March 25, 2026
CO680.02

Farrow Partners Architects
60 Pleasant Boulevard, Suite 801
Toronto, Ontario
M4T 1K1

Attention: Christopher Blackwell
Studio Manager, Graduate Architect

Sent via email: christopherb@farrowpartners.ca

**Subject: Shear Wave Velocity Sounding for the Seismic Site Designation
Elmwood Senior School Addition Project
261 Buena Vista Road, Ottawa, ON, K1M 0V9**

Dear Christopher Blackwell:

Frontwave Geophysics Inc. has been retained by **Terrapex Environmental Ltd.** (**Terrapex**) to conduct a seismic survey in support of the proposed addition to the existing Elmwood Senior School Building (the Project) located at 261 Buena Vista Road (Site) in Ottawa, Ontario.

The geophysical investigation used the Multi-channel Analysis of Surface Waves (MASW) and Seismic Refraction Methods.

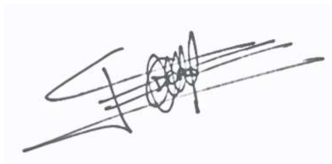
The survey was conducted on March 18, 2026, by Ilia Gusakov of Frontwave Geophysics Inc.

Based on the results of the seismic survey performed using the MASW method to measure the Vs30 value at the proposed addition location, the Site Designation is X_{1372}, corresponding to Site Class B.

The geophysical survey report is presented in **Appendix A**.

Sincerely,

TERRAPEX ENVIRONMENTAL LTD.



Yacouba Doro, MBA-PM, PMP®, P. Eng,
Senior Project Manager, Geotechnical
Services

Attachment: Appendix A: Frontwave Geophysics Inc. MASW Report

APPENDIX – A
MASW SURVEY REPORT

SHEAR WAVE VELOCITY TESTING
FOR SEISMIC SITE CLASSIFICATION
ELMWOOD SCHOOL
261 BUENA VISTA ROAD, OTTAWA, ONTARIO

Submitted to:

Terrapex
20 Gurdwara Road, Unit 1
Ottawa, Ontario K2E 8B3

Attention:

Mr. Yacouba Doro, BScEng, MBA-PM, P.Eng., PMP Email: y.doro@terrapex.com

File No. F-26498

March 23, 2026
Rev. March 24, 2026

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1 INTRODUCTION

Frontwave Geophysics Inc. was retained by Terrapex to carry out a geophysical investigation for the proposed addition to the Elmwood School building located at 261 Buena Vista Road in Ottawa, Ontario.

The objective of the survey was to determine site designation for seismic site response based on the average shear wave velocity value measured over the upper 30 m (V_S30). The multi-channel analysis of surface waves (MASW) and seismic refraction methods were employed for this investigation. The MASW aimed to obtain shear wave velocity depth profiles in the overburden; the purpose of the seismic refraction survey was to obtain shear wave velocity values for the top of bedrock.

The fieldwork was conducted on March 18, 2026. The location of the seismic survey line is shown in Figure 1.

This report describes the basic principles of the seismic refraction and MASW methods, survey design, interpretation method, and presents the results of the investigation in the chart and table format.

2 INVESTIGATION METHODOLOGY

2.1 Multichannel Analysis of Surface Waves (MASW)

Overview

The Multi-channel Analysis of Surface Waves (MASW) is a seismic method widely applied to produce shear wave velocity (V_S) profiles. It is based on the dispersive nature of Rayleigh or Love surface waves in layered media. Surface waves with longer wavelengths propagate deeper in the subsurface, hence, their phase velocity is more influenced by the elastic properties of deeper layers. The velocity of surface waves depends mainly on the shear wave velocity of the medium. The distribution of surface waves phase velocities as a function of wavelength (or frequency) can be visualized as a dispersion curve. The inverse problem is then solved by modelling the experimental data with a theoretical dispersion curve; the model parameters are typically limited to layer thickness and shear wave velocity with an assumption of horizontally layered strata. As a result of the inversion, a shear wave velocity depth profile is obtained. Figure 2 illustrates the overall procedure of the MASW method.

Survey Design

The acquisition layout consisted of 24 receivers in a linear array (spread), connected with a multicore cable to a DAQLink 4 seismograph. 4.5 Hz natural frequency vertical geophones were used for this survey. The measurements were conducted with a spread length of 23 m (1 m spacing between geophones).

An 8-kg sledgehammer was used as an energy source. Shots were executed at five locations per spread: one shot in the middle of the spread, two shots close to the ends of the spread, and two shots with an offset of 10 m from the ends of the spread. The record length was set to 1500 ms with a 0.125 ms sampling interval.

Legend

Location of 23 m, 24-geophone MASW spread

Location of 46 m, 24-geophone seismic refraction spread

Image: Google Earth 2024

Date:	2026-03-23
File No:	F-26498
Title:	Survey location plan
Location:	261 Buena Vista Rd Ottawa, ON
Figure:	**1**

FRONTWAVE GEOPHYSICS

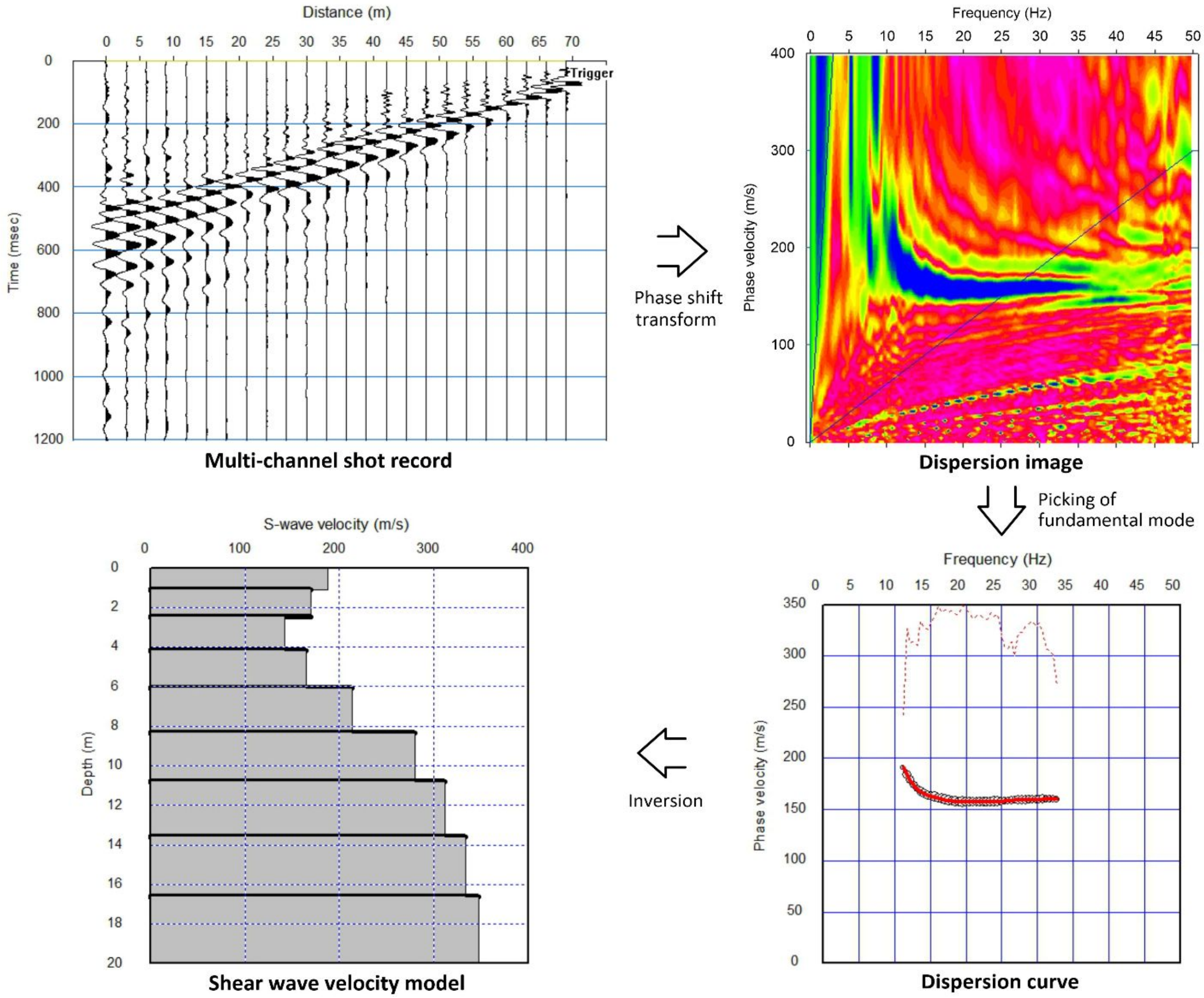


Figure 2 *The procedure of MASW data processing using the SeisImager SW software package.*

<u>Interpretation</u>

A dispersion curve is obtained from each field record by converting the shot gather into a dispersion image and then identifying and picking the fundamental mode. A shear wave velocity profile is obtained through inversion of the dispersion curve by modelling the subsurface as a horizontally layered medium with the model parameters limited to the number of layers, their thickness and shear-wave velocity.

ZondST2D software package was used for processing, picking and inversion of the MASW data.

Accuracy of the results

The accuracy of MASW generally depends on the complexity of the subsurface and specific site conditions (noise levels, topography, etc.). Lateral velocity variations and steeper bedrock topography increase the dispersion uncertainty. The presence of high-velocity contrast layers such as bedrock will require the use of a-priory information to optimize model parameters for more accurate results. Hence, if the a-priory information is not available (e.g. when the data are overly noisy to carry out refraction analysis), the accuracy decreases.

At bedrock sites and sites with very shallow overburden overlying bedrock, the MASW method performs poorly. Very strong velocity contrast between layers at shallow depths often results in a superposition of fundamental and higher Rayleigh wave modes which, when superimposed, cannot be distinguished. At sites where the thickness of the overburden is sufficient to obtain a coherent dispersion, the inversion would significantly underestimate the S-wave velocity within the rock. For this reason, it is preferred to supplement the MASW with shear wave refraction data which provide accurate shear wave velocity values for bedrock.

2.2 Seismic Refraction

Overview

The seismic refraction method is based on the measurement of arrival times of seismic waves refracted at interfaces between geological layers. The method is used to obtain velocity depth models and to map interfaces between layers with significant velocity contrast such as water table and bedrock surface. Compressional (P) wave or shear (S) wave refracted arrivals can be recorded using vertically or horizontally oriented sensors and sources, respectively. Figure 3 is a schematic of a simplified seismic model showing the basic principle of the refraction method.

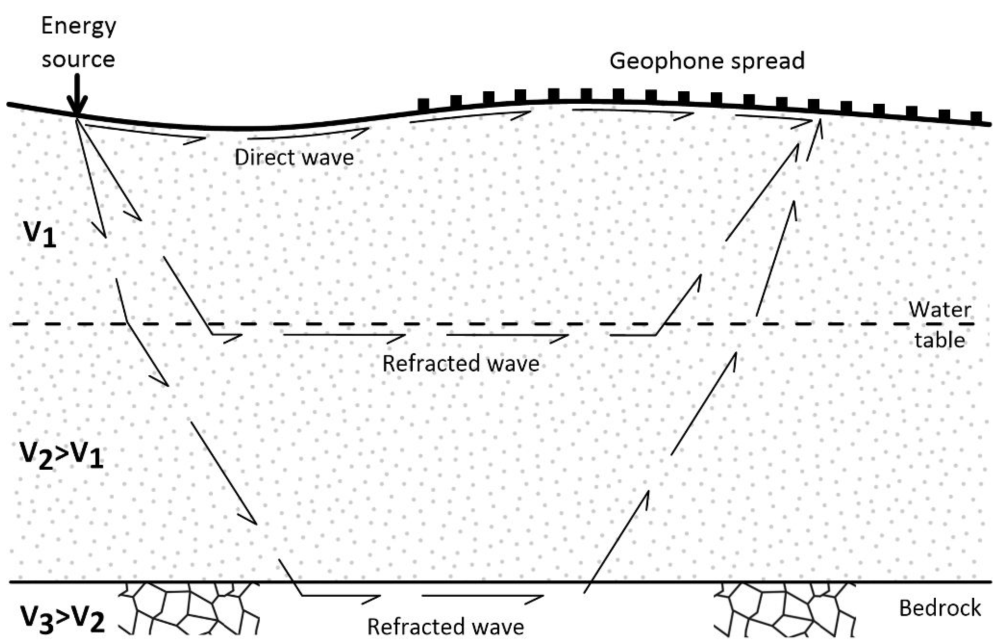


Figure 3 *Seismic model showing the basic principle of refraction method.*

Survey Design

The acquisition layout consisted of 24 receivers in a linear array (spread), connected with a multicore cable to a DAQLink 4 seismograph. 10 Hz natural frequency horizontal geophones were used for this survey. The measurements were conducted with a spread length of 46 m (2 m spacing between geophones).

An 8-kg sledgehammer was used as an energy source. Shots were executed at four locations per spread: two shots at the ends of the spread and two shots with an offset of 25 m from the ends of the spread. Preferential S-wave energy was generated by horizontally striking a metal bar in a direction perpendicular to the survey line. Shots in two opposite directions were recorded at each shot location to record S-wave arrivals of opposite polarity. The record length was set to 500 ms with a 0.1 ms sampling interval.

Interpretation

The reciprocal (plus-minus) method was used for the interpretation of the seismic refraction data. The method assumes the subsurface as a series of discrete layers (refractors) with simple velocity distributions. It allows calculating the depth and velocity of a continuous undulating refractor, providing the target layer is of sufficient thickness and the dip angles are moderate.

ZondST2D software package was used for processing of the refraction data. The processing involved stacking of shot records obtained with opposite source directions, identification and picking of S-wave first arrivals.

Accuracy of the results

The accuracy of bedrock velocity determination at this site was estimated to be within 10%.

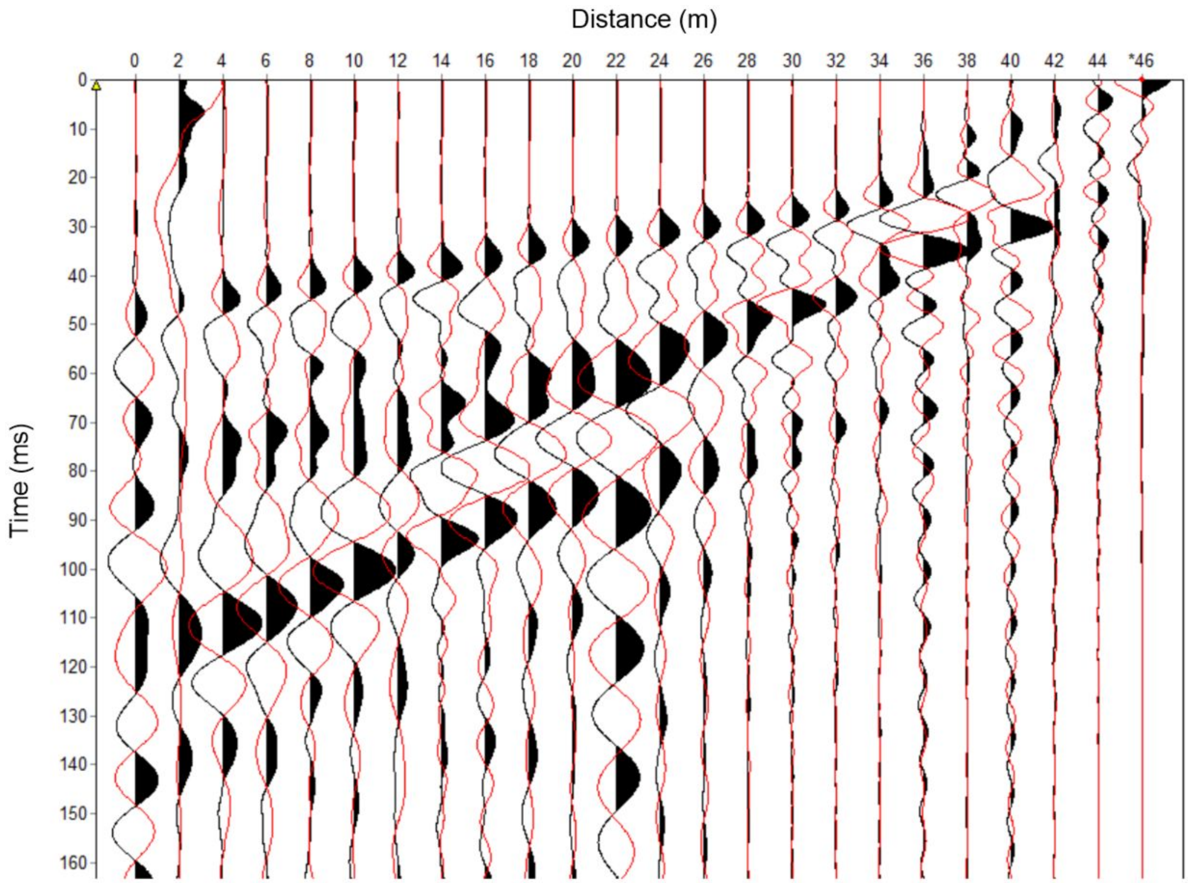
3 RESULTS

The quality of seismic data was good; first arrivals of refracted waves and MASW dispersion curves were well defined. Example shot record and MASW dispersion image obtained at this site are presented in Figure 4.

The results of the interpretation of S-wave refraction data are presented in Figure 5 in the form of a bedrock profile. The interpreted depth to bedrock ranged approximately from 1.4 to 2.5 m below the ground surface. The shear wave velocity in the competent bedrock measured using the refraction method was 2093 m/s.

Refraction data were used for parameterization of the initial MASW inversion model. The measured shear wave velocity for the bedrock is representative of the top of the rock. According to Commentary J (Paragraph 145) of the National Building Code of Canada 2020 (NBC 2020), the measured value may be extrapolated if the rock conditions are known to be continuous to a depth of 30 m.

The resulting shear wave velocity depth profile is presented in Figure 6. The average S-wave velocity is plotted in the chart as a solid line. The dashed lines represent the upper and lower bound S-wave velocity profiles.



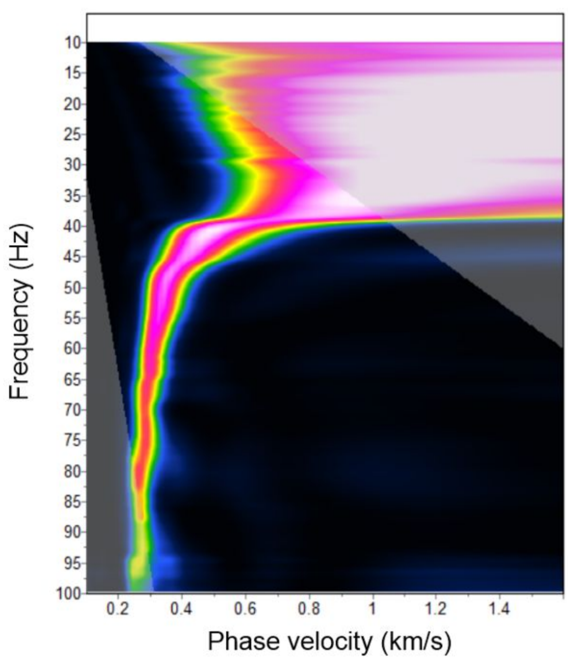


Figure 4 *Data examples displaying a stacked S-wave refraction shot record (top), and MASW dispersion image (bottom).*

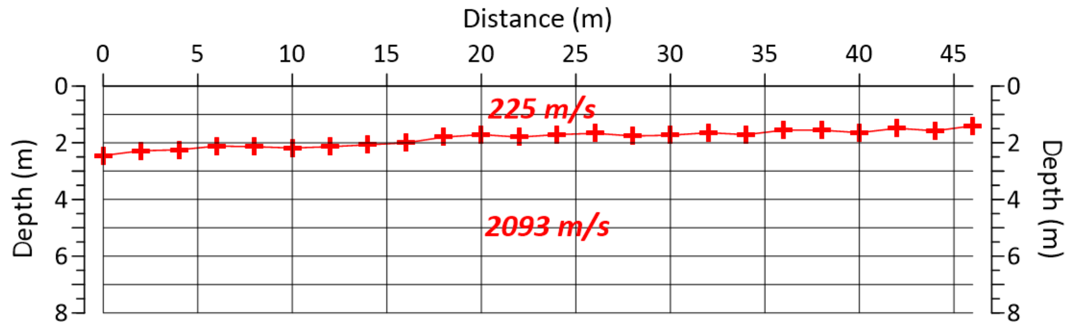


Figure 5 *Interpreted depth to bedrock from S-wave refraction.*

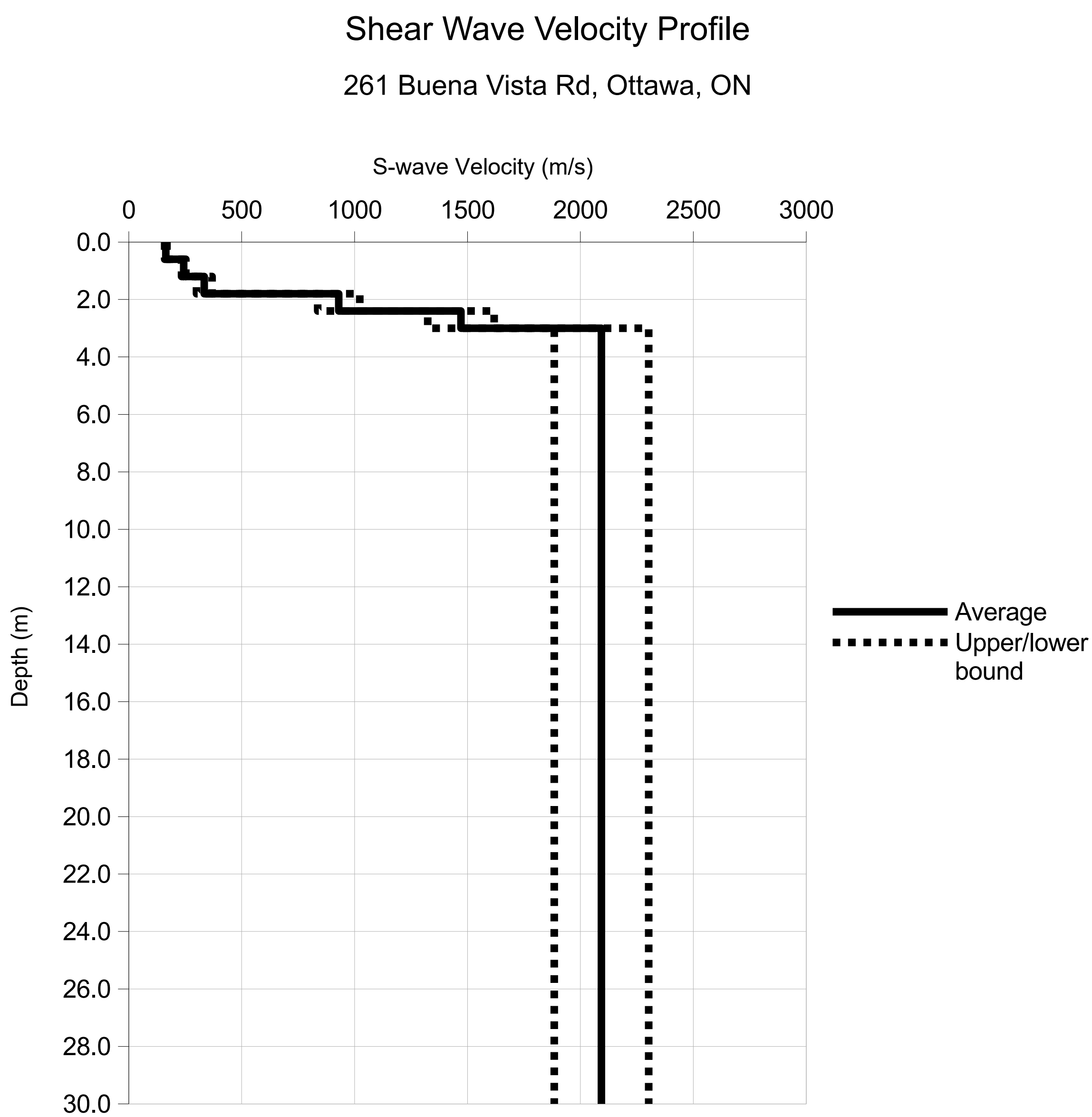


Figure 6 *Shear wave velocity profile from MASW sounding and S-wave refraction.*

The tabulated shear wave velocity model is presented in Table 1.

Table 1 *Shear wave velocities from MASW sounding and S-wave refraction.*

Depth Interval (m)		S-wave Velocity (m/s)
From	To	
0.0	0.6	164
0.6	1.2	244
1.2	1.8	335
1.8	2.4	930
2.4	3.0	1471
3.0	30.0	2093

The average shear wave velocity within the upper 30 meters (V_S30) is defined as the travel-time weighted average velocity from surface to a depth of 30 m and calculated using the following formula:

$$V_S30 = 30 / \Sigma (d/V_S),$$

where d is the thickness of any layer and V_S is the layer S-wave velocity. In other words, V_S30 is calculated as 30 m divided by the sum of the S-wave travel times for each layer within the topmost 30 m.

The calculated V_S30 values are presented in Table 2.

Table 2 *V_S30 values from MASW sounding.*

Depth Range (m)	Minimum V_S30 (m/s)	Average V_S30 (m/s)	Maximum V_S30 (m/s)	NBC 2020 Site Designation
0 to 30	1258	**1372**	1483	$\mathbf{X_{1372}}$

The V_S30 values obtained from the MASW sounding varied from 1258 m/s to 1483 m/s with an average of 1372 m/s.

Based on Sentence 4.1.8.4.(2b) of the 2024 Ontario Building Code (2024 OBC), the **Site Designation** is $\mathbf{X_{1372}}$.

4 CLOSURE

Shear wave velocity testing involving the MASW and seismic refraction methodologies was carried out for the proposed addition to the Elmwood School building located at 261 Buena Vista Road in Ottawa, Ontario.

The average shear wave velocity (V_S30) value calculated from in situ shear wave velocity measurements was **1372 m/s**. Based on Sentence 4.1.8.4.(2b) of the 2024 Ontario Building Code (2024 OBC), the applicable **Site Designation** is $\mathbf{X_{1372}}$.

Based on the requirements of Table 4.1.8.4.-A of 2024 OBC, if the ground profile contains more than 3 m of soil between rock and the underside of footing or mat foundations, the applicable Site Designation is X_{760} even if the calculated V_S30 value is greater than 760 m/s.

We hope you find this report satisfactory. Should you have any questions or require additional information, please do not hesitate to contact the undersigned.

Frontwave Geophysics Inc.

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