

Medium Depth Borehole Sensor Installation

Technical note, GEObit, 2016-Revised Jan 2017

Middle depth boreholes for sensor installation are those with depth from 50 meters down to 300 meters. We cannot provide accurate instructions covering each specific case since there are different variables at each site: different geology, different drill equipment, and different expertise of the installers. However, we can suggest some guidelines that will be helpful. It is highly recommended to contact our technical department for each specific case and our experienced engineers will provide a solution.

1. Drilling the well

The driller must provide a clean of mud well at the desired depth. It is very important that the part of well that the sensor is going to be installed, and at least 15 – 25 meters above (if possible) the well must be free of well protective casing so the sensor will be coupled directly with the sensor casing and the ground.

Drilling into soft ground or drilling into the water tank zone, there is high risk of collapse. To avoid any collapse the driller should put protection casing. He shall start drilling at large diameter and progressively drill with narrower diameter. If the well is going to be used for sensor installation the protection casing must be stopped at least 15-25m above the sensor position.

This lower part will be still under risk of collapse. The driller must use bentonite to provide a stable well in the case that there is risk of collapse. If this last part of the well is drilled into limestone which is the ideal case, there is no need for any further stabilization with bentonite.

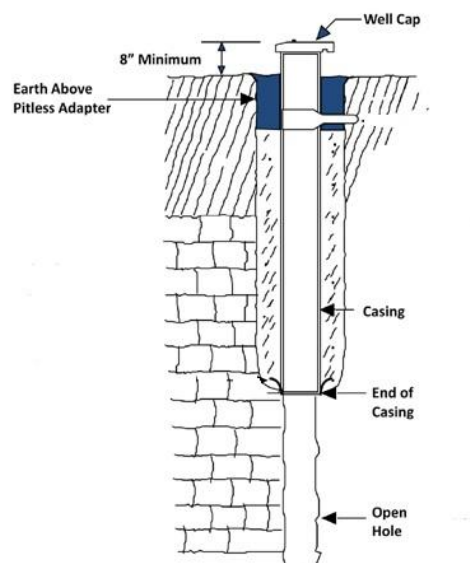


Figure 1: Drawing of the seismic sensor installation well

Once the drilling work is ended, the driller must clean the well with fresh water and remove all the mud and cuttings. Immediately he has to insert the sensor casing down to the bottom and start the grouting procedure. Once the bottom part is grouted, it avoids any risk of collapses and ensures good coupling between the sensor casing and the ground.

2. Chose the appropriate sensor casing

Basically sensor casing is made by two types of materials, aluminum and ABS. Aluminum casing is more strength sensitive, and in general more cost effective. Special care must be taken when connecting the casing pipes with the provided junctions. ABS casing provides easier connection trough the build-in connection mechanism and the special glue provided by the manufacturer. They are more expensive and less strength sensitive.

Both materials provide very good collapse strength and they are able for installations even at 400m



Figure 2,3: ABS inclinometer casing (left) and aluminum inclinometer casing (right)

3. Casing installation into the well

Immediately after the well clean-up the driller must install the sensor casing. It is recommended that the well will be full of water in order to provide flotation to the inserted tubes. He has to make sure that he has all the necessary parts and tools to do this work without any interruptions. These are

- ✓ casing pipes
- ✓ casing connections
- ✓ casing bottom – top cups
- ✓ waterproof pop-rivets with o-ring
- ✓ rivets gun
- ✓ battery drilling machine
- ✓ silicone or ABS glue

- ✓ tape
- ✓ two (top - bottom) casing clamps
- ✓ casing rig attachment
- ✓ side pipe for the grouting (grouting pipe)
- ✓ plastic cable straps
- ✓ hand saw
- ✓ water supply with water hose

The driller at first has to put the bottom tap and make sure that it has inserted properly and no risk of leak even at high pressure. Then he has to insert the first casing tube into the well and he has to stabilize it with the bottom clamp. The casing is now stable over the water wellhead so the driller is able to work with the connection. He has to make the connection according the casing manufacturer instructions. Prior connecting the next pipe, the driller must have attached the upper casing clamp for making sure that there is no risk to allow the casing to be slinked into the well. If the casing floats because of the buoyancy, he has to add fresh water for cancelling flotation and have control the casing as it is lowered into the well. It is assumed that the water well is filled with water as mentioned before. If the water level is low, the driller must attach the casing with a metallic wire and provide control with the winch. Alternatively the driller can control the casing using the casing rig clamp and it's rig.



Figure 4: ABS casing installation

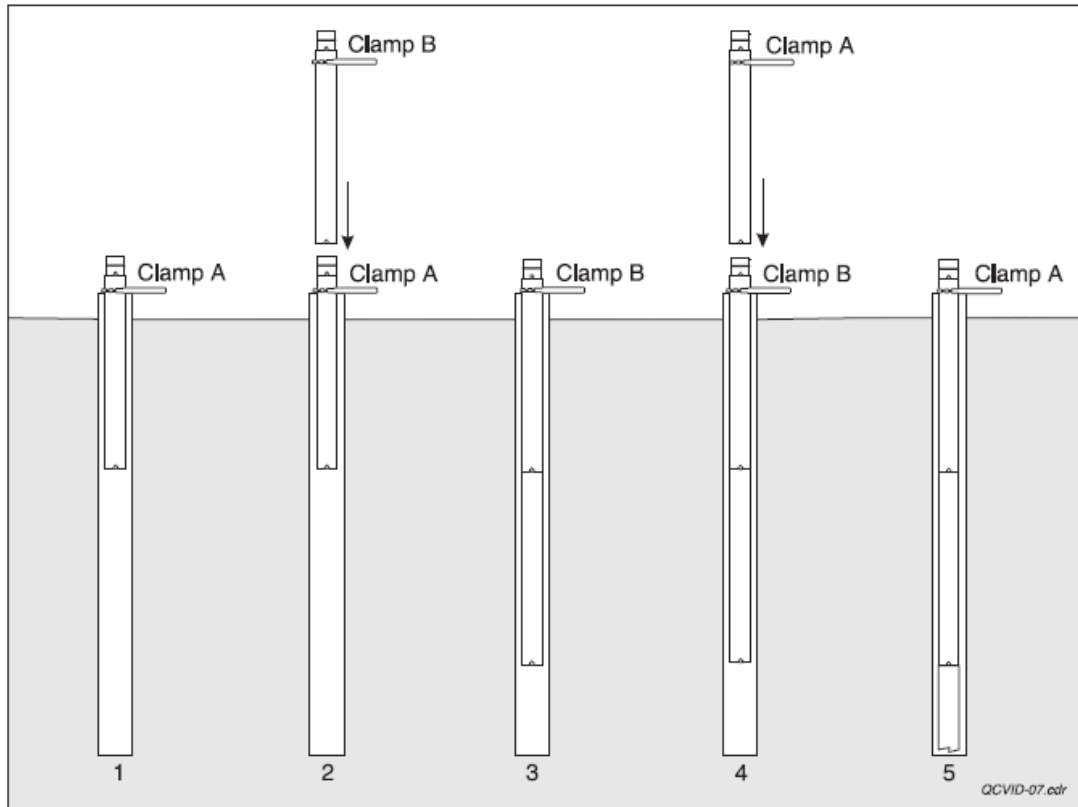


Figure 5: Casing insertion procedure

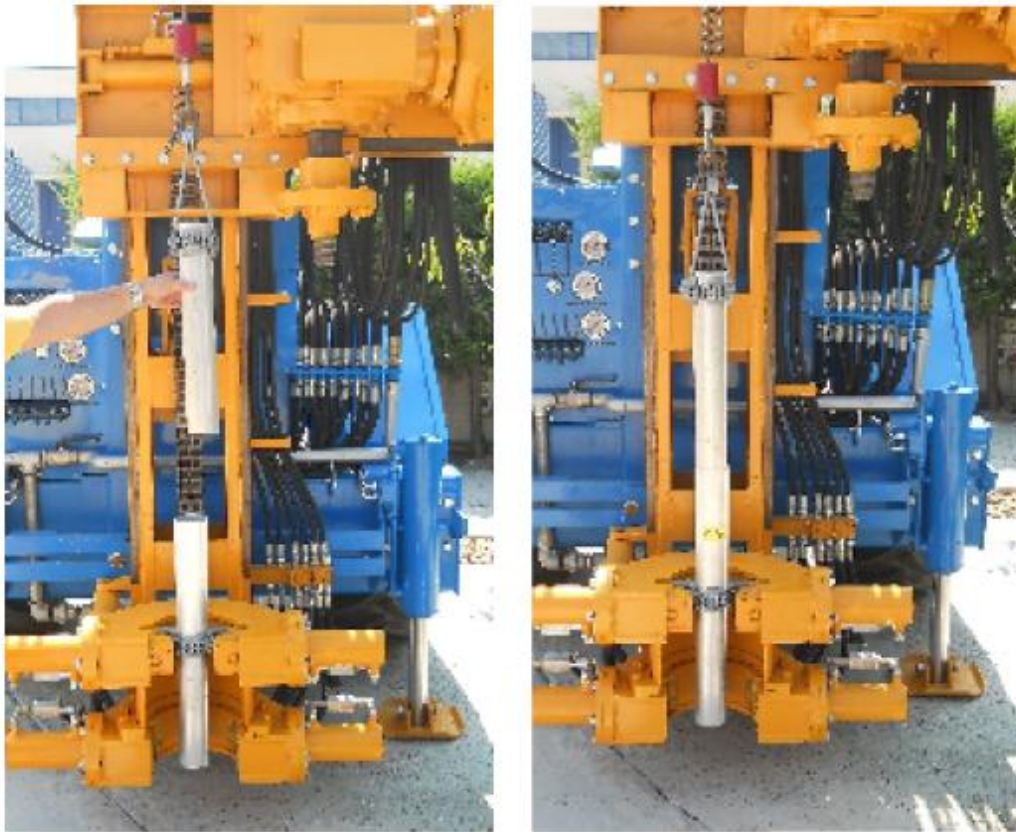


Figure 6.7: Casing control with the drilling machine



Figure 8.9: Casing rig clamp (left) and casing clamp (right)

In parallel, the driller must attach the secondary pipe (grouting pipe) next to the casing pipes and tight it with cable straps and insert it into the well together with the sensor casing. The grouting pipe can be attached in the middle of the first casing pipe having its end at 1.5m from the bottom. In the case of step grouting, a second grouting pipe with different color must be attached at the appropriate point.

Following this procedure, the casing will reach the bottom of the well. The driller has to stabilize the casing prior start inserting grout. However, when he pumps grout into the borehole, the water-filled casing becomes buoyant again, because the grout is denser than water. To counter this buoyancy, the driller should apply a down force at the bottom of the casing. The driller can lower a steel pipe to the bottom of the casing or he can suspend a non-retrievable weight from the bottom of the casing when you install it. A suspended weight requires a deeper borehole and may require use of a safety line.

Note that a down force applied at the top of the casing is likely to distort the casing profile. For this reason, we recommend that you do not park a drill rig over the casing or apply any other top-down method of counteracting buoyancy.

4. Casing cementing (grouting)

At this stage, what is needed is a cement mixer, a grout pump, and a pipe or hose for delivering the grout. It is recommended that not mixing the grout by hand. It is also recommended that do not use a water pump to place the grout, since pumping grout would damage it. A bentonite pump may be a good choice and most of the drillers use this kind of equipment (drilling pump or mud pump). Alternatively a grout mixer with integrated grout pump can be used.



Figure 10: Grout mixer with integrated grout pump

Properly mixed grout should be free of lumps. It has to be thin enough to pump but thick enough to set in a reasonable length of time. If the mixture is too watery, it will shrink

excessively, leaving the upper portion of the borehole un-grouted. Also, avoid the use of admixtures and grouts that cure at high temperature since these may damage the casing. Ideally, the grout should be mixed to match the strength and deformation characteristics of the ground around the borehole. In practice, the main consideration is to use a grout that allows the casing to move with the surrounding soil. If there is no other guidance, try one of the following “general purpose” mixtures. The compressive strength of these mixtures is about 500 lb/ft² at a 28 day cure time.

	HARD SOILS		MEDIUM SOILS		SOFT SOILS	
Materials	Unit	Weight ratio	Unit	Weight ratio	Unit	Weight ratio
Cement (OPC)	50Kg	1	50 Kg	1	50 Kg	1
Bentonite	15 Kg	0.33	15 Kg	2	20 Kg	0.4
Water	125 Lit	2.5	260 Lit	4.0	325 Lit	6.5

Table 1: Grout materials presentence

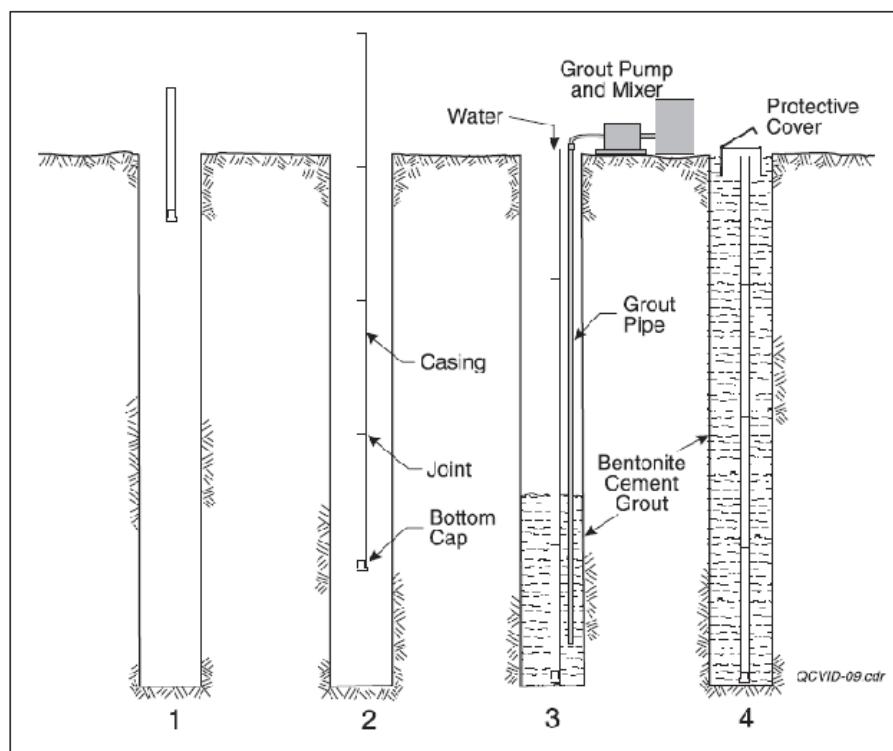


Figure 11: Grouting the well

4.1 Stage Grouting

At stage grouting, grout backfill is placed in stages, so that the pressure of grout never exceeds the collapse strength of the casing. In general, you should consider stage grouting when the depth of the borehole exceeds 200 feet.

- Grout can be delivered by hose or pipe. Hose must be installed with the casing, but it is disposable and can be left in place after grouting.
- Stage grouting with hoses requires at least two hoses. The first pipe should extend to the bottom of the borehole. The next pipe should extend to bottom of the the next stage, and so on.
- Be sure to label or color-code each grout pipe to avoid accidentally pumping grout or water down the wrong pipe.
- Make some provision to counter buoyancy of the casing. This is best done by applying a down force at the bottom of the casing.

4.2 Overview of Stage Grouting with Hoses

Hoses are fixed to the casing as shown in the drawing below. Initially calculate the volume of grout needed to backfill the borehole above the end of the Stage 2 grout hose. Pump in that volume of grout plus about 30%. Leave the Stage 1 grout hose in place.

Pump water through the Stage 2 grout hose. The bottom of the Stage 2 hose should be below the surface of the grout, and pumping in water should flush grout out from the borehole. If no grout appears, pump more grout through the Stage 1 hose and then test again. Using this method, you can be relatively certain that Stage 1 is grouted satisfactorily. Continue pumping water through the Stage 2 hose until “clear” water flushes from the borehole. This ensures that the Stage 2 hose will be clear for use later. When the State 1 grout has set, grout Stage 2. Since the bottom of the casing is now grouted in place, buoyancy will no longer be a problem.

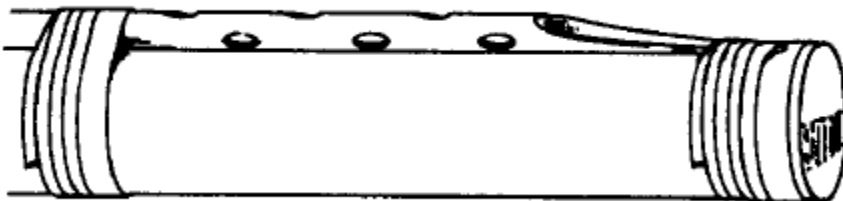


Figure 12: Grouting pipe

5. Sensor installation

Once the casing is properly installed and the grout is frozen, there may be a need to add some cement at the top because the grout level will become lower at the surface. The user has to prepare the sensor, the guiding wheels, and the anchor.

First he has to start with the sensor orientation according to the north. The orientation of the sensor has to be preset before inserted into the tube, using the screw at the bottom of the casing. The user has to mount the guiding wheels on the bolt at the bottom of the enclosure of the sensor, paying attention to the orientation of the sensor which is determined by the bullets code on the white cover of the sensor.

Thereafter, the user must attach the anchor at the bottom side of the guiding wheels and put the sensor inside the inclinometer case (sensor casing) and let it slowly slip down to the bottom of the case. The wheels follow the channels of the tube and the orientation of the sensor stays the same as initially inserted into the tube. Tilt also remains into ± 5 degrees, regarding to the vertical position, where the sensor works well. Tilt greater than ± 5 degrees from the vertical position will may cause malfunction of the instrument.

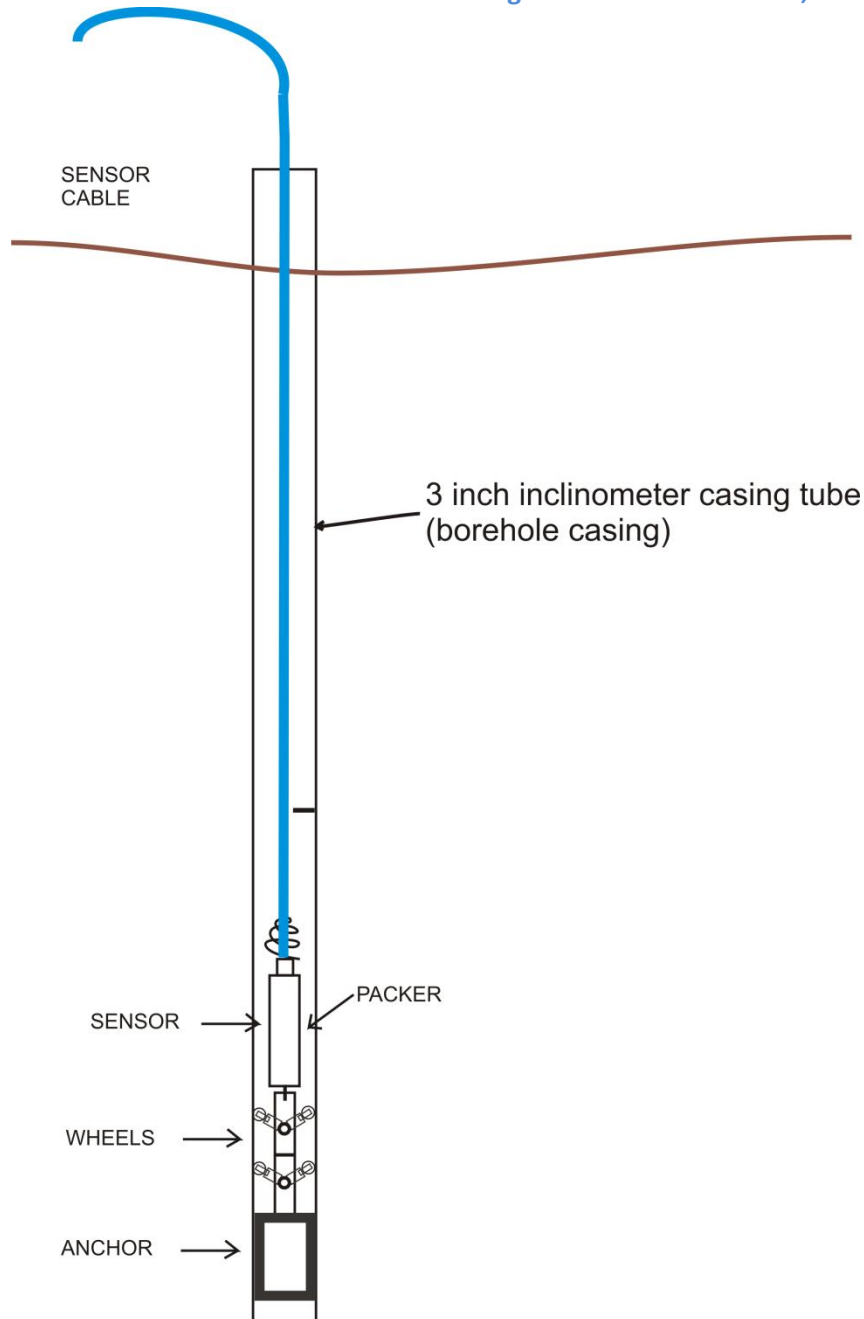


Figure 13: S100 sensor installation

The sensor has to be rigged-down slowly-slowly handled from its cable. The cable is strong enough and can support its weight, the sensor's and the anchor's weight. When the sensor reaches the bottom of the well, the user has to slightly pull up the cable to ensure that the sensor is hanging by its cable and the leveling is totally vertical.

Finally, the inclinometer tube should be filled with cement at least 5 meters above the sensor providing a very good contact between the sensor and the ground. So the user has to calculate how much quantity of grout must put inside the casing. Grout of cement must be used, to ensure absolute contact between the case and the sensor.

6. Testing the installation

The sensor must be tested prior to the final connection with the recorder.

6.1. Noise Level Estimation – natural ground noise.

Once the seismic sensor has been installed, the operator must check the signal noise level. This can easily be done using “DataMonitor124”. The signal waveform must look like the fig 2, clear of any “spikes” or any other type of noise.

Signal level (Volts Peak-to-peak) must be in the area of **5e-005 to 0.0001 Vpp** when the station is totally noise-free and a little more (**0.0002 – 0.0003 Vpp**) for a “good” station in terms of noise. The electronic noise of the instrument is in the range of **of 5e-005 Volts Peak to Peak (Vpp)**. Values in the range of 0.0001Vpp decrease the noise quality by 0 to -3dB which is still an excellent noise performance. Greater noise level, in the range of 0.0002Vpp to 0.0003Vpp decrease the noise performance by -4dB to -6dB which does not affects so much signal quality given that the instrument’s sensitivity is very high (1500V/m/sec)

The signal spectrum on the right must be free of any resonant frequencies

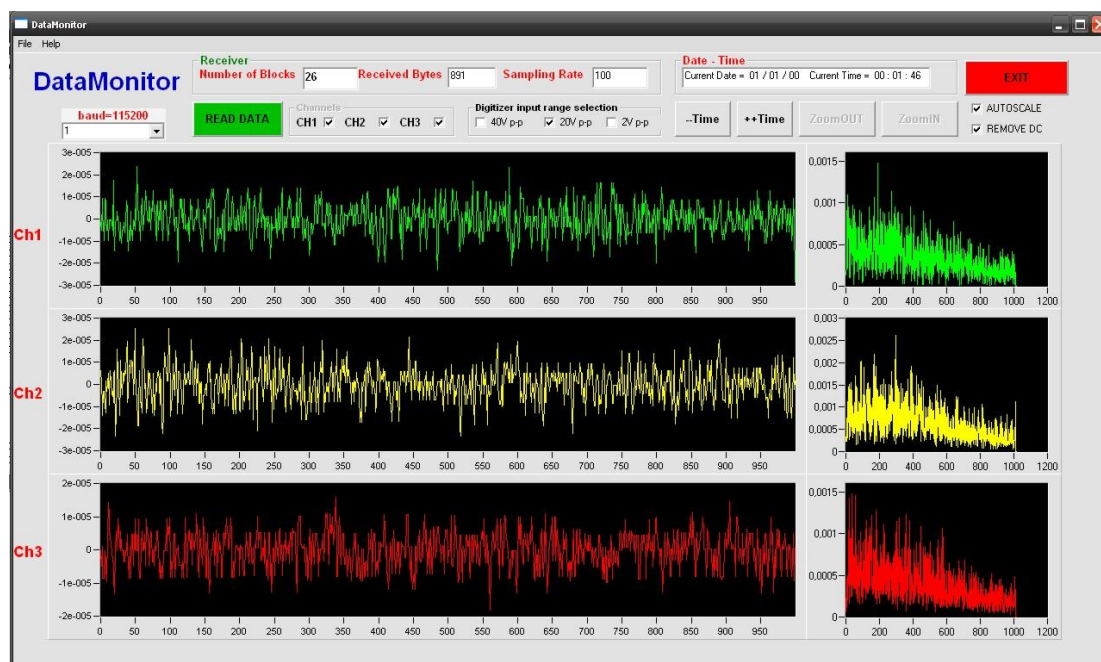


Figure 14: S100 sensor test

In the case that noise exceeds the above limits the noise performance becomes worse than -6dBs, so action must be taken from the operator in order to detect noise source and eliminate it. If the site is “noise-free”, the sensor must be better coupled, or being placed deeper. If the site is noisy, the station must be re-located.

In the case that there is some electronic interference to the signal from any local noise source (e.g. power transformer), the time window of the signal will look like Ch2 at fig 15. The frequency of the interference noise is clearly plotted at the spectrum window. The operator can very easily detect possible noise sources in the installation area, eliminate them if possible, or shield the station. If still no effect, the station must certainly be relocated.

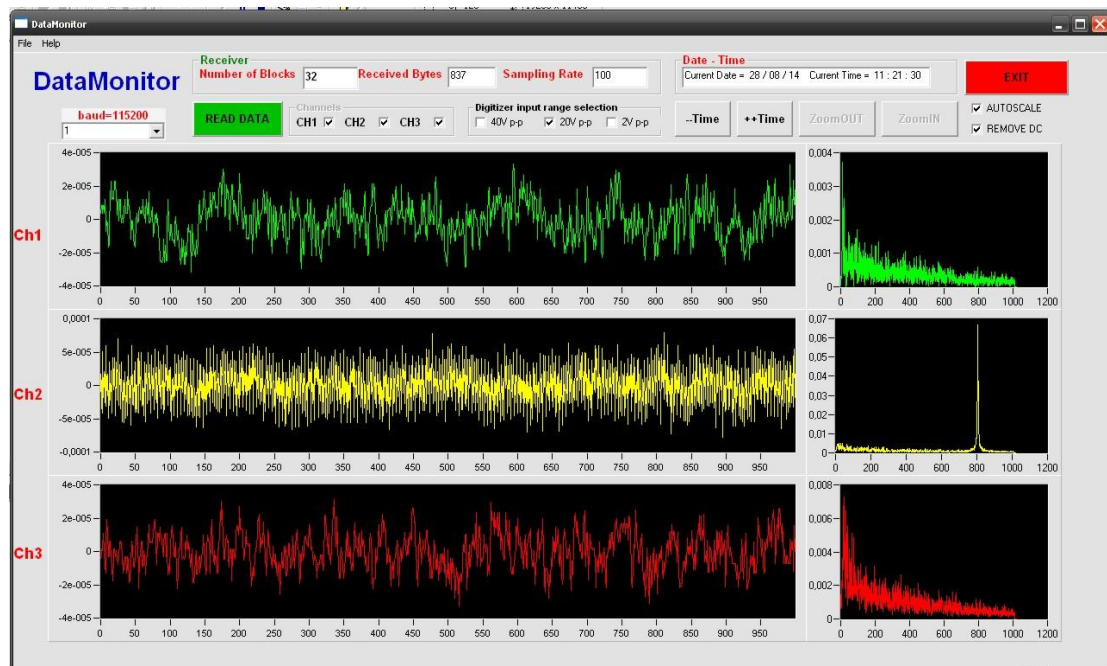


Figure 15: S100 sensor test with interference at ch2

6.2 Recording station response with dropping weight

A special dropping weight has been designed to be used as standard energy source and generate seismic signal. The dropping weight will be placed at a distance of $0.5 \times (\text{borehole depth})$ meters and $1.0 \times (\text{borehole depth})$ meters at directions N & E from the head of the borehole. The operator has to plot the signal using "DataMonitor124" and check proper station response. Once the test is finished, the operator will switch off the datalogger, remove the flash card and copy the test data to the laptop for further inspection if necessary.



Figure 16: Weight drop

The seismic signal that the dropping weight produces, must be recorded clearly, noise free with good signal to noise level. The voltage scale of the plot should be in the range of 0.005V when auto scaling traces are selected in DataMonitor, while the voltage of the horizontal scale should be equal or a little less.

Attention has to be paid to the direction of the drop. Signal towards the direction of the drop will be stronger than the other directions. It is clearly seen at fig 17 that the amplitude of the NS (ch2) component is greater than the amplitude of the EW (ch3) component. The weight drop has been fallen at the NS direction at this example. Vertical signal amplitude does not affected from the direction of the weight drop.

Additionally the weight drop can be any standard weight felled from a standard height.

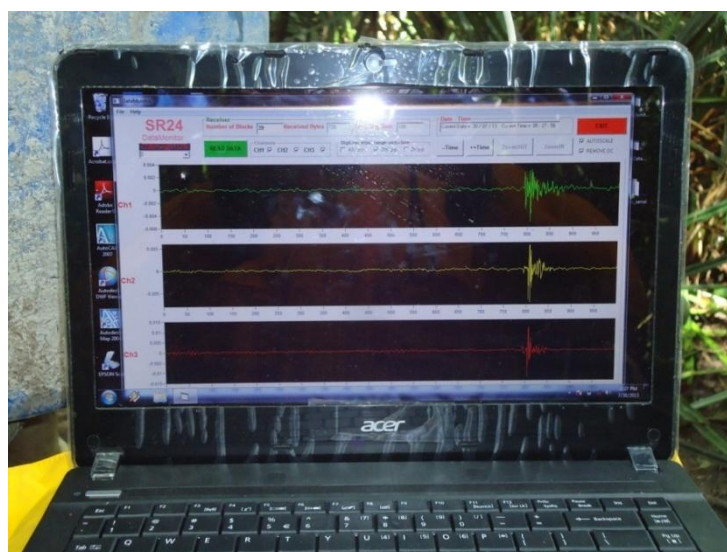


Figure 17: Weight drop result

7 Recorder connection and final configuration

The final step of the seismic station installation is the recorder connection and setup and the final testing. Regarding instrument setup please refer to the instrument's manual. The data are stored locally into the microSD card but also transmitted in real time over seedlink protocol. The user can simply verify data flow using the freeware software "Seisgram2K".

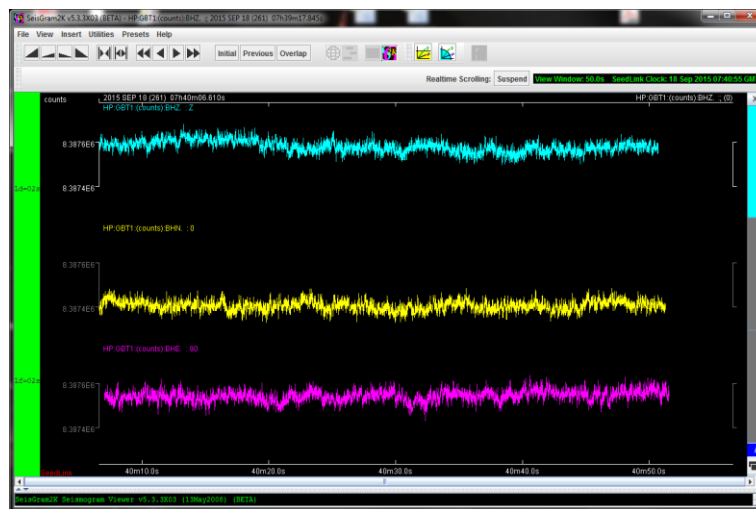


Figure 18: Seismic Signal

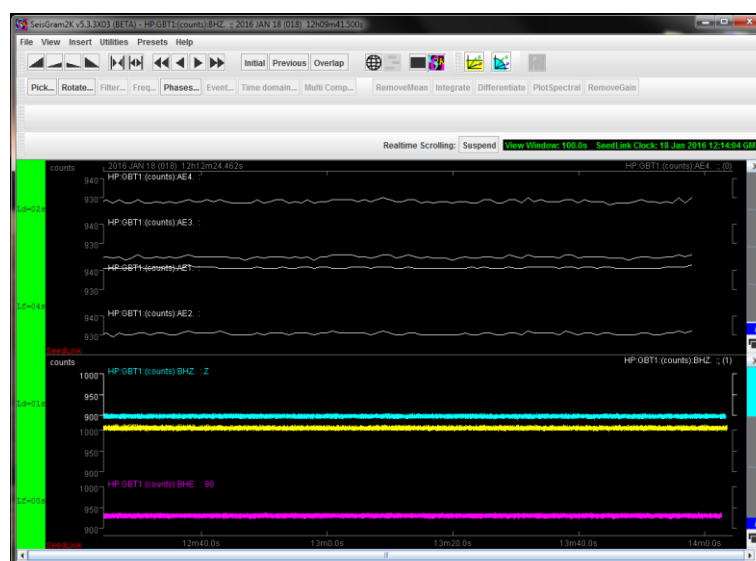


Figure 19: Seismic Signal and four extra analog channels plot

Alternatively the user can connect with the station with SSH (for example winSCP software for windows), download data files, which are in miniSEED format and process then in playback. For more details please refer to SRI32S manual.

State of health of the instrument can be monitored by SOH stream. The user can use the UDP.exe software to plot the SOH information or the SeismNetWatch (www.isti.com) software for detailed seismic network SOH monitoring.

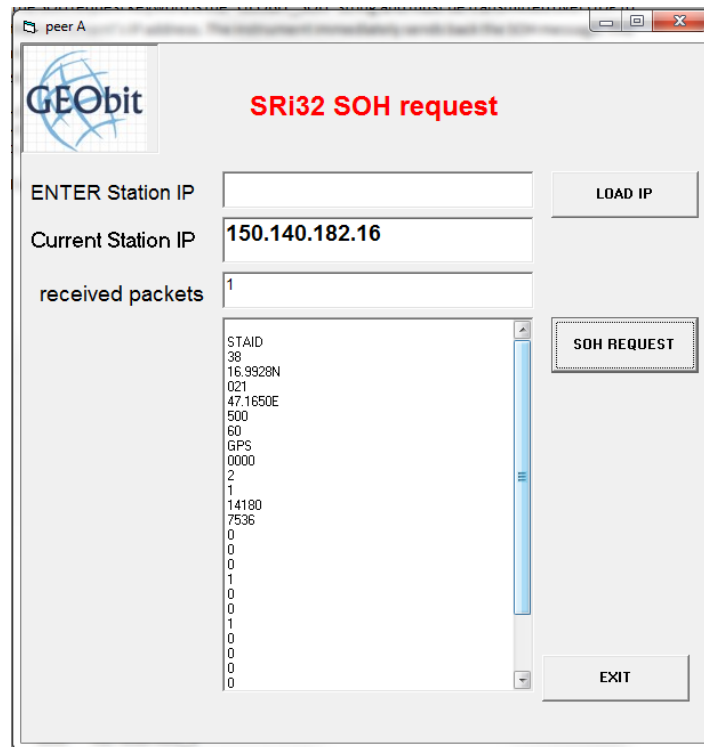


Figure 20: SOH monitor

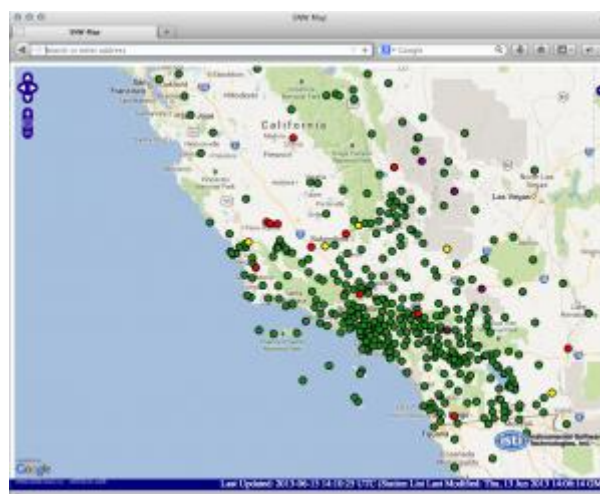


Figure 21: SeisNetWatch by ISTI

