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in the Marmara Supersite

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D9.2

Prototype Landslide Early Warning Monitoring System for the Marmara Region

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PU	Public	
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

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1 CONTEXT

The FP7 MARSITE WP9 workpackage (http://marsite.eu/), leaded by KOERI, has the objective to improve the existing earthquake early warning (EW) and Rapid Response (RR) systems in the Marmara Region, including the installation and test of a pilot seismic landslide monitoring system.

In the framework of the WP9 a first observation prototype system was set up on an active but slow landslide in the Avcilar-Beylikdüzü Peninsula, a large landslide prone area located in westward part of Istanbul and facing the NAF. The survey and investigations were part of WP6.

The prototype observational system is a multi-parameter type. It is composed of GPS devices to measure 3D displacement, seismic probes for seismic shaking, piezometers for pore pressure in the subsurface soils, and a rainfall meter to monitor

Data are transmitted in near to real-time using high speed cellular mobile network to an infrastructure featuring seamless data base management of raw data, processing and sharing both data and results of the monitoring through a dedicated web-monitoring secured page playing the role of a monitoring desk.

This monitoring aims first to collect data on a large and slow landslide on the geological setting of the Avcilar peninsula for a better understanding of the landslide mechanism versus time, underground pore pressure and seismic ground motion. Second, it is aimed to assess the technological integration of the system for both real-time warning (development of large displacements induced by a combination of precipitations and seismic ground motion) towards potential end-users in both situations: response of the mass during a major event, and response assessment after a major event for better decision making. Time series obtained in the near future will contribute to the development of procedures aiming at the detection and definition of a seismic landslide warning system.

As it results from previous studies, the Avcilar-Beylikdüzü peninsula has a high susceptibility to slope instabilities as almost the 84% of the area is landslide-prone (Duman et al., 2006). About 19% of the area is covered by deep-seated landslides that are primarily located in sandstones with interbedded permeable and impermeable layers such as clay-stone, siltstone and mudstone and about 32% of the total landslide area corresponds to these deposits.

This deliverable synthesizes the installation of this pilot landslide monitoring system.

Partial overview of the Beylikduzu landslide from the roof terrace of the shopping center.

2 INTRODUCTION

The first step of the installation had begun on the 15th July 2014 and the second phase on the 20th October 2014. INERIS in collaboration with UNIVERSITY OF ISTANBUL, KOERI and TUBITAK was in charge of the installation, testing and preliminary validation of a surface ground movement tracking device GPS measurements.

Recall that the instrumented borehole was drilled and equipped as part of a large scale geological and geotechnical survey of the area driven by the Istanbul Metropolitan Municipality and TUBITAK.

The monitoring system on the field is made up of:

A GPS-RTK system based on the state of the art technologies of differential GPS, this station is designed for periodic 3D displacement measurements with a precision up to a couple of centimeters. Its rugged, wireless and low power consumption conception allows it to be easily deployed on the field in most situations. This system is composed by:

- A reference GPS station, located in a steady renowned area, on the upper roof of the Shopping Center in Gürpınar. Because of its stability, it transmits measurement corrections to GPS measurement devices on the field, offering much better precision in the displacements. It is necessary that the radio antenna of each GPS station has a reasonable line-of-sight to the reference station and a distance less than 1.000 meters.
- Two measurement stations, installed in the active area: Station 1 – so-called "Farm" station, is installed on a first morphological compartment of the landslide. This station is installed in a private property.
- Station 2 – "House", also installed on a second compartment of the landslide, on the roof of a house under construction.

Seismic measurements consist in:

- Two 3D seismic probes (installed at the bottom, -45m, and on the surface of a 70 meters deep borehole close to the farm station) to measure seismic ground motion.

Geotechnical system:

- Two Piezometers installed at the Farm station measuring pore pressure at different depth (-36m and -51m) in the borehole.
- A moisture sensor, installed at the farm station horizontally and about 30 cm deep.
- A rainfall meter and a temperature sensor at the House station.

Digital raw data are concentrated to a SYTGEM-vlp acquisition unit which was also installed at the Farm station.

A layout diagram and a technical diagram are available in Appendices A and B while pictures of the installation are shown in Appendices C, D and E.

3 TIME SCHEDULE OF FIELD WORKS

DATE	ACTIONS PERFORMED
15-17/07/2014	- Site survey, administration work, technical preparation
18/07/2014	- Equipment delivery - Masts preparation and installation (Farm station and House station)
19/07/2014	- RGPS installation and pairing (Farm station and House station) - RM receiver & rainfall meter installation at the House station - Batteries boxes installation at the house station and the farm station - Piezometers and probes instrumentation in boreholes - Starting of data acquisition
20/10/2014	- Replacement of the omnidirectional antenna at the Shopping Center with a more powerful one : YAGI antenna - Orientations measures of the two probes (using an electronic compass – 3D Pod) - Probes cabled to the Acquisition unit - Moisture sensor installation and cabled at the farm station
21/10/2014	- Piezometers wiring - Monitoring and control of the microseismic measurements (triggering, noise measurements, dynamic solicitation of the sensor, duration, etc.) - Rainfall meter calibration - GPS measurements calibration

4 HARDWARE ITEMS INSTALLED

STATION	DESIGNATION	REFERENCE	SERIAL NUMBER	QUANTITY
Shopping Center	SYTGEO RGPS receiver with radio antenna + GPS antenna (reference GPS)	50-03-029-003	04820902	1
	RGPS Trimble Antenna	AT1675-382PW	10118	1
	YAGI directional antenna	50-03-049-000	-	1
Farm Station	SYTGEO RGPS receiver with radio antenna integrated + GPS antenna (MES 1)	50-03-029-003	04820901	1
	RGPS Trimble Antenna	AT1675-382PW	10123	1
	SYTMIS seismic Probe (at the bottom – 46m)	3DBSS-PVC-X-OD-HS1LT-LP30/50	14005	1
	SYTMIS seismic Probe (at the surface – 1m)	3DBSS-PVC-X-HS1LT-LP20/40	14006	1
	Piezometer (51m)	VWP-3001	329957	1
	Piezometer (36m)	VWP-3001	329889	
	Moisture sensor	AT210	-	1
	Acquisition Unit	SYTGEM-vlp	12002	1
	Timestamp GARMIN GPS	19XHVS	2J5020001	1
	SYTGEO R4 board	50-03-033-000	03022202	1
	Batteries	12V 120Ah		3
House station	SYTGEO RGPS receiver with radio antenna integrated + GPS antenna (MES 2)	50-03-029-003	03021602	1
	RGPS Trimble Antenna	AT1675-382PW	10124	1
	Rainfall meter	R23029	-	1
	Temperature sensor	6470	-	1
	SYTGEO RM receiver	50-03-034-000	03136201	1

	Batteries	12V 120Ah		1

Batteries are :

- Recharged once every two months by our partners in Turkey. To do so, the batteries are removed, put in charge at the University and replaced by those fully recharged.

5 VALIDATION OF MEASUREMENTS

5.1 Reference Frame

For each of the GPS station, displacements along Latitude, longitude, and Altitude axis are measured versus time. The measurements obtained are analyzed based on the following conventions:

Latitude	↗	Northwards
	↘	Southwards
Longitude	↗	Eastwards
	↘	Westwards
Altitude	↗	Up
	↘	Down

5.2 Initialization and recording of the gps station positions

Several measures of a few minutes each were realized at each station in order to input the initial altitude, longitude and latitude of the positions in the acquisition system configuration.

5.2.1 Reference station “shopping center”

The average value – plus the geoid height (the value of the geoid height is added only over the reference value because it is a fixed data which does not vary) is:

Station	ID	Latitude	Longitude	Altitude
Shopping Center	RGPS_REF	41°0’ 941960 N	28°37’619712 E	299 m

5.2.2 “Farm” station

The average value is:

Station	ID	Latitude	Longitude	Altitude
Farm	RGPS_MES1	41°0’ 575211 N	26°37’023350 E	118,37 m

5.2.3 “House” station

The average value is:

Station	ID	Latitude	Longitude	Altitude
House	RGPS_MES2	41°0’ 512230 N	28°36’759728 E	84,98 m

5.3 Calibration of GPS-RTK measurement

A calibration of the two stations was performed using a GPS calibration device. This operation (done on the "shopping center" as the reference marker) consists in shifting the antenna of a predefine amplitude (typically a few centimeters) along a reference well oriented axis (longitude, latitude, vertical). It allows us to check the correct measurement of each GPS station including amplitudes, directions and polarity convention (positive, negative) for each measurement axis. The measurements are performed during 15 minutes.

The calibration device has 5 axes of different measures. Calibration position No. 1 will be used as the reference. Relatively to this position, two extra measures, called No. 2 and No. 3 were then tested:

- Position No. 2 is 50mm down and 50mm northwards
- Position No. 3 is 50mm down and 20mm eastwards

5.3.1 Calibration of the “Farm” station – measure No. 1

Position No. 1 (Reference):

	Latitude mm	Longitude mm	Altitude mm
Reference value (mm)	0	-3,6	176

Position No. 2:

	Latitude mm		Longitude mm		Altitude mm	
Abs. Measurement (mm)	+47,3		-15,8		+122	
Theoretical variation (mm)	**+50**		**0**		**-50**	
Measured variation (mm)	**+47,3**		**-12,2**		**-54**	
Error	-2.7		-12,2		-4	
Conform variation according to ± 20mm with the theoretical variation	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
	X		**X**		**X**	

Position No. 3:

	Latitude mm		Longitude mm		Altitude mm	
Abs. Measurement (mm)	-9,2		-19		125	
Theoretical variation (mm)	**0**		**-20**		**-50**	
Measured variation (mm)	**-9,2**		**-22,6**		**-51**	
Error	-9.2		-2.6		-1	
Conform variation according to ± 20mm with the theoretical variation	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
	X		**X**		**X**	

5.3.2 Calibration of the "House" station – measure No. 2

Position No. 1 (Reference):

	Latitude mm	Longitude mm	Altitude mm
Reference value (mm)	-0,2	-3	171

Position No. 2:

	Latitude mm		Longitude mm		Altitude mm	
Abs. Measurement (mm)	47,4		-15,7		121	
Theoretical variation (mm)	**+50**		**0**		**-50**	
Measured variation (mm)	47,6		-12,7		-50	
Error	+3,4		-12,7		0	
Conform variation according to ± 20mm with the theoretical variation	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
	X		**X**		**X**	

Position No. 3:

	Latitude mm		**Longitude** mm		**Altitude** mm	
Read value (mm)	-5,6		-19,5		121	
Theoretical variation (mm)	**0**		**-20**		**-50**	
Read variation (mm)	-5,4		-16,5		-51	
Error	-5,4		+3,5		+1	
Conform variation according to ± 20mm with the theoretical variation	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
	X		X		X	

5.3.3 Data interpretation

The measurements are conform with theoretical variations indicating that GPS positions are correct.

5.4 Control of the seismic acquisition system

5.4.1 Sensor characteristics

The sensor has been chosen as a trade-off between frequency range sensitivity and compactness for installation in a probe and then in a small borehole.

Sensor Type	2 Hz GEOSPACE
Bandwidth +-3dB	1.5 Hz – 250 Hz
Inherent sensibility	2.00 V/in/sec

Technical file product in appendix H.

5.4.2 Autotest

The seismic noise (manually triggered on files) is conform, as well as AUTOtests. Indeed the functioning of the microseismic acquisition system is daily tested by the triggering of a calibrated signal (double square wave) generated inside the seismic probes. The automatic transmission, reception and processing of the calibrated signal at expected time intervals guarantees the correct functioning of the measuring system from downhole up to the datacenter at INERIS.

5.4.3 Triggering criteria for seismic acquisition

Sampling frequency	1 kHz
Pre-event	Fixed, 20s

Threshold	≈ 1.10^{-3} mm/s
Duration of exceeding threshold	0.05 s
Duration	Auto-adaptative, 25s minimum
Triggering probe	Bottom

Channel name	Position	Sensibility	Gain (dB)	Gain (cfg)
1. MFoX	Bottom -45 m below surface	76,2 V/m/s	50	316
2. MFoY			50	316
3. MFoZ			50	316
4. MFoz			30	31,6
5. MSuX	Surface		40	100
6. MSuY			40	100
7. MSuZ			40	100
8. MSuz			20	10

Autotest, seismic noise measurements and technical file products are provided in Appendices F, G and H.

5.5 Rainfall meter calibration

The calibration of the rainfall meter ("House" station) was done using a 0,5L water bottle poured quietly and directly in the rainfall meter. The 0,5L of water generated 58 tilts of the bucket mechanism the data indicates 60 tilts by counting the 2 manual tilts to test out the equipment (SytgemMarsite2_004). In theory for 400cm² surface, it should have been 62,5 tilts, so we have a **7% error on rainfall meter**.

5.6 Moisture sensor

The Global Water Soil Moisture Sensor is based on Time Domain Reflectometry (TDR) technology to accurately measure the water content of soil. What this means is that this sensor is a no hassle, no maintenance, long lasting, probe. How TDR sensors work is similar to radar. A high frequency electric signal is pulsed down the probe. The reflection of this signal is proportional to the dielectric constant of the soil surrounding the sensor. The dielectric reading from the sensor is then converted to water saturation and transmits to the monitoring equipment via a 4-20mA signal.
The calibration of the sensor on the field is not easy task to undertake. Since the transduction proposed by the manufacturer is a standard one for common soils, the measurement must be read carefully on the basis of its variation more than its absolute values. Measurement accuracy is not yielded by the manufacturer. Anyway, when plunged in a loose saturated soil the measurement value comes to 100%.

5.7 Piezometers

The vibrating wire piezometers are intended for long-term accurate monitoring of pore pressure in soils. Piezometric sensors are composed of 4 conductors, two for temperature measurement (resistance measurement) and two measurement of piezometric pressure (vibrating wire). It is not possible that a sensor is connected simultaneously to two interfaces, even if one is off.

With these sensors the measuring range is from 0 to 2 bars.

In Appendix I is the calibration table provided by the manufacturer.

5.8 Control, Measuring and Testing Equipment

A detailed list of calibrated equipments and softwares used for this installation are provided in Appendix K.

6 MONITORING MODES

6.1 Sampling frequencies

The acquisition sampling frequencies are fixed as a trade-off considering the expected velocities of physical changes in the different measurements (pore pressure, displacement, etc) and the need to limit the unloading of the batteries packs. Then, to face specific situations with a need for a faster sampling, the system can switch automatically:

- from the **Normal Mode** to a **Vigilance Mode** (Vigilance thresholds exceeded): new sampling frequencies are adopted as parametrized by the operator
- From the **Normal or Vigilance mode** to the **Alarm mode** (Alarm thresholds exceeded), new sampling frequencies are automatically switched to continuous sampling, that is new measurements are done as soon as previous ones are done.

	Normal Mode	**Vigilance Mode**	**Alarm mode**
Rainfall / piezometers / soil humidity	3h (180 min) (1srt at 0 am)	1h (60 min)	≈ 1 min
GPS	12h (1srt at 4 am)	4h	≈ 30 min
Seismic	On trigger	On trigger	On trigger
Data transmission to Cenaris data center, france	8h	4h	Permanent connection

6.2 Alarms management

A software (ALERT) permits the transmission of the detected malfunctions as below:

Autodiagnostic	Alarm if	ALERT
Voltage measurement MES_1 Farm	$Value_{min}$ < 12 V $Value_{max}$ > 28 V	Activated
Voltage measurement MES_2 House	$Value_{min}$ < 12 V $Value_{max}$ > 28 V	Activated
Voltage measurement Acquisition unit	$Value_{min}$ < 22 V $Value_{max}$ > 30 V	Activated
Temperature measurement	$Value_{min}$ < -10 °C $Value_{max}$ > 60 °C	Non Activated
Response time	The response time depends on the type of measurement (meteo, GPS, piezometers…)	Activated
Autotest	If absent or deficient	Activated

6.3 Vigilance Mode

The vigilance mode permits to change automatically the sampling frequency of the different sensors during a given period of time. Vigilance mode is activated on a combination thresholds based on the following criteria:

- High rainfall : threshold setting is in progress
- Displacements : threshold setting is in progress

6.4 Alarm Mode

Alarm mode has not been activated at this early stage of installation due to the lack of background experience on this specific field of experiment. It should be activated as soon as the times series will be more comprehensives.

7 PRELIMINARY DATA ANALYSIS

7.1 GPS data

The quality of GPS data can be monitored through the recording of parameters such as the satellites geometry (DOP – Dilution Of Precision), the average number of satellites, the number of measures and corrections received, the quality of radio link, measurements statistics (min/max, standard deviation), etc. This provides essential information especially when an unusual evolution is observed or during the setting up of the GPS network. These parameters confirm or not the validity of the measures.

The first GPS measurements are stable with just a constant noise of less than a value of 10 mm (Appendix L).

The following table shows minimums, maximums and average measure of detected satellites and DOP for the « Farm » and « House » stations on the given period (01/11/14 to 30/11/14). For the measurements to be valid, the DOP should be less than 2 and the number of satellites greater than 8.

Station	Nb of measures	Measure	Min	Max	Moy
Farm	53	Nb Satellites	14	14	14
		DOP	0,7	0,9	0,8
House	53	Nb Satellites	14	14	14
		DOP	0,7	0,9	0,8

The preliminary GPS measurements are in Appendix L.

7.2 Rainfall data

The rainfall recorded in November is about 50mm which is corresponding to the rainfall recorded by the official weather station (Istanbul / Ataturk weather station) in Istanbul for the same period.

The temperature sensor was placed under cover from the sun. The data are also similar to those recorded by the Istanbul weather station.

The first weather measurements are in Appendix M.

7.3 Piezometers

The deepest piezometer is expected to measure the highest pore pressure (Appendix N). Variations are expected to be quite similar although the complexity of the soil mass is high and disparities in the variations measured by the two sensors are possible.

7.4 Moisture sensor data

The measurements recorded by the moisture sensor (Appendix O) are inconsistent in comparison with other data from the weather station. This problem may come from:

- A soil saturated with water;
- A technical problem directly related to the sensor.

A technical checking of this sensor is to be realized in the near future.

7.5 Seismic data

Instrumental corrections are applied to the waveforms (2 Hz sensor) as well as to those recorded by the TEPTK reference station of TUBITAK (1 Hz sensors), thus enabling a better quantitative comparison of seismic data in terms of amplitudes and frequencies. The first seismic records are in Appendix P and a seism is provided in Appendix Q.

8 e.cenaris WEB MONITORING

The data recorded and processed by INERIS can be viewed and downloaded from the e.cenaris (http://cenaris.ineris.fr/). The site is open to the partners of the WP6 and WP9 project using only a "username" and a "password".

The newly recorded data are transmitted several times a day and automatically integrated in the database management system of the e.cenaris infrastructure.

From the web monitoring desk, pre-defined graphics, tables and maps offer a easy-to-read and precise insight on the incoming dataset to make easier the understanding of the physical measurements, more accurate the interpretation and more efficient the decision making.

Most plots, tables and maps are easily exported to compile reports on line. Documentation related to the project is accessible to share the information between the different partners involved.

It is possible to select and zoom any graphic, XY windows, display options, download any combination of freshly updated plots anytime and anywhere to build your own edition tasks easily. You can also force the page to update, edit and export easily raw and transformed data to complete further analysis with your own tools.

9 CONCLUSIONS

A multi-parameter monitoring system has been set up on the Beylikdüzü landslide, in the Avcilar peninsula, as a pilot site in WP6 Marsite operation. It encompasses with displacement measurement, seismic ground motion, pore pressure underground and rainfall.

This system has been calibrated and started to collect time series from October 20, 2014.

Since the beginning of the installation we recorded 54 seismic events with a maximum magnitude of 5,6 and a minimum magnitude of 1,9 and an epicentral distance ranging from 20 km to 540 km.

All measurements have been checked and qualified, except for the soil moisture sensor.

Data are recorded and transmitted on a near-to-real-time basis to a monitoring infrastructure on a seamless basis for database integration.

It is planned to collect time series in the next few months and then work out the system from purely observational monitoring to early warning prototype.

Appendices

Appendix	Title	Number of pages
Appendix A	Marsite implantation diagram	1 A4
Appendix B	Geological log of the instrumented borehole	1 A4
Appendix C	Pictures of the « Farm » Station	2 A4
Appendix D	Pictures of the « House » Station	2 A4
Appendix E	Pictures of the « Shopping Center » Station	2 A4
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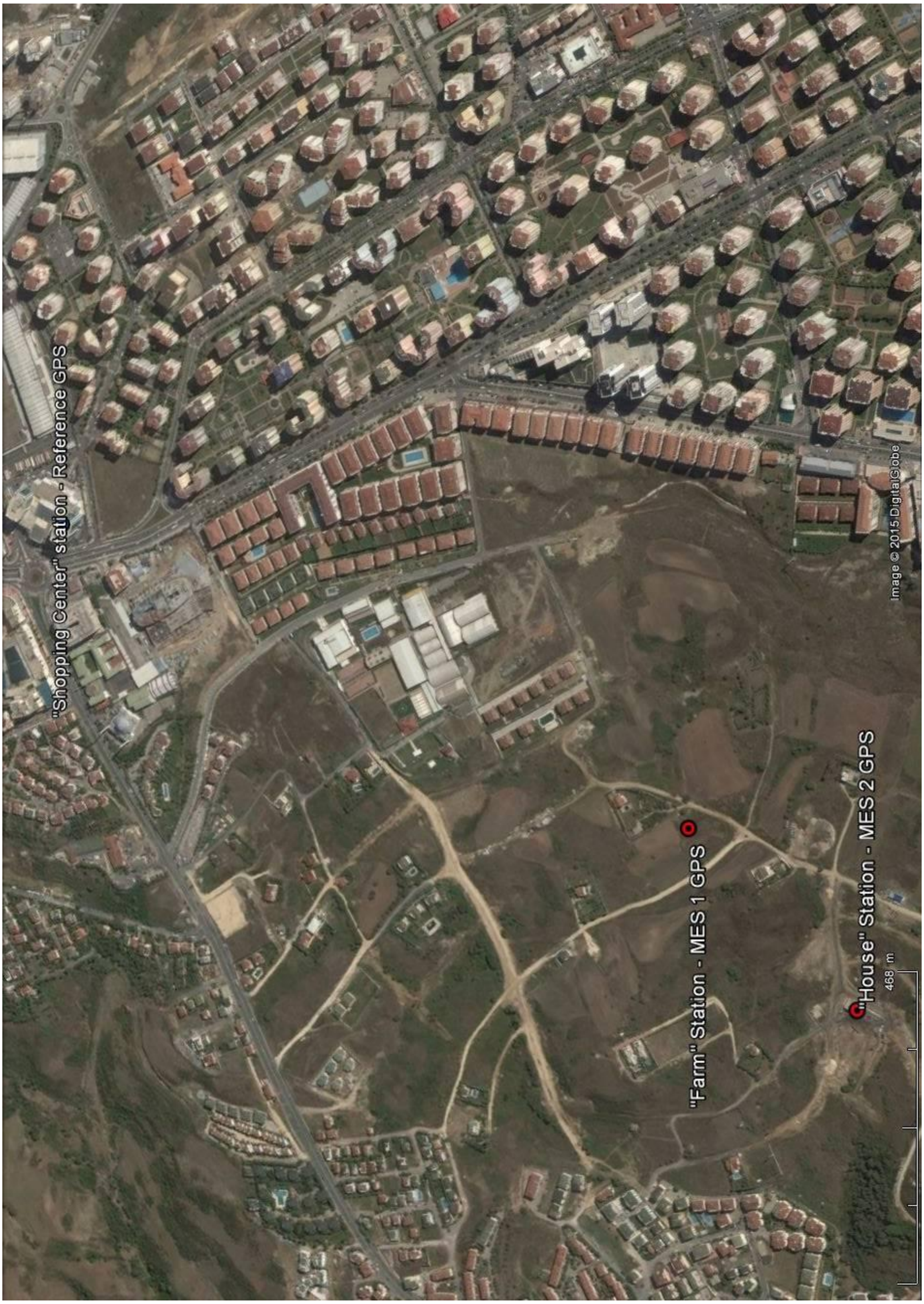
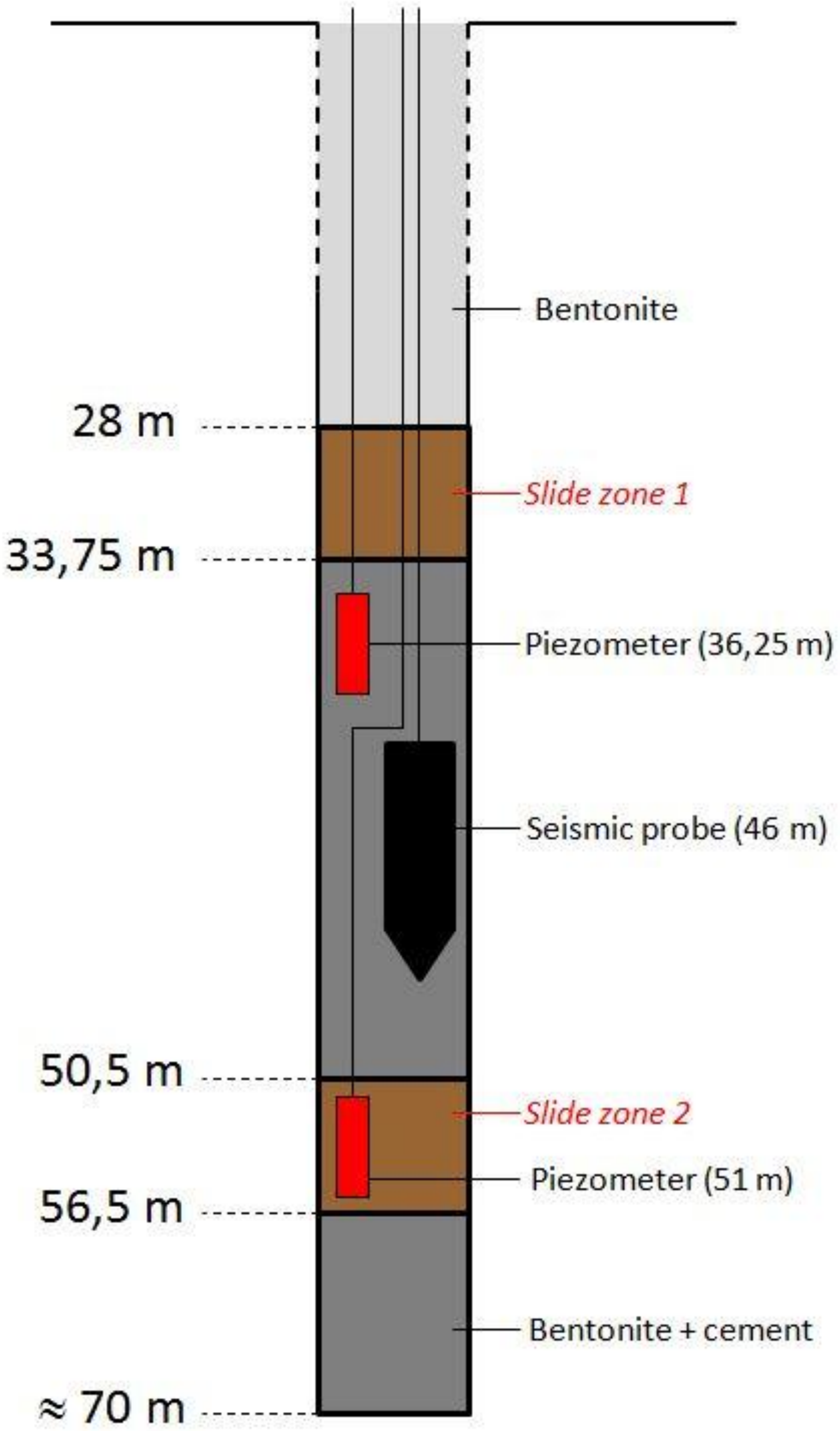
Appendix O	First recorded measurements – Moisture sensor	1 A4
Appendix P	First recorded measurements – Microseismic	3 A4
Appendix Q	22/10/2014 Earthquake	1 A4
Appendix R	Description of the Web Monitoring page opened to the WP6 and WP9 partners	1 A4

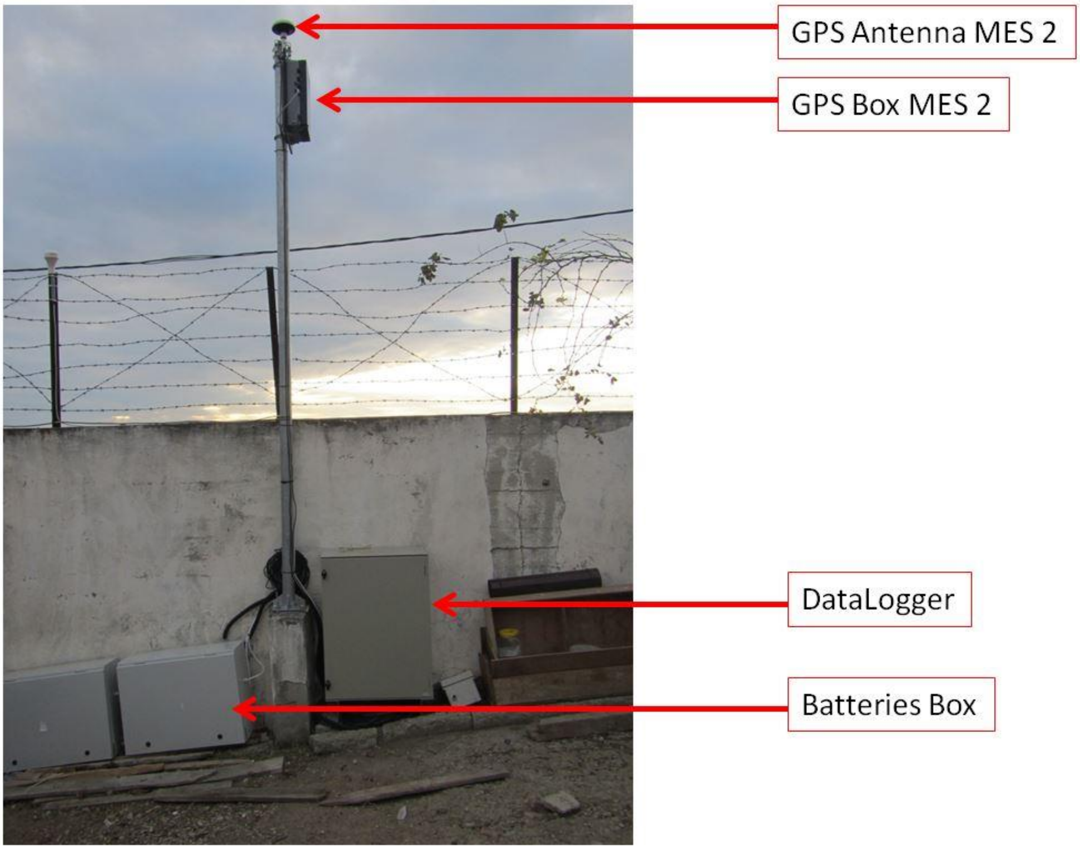
APPENDIX A – MARSITE IMPLATATION DIAGRAM



APPENDIX B – GEOLOGICAL LOG OF THE INSTRUMENTED BOREHOLE



APPENDIX C – PICTURES OF THE "FARM" STATION



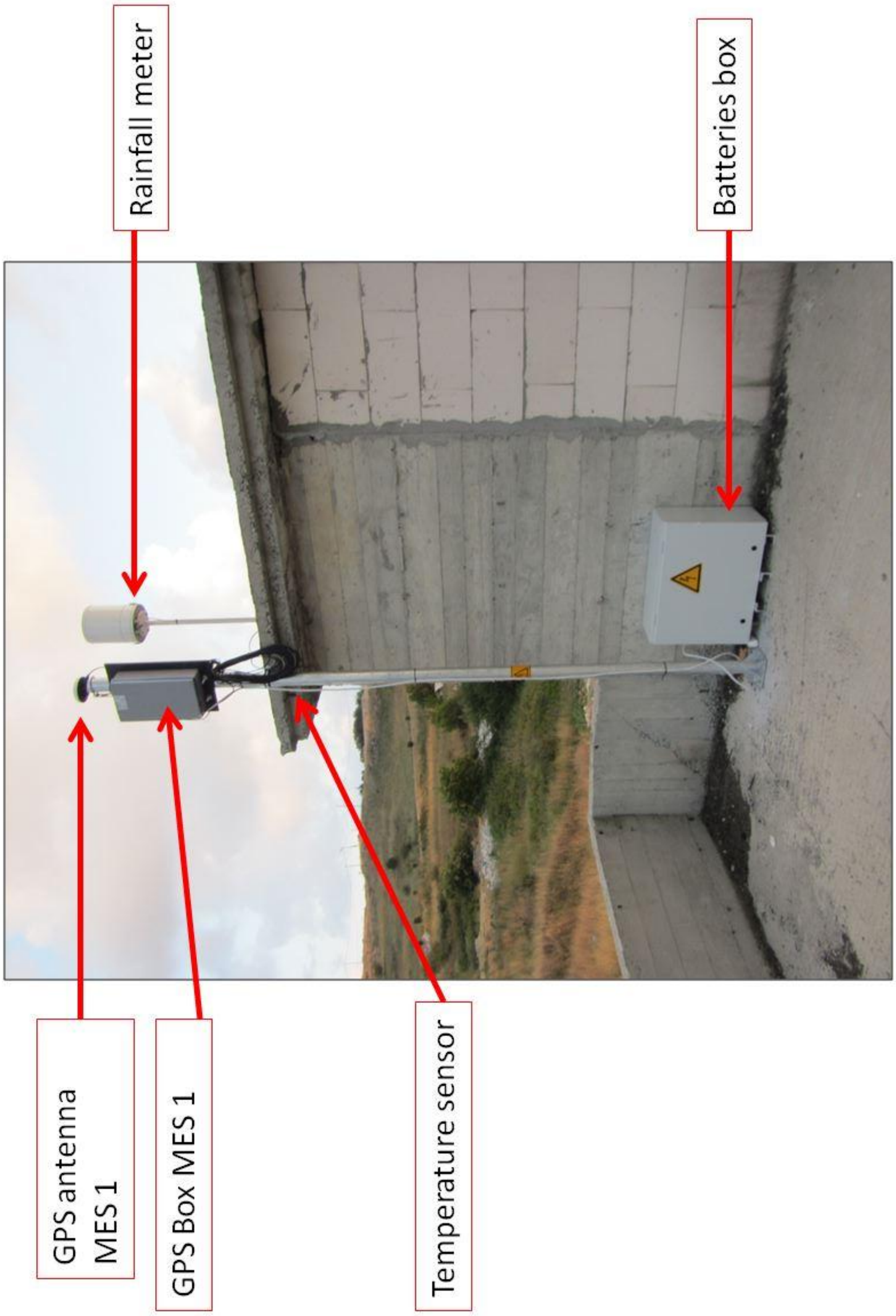
Moisture sensor – Farm Station

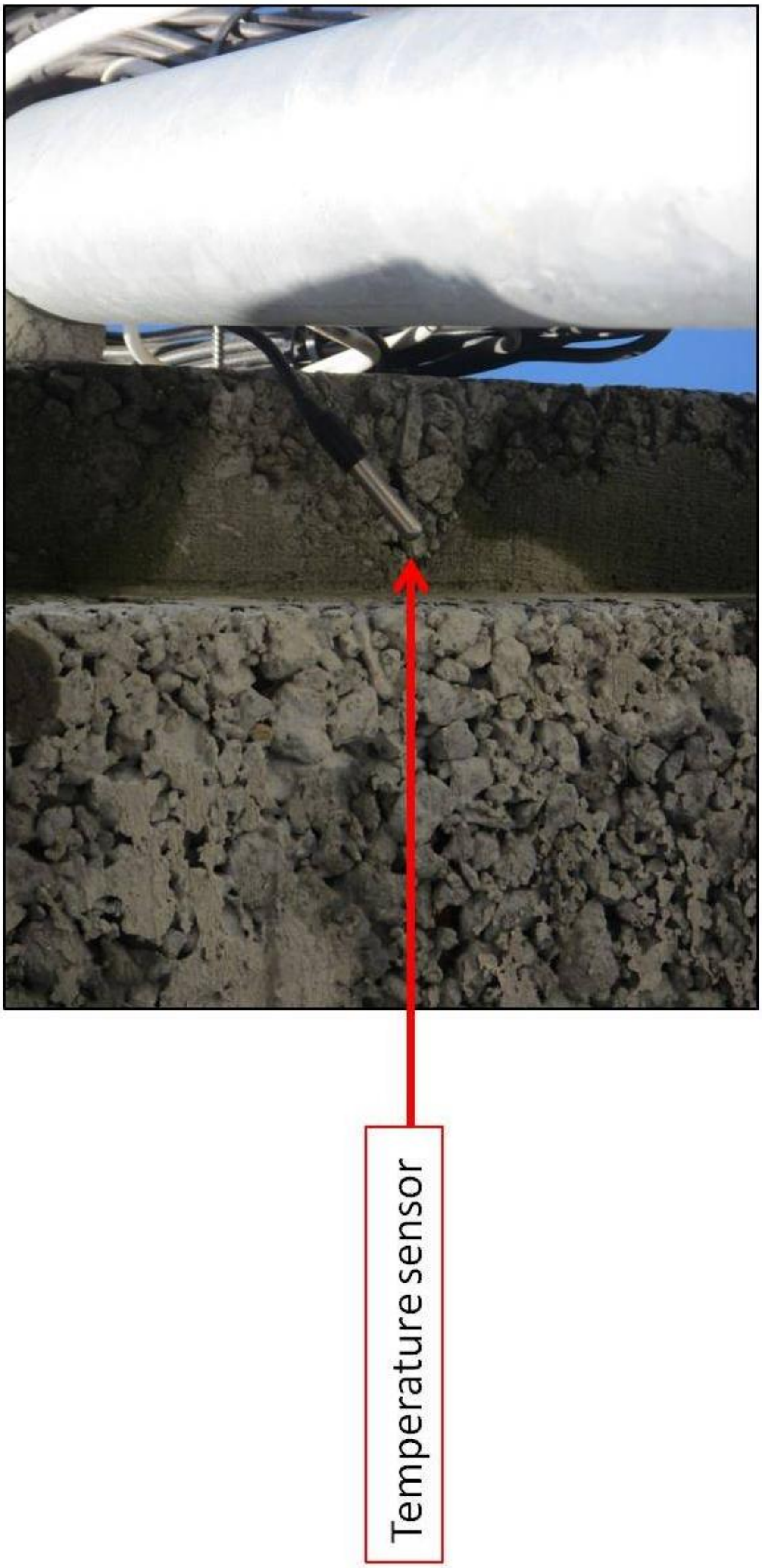
3D Surface probe – Farm Station

Piezometers – Farm Station

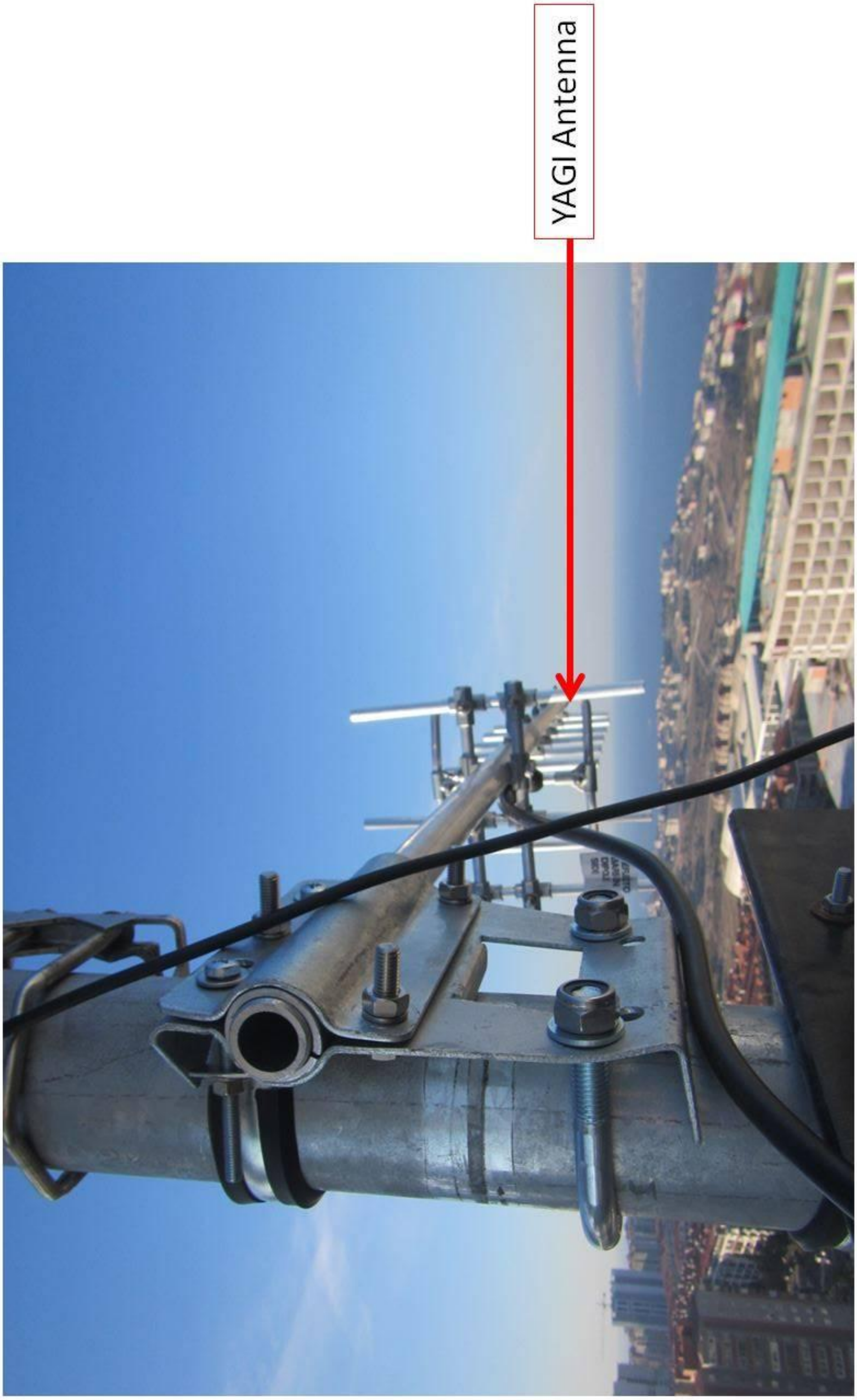
DataLogger – Farm Station

APPENDIX D – PICTURES OF THE "HOUSE" STATION

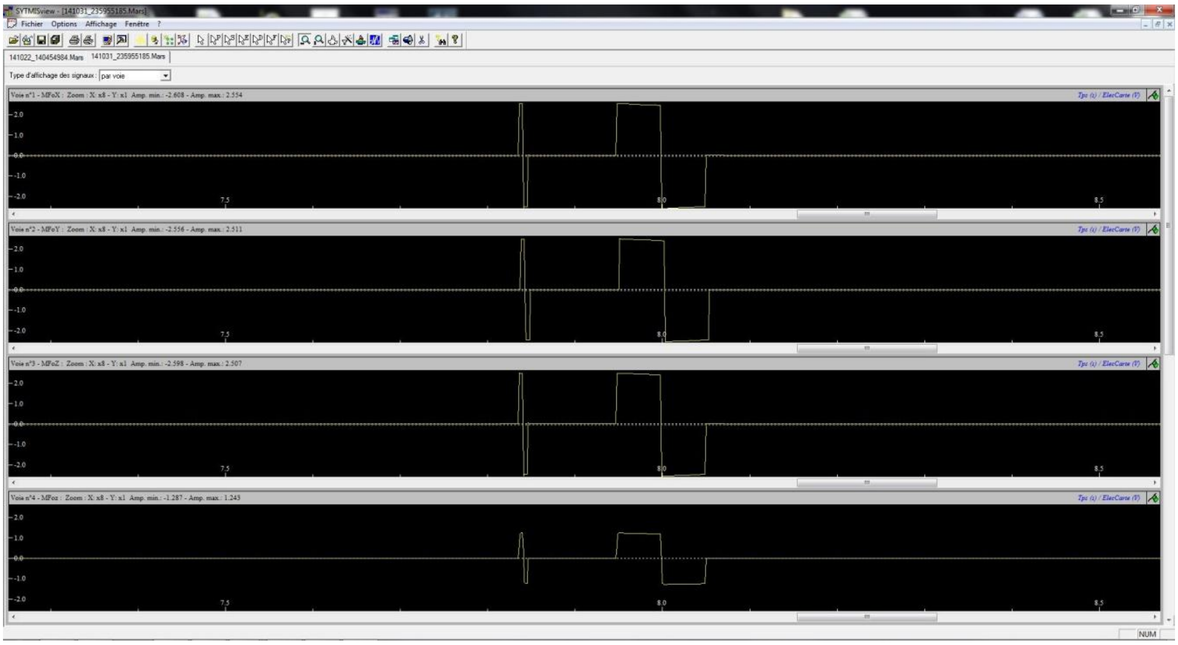


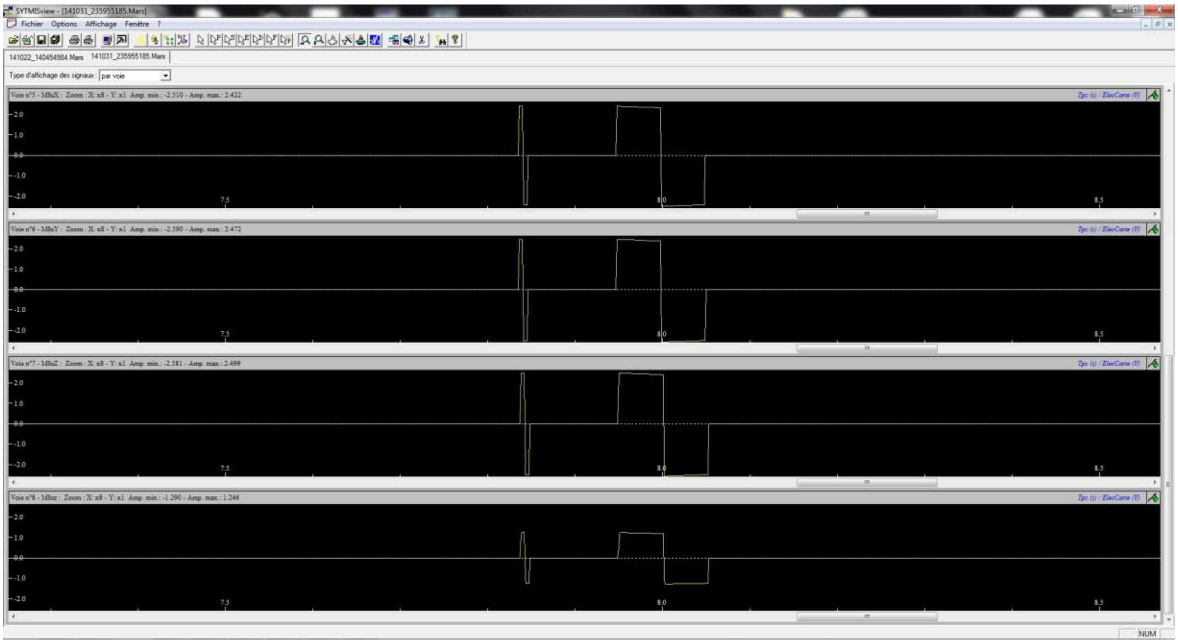

Temperature sensor

APPENDIX E – PICTURES OF THE "SHOPPING CENTER" STATION

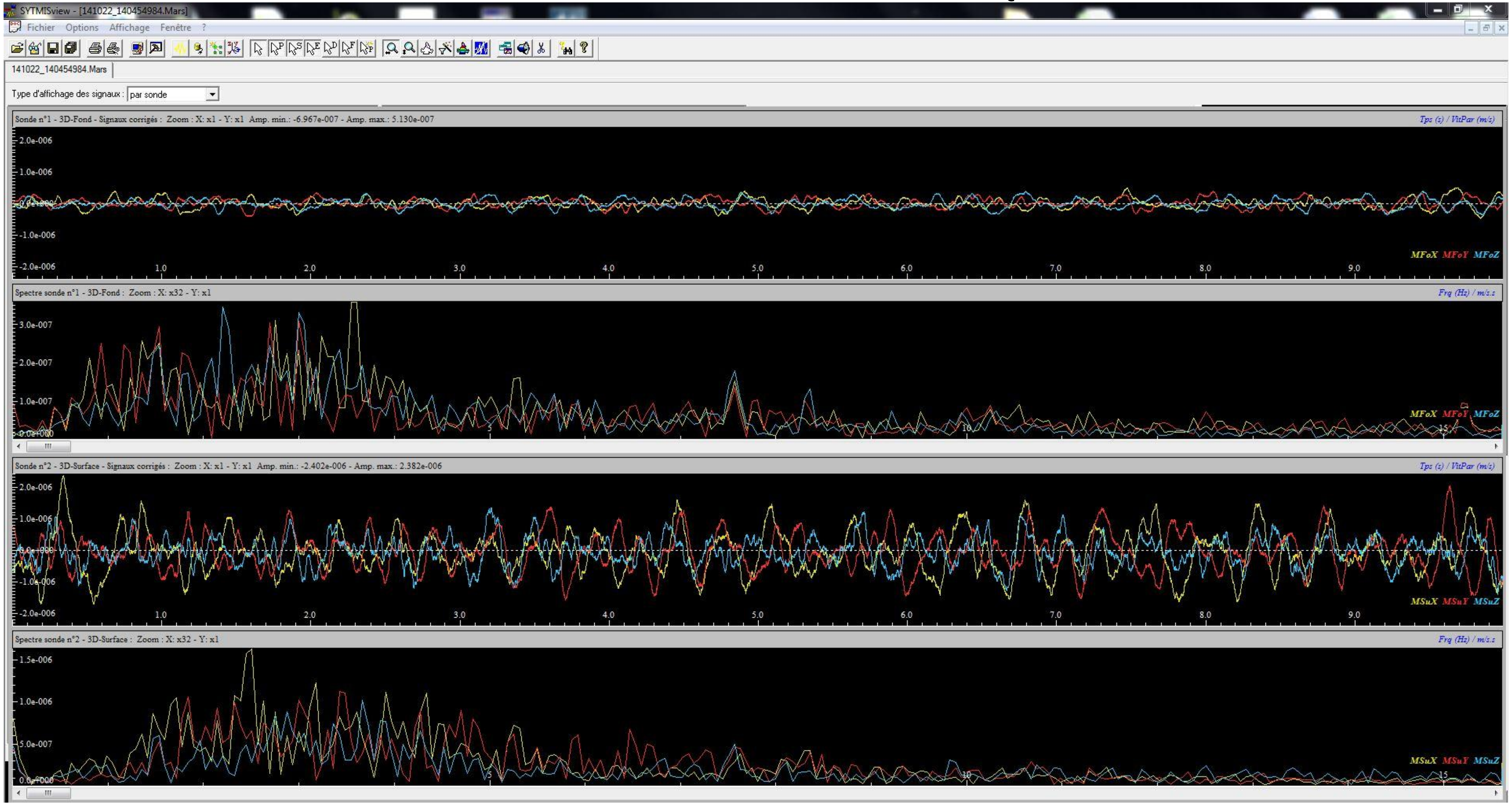

YAGI Antenna

APPENDIX F – SEISMIC AUTOTEST





APPENDIX G – SEISMIC NOISE MEASUREMENT: TIME AND FREQUENCY DOMAINS



APPENDIX H – GEOPHONE TECHNICAL FILE PRODUCT

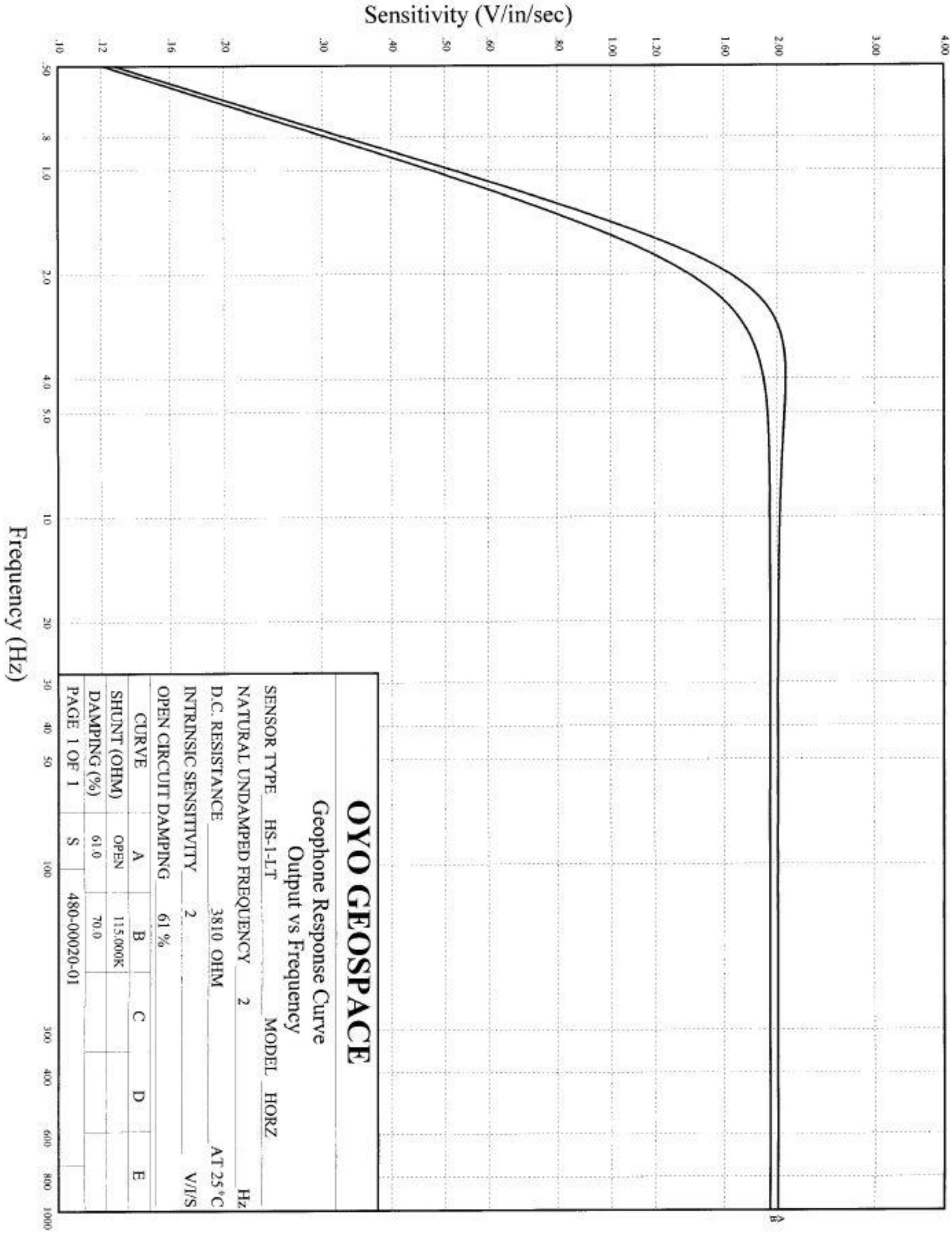
PRODUCT/CUSTOMER SPECIFICATION

GEOPHONE MODEL: HS-1-LT **PART NUMBER:** 480-00020-01

DESCRIPTION	SPECIFICATION @ 25°C	TOL±
ORIENTATION	HORIZONTAL	
OPERATIONAL RANGE	± 0.50 °	
NATURAL FREQUENCY (Fn)		
@ OPTIMUM ORIENTATION	2.0 Hz	.75 Hz
@OPERATIONAL RANGE	2.0 Hz	1.25 Hz
COIL EXCURSION P-P		
@ OPTIMUN ORIENTATION	>.150 in, >.381 cm	MAX: .300 in, .762 cm
@ OPERATIONAL RANGE	>.060 in, >.152 cm	
CLEAN BAND PASS (SPURIOUS RESPONSE)	N.S.	
DC RESISTANCE	3810 Ω	5 %
INTRINSIC VOLTAGE SENSITIVITY (G)	2.00 V/in/sec	10 %
NORMALIZED TRANSDUCTION CONSTANT Coil Resistance (R_c) 3800 Ω	.032 $\sqrt{R_c}$ V/in/sec	
OPEN CIRCUIT DAMPING (B_o)	.61	.25
MOVING MASS (M)	23 gr	5 %
HARMONIC DISTORTION @ ___ Hz WITH DRIVING VELOCITY OF .7 in/sec (1.8 cm/sec) P-P		
@ OPTIMUN ORIENTATION	N.S	
@OPERATIONAL RANGE	N.S.	
DAMPING CONSTANT (B_cR_t)	10726	
OPERATING AND STORAGE TEMPERATURE	- 45 to +100 °C	
MAXIMUM OPERATING TEMPERATURE	+100 °C continuous duty	
DIMENSIONS		
WEIGHT	8.70 oz, 247 g	
DIAMETER	1.62 in, 4.12 cm	
HEIGHT (Less stud)	2.00 in, 5.08 cm	
STUD LENGTH	.31 in, .79 cm	

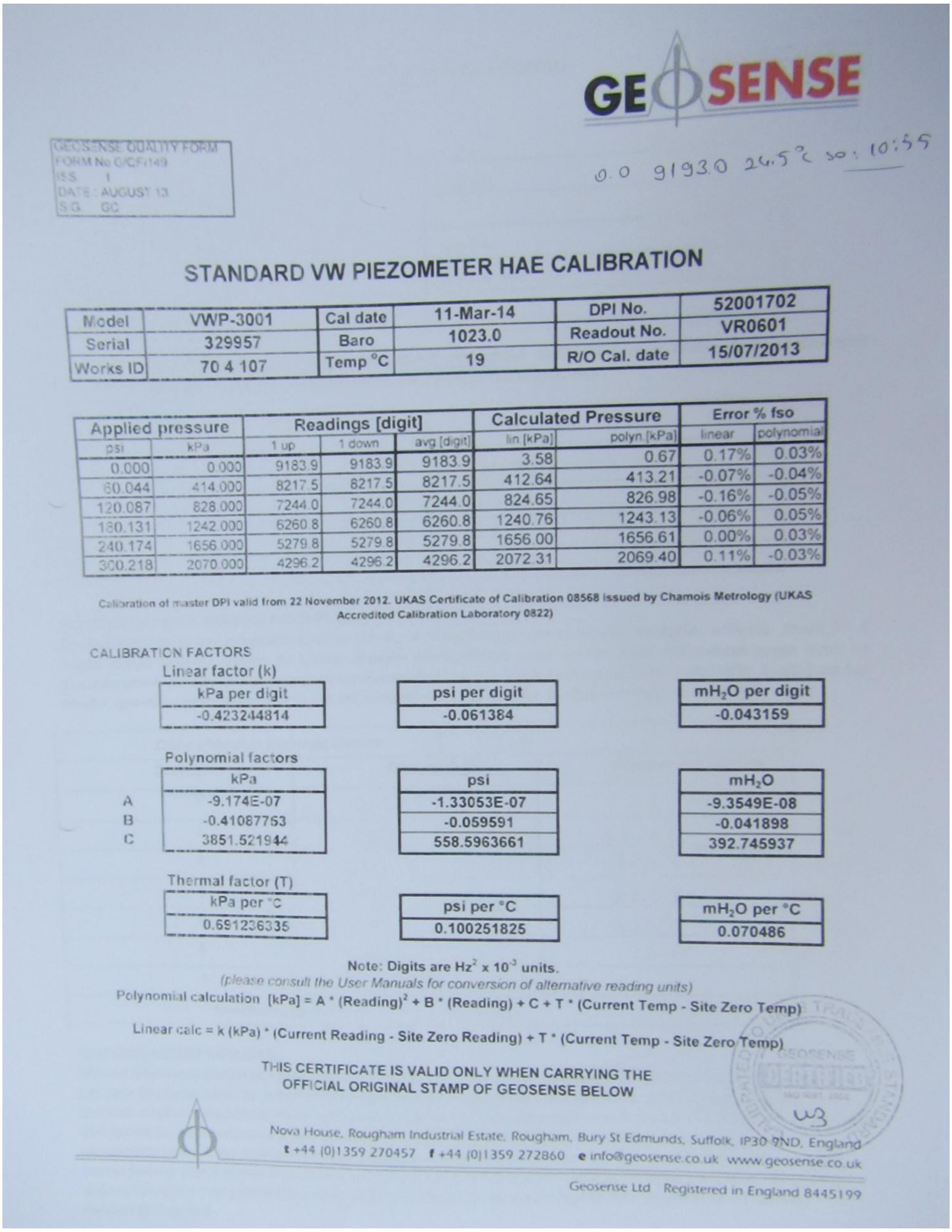
GEO SPACE TECHNOLOGIES, Inc.

SHEET 2 OF 3 **S-480-00020-01**



Sensitivity (V/in/sec)
Frequency (Hz)
OYO GEOSPACE
Geophone Response Curve
Output vs Frequency
SENSOR TYPE HS-1-LT MODEL HORZ
NATURAL UNDAMPED FREQUENCY 2 Hz
D.C. RESISTANCE 3810 OHM AT 25°C
INTRINSIC SENSITIVITY 2 V/I/S
OPEN CIRCUIT DAMPING 61 %
CURVE A B C D E
SHUNT (OHM) OPEN 115.000K
DAMPING (%) 61.0 70.0
PAGE 1 OF 1 S 480-00020-01

APPENDIX I – PIEZOMETER TECHNICAL FILE PRODUCT



GEOSENSE

GEOSENSE QUALITY FORM
FORM No G/CF/149
ISS. 1
DATE : AUGUST 13
S.G. GC

0.0 9193.0 24.5°C so: 10:55

STANDARD VW PIEZOMETER HAE CALIBRATION

Model	VWP-3001	Cal date	11-Mar-14	DPI No.	52001702
Serial	329957	Baro	1023.0	Readout No.	VR0601
Works ID	70 4 107	Temp °C	19	R/O Cal. date	15/07/2013

Applied pressure		Readings [digit]			Calculated Pressure		Error % fso	
psi	kPa	1 up	1 down	avg [digit]	lin [kPa]	polyn [kPa]	linear	polynomial
0.000	0.000	9183.9	9183.9	9183.9	3.58	0.67	0.17%	0.03%
60.044	414.000	8217.5	8217.5	8217.5	412.64	413.21	-0.07%	-0.04%
120.087	828.000	7244.0	7244.0	7244.0	824.65	826.98	-0.16%	-0.05%
180.131	1242.000	6260.8	6260.8	6260.8	1240.76	1243.13	-0.06%	0.05%
240.174	1656.000	5279.8	5279.8	5279.8	1656.00	1656.61	0.00%	0.03%
300.218	2070.000	4296.2	4296.2	4296.2	2072.31	2069.40	0.11%	-0.03%

Calibration of master DPI valid from 22 November 2012. UKAS Certificate of Calibration 08568 issued by Chamois Metrology (UKAS Accredited Calibration Laboratory 0822)

CALIBRATION FACTORS

Linear factor (k)

kPa per digit	psi per digit	mH_2O per digit
-0.423244814	-0.061384	-0.043159

Polynomial factors

	kPa	psi	mH_2O
A	-9.174E-07	-1.33053E-07	-9.3549E-08
B	-0.41087763	-0.059591	-0.041898
C	3851.521944	558.5963661	392.745937

Thermal factor (T)

kPa per °C	psi per °C	mH_2O per °C
0.691236335	0.100251825	0.070486

Note: Digits are $Hz^2 \times 10^{-3}$ units.

(please consult the User Manuals for conversion of alternative reading units)

Polynomial calculation [kPa] = A * (Reading)^2 + B * (Reading) + C + T * (Current Temp - Site Zero Temp)

Linear calc = k (kPa) * (Current Reading - Site Zero Reading) + T * (Current Temp - Site Zero Temp)

THIS CERTIFICATE IS VALID ONLY WHEN CARRYING THE OFFICIAL ORIGINAL STAMP OF GEOSENSE BELOW

GEOSENSE CERTIFIED

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Geosense Ltd Registered in England 8445199

GEOSENSE QUALITY FORM
FORM No G/CF/149
ISS: 1
DATE: AUGUST 13
S.G.: GC

0.0. 9435.8 24.0°C 10:55

STANDARD VW PIEZOMETER HAE CALIBRATION

Model	VWP-3001	Cal date	12-Mar-14	DPI No.	52001702
Serial	329889	Baro	1023.0	Readout No.	VR0601
Works ID	70 4 39	Temp °C	19	R/O Cal. date	15/07/2013

Applied pressure		Readings [digit]			Calculated Pressure		Error % fso	
psi	kPa	1 up	1 down	avg [digit]	lin [kPa]	polyn [kPa]	linear	polynomial
0.000	0.000	9410.6	9410.6	9410.6	2.73	0.24	0.13%	0.01%
60.044	414.000	8417.9	8417.9	8417.9	413.32	413.81	-0.03%	-0.01%
120.087	828.000	7421.3	7421.3	7421.3	825.56	827.56	-0.12%	-0.02%
180.131	1242.000	6419.3	6419.3	6419.3	1240.03	1242.04	-0.10%	0.00%
240.174	1656.000	5413.0	5413.0	5413.0	1656.26	1656.78	0.01%	0.04%
300.218	2070.000	4407.7	4407.7	4407.7	2072.05	2069.56	0.10%	-0.02%

Calibration of master DPI valid from 22 November 2012. UKAS Certificate of Calibration 08568 issued by Chamois Metrology (UKAS Accredited Calibration Laboratory 0822)

CALIBRATION FACTORS

Linear factor (k)

kPa per digit	psi per digit	mH_2O per digit
-0.413627777	-0.059990	-0.042178

Polynomial factors

	kPa	psi	mH_2O
A	-7.48502E-07	-1.08557E-07	-7.6326E-08
B	-0.40328471	-0.058489	-0.041124
C	3861.680598	560.0697024	393.781832

Thermal factor (T)

kPa per °C	psi per °C	mH_2O per °C
0.219884644	0.031890449	0.022422

Note: Digits are $Hz^2 \times 10^{-3}$ units.

(please consult the User Manuals for conversion of alternative reading units)

Polynomial calculation [kPa] = A * (Reading)^2 + B * (Reading) + C + T * (Current Temp - Site Zero Temp)

Linear calc = k (kPa) * (Current Reading - Site Zero Reading) + T * (Current Temp - Site Zero Temp)

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APPENDIX J – TDR MOISTURE TECHNICAL FILE PRODUCT

I. Inspection

Your soil Moisture Sensor was carefully inspected and certified by our Quality Assurance Team before shipping. If any damage has occurred during shipping, please notify Global Water Instrumentation, Inc. and file a claim with the carrier involved.

II. Description

Global Water's AT210 is a reliable and accurate sensor which measures the water saturation of soil. It can be used in a variety of applications, such as:

- Bioremediation
- Wastewater Reclamation
- Landfill Management
- Agriculture Monitoring and Irrigation

The Global Water Soil Moisture Sensor utilized Time Domain Reflectometry (TDR) to accurately measure the water content of soil. What this means for you is that this sensor via a no hassle, no maintenance, long lasting, probe this is very accurate.

How TDR sensors work is similar to radar. A high frequency signal is pulsed down the probe. The reflection of this signal is proportional to the dielectric constant of the soil surrounding the sensor. The dielectric reading from the sensor is then converted to water saturation and transmits to the monitoring equipment via a 4-20mA signal.

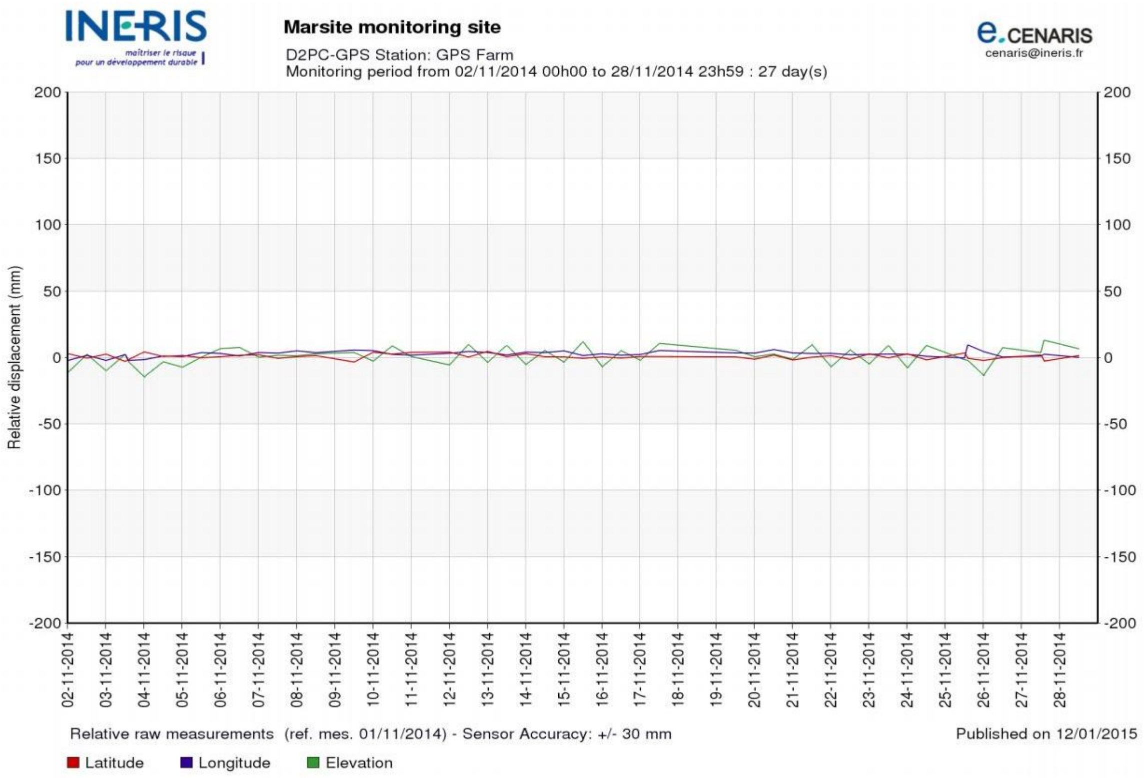
III. Specification

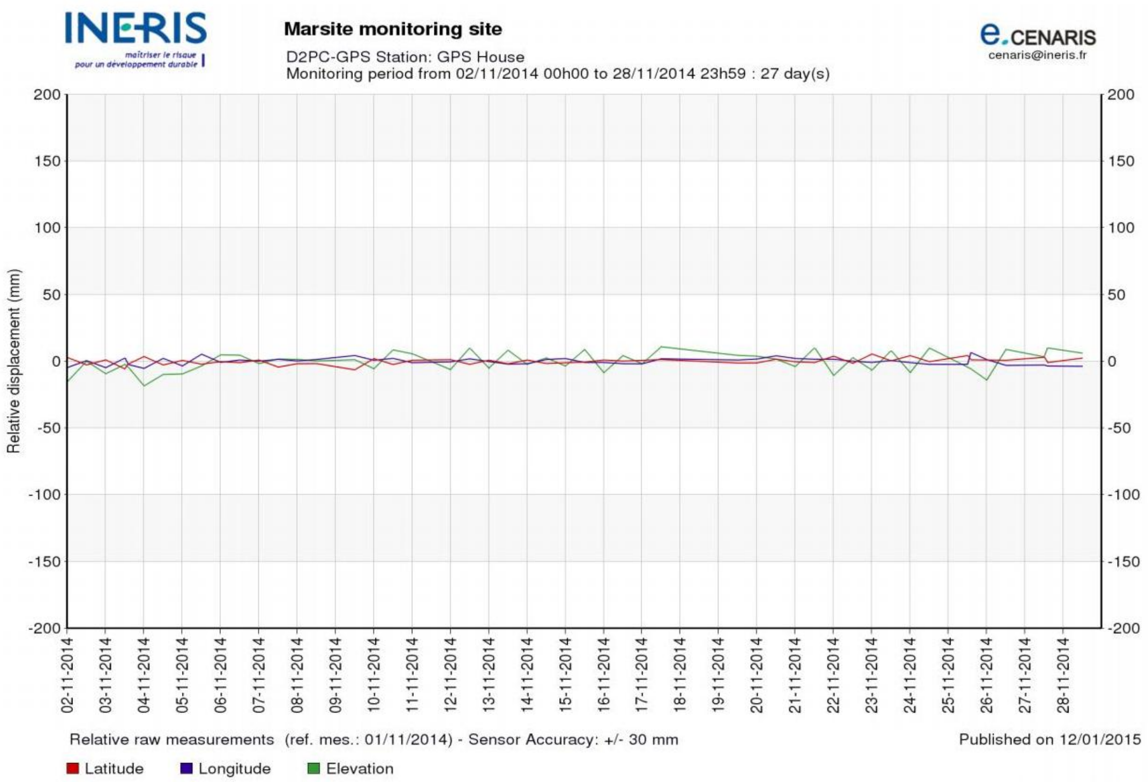
Power Requirements	12 VDC +/- 20% @ 40mA
Output	4-20 mA DC
Power Up Time	1 second from power up

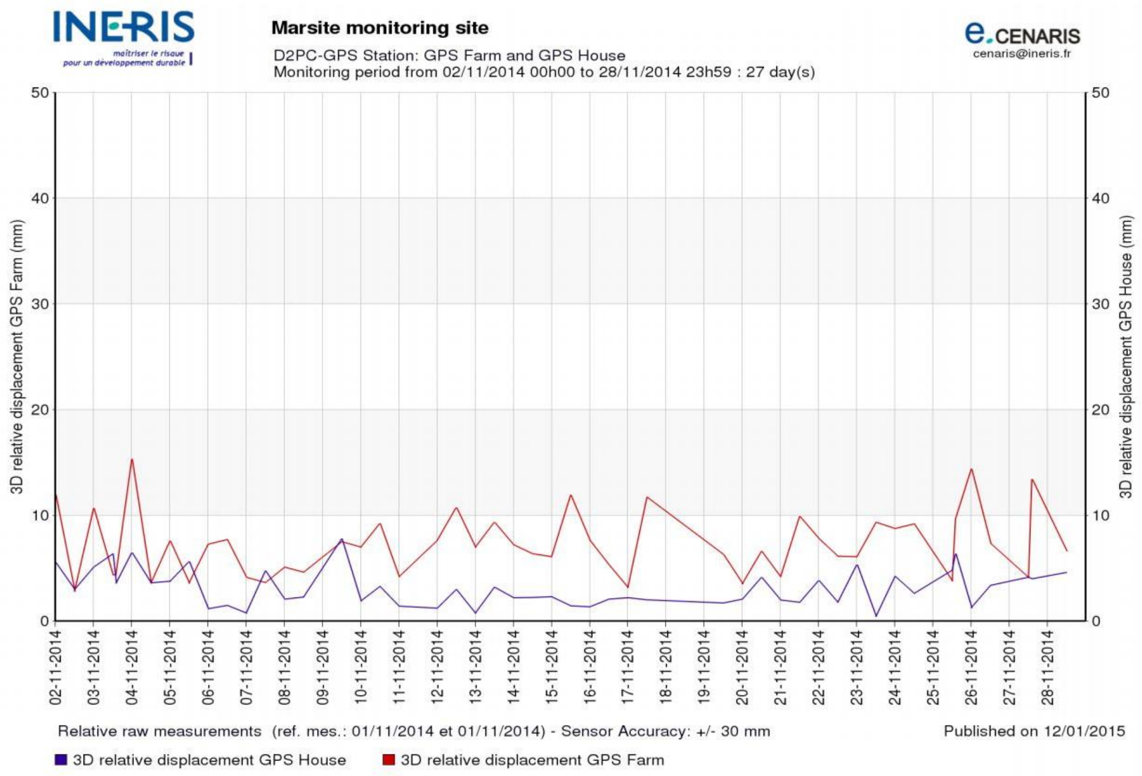
APPENDIX K – LIST OF EQUIPMENTS AND SOFTWARES USED

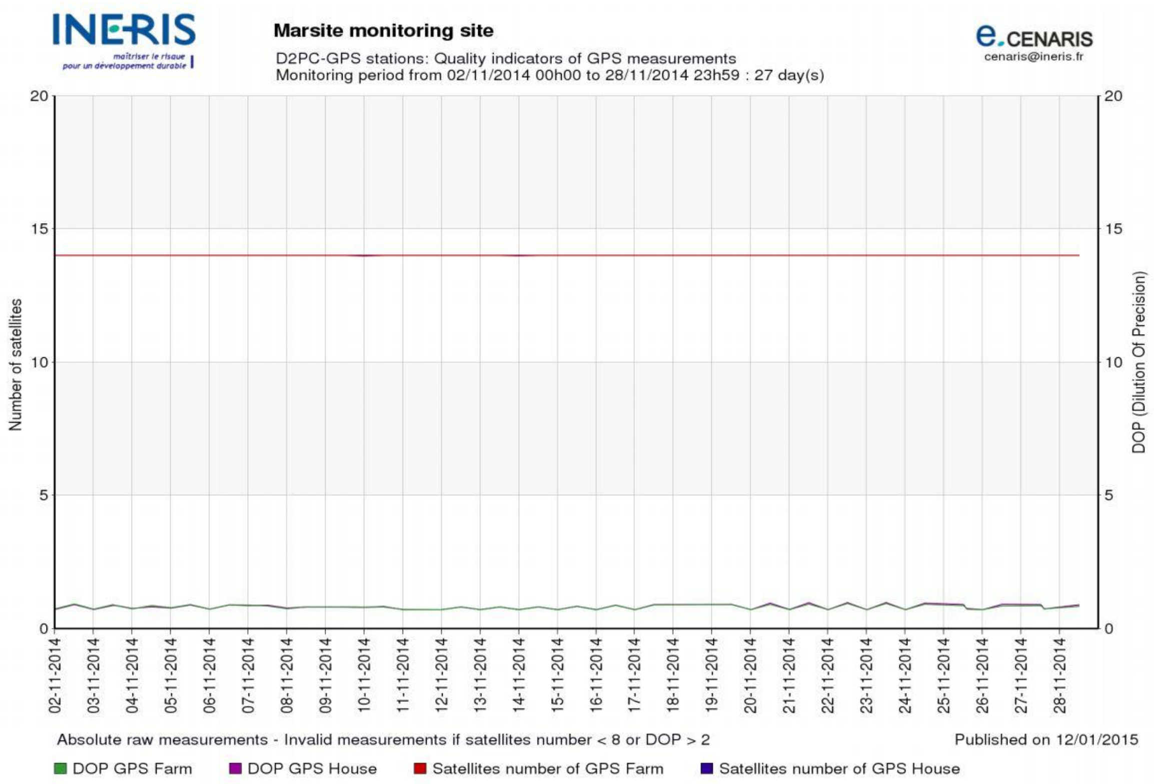
SOFTWARES	VERSION / CONFIGURATION
SYTMISauto	V 6.20 / SYTMISauto-MarSite-01.aut
SYTGEObridge	V 1.20
SYTMISview	V 4.10
SYTGEOscop	V 2.21 / sytgemMarsite_006.bin
SYTMISscop	V 3.42 / SytmisScop-Marsite3.42-02.cfg

APPENDIX L – GPS INITIAL TIME SERIES

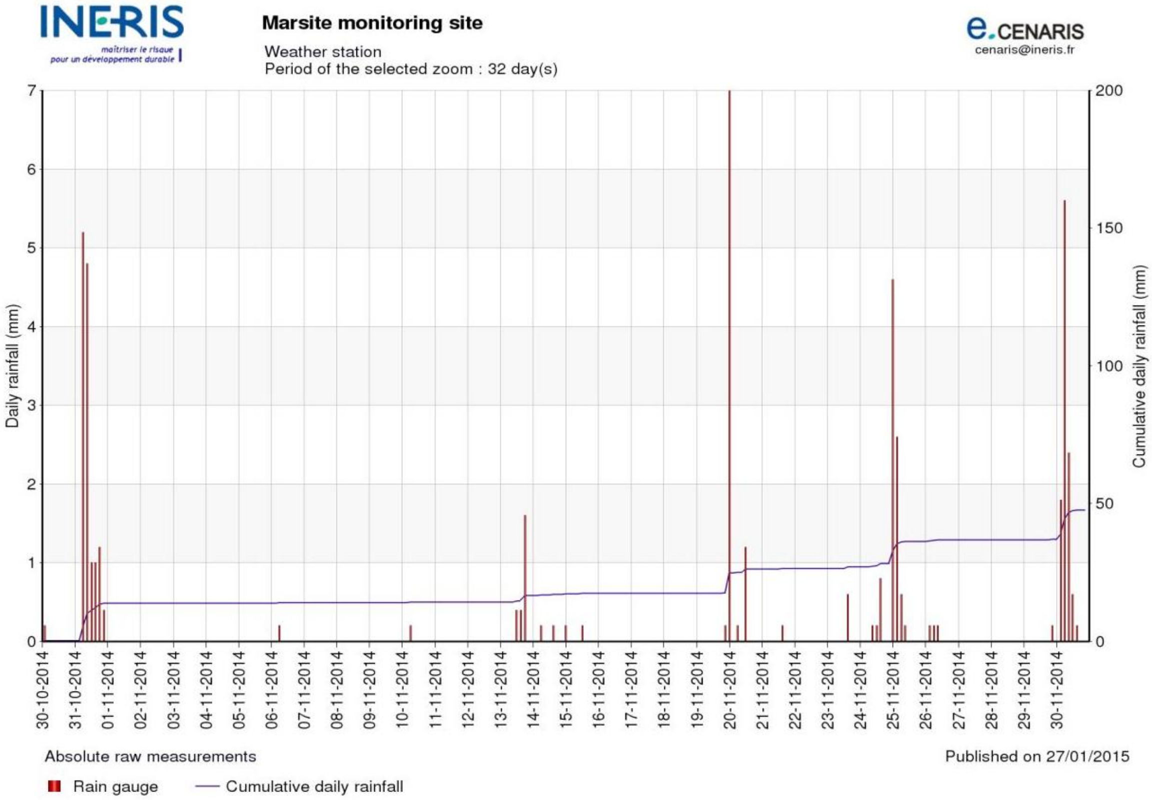


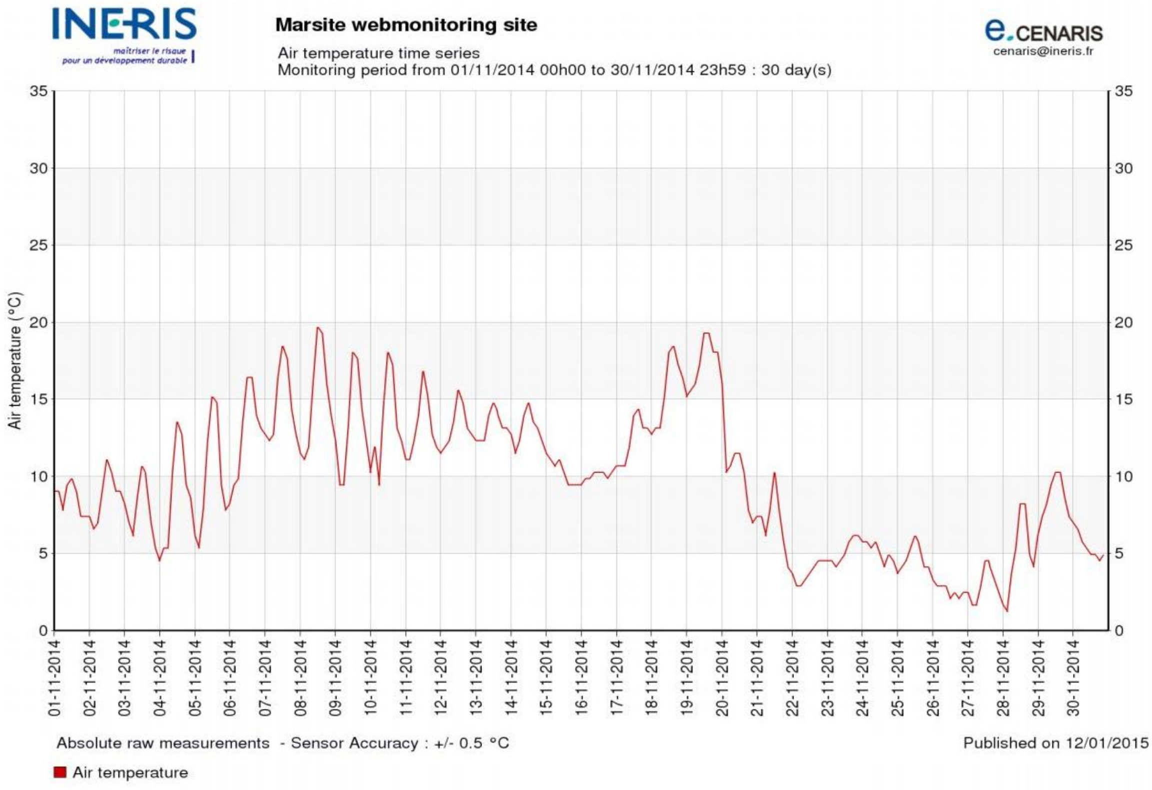



INERIS
maîtriser le risque pour un développement durable
Marsite monitoring site
D2PC-GPS Station: GPS Farm and GPS House
Monitoring period from 02/11/2014 00h00 to 28/11/2014 23h59 : 27 day(s)
e.CENARIS
cenaris@ineris.fr
3D relative displacement GPS Farm (mm)
3D relative displacement GPS House (mm)
Relative raw measurements (ref. mes.: 01/11/2014 et 01/11/2014) - Sensor Accuracy: +/- 30 mm
Published on 12/01/2015
3D relative displacement GPS House
3D relative displacement GPS Farm

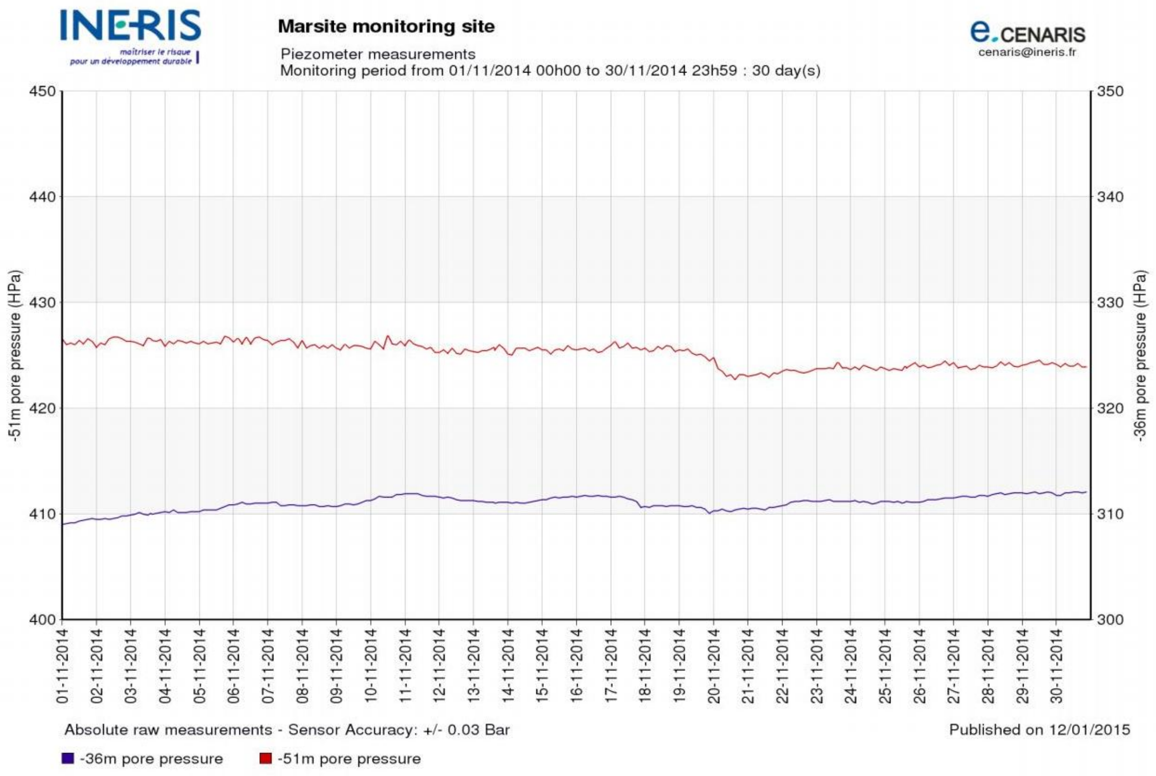

INERIS
maîtriser le risque pour un développement durable
Marsite monitoring site
D2PC-GPS stations: Quality indicators of GPS measurements
Monitoring period from 02/11/2014 00h00 to 28/11/2014 23h59 : 27 day(s)
e.CENARIS
cenaris@ineris.fr
Number of satellites
DOP (Dilution Of Precision)
Absolute raw measurements - Invalid measurements if satellites number < 8 or DOP > 2
Published on 12/01/2015
DOP GPS Farm
DOP GPS House
Satellites number of GPS Farm
Satellites number of GPS House

APPENDIX M – WEATHER INITIAL TIME SERIES

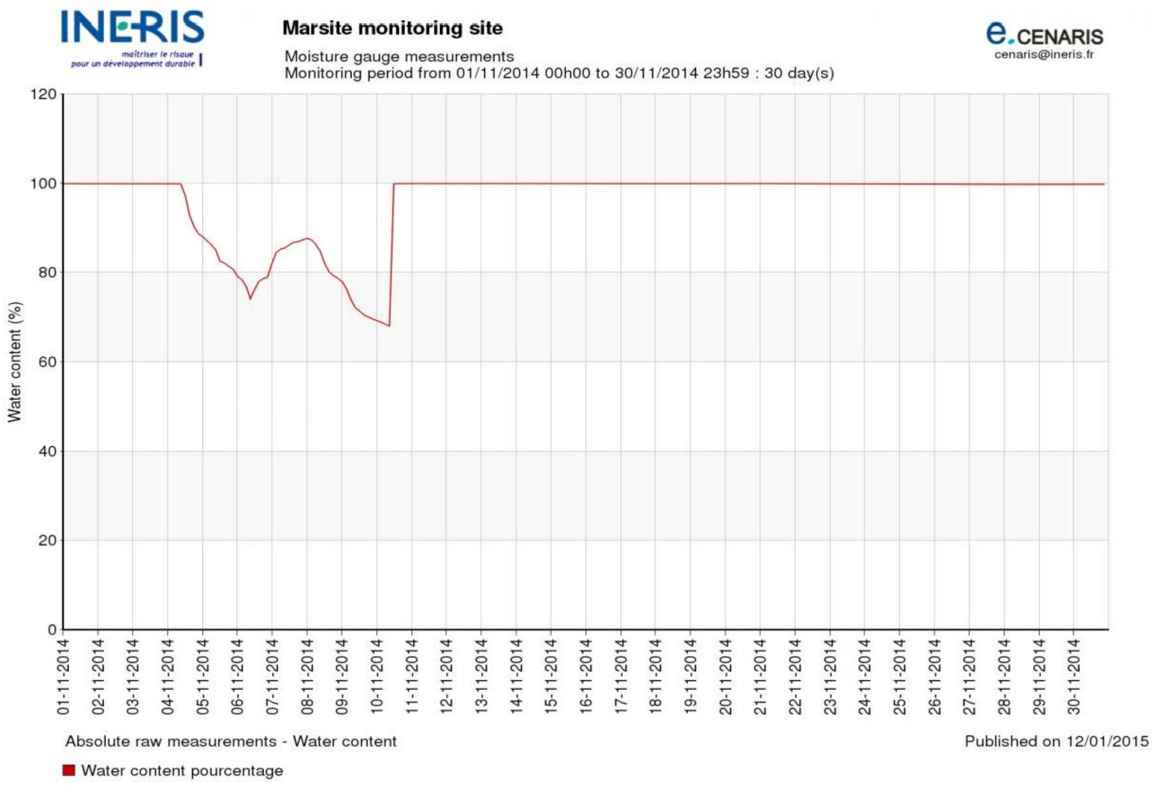




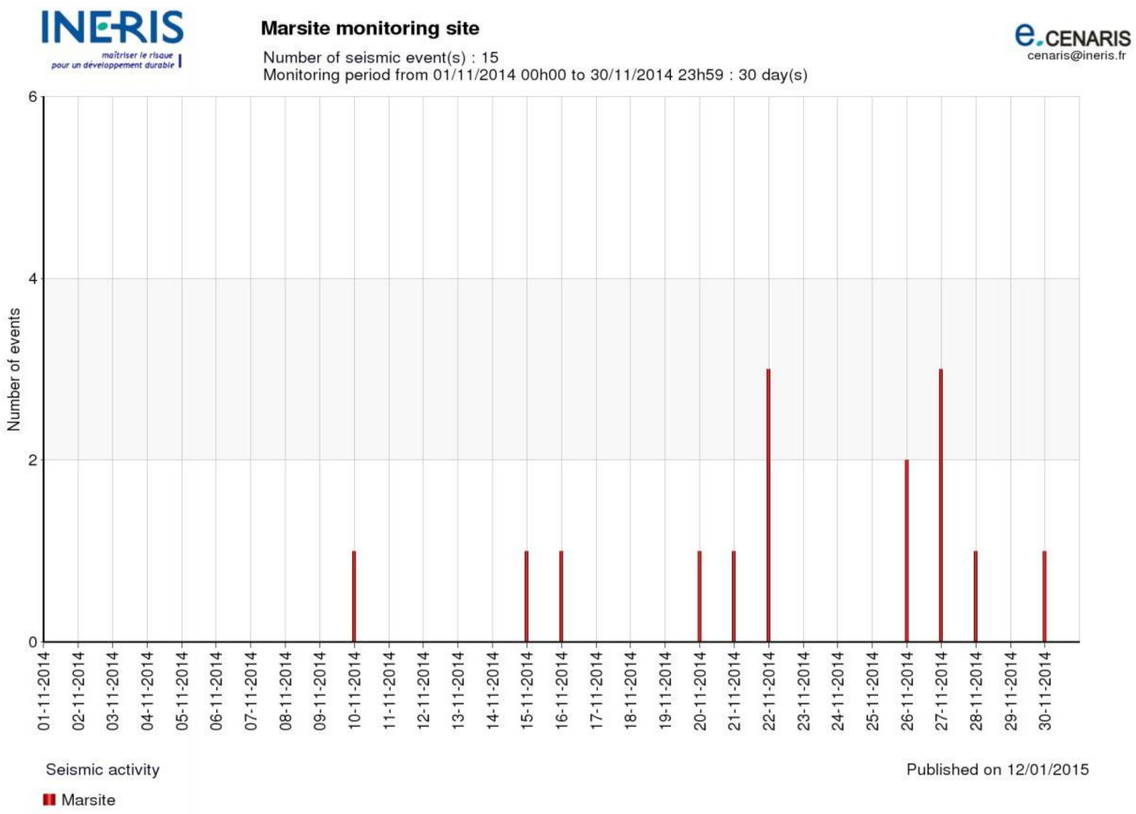
APPENDIX N – PORE PRESSURE INITIAL TIME SERIES

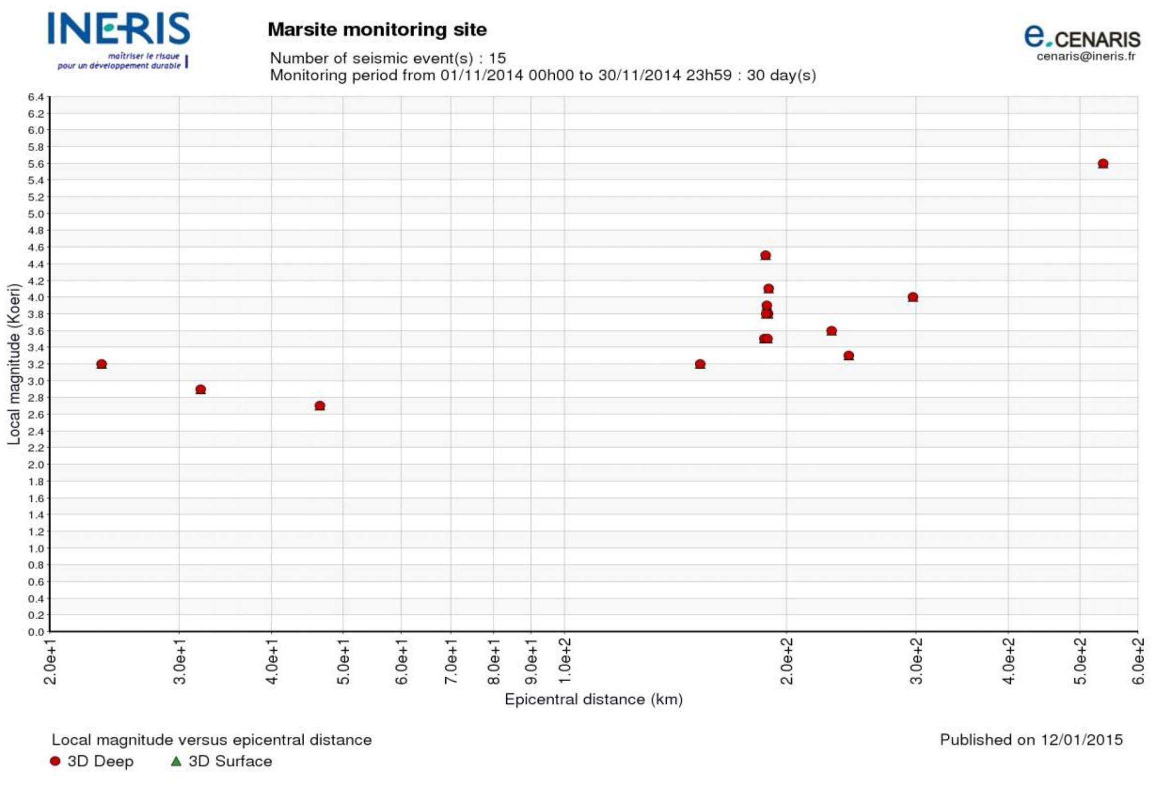


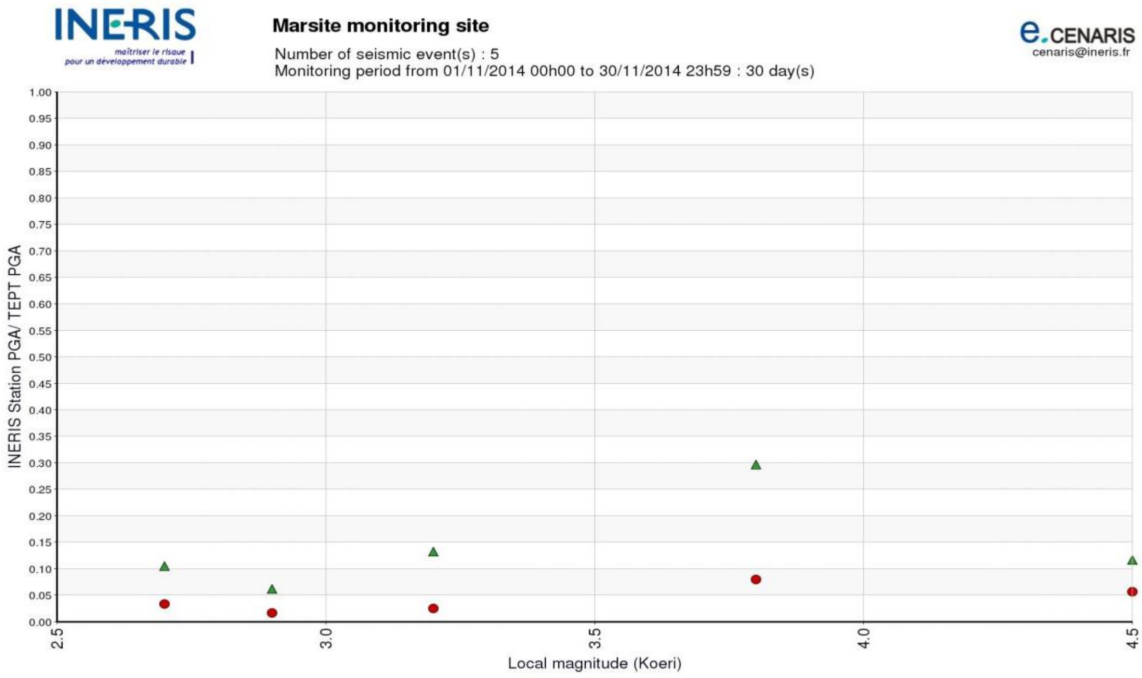
APPENDIX O – FIRST RECORDED MEASUREMENTS – MOISTURE SENSOR



APPENDIX P – FIRST RECORDED MEASUREMENTS – MICROSEISMIC



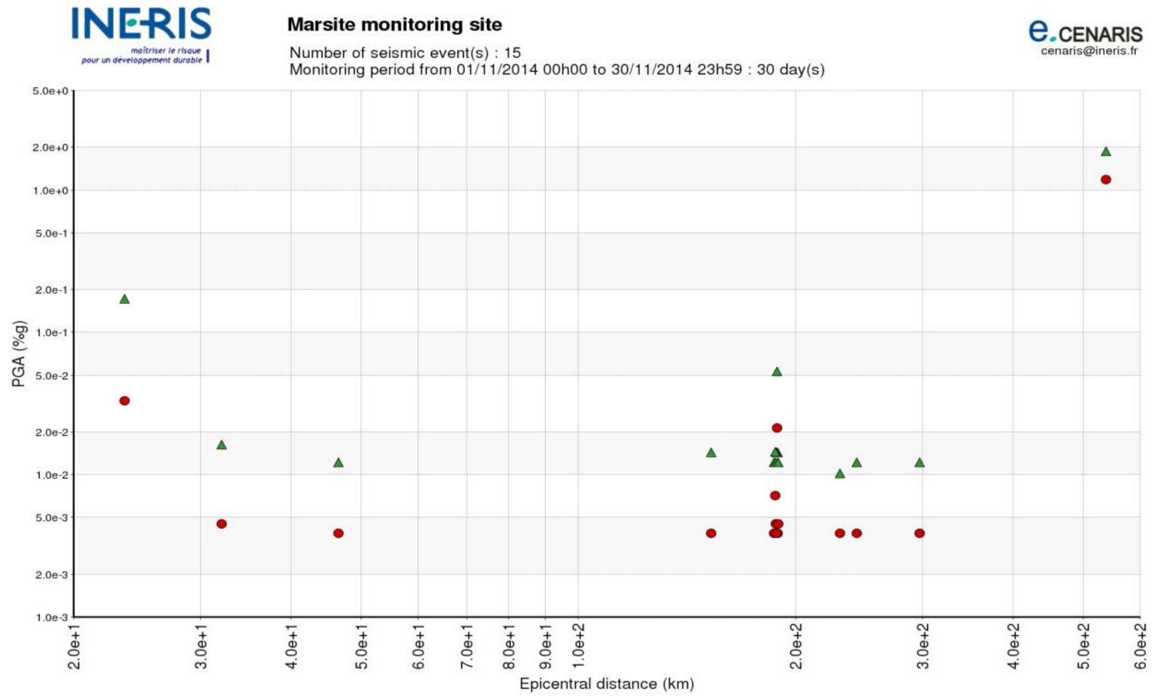




Amplification in term of PGA (Peak ground acceleration) versus local magnitude

● PGA 3D Deep / TEPT ▲ PGA 3D Surface / TEPT

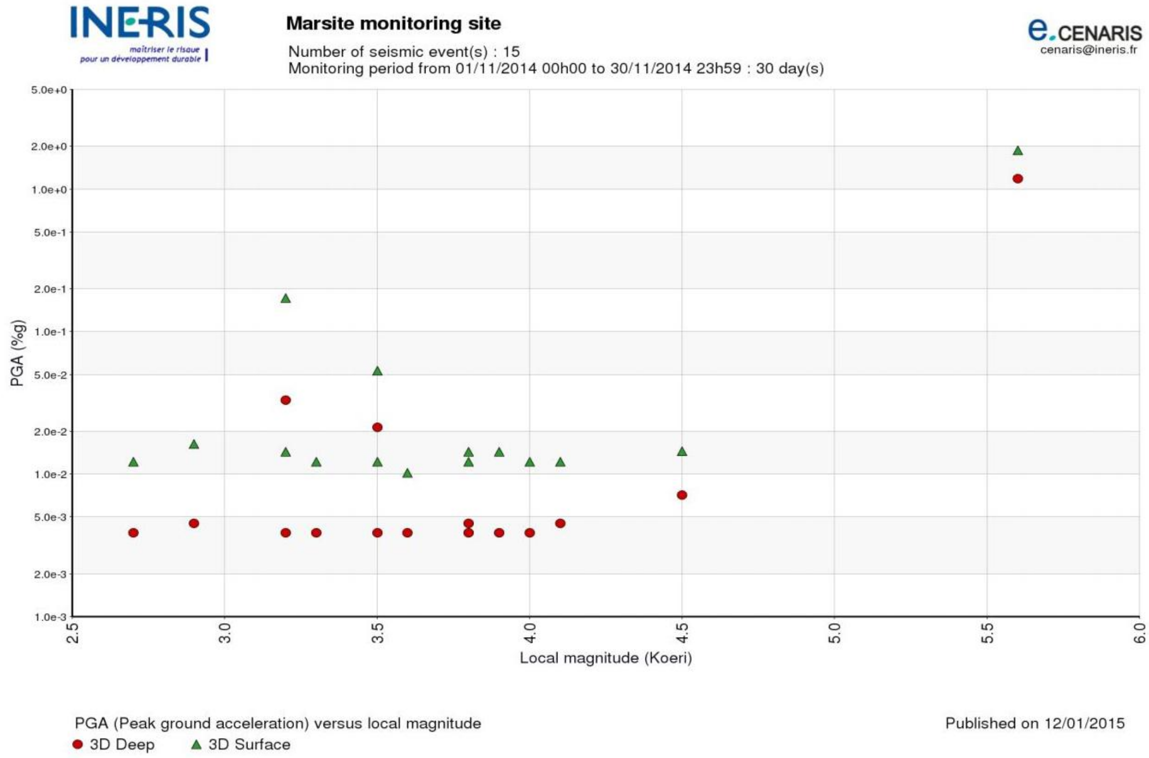
Published on 12/01/2015

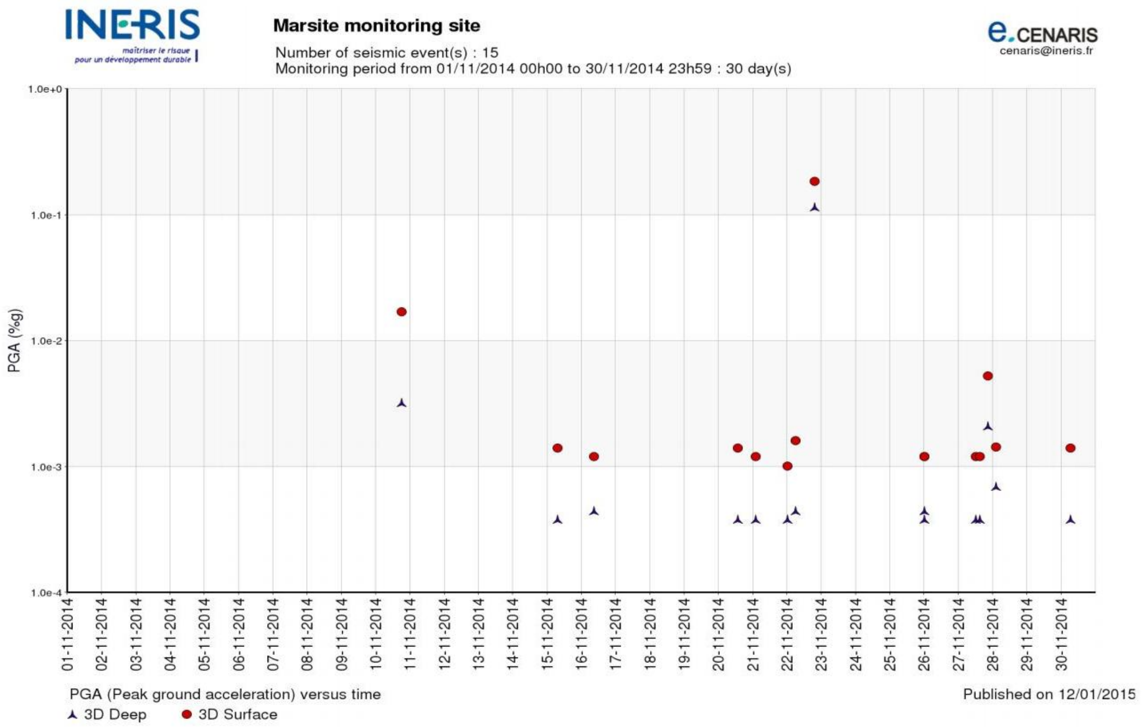


PGA (Peak ground acceleration) versus epicentral distance

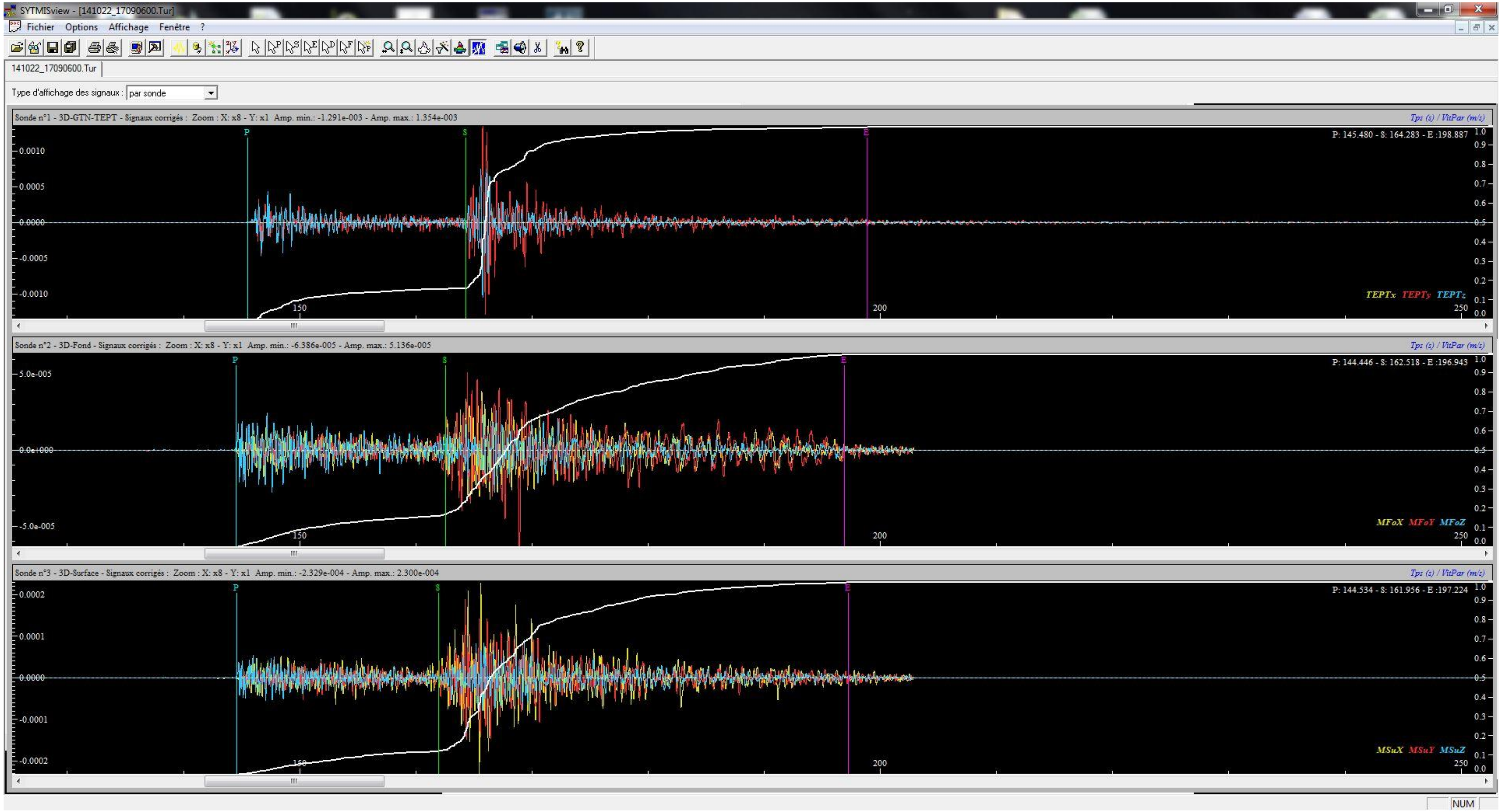
● 3D Deep ▲ 3D Surface

Published on 12/01/2015


INERIS
maîtriser le risque pour un développement durable
Marsite monitoring site
Number of seismic event(s) : 15
Monitoring period from 01/11/2014 00h00 to 30/11/2014 23h59 : 30 day(s)
e.CENARIS
cenaris@ineris.fr
PGA (%g)
Local magnitude (Koeri)
PGA (Peak ground acceleration) versus local magnitude
3D Deep
3D Surface
Published on 12/01/2015


INERIS
maîtriser le risque pour un développement durable
Marsite monitoring site
Number of seismic event(s) : 15
Monitoring period from 01/11/2014 00h00 to 30/11/2014 23h59 : 30 day(s)
e.CENARIS
cenaris@ineris.fr
PGA (%g)
PGA (Peak ground acceleration) versus time
3D Deep
3D Surface
Published on 12/01/2015

APPENDIX Q - 22/10/2014 Earthquake



APPENDIX R – DESCRIPTION OF THE WEB MONITORING PAGE