ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Site characterization report at the seismic station IT.FOCC – Foligno (PG)

Report di caratterizzazione di sito presso la stazione sismica IT.FOCC – Foligno (PG)

Working Group **Geology:** Brunori C.A. **Geophysics**: Famiani D., Brunori C.A., Cultrera G., Mercuri A., Milana G., Pucillo S., Riccio G.	Date: December 2021
Subject: **Final report illustrating the site characterization for seismic station IT.FOCC**	

Convenzione DPC-INGV 2019-21, All.B2- WP1, Task 2: "Caratterizzazione siti accelerometrici" (Coord.: G.Cultrera, F. Pacor)
Cite as: Working group INGV "Agreement DPC-INGV 2019-21, All.B2- WP1, Task 2", (2020). Site characterization report at the seismic station IT.FOCC – Foligno (PG) - http://hdl.handle.net/2122/15057

INTRODUCTION

In this report we present the geological setting, geophysical measurements and results obtained in the framework of the 2019-2021 agreement between INGV and DPC, called *Allegato B2: Obiettivo 1 - TASK 2: Caratterizzazione siti accelerometrici (Responsabili: G. Cultrera, F. Pacor)* for the site characterization of station IT.FOCC (Foligno).

Location and coordinates are reported in Table 1.

Table 1.

CODE	NAME	LAT [°]	LON [°]	ELEVATION [m]
IT.FOCC	Foligno	42.95740*	12.70790*	283*
ADDRESS	Via dei Monasteri, 4 - 06034 Foligno PG			

* Reference table from ITACA (December 2020)

A. Geological setting

A1. TOPOGRAPHIC AND GEOLOGICAL INFORMATION

Topographic information related to the site is reported in Table 2.

Table 3 summarizes all available geological maps from literature for geological analyses.

Table 2.

Topography	Description	Topography Class	Morphology Class	EC8 Class
	Flat surfaces, isolated slope and reliefs with slope i<=15°	T1	P*	C*

* According to nomenclature of ITACA (December 2020)

Table 3.

Geological map	Source	Scale
IT.FOCC	Geological map of Italy sheet *N.131* (Foligno)	1:100.000
IT.FOCC	Geological Map - Umbria Region, Servizio Geologico, sheet N.314010 (Foligno) - 2014	1:10.000
IT.FOCC	CARTA GEOLOGICA D'ITALIA alla scala 1:50.000 - Barchi and Lemmi, 2015 (Foglio 324 - FOLIGNO	1:50.000
IT.FOCC	Litho-morphological map – Seismic Microzonation (Foligno / PG)	1:5.000

In Table 4 Geological and Lithotechnical Units (according to Seismic Microzonation classification; Technical Commission SM, 2015) are described and are concerned to the maps of following chapters. The term "original" means the result comes from a pre-existing cartography (Table 3); the term "deduced" means the result comes from an interpretation of a pre-existing cartography according to the nomenclature of corresponding cartography.

Table 4

GEOLOGICAL UNITS		**LITHOTECHNICAL UNITS**	
Geological Map - Umbria Region, Servizio Geologico, 2014 (original)		Litho-morphological map – Seismic Microzonation III Liv. *MZS (Foligno / PG) (original)	
code	**description**	**code**	**description**
b	Alluvial and conoid deposits	GMca	Silty gravels, mixture of alluvial fan gravel, sand and silt - moderately thickened
h	Antropic deposits	RIzz	Soils containing anthropic elements - poorly coherent

A2. GEOLOGICAL MAP

In Figure 1 Geological Map is reported in a 1km x 1km square around the station.

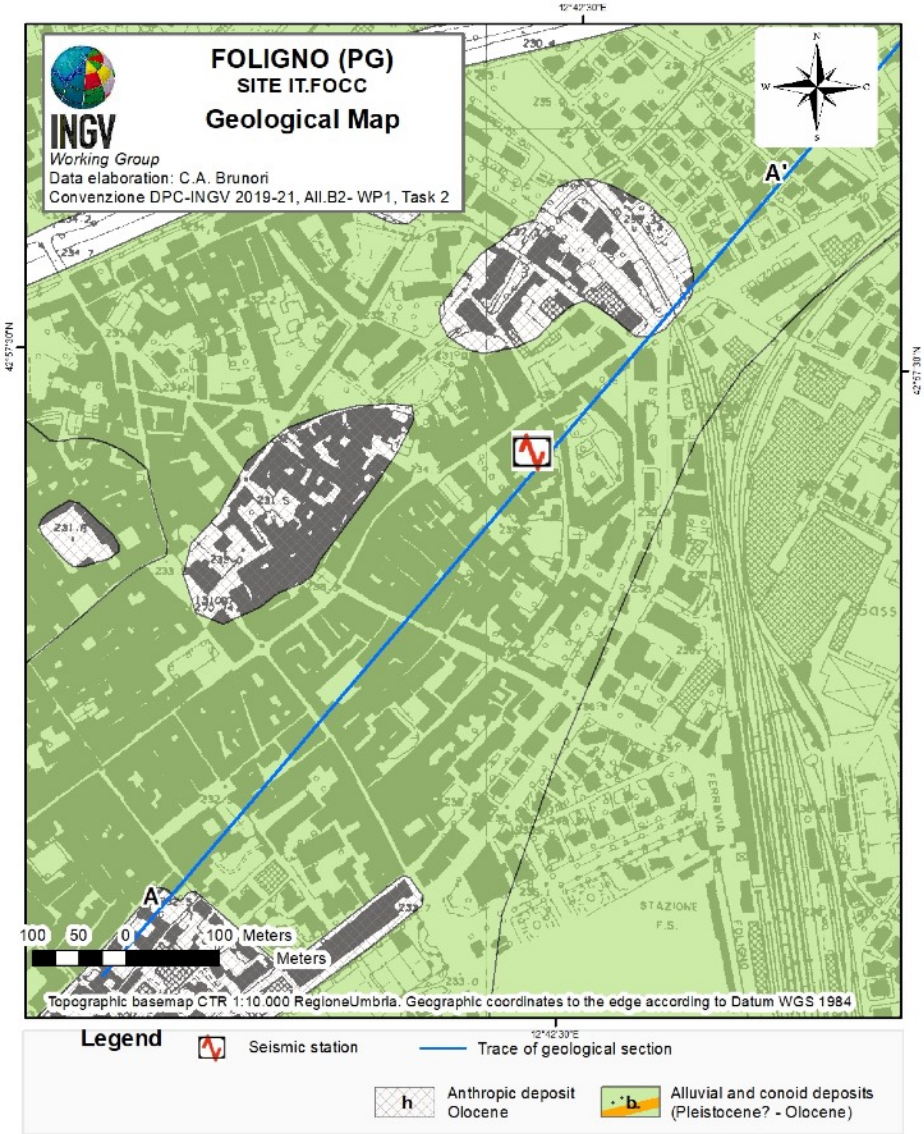

Figure 1. Geological map of seismic station site IT.FOCC - scale 1:5.000. Geological units are mapped according to the nomenclature of the Regione Umbria geological map 1:10.000 - sheet N.314010 (Foligno).

A3. LITHOTECHNICAL MAP

In Figure 2 Lithotechnical Map is reported in a 1km x 1km square around the station.

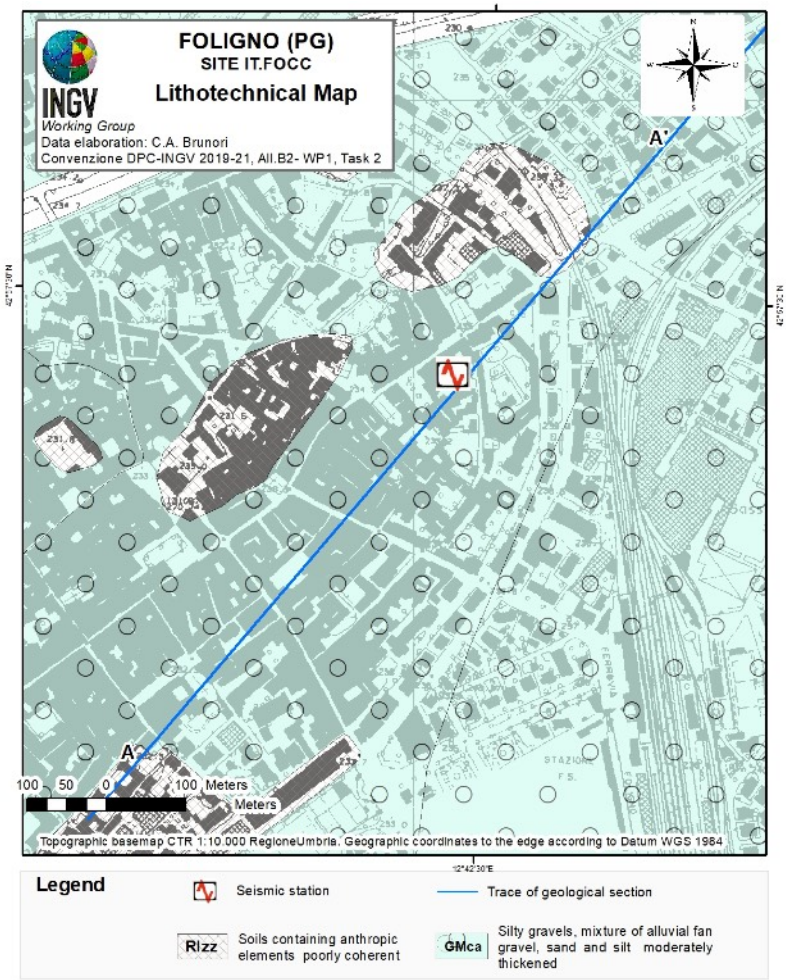

Figure 2: Lithotechnical map of the seismic station site IT.FOCC - scale 1:5.000. The lithotechnical units are attributed according to the nomenclature of Seismic Microzonation study (Technical Commission SM, 2015).

A4. SURVEY MAP

Figure 3 shows the Survey Map reporting both previous investigations and geophysical surveys conducted by the INGV Working Group.

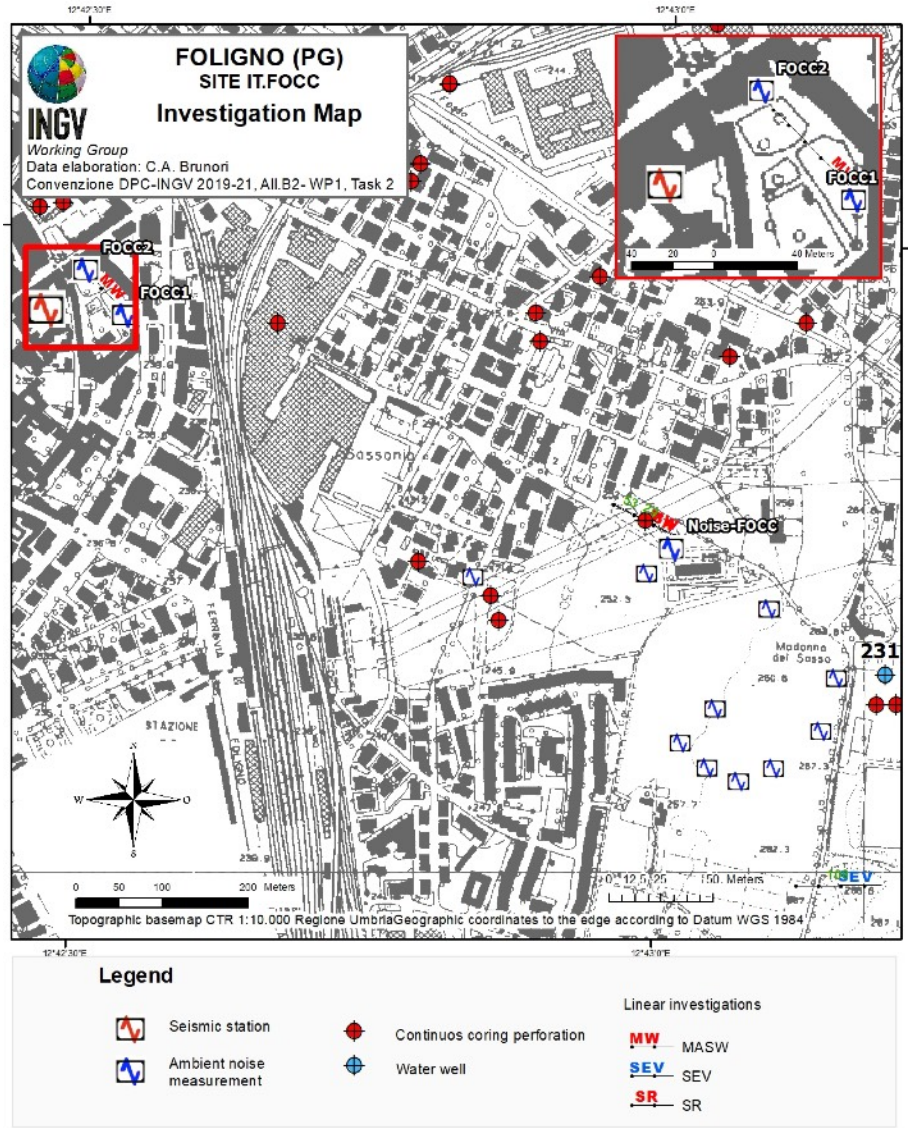

Figure 3: Map of the geophysical surveys made in the sectors around the seismic station IT.FOCC - scale 1: 5.000. The box at the top right contains a zoom of the area with the detail of the geophysical investigation conducted by INGV Working Group for the seismic characterization of the site (Convenzione DPC-INGV 2019-21, Allegato B2-WP1, Task B, Velocity profile at the seismic station report IT.FOCC).

A5. GEOLOGICAL MODEL

5.1 General description

The IT.FOCC station, located in Foligno downtown, on the Eastern side of the Valle Umbra (hereafter UV). The UV intermountain basin is 50 km long, with a NNW-SSE trending alignment of extensional faults, crossing the Umbria region from North to South and is the eastern segment of the Tiberino Basin (TB), the largest of the intermountain basins in the Umbria region with an area of about 1800 km2 (Fig. 5). The TB crosses entirely the region from the north (Sansepolcro) to the south with an overturned Y shape, splitting close to Perugia into two segments. The western branch is elongated southwards up to the city of Terni while the eastern one is the UV (Ambrosetti et al., 1995; Basilici, 1997).
The TB is active since Late Pliocene and is bounded by a complex segmented system of both ENE-dipping and WSW-dipping normal faults, dissecting the pre-existing (Late Miocene) compressional structures of the Umbria-Marche Apennines (e.g. Malinverno and Ryan, 1986; Martini and Sagri, 1993; Barchi and Ciaccio, 2009; Barchi, 2010). Some of these faults are still active and seismogenic, as suggested by the distribution of both instrumental and historical seismicity (Fig. 4; Rovida et al., 2016).
The Late Pliocene-Pleistocene continental sequence infilling the UV consists of a complex succession of laterally discontinuous deposits, mainly composed of lignitiferous clays, sands, sandy clays and conglomerates, deposited within the “ancient Tiberino lake” (Albani, 1962), a depositional environment characterized by braided rivers and shallow lakes (Ambrosetti et al., 1995; Barchi et al., 1991; Basilici, 1997; Coltorti and Pieruccini, 1997; Bucci et al., 2016). In the following, we will refer to this complex succession as the “Tiberino Lake Succession'' TLS (Fig 5). The TLS uncomfortably overlies a previously deformed and eroded bedrock, mainly consisting of Late Miocene turbidites of the Marnoso-Arenacea Fm. (hereinafter MA, Ricci Lucchi, 1986) or, locally, of the older Mesozoic-Paleogene Umbria-Marche multilayer (hereinafter UMm, e.g. Cresta et al., 1989). Along the present-day alluvial plains of the Valle Umbra basins, the TLS is unconformably overlain by Late Pleistocene-Holocene alluvial gravel and sands, more directly referable to the activity of the present-day fluvial network. At the connection with the slopes bordering the valley, the clastic sediments of the alluvial plain are laterally inter-fingered with coarser alluvial fan deposits, larger and more frequent on the NE side of the basins. The thickness of the recent alluvial deposits is quite irregular, varying from few meters up to about 200 m in the deepest depocenters, highlighting significant longitudinal variations of subsidence and activity (Mirabella et al., 2008). The IT.FOCC is located in the upper part of the Topino Conoid (Fig 4 and 5)

5.2 Geological Section and Subsoil model

Famiani et al. (2020), combining single station ambient noise measurements and passive array techniques, reconstruct the general trend of the hidden geometries and associate a geological interpretation to them of the Northern VUM. The subsurface structure of the basin, along with the position and geometry of the major faults which are thought to control the basin onset and evolution, is illustrated in the schematic geological cross-section of Figures 4 and 5. The geological section is the synthesis of the information and interpretations present in Famiani et al. (2020) and previous geological and geophysical knowledge.
The section in Figure 4 is the geological interpretation of the subsoil under the IT.FOCC station. Here, as described in the stratigraphy of the water well (stratigraphy number 23 , see Figure 3 for the location) the formations of the first 84 meters are alluvial fan sequences with alternances of washed gravels with H2O and compact sandy clay. The section in figure 5 shows the more deep interpretation of this sector of the UV interpreted as a graben, controlled by two sets of opposite dipping (i.e. NE and SW-dipping) normal faults. The SW flanks of the UV is characterized by the presence of Miocene turbidites (Marnoso-Arenacea Fm.) while the older Mesozoic-Paleogene carbonates (UMm) outcrops in the NE flank, corresponding to the large anticline of M. Subasio and the chain bordering the eastern side of the southern UV. However, along the NE flank, the MA turbidites crop out in an intermediate fault block, suggesting that the central part of the basin is also floored by deformed Miocene turbidites, unconformably overlain by the lacustrine succession TLS. In this central part, the survey indicates that the total thickness of the sedimentary succession is in the order of 800 m, a value which is consistent with previous studies, mostly based on seismic reflection survey (Barchi et al., 1991; Barchi and Lemmi, 2020) or on geoelectrical prospections (AA.VV., 1991).

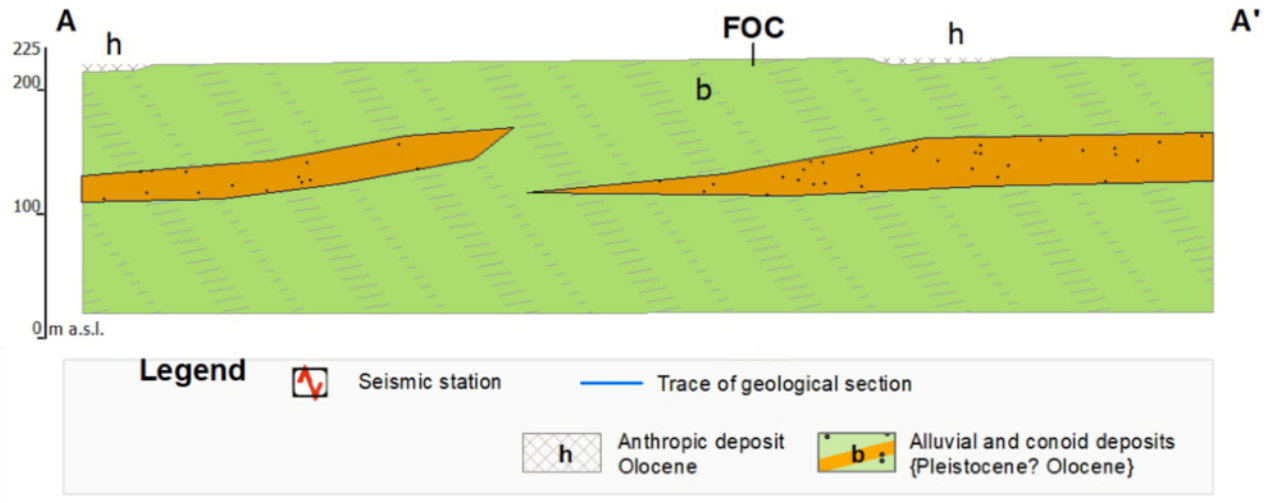

Figure 4: Schematic geological cross section, oriented NE-SW, showing the conoid and Anthropic deposits in the surroundings of the seismic station.

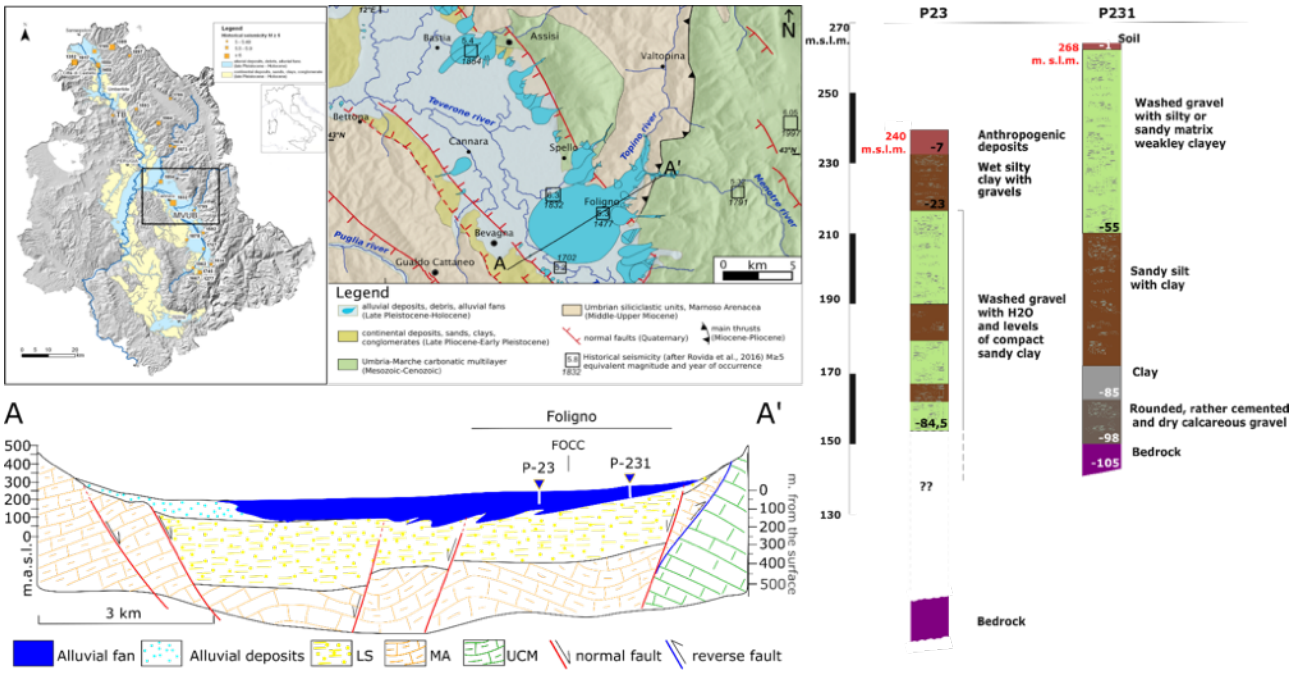

Figure 5: Top left panel - Umbria Region, in background, the shaded relief derived from DTM 10 m (TINItaly, Tarquini et al., 2017), in yellow and light blue the recent and quaternary formations filling the Tiberina Valley (TB) and the Umbria Valley (VUM). The study site is located in Foligno town. The black box locates the Northern Umbria Valley (in the upper right panel).
Upper right panel - simplified geological map of the Northern Valle Umbra; the FOCC station is located in Foligno town. Bottom panel - Geological section (A-A' trace in the geological map) crossing seismic station IT.FOCC. LS - Lacustrine Succession (the Bevagna Formation); MA - Miocene turbidites (Marnoso-Arenacea Fm.); UCM - Mesozoic-Paleogene Umbria-Marche multilayer.
Right panel - simplified stratigraphy of 23 and 231 well (Figure 3 for the locations).

B1. GEOPHYSICAL INVESTIGATIONS

The collected geophysical measurements consist in:

i) four ambient-vibration measurements executed as follows:

- next to the station
- at the two edges of the linear array with the aim to infer the resonance frequency of the site and verify the mono-dimensional condition of the site where to apply array techniques respectively;
- close to the 2D array site to confirm the similarity of the geophysical response of the area with IT.FOCC site;

ii) a 1D linear array of geophones close to the station in both active and passive acquisition (MASW-ReMi);

iii) a 2D array of velocimeters with spiral shape and passive acquisition.

These measurements provide results in terms of dispersion curves that are inverted to obtain the shear-wave velocity (V_s) profile for the studied area. The obtained results are suitable for assigning the soil class according to the current Italian seismic code (NTC18) and the current Eurocode (EC08).

Figure 6 shows the map of all the geophysical investigation performed by INGV: the location of station IT-FOCC (Latitude 42.95740, Longitude 12.70790 WGS84) installed inside the parking area of Comando dei Carabinieri in Foligno municipality and the line of geophones used for the 1D linear array (MASW) in the zoomed area.

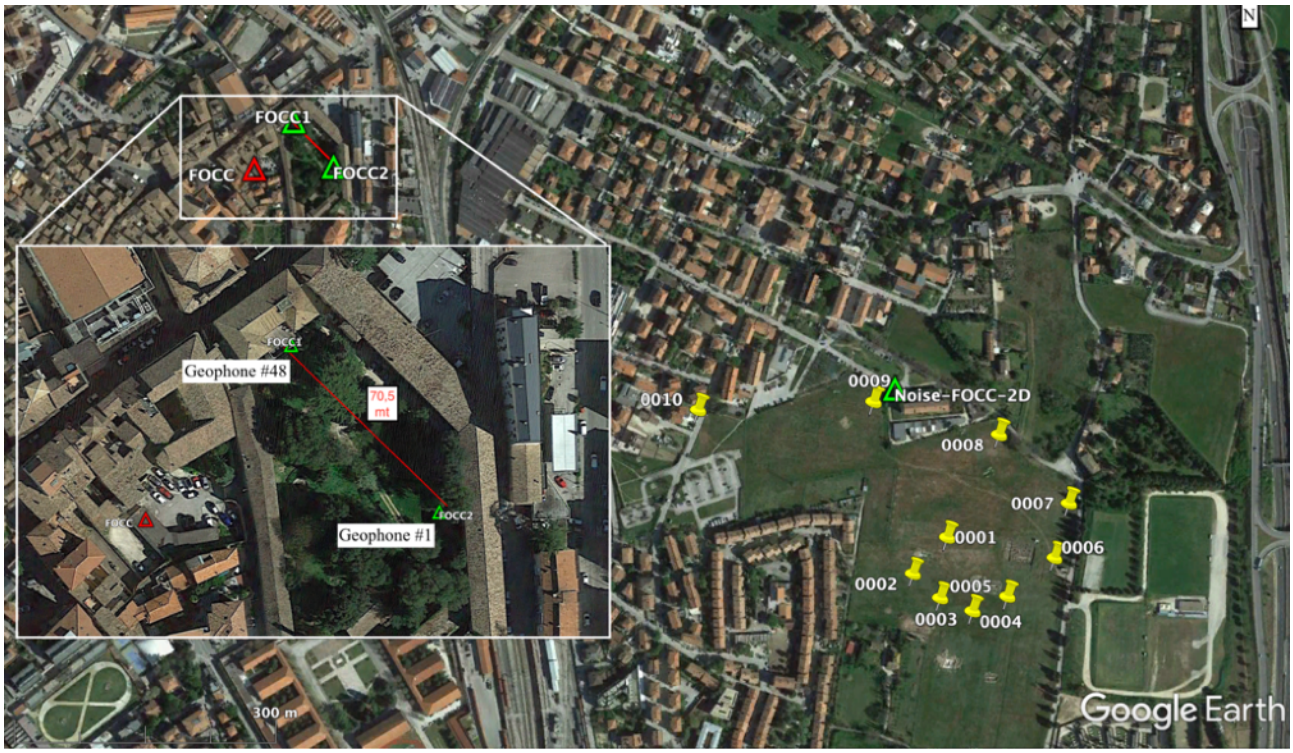

Figure 6: Map of Foligno center (image from Google Earth http://www.earth.google.com) showing the general map of the investigations (full-size image) and the position of IT-FOCC station (red triangle) and the line of 48 geophones (red line) used for active and passive MASW (zoom).

Figure 7 shows the location of the 2D-array of velocimeters in spiral geometry, used only in passive acquisition with the aim to increase the depth of investigation.

Figure 7: Map of Foligno, close to Campo di Marte rugby field (image from Google Earth http://www.earth.google.com), 850 m far from IT.FOCC site, showing the position of the preliminary ambient noise station (green triangle) and the spiral geometry of the ten 3-c velocimeters (yellow placemarks) used in passive acquisition. The green and red lines represent the shorter and longer interstation distances respectively.

Figure 8 shows the place where the accelerometric station IT-FOCC is deployed (left), the instrumentation used (central zoom) and the velocimetric sensor used for the noise measurement (right).

Figure 8: The location of the accelerometric station IT_FOCC (on the left) which is installed on a concrete floor inside a garage of the Comando dei Carabinieri in Foligno. The zoom in the middle shows the detail of the accelerometric station. On the right it is visible the Lennartz 5sec (the cyan sensor), connected to a Marslite digitizer, used for the noise recording.

The noise has been acquired with a medium-period seismometer (i.e., Lennartz Le3d-5s) and it lasted about an hour and twenty minutes. The sampling rate was set to 200sps.
To assess the resonant frequency of the site, the horizontal-to-vertical (H/V) spectral analysis has been calculated, using the *Geopsy* software (http://www.geopsy.org).
Figure 9 shows the Fourier spectra of the three components (NS, EW, UP), the directional H/V and the H/V curves (mean and plus/minus one standard deviation).

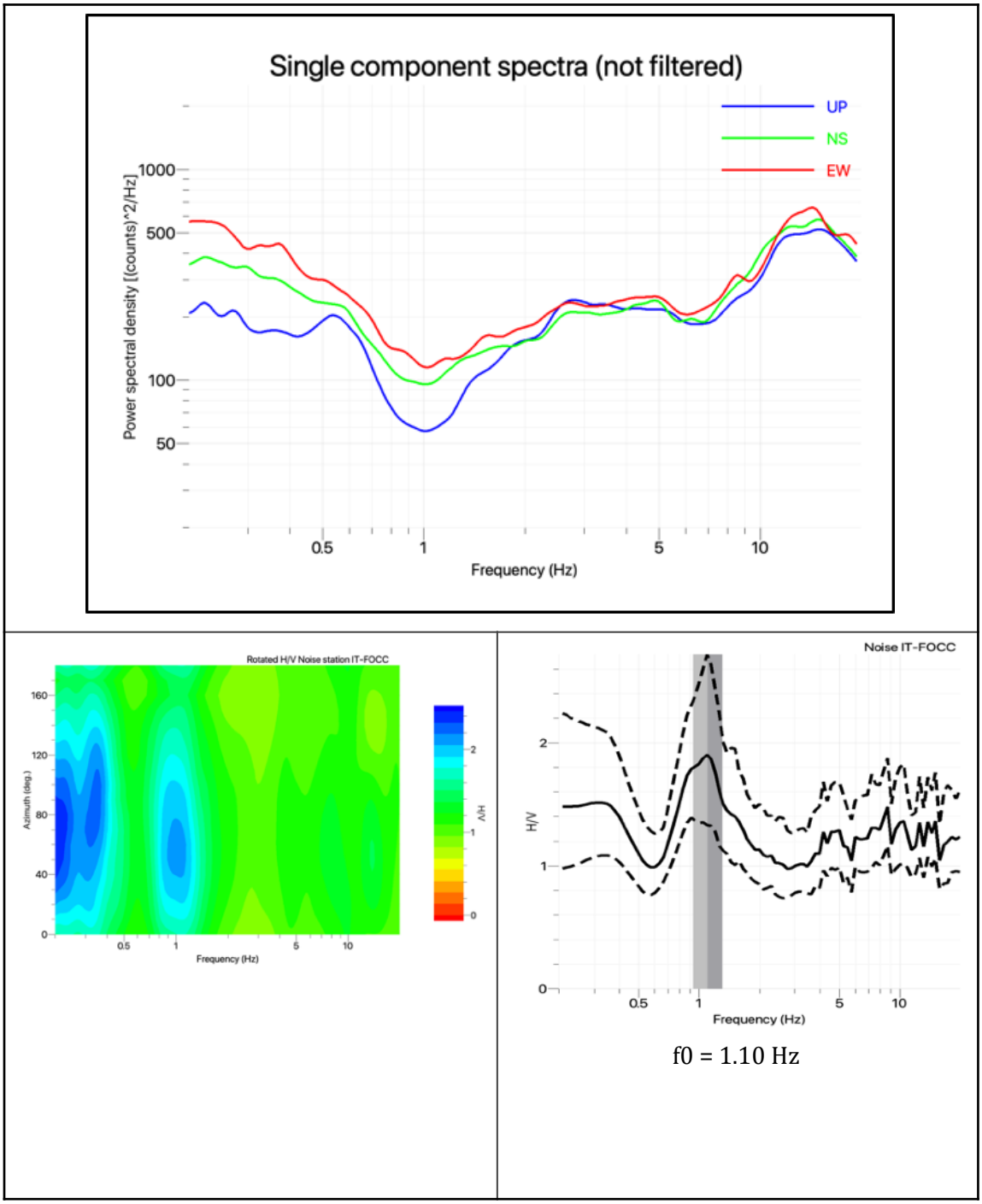

Figure 9: Summary of the analyses on the ambient-vibration measurement. Top: Fourier spectra of the three components. Bottom left: directional H/V. Bottom right: H/V curve (with mean and standard deviation).

The H/V peak is observed at the frequency f_0 = 1.10 Hz, but the amplitude value is very low, around 2, then it's not completely meaningful following the SESAME criteria (SESAME Guidelines, 2004). A smaller peak at around 0.3 Hz is observed. The rotated H/V spectral ratios do not show any significant polarization effect (amplitude values around 2). The ambient noise recordings at the two edges of the linear array show the same peaks ensuring the 1D subsoil condition for the entire line.

The 1D linear array (Figure 7) consisted of 48 vertical geophones (4.5 Hz as natural frequency) placed at 1,5 m of distance from each other, for a total length of 70,5 mt. In the active acquisition we used five shot positions: -7 m from geophone #1, -1 m from geophone #1, 35.3 m (middle of the line), +1 from geophone #48 and +7 from geophone #48. For each of them we hammered three times a metallic plate. We recorded signals with a sampling rate of 8000 sps for 2 seconds. The passive acquisition consisted of several 4-minutes length windows of noise collected with a sampling rate of 250 sps.

The 2D spiral array (Figure 8) consisted of ten 3-component velocimetric stations. For this array we collected more than two hours of noise with a sampling rate of 200sps.

a. 1D linear array

We first analyzed the 1D linear array in active acquisition in the area close to the accelerometric station. Figure 19 shows the comparison between the dispersion curves obtained with the FK analysis for the stack of all the shots located in the same position of the linear array (-7 and -1 m from geophone #1, in central position, +1 and +7 m from geophone #48).

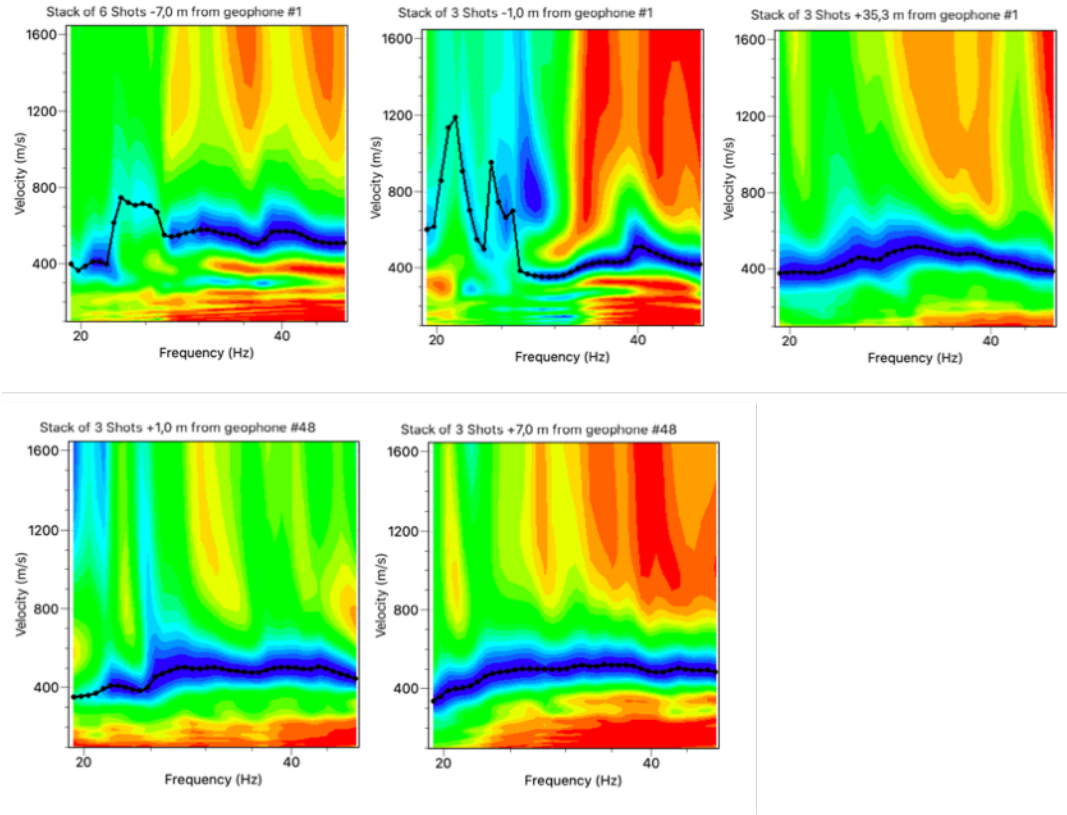

Figure 10: FK analysis for stacked shots located -7, -1, +35,3 +71,5 and +78,5 meters from geophone #1 (from left to right)

The two parts of the linear array have a different response, especially for frequencies around 25 Hz. Comparing these results with the single station ambient noise recordings at the two edges of the linear array and considering the logistics of the area, we decide to consider reliable the results of this investigation above 30 Hz. Below this value, MASW data are influenced by the presence of an electronic source which has typical frequency of 50 Hz and submultiples of this value. This leads us to consider more reliable the dispersion curve obtained stacking the shots located +7,0 m from geophone #48 (reported in Figure 11) which seems to be less affected by this disturbance.

Considering that, we stacked the different shots in the northern-western part and picked the dispersion curve from 30 to 50 Hz (Figure 11).

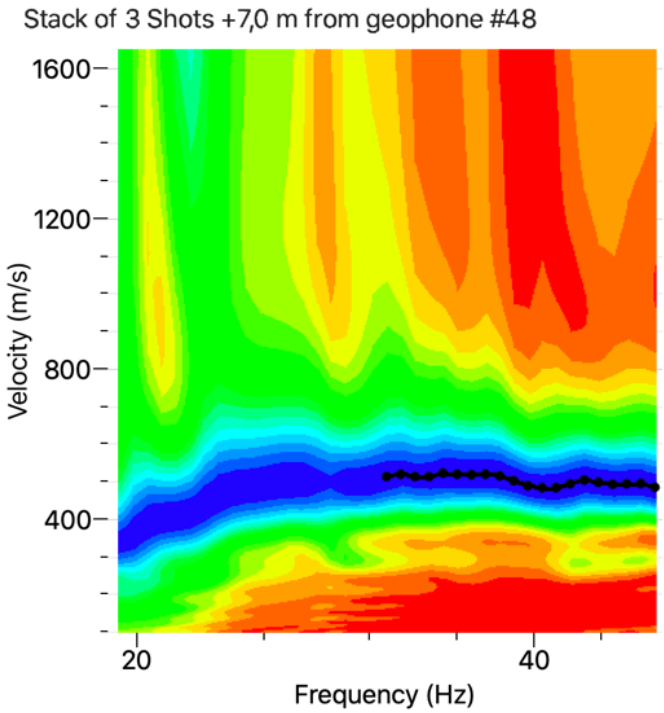

Figure 11: Stacked FK analyses for shots in the north-western part of the 1D linear array. The picked part (black dotted line) is the part of DC considered reliable for this study.

After the active acquisition of the linear array, we recorded data in passive mode with the same 1D linear array installation. We collected twenty 4-minutes length windows of noise (80 minutes) with a sampling rate of 250 sec, and proceeded with FK analysis of passive data, obtaining the DC in Figure 12.
It is possible to notice that also passive data are strongly affected by the electronic disturbance at 25 Hz and below.

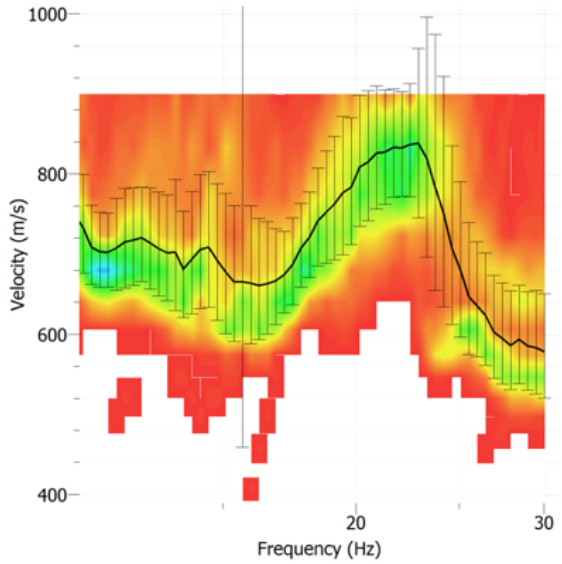

Figure 12: Stacked FK analyses and picked dispersion curve for shots in the north-western part of the 1D linear array

We consider as reliable the part of the dispersion curve between 27 and 30 Hz (lower standard deviation values).

b. 2D array

To better constrain the frequencies below 25 Hz, because of the difficult logistics of the area, we had to move 900 meters away from the RAN station site and perform a large 2D array (see Figure 5). We first checked the similarity in the seismic response of the two sites by performing HVNSR measurements. Spectral ratios of ambient noise of the two sites are very similar in shape, frequency peaks and in average amplitude (Figure 13).

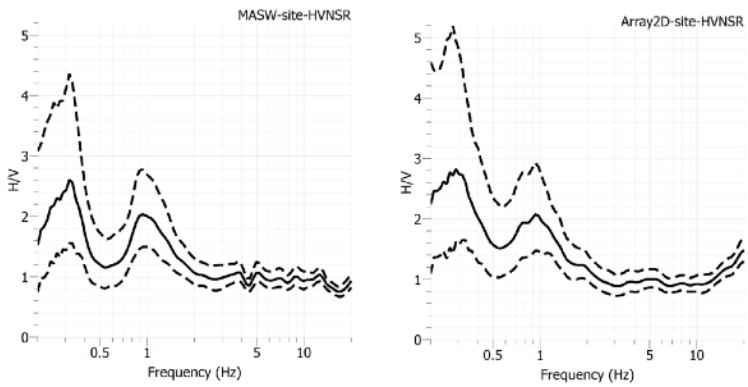

Figure 13: HVNSR of the MASW site and the 2D-array site.

We recorded 2 hours of contemporary ambient noise with 10 seismic stations equipped with MarsLite digitizers and Lennartz 3D-5s velocimeters. The array was designed with spiral shape and minimum and maximum inter-station distances of about 55 m and 440 m respectively. We performed FK analysis on data collected obtaining a very clear dispersion curve from 2 to 11 Hz (Figure 14). Considering the array response function limits (black curves in Figure 14), the part of the dispersion curve reliable is included between 2 and 7 Hz.

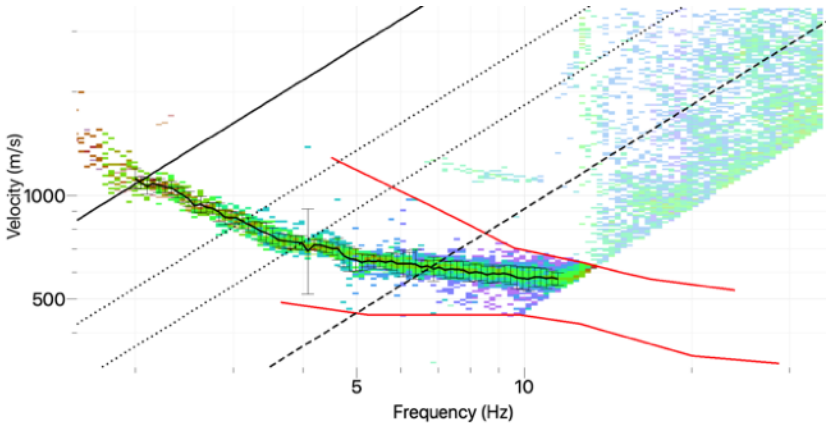

Figure 14: FK analyses and picked dispersion curve for the 2D-array. Red lines delimit the higher and lower values excluded before computing the automatic picking of the dispersion curve. The array response limits are shown with black continue and dotted curves crossing the DC

The synthesis of the DC considered useful for the site characterization of IT.FOCC site is shown in Figure 15.

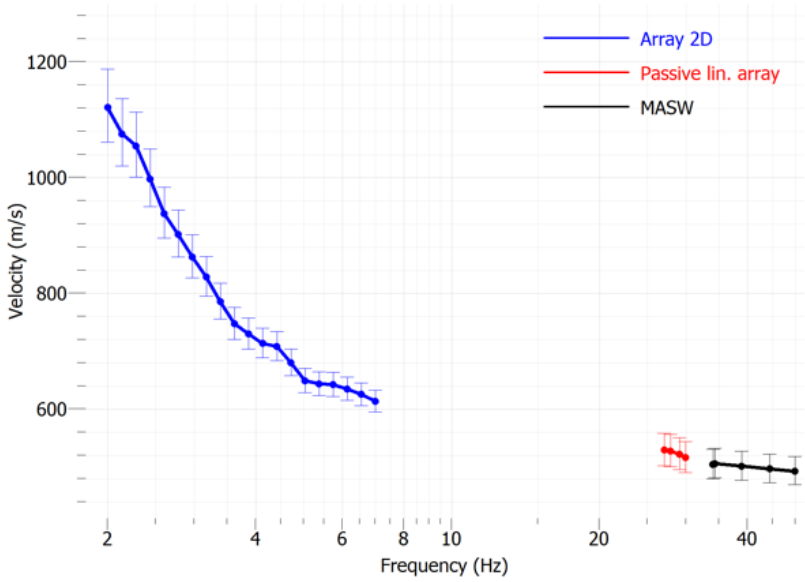

Figure 15: Targets considered for the inversion process. The three parts of the DC obtained from each survey are plotted with different colors.

As we can see, there is a lack of constraints in the DC in the frequency band between 7 and 27 Hz because of the bad quality of data collected due to the difficult logistics of the site. This could influence the reliability of the result in terms of error associated with the values of the velocity profile.

B2 SEISMIC VELOCITY MODEL

To proceed with the inversion, we decided to use the three parts of dispersion curves obtaining the Vs profile as shown in Figure 16

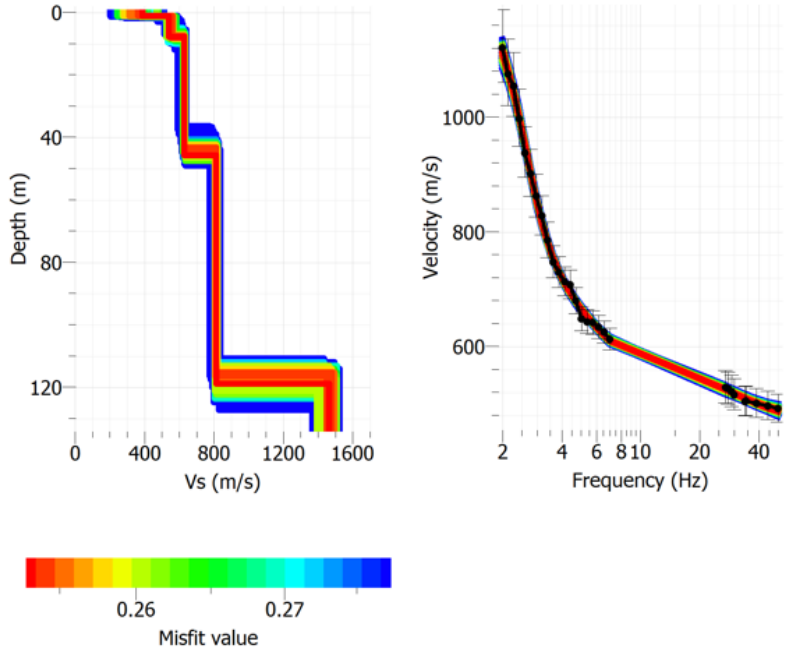

Figure 16: Left: Vs profile obtained through the inversion of the dispersion curve of Figure 10. Right: fit between the experimental dispersion curve and the theoretical dispersion curves of the investigated models.

The geology of the area where the IT-FOCC station is installed can be described as an alluvial fan made by deposits coming from the Topino river. These deposits are made by a thick layer of gravel, washed or in sandy, silty and clayey matrix and the bottom part of them with an increased fine portion (clay and silt) overlying a final layer of calcareous cemented gravel deposits.

With this information in mind, derived also thanks to some borehole logs made available by Regione Umbria for the Foligno urban area, we decided to use a starting model with 4 layers with uniform velocity over a half-space.

In order to obtain a seismic velocity model, we performed an inversion using the GEOPSY tool dinver, considering as targets the dispersion curves coming from the active and passive geophysical surveys. To proceed with the inversion step, the dispersion curve derived from the vertical component of motion was associated with the fundamental mode of surface Rayleigh-wave. The inversion processing uses the Neighbourhood Algorithm (Sambridge, 1999; Wathelet et al., 2005).

Shear wave velocities (VS) were set to vary for all the four layers within a wide range of values and without constraining possible velocity inversions for the third and fourth layer, according to the stratigraphic boreholes examined in the surroundings.

Several tests have been carried out and the final result of the inversion is shown in Figure 16 along with the fit with the dispersion curve.

The inversion is able to reproduce fairly well the three experimental parts of the dispersion curve. The V_p profile is poorly constrained, and then we decided not to mention it in this report. Since obtained misfit values are reasonably low (<0.26 for the best-fit model) we consider this to be a good fit between experimental and theoretical curves. The color scale is related to the misfit value associated with each model.

The best -fit model of V_s is represented in Figure 17 and Table 17.

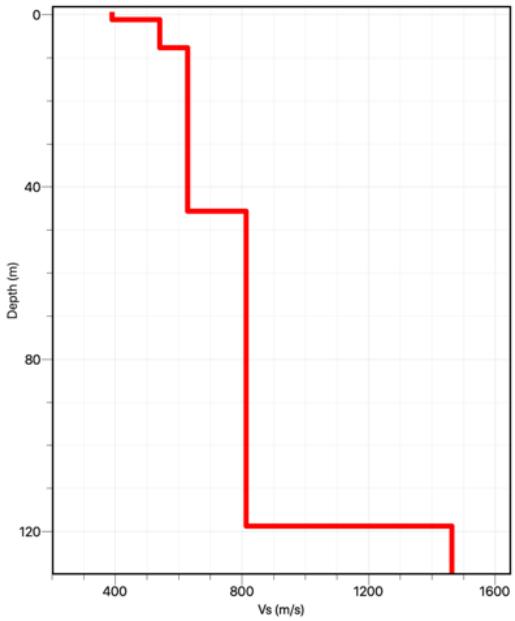

Figure 17: Best-fit model of Vs values

From	*To*	*Thickness (m)*	*V_s (m/s)*
0	1.17	1.17	389
1.17	7.69	6.52	541
7.69	45.6	37.91	628
45.6	118.7	73.1	814
118.7			1464

Table 5: Best-fit model

The best-fit velocity model is composed of four layers over the bedrock. The first one corresponds to anthropic deposits with V_S of 389 m/s. The second layer is possibly related to recent alluvial deposits of the Topino river, with V_S of 541 m/s, the third layer can be associated with the wet part of the gravel deposits with average V_S of 628 m/s, the fourth layer can represent the dry part of the alluvial fan deposits probably overlying some overconsolidated clays and silts deposits and a deeper cemented dry calcareous gravel, as highlighted by a borehole log which reaches around 100 meters below the ground surface with average V_S of 814 m/s. The top of the bedrock is attested at around 120 meters of depth but this value is not very constrained because the dispersion curve has few information at those depths and we decided not to add the ellipticity curve to the inversion because the big array was performed around 900 meters away from the site where IT.FOCC station is installed.

B3. CONCLUSIONS

According to the current Italian seismic code [1], if the bedrock (Vs > 800 m/s) is more than 30 m in depth, the equivalent velocity ($V_{s,eq}$) is equal to the $V_{S,30}$. From Figure 15, the velocity of 800 m/s is reached at 45.6 m, well above the depth of 30 m. Therefore the equivalence between $V_{s,eq}$ and $V_{S,30}$ is the case to consider for the IT.FOCC site, where the $V_{S,30}$ retrieved from the inversion of the dispersion curves is 593.6 m/s, and the site is classified in the soil category B for both the NTC18 and EC8 seismic classifications (Table 6).

We have to take into account that the inversion process of the data array is poorly constrained between 7 and 27 Hz. Other independent information for this site as the advanced Microzonation study allowed us to compare the velocity profile of this site with others retrieved in the neighborhoods in the same geological setting. Data available suggest that velocity values, especially of the shallower layers, are similar but a little lower in general. Results of this characterization could change adding some more info in the aforementioned frequency band to better constrain the velocity profile, whenever available.

$V_{s,eq} = V_{s30}$ [m/s]	Soil class (NTC 2018)	Soil class (EC8)
593.6	B	B

Table 6: Soil Class

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GENERAL INFORMATION

Authors	Institutions	Contacts [email]	Compiling date [DD/MM/YY]

Station description

Station name	Network code	Latitude [WGS84]	Longitude [WGS84]	Sensor depth [m]

Site characterization summary

Indicators		
fo +/ std [Hz]	Value	Quality index Qi1
	References	
	URL of report	
Velocity profiles [YES/NO]	Value	Quality index Qi1
	References	
	URL of report	
Vs30 +/ std [m/]	Value	Quality index Qi1
	References	
	URL of report	
Surface geology [short description]	Value	Quality index Qi1
	References	
	URL of report	
Seismological bedrock depth +/ std [m]	Value	Quality index Qi1
	References	
	URL of report	
Site class EC8	Value	Quality index Qi1
	References	
	URL of report	
Engineering bedrock depth +/ std [m]	Value	Quality index Qi1
	References	
	URL of report	

Distance from the seismic station [m]		Final quality index (Final_QI)	Comments
min	min		

RESONANCE FREQUENCY

fo +/ STD [Hz]
Quality index 1

Source	Earthquake	Ambient noise

Ambient noise

Method	H/V	Ellipticity	Other
fo +/ std [Hz]			

Experiment date [DD/MM/YY]	Distance from station [m]	Lat. [WGS84]	Lon. [WGS84]

Environment

Weather conditions	Sunny	Windy	Rain
Soil sensor coupling	Earth	Asphalt	Artificial
Urbanization	None	Dense	Scattered

Equipment

Sensor	Type [acc/vel]	manufacturer	cut off frequency [Hz]
Digitizer	Type	Manufacturer	Sampling frequency [Hz]
Measurement	Number	Duration [min]	

Analysis

Software	
Smoothing type (e.g. triangular, Konno Ohmachi, ...)	Window length [s]

Fo uncertainty estimate from

Fo from individual windows	H/V curve width	Manual picking

Earthquake

Method	HVSR	SSR	GIT	Other
fo +/ std [Hz]				

Recording period [DD/MM/YY]		Number of earthquakes	Epicentral distance [km]		Magnitude range	
from	to		from	to	from	to

HVSR

Seismic phase	P	S	Coda	S + coda	All	window duration [s]	Min	Max

SSR

Seismic phase	P	S	Coda	S + coda	All	window duration [s]	Min	Max
Reference station	Lat. (WGS84)	Lon. (WGS84)						

GIT

Parameters	Free (to be inverted)	Imposed
Reference paper		
Reference station	Lat. (WGS84)	Lon (WGS84)

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Vs30

Vs30 +/ STD [m/s]
Quality index 1

Source	Geophysical measurements	Geotechnical measurements	Digital Elevation Model (DEM)	Geology	DEM & Geology

Geophysical measurements

Method	Surface waves methods (active, passive methods)	Borehole methods (DH, CH, PS Logging)
Vs30 +/ STD [m/s]	From Vs(z)	From Down Hole
	From Vr40	From Cross Hole
	From Vsz Vs30 correlation	From PS Logging
Reference relationship Vsz Vs30		

Geotechnical measurements

Method	N SPT	CPT	Shear strength	OTHER
Vs30 +/ STD [m/s]				
Experiment date [DD/MM/YY]	Distance from station [m]	Lat. [WGS84]	Lon. [WGS84]	

Reference relationship Vs30 geotechnical parameter	N-SPT
	CPT
	Shear strength
	Other

Geology

Method	Geological map	Stratigraphic log
Vs30 +/ STD [m/s]		
Geological map scale		
Geological unit name		
Stratigraphic log	Experiment date [DD/MM/YY]	Lat. [WGS84]	Lon. [WGS84]
Reference relationship Vs30 geology		
Reference relationship Vs30 Stratigraphic log		

Digital Elevation Model

Vs30 +/ STD [m/s]
DEM resolution
Reference relationship Slope Vs30

Slope range (degree)	from
	to

DEM & Geology

Vs30 +/ STD [m/s]
Reference relationship Slope Vs30 geology

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SERA Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe

Vs profile

Quality index 1

Source	Non invasive methods (active and/or passive seismics)		Invasive methods (measurement in borehole)
	Active surface waves	Refraction	Cross-hole / Down-hole
	Passive surface waves	Refection	Geotechnical methods (CPT, SPT, ...)
	HV / ellipticity		PS-Logging

Non invasive : surface waves methods

Experiment date [DD/MM/YY]	Distance from station [m]		Lat. [WGS84] center location	Lon. [WGS84] center location
	Min	Max		

Active surface waves acquisition layout

Minimum receiver spacing (m)	Geophone cut-off frequency (Hz)
Profile length (m)*	Geophone type (vertical / horizontal)
Geophones number	Geophone manufacturer
Number of profiles	Source (hammer, vibrator, ...)
	Digitizer type
	Digitizer manufacturer

* Provide the length for the various profiles (e.g. 46 m, 94 m)

Weather conditions	Sunny	Windy	Rain	Soil sensor coupling	Earth	Asphalt	Artificial	Urbanization	None	Dense	Scattered

Passive surface waves acquisition layout

Number of sensors	Sensor cut-off frequency (Hz)
Minimum array aperture	Sensor type (vertical / horizontal)
Maximum array aperture	Sensor manufacturer
Number of arrays	Digitizer type
Minimum duration [min]	Digitizer manufacturer

Weather conditions	Sunny	Windy	Rain	Soil sensor coupling	Earth	Asphalt	Artificial	Urbanization	None	Dense	Scattered

Type of dispersion and/or H/V estimates

	Reference paper (Name, Journal, DOI)
Rayleigh DC	
Love DC	
Ellipticity	
H/V (DFA, EHVR)	
H/V (SH)	

Dispersion curves

	Rayleigh	Love
Min wavelength (m)		
Max. wavelength (m)		
Min. phase vel. (m/s)		
Max. phase vel. (m/s)		
Modes (R0, L0, ...)		

H/V or Ellipticity curves

Min. frequency (Hz)	Max. frequency (Hz)

Inversion

Rayleigh waves	Love waves	Ellipticity curves	H/V (DFA, EHVR)	H/V (SH)	resonance frequency

A priori information used in inversion	seismic refraction	stratigraphic log	geotechnical information	water table depth

Inversion algorithm/code
Reference

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Non invasive : body waves methods

Experiment date [DD/MM/YY]	Distance from station [m]		Lat. [WGS84] center location	Lon. [WGS84] center location
	Min	Max		

Acquisition layout

Receiver spacing (m)	
Profile length (m)*	
Geophones number	
Number of profiles	
Shot spacing (m) - reflection meas.	

* Provide the length for the various profiles (e.g. 46 m, 94 m)

Geophone cut-off frequency (Hz)	
Geophone type (vertical / horizontal)	
Geophone manufacturer	
Source (hammer, vibrator, ...)	
Digitizer type	
Digitizer manufacturer	

Weather conditions	Sunny	Windy	Rain	Soil sensor coupling	Earth	Asphalt	Artificial	Urbanization	None	Dense	Scattered

Processing methods

	Reference paper (Name, Journal, DOI)
classical refraction	
refraction tomography	
classical reflection	
advanced method	

Invasive methods

	Down Hole	Cross Hole	PS Logging	SPT	CPT	OTHER
Borehole depth (m)						
Geophone type						
Source type						
Distance between wells						
Depth resolution (m)						
Latitude (WGS84)						
Longitude (WGS84)						
Distance from station (m)						
P-wave velocity						
S-wave velocity						

Processing methods

	Reference paper (Name, Journal, DOI) or ASTM norm
Down-Hole	
Cross-Hole	
PS-Logging	
SPT	
CPT	
OTHER	

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Authoritative velocity profile

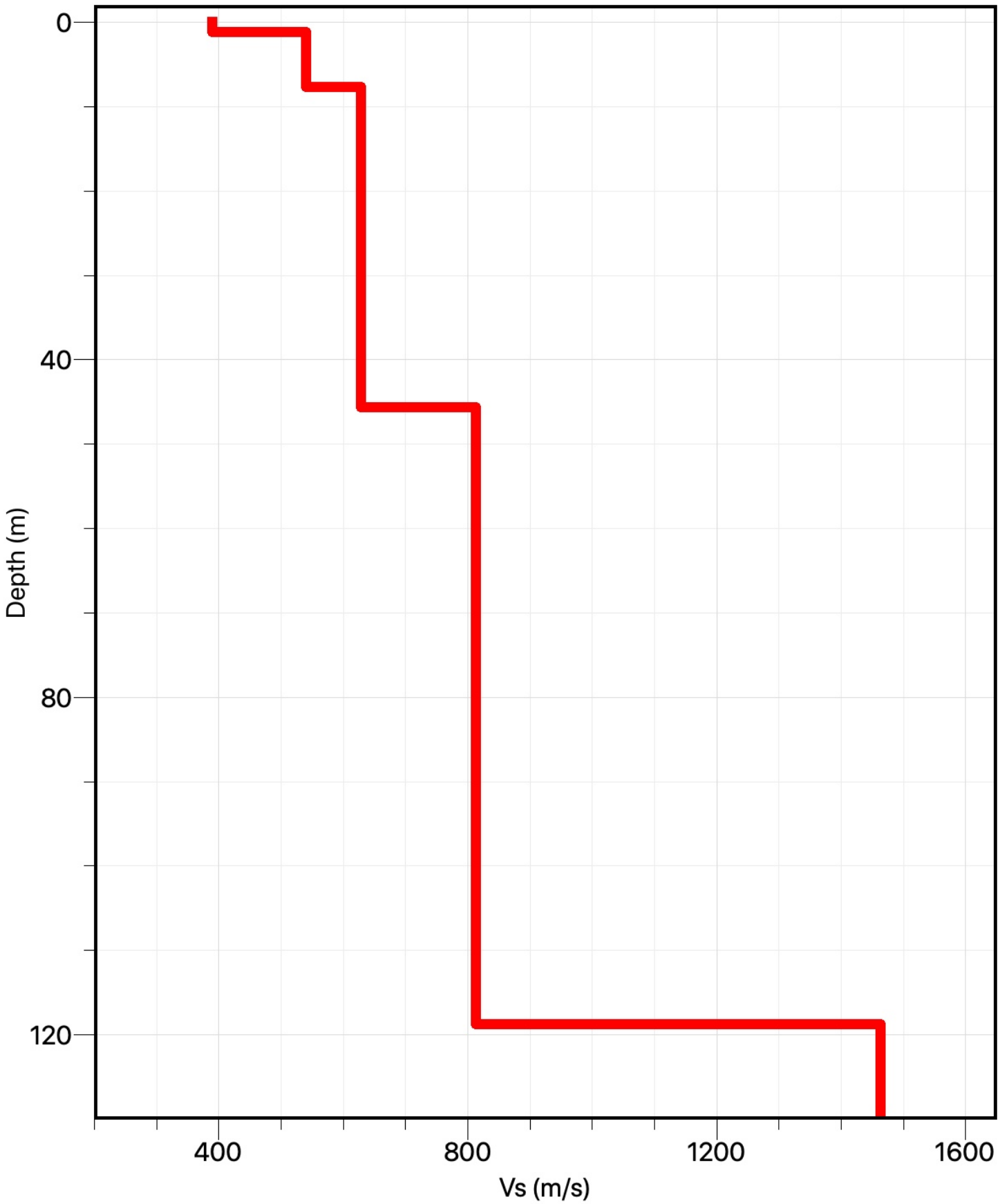
Note: You do not have to fill in all the columns. You can provide either single values for Vp or Vs (e.g. profiles derived from borehole measurements) or either a range for Vp and Vs (e.g. profiles derived from stochastic surface waves inversion)

Is Vs derived from Vp ?	Yes	No

Top depth (m)	Bottom depth (m)	Vp (m/s)	STD Vp (m/s)	Vs (m/s)	STD Vs (m/s)

Vs range		Vp range	
Vs min (m/s)	Vs max (m/s)	Vp min (m/s)	Vp max (m/s)

Figure with authoritative velocity profiles


0
40
80
120
Depth (m)
400
800
1200
1600
Vs (m/s)

Surface geology

Quality index 1

Source	Cartography (geological, lithological, ...)	Field survey	Stratigraphic log

Geological map

Map reference	
Map scale	
Map sheet	
Predominent geologic/lithologic unit	Name :
	Description :
	Age :
	Thickness :
	Rock mass structure :
Fault presence	
Weathering	
Cross section	

Field survey

Map reference	
Map scale	
Predominent geologic/lithologic unit	Name :
	Description :
	Age :
	Thickness :
	Rock mass structure :
Fault presence	
Weathering	
Cross section	

Stratigraphic log

log depth (m)

Top depth (m)	Bottom depth (m)	Stratigraphic description

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Map

Site class

Site class
Quality index 1

Reference building code for site classification
(EC8 1, EC8 2, NEHRP, national code, ...)

Source	Geophysical measurements	Geotechnical measurements	Digital Elevation Model (DEM)	Geology	DEM & Geology

Reference relationship geology soil class
Reference relationship slope from DEM soil class
Reference relationship slope from DEM geology soil class

Parameters for deriving soil class as prescribed in building code

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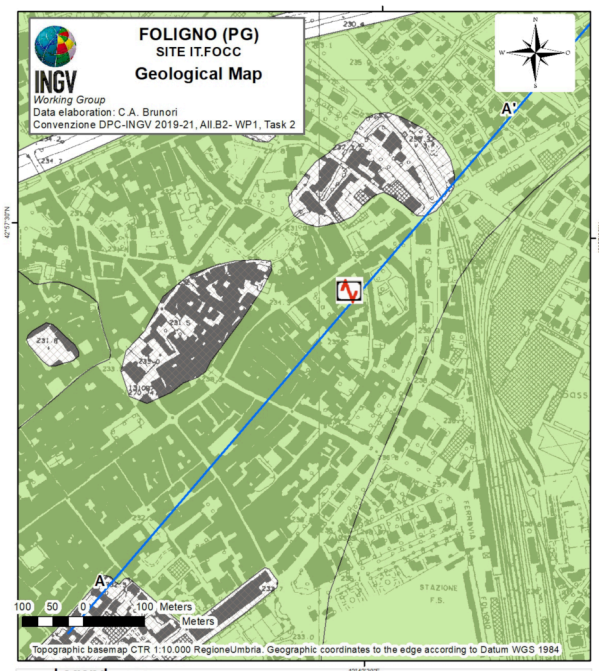

Legend

- Seismic station
- Trace of geological section
- h — Anthropic deposit Olocene
- b — Alluvial and conoid deposits (Pleistocene? Olocene)

Seismological bedrock depth

Depth +/ STD [m]
Quality index 1

Source	Vs profiles	Geology	Other (gravity, seismic refraction, TDEM, ...)
	Resonance frequency	Stratigraphic log	

Vs profile

	Non invasive methods	Invasive seismic methods	Geotechnical methods
Bedrock depth +/ STD(m)			
Bedrock Vs +/ STD(m)			
Bedrock Vp +/ STD(m)			
Is Vs derived from Vp ?	Yes	No	

Resonance frequency

Bedrock depth +/ STD(m)
Reference relationship Fo bedrock depth

Geology

Bedrock depth +/ STD(m)
Bedrock geological unit
Reference

Stratigraphic log

Bedrock depth +/ STD(m)
Bedrock geological unit
Reference

Other methods

	Bedrock depth +/ STD(m)	Reference
Gravity		
Seismic refraction		
Seismic reflection		
TDEM		

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Engineering bedrock depth

Depth +/ STD [m]
Quality index 1

Reference Vs related to engineering bedrock in m/s	Reference building code for site classification (EC8 1, EC8 2, NEHRP, national code, ...)

Source	Vs profile	Geology	Stratigraphic log

Vs profile

	Non invasive methods	Invasive seismic methods	Geotechnical methods
Bedrock depth +/ STD(m)			

Is Vs derived from Vp ?	Yes	No

Geology

Bedrock depth +/ STD(m)
Bedrock geological unit
Reference

Stratigraphic log

Bedrock depth +/ STD(m)
Bedrock geological unit
Reference

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