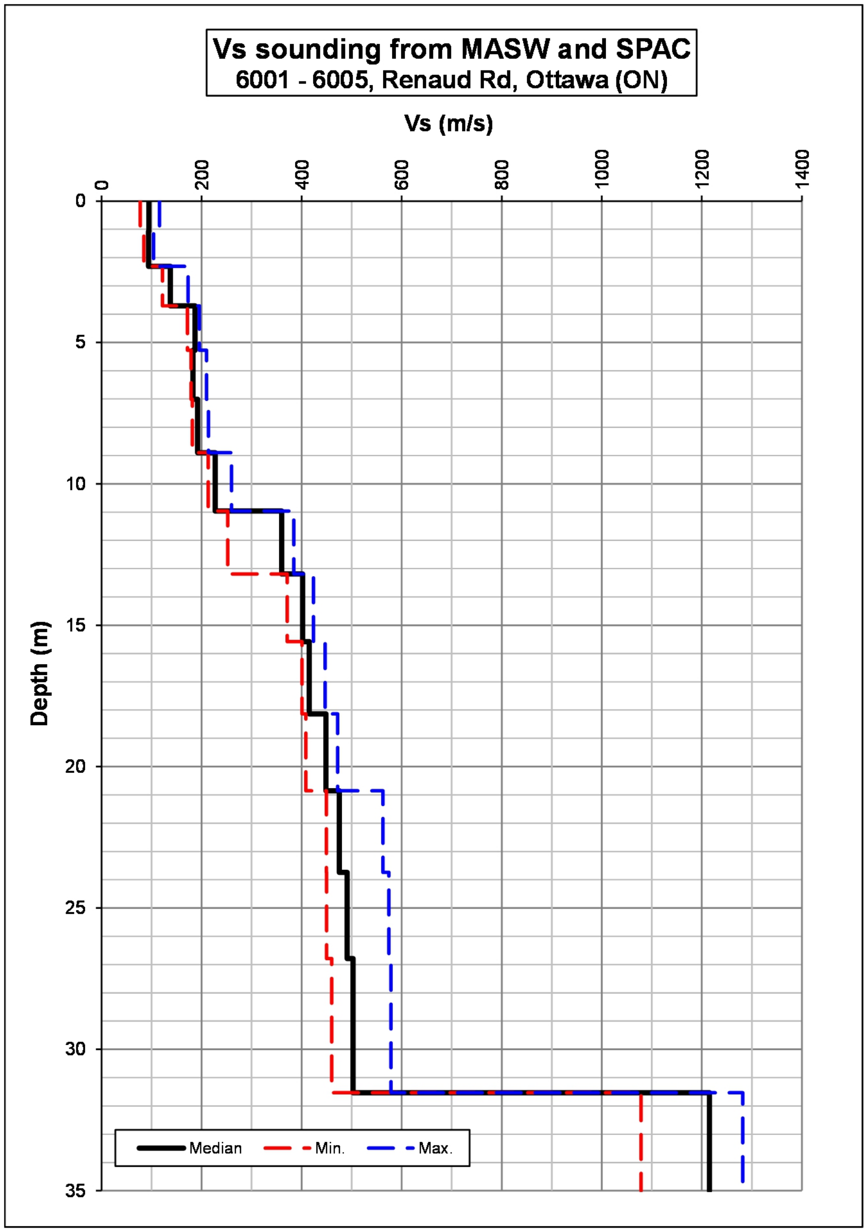

Figure 5: MASW Shear-Wave Velocity Sounding

TABLE 1

V_{S30} Calculation for the Site Class (actual site)

Depth	Vs			Thickness	Cumulative Thickness	Delay for Med. Vs	Cumulative Delay	Vs at given Depth
	Min.	Median	Max.					
(m)	(m/s)	(m/s)	(m/s)	(m)	(m)	(s)	(s)	(m/s)
0	**77.5**	**94.7**	**116.0**	**Grade Level (November 5th, 2021)**				
1.07	**84.7**	**93.8**	**103.9**	1.07	1.07	0.011311	0.011311	94.7
2.31	**121.8**	**137.4**	**173.0**	1.24	2.31	0.013173	0.024484	94.3
3.71	**171.7**	187.1	195.6	1.40	3.71	0.010200	0.034685	106.9
5.27	179.1	182.6	209.8	1.57	5.27	0.008368	0.043052	122.5
7.01	181.7	192.0	213.6	1.73	7.01	0.009478	0.052531	133.4
8.90	213.1	227.3	259.7	1.90	8.90	0.009872	0.062403	142.6
10.96	252.3	360.1	384.2	2.06	10.96	0.009063	0.071466	153.4
13.19	371.1	401.9	423.7	2.23	13.19	0.006180	0.077645	169.8
15.58	400.7	415.3	447.0	2.39	15.58	0.005947	0.083592	186.3
18.13	408.5	448.5	472.1	2.55	18.13	0.006152	0.089744	202.0
20.85	449.5	475.4	562.7	2.72	20.85	0.006064	0.095808	217.6
23.74	449.9	490.8	574.3	2.88	23.74	0.006068	0.101876	233.0
26.79	459.9	502.9	578.7	3.05	26.79	0.006213	0.108090	247.8
30				3.21	30.00	0.006391	0.114481	262.1

V_{S30} (m/s)	**262.1**
Class	**D (1)**

(1) Some very low to low seismic velocities were calculated from the surface to approximately 4 metres deep. A geotechnical assessment of the corresponding materials could be required.