GPR surveys at Nõmmküla 2009

Detection of underground water routes

Tomi Herronen & Timo Saarenketo

2009

ROADSCANNERS

1. Introduction

The purpose of this survey was to locate possible underground water routes (rivers) and other geological structures around Nõmmküla, Estonia utilising the Ground Penetrating Radar (GPR) method. This is supportive survey for previous project near Nõmmküla (November 2008).

The field survey is done in February 2009 for the Inseneribure Steiger, contact person Jan Johanson.

2. Survey methods

2.1 Ground penetrating radar theory in brief

A ground penetrating radar transmits electromagnetic energy in microwave frequencies (50-1500 MHz) into the ground and the twoway travel time together with its' amplitude is measured with the receiver antenna(Figure 1). Transmitter and receiver antennas are usually packed in a single frame.

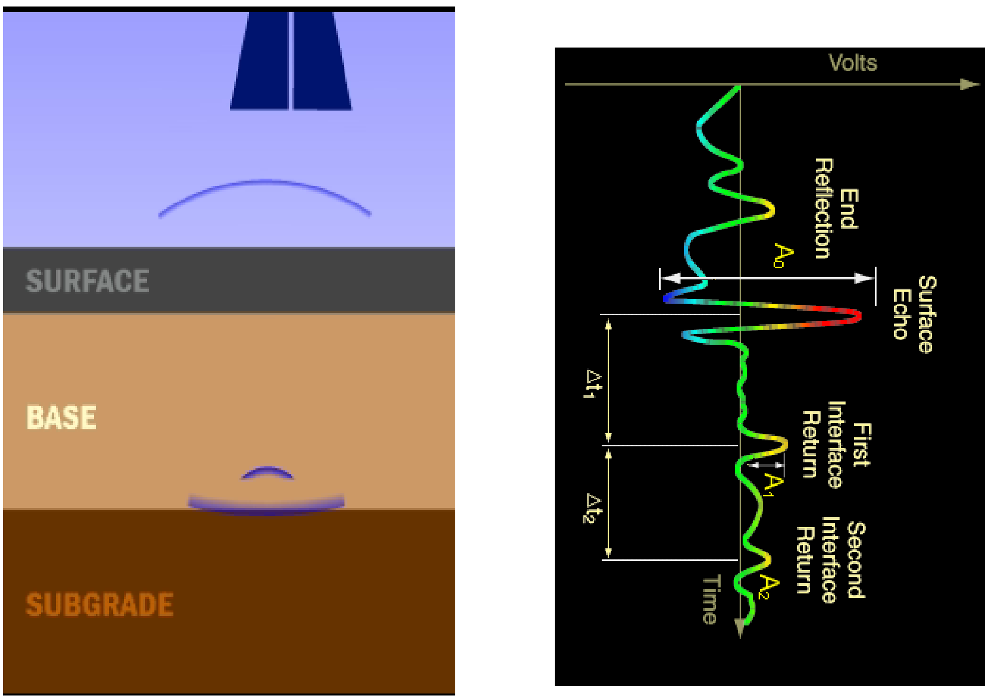


Figure 1. Basic principle of ground penetrating radar and a sketch of a single pulse (on the right).

The energy is sent to the ground as polarized pulse through a GPR antenna that has a certain central (main) frequency. In the ground the signal is either attenuated, reflected, refracted or scattered depending on the physical properties of the material. As the antenna moves, the pulses are repeated and a profile over soil properties is formed (Figure 2). The most important physical properties of the material are its' dielectrical properties and electric conductivity.

The dielectric value of the material (Er-value) defines the speed of the electromagnetic wave (signal). The smaller the dielectric value is the faster the EM-wave propagates in the media. The change in the dielectricity between the materials causes reflection of the EM-wave. The most important cause for changes in dielectric value in natural environment is water.

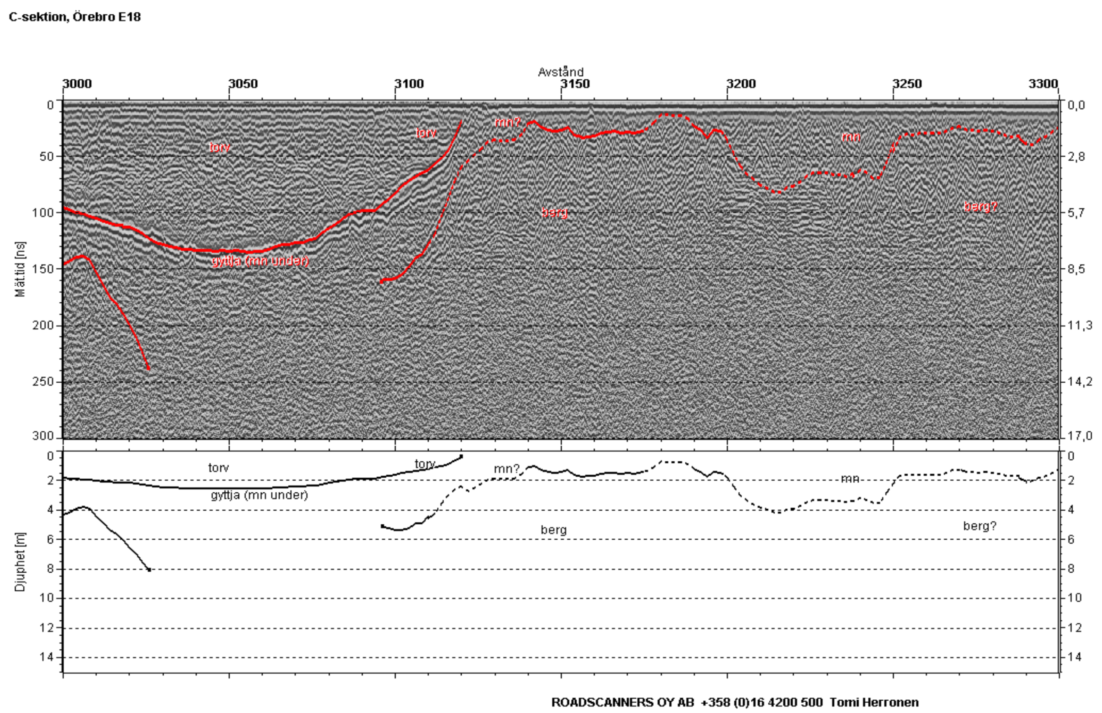


Figure 2. A GPR profile with the interpretation. In the profile upper right the twoway travel time in nanoseconds and below depth scale in meters.

The electrical conductivity is the most important factor in attenuation of the signal. Electrically conductive material (for example clays) will attenuate the signal effectively. Heterogenic soil (as boulders or gravel with big grain size) can scatter the signal and weaken the signal received by the receiver antenna.

A GPR antenna is chosen by considering the desired survey depth and survey resolution. As the antenna main frequency gets higher, the penetration depth gets smaller and the resolution gets better. A simplified example gives 30 meters penetration depth for 50 MHz antenna on dry sandy soil while the 800 MHz antenna reaches about 1 meters depth at the same site. On the other hand, for example 1.5

GHz antenna produces detailed information on road pavements, which cannot be examined with low frequency antennas.

The survey can be done by using a vehicle or carrying the equipment. The scans (pulses) of the GPR system is done either using a optical encoder or surveying free run, when markers are used to help positioning. The latter means that the survey line has to be measured by other devices to get correct distance. The recording interval or scan frequency is usually between 5-50 scans/meter, depending on the survey purposes.

After the collection it is possible to post process data with several different operations, as cutting, joining, filtering and gaining to improve data quality. In the interpretations the important interfaces and reflections are marked and the time scale is inverted to depth scale.

There are several applications for GPR. A few to be mentioned here are road surveys (structure layers and quality, pavement thickness and quality), ground water surveys, soil surveys (layers thicknesses, soil types), bedrock depth and quality (fracture zones), infrastructure and utilities (pipes etc.), glacier surveys, peat surveys and archaelogical and military targets.

2.3 Equipment used, field procedures and data processing

In this survey a GSSI SIR-20 central unit was used together with 100 MHz ground coupled antenna. The time range used was 350 ns. The equipment was carried in the forest and optical encoder was used for distance measure by survey wheel. Scan interval was 10 cm (10 scans per meter).

Also experiences of previous surveys in the area (February 2008, ”Maatutkamittaukset Tuhalan alueella – maanalaisten jokien esiintyminen and November 2008, ”GPR surveys at Nõmmküla”) were taken into account.

Road Doctor Pro®–software was used for data processing, interpretation, maps and analysis.

3. Field work

The survey was done in winter conditions. At the site was snow cover of few tens of centimeters. The first time survey was done (there was an equipment failure, but second time (11.2.2009) the survey was succesful. The survey lines were in a rectangular shape around the planned quarry site totalling approximately 1,5 km, see Fig 3. The site and the survey lines were chosen by the client.

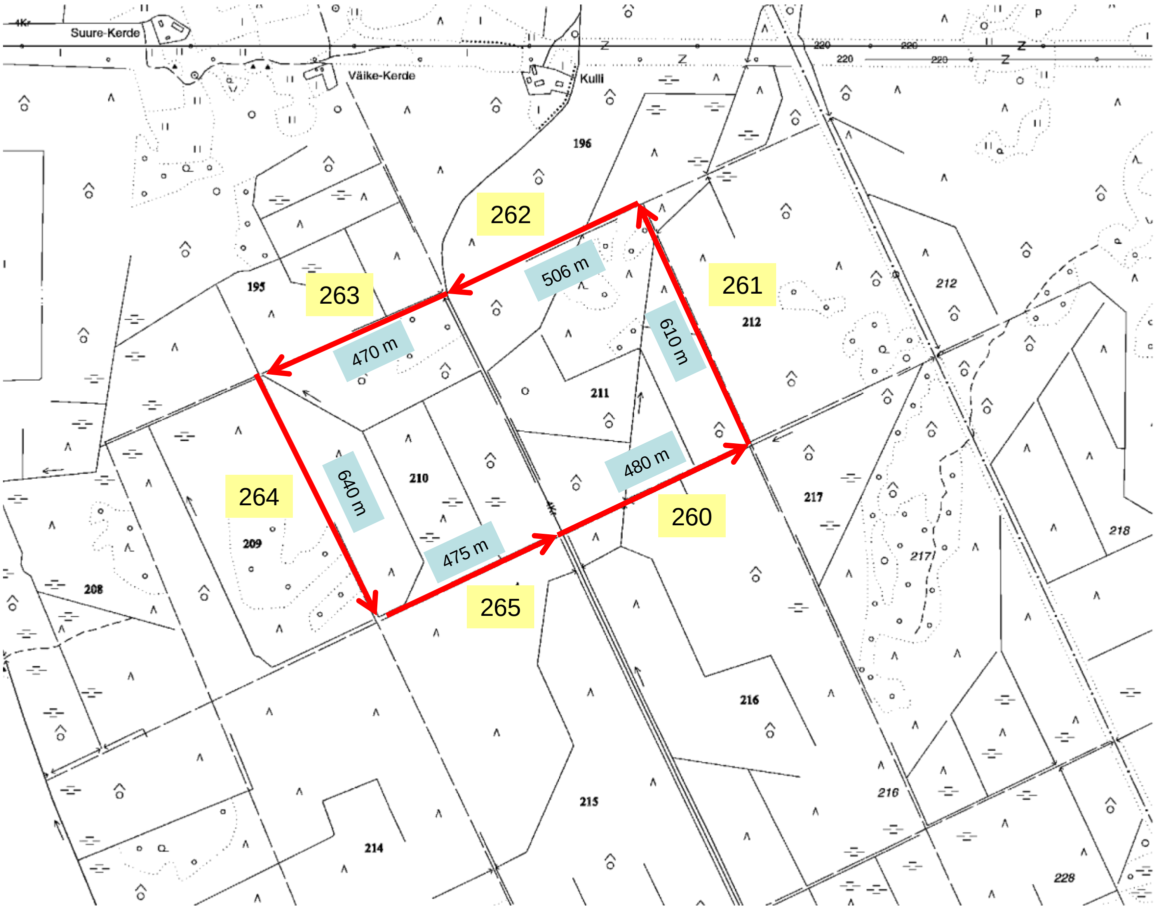


Figure 2. The survey lines. Yellow boxes show the file number, the blue boxes present the survey line length.

Frozen soil together with snow cover helped to collect data with satisfying quality.

4. Data analysis

The collected data was processed with horizontal and vertical filtering, background removal and gaining with different parameters to get the best possible settings to point out the anomalies. Analogies to Nõiakaev test site and previous surveys at the site were takin in to consideration.

An analysis bar was used to mark and class suspectible locations. The class is divided in three: no indications, porous structure and possible underground river. In this classification, porous structure means limestone bedrock with fractured and eroded (small) holes and layers that are filled water.

5. Results

5.1 General, stratigraphy of top soil and bedrock

Based on GPR results the soil and the bedrock stratigraphy is the following:

1. Glaciogenic and postglacial top soils (1-3 m)

Top soils in Nõmmküla area are mostly between 1-2 m and rarely over 3 m. These layers have formed during the last ice age or after it and include moraines, silts and clay or peat.

2. Weathered rock (locally)

Locally under the top soil there is a zone of weathered rock. At these sites the bedrock changes from loose to firm within few meters. As the figure 3 shows, in weathered rock the sediment layers are sometimes easily spotted from the GPR profile.

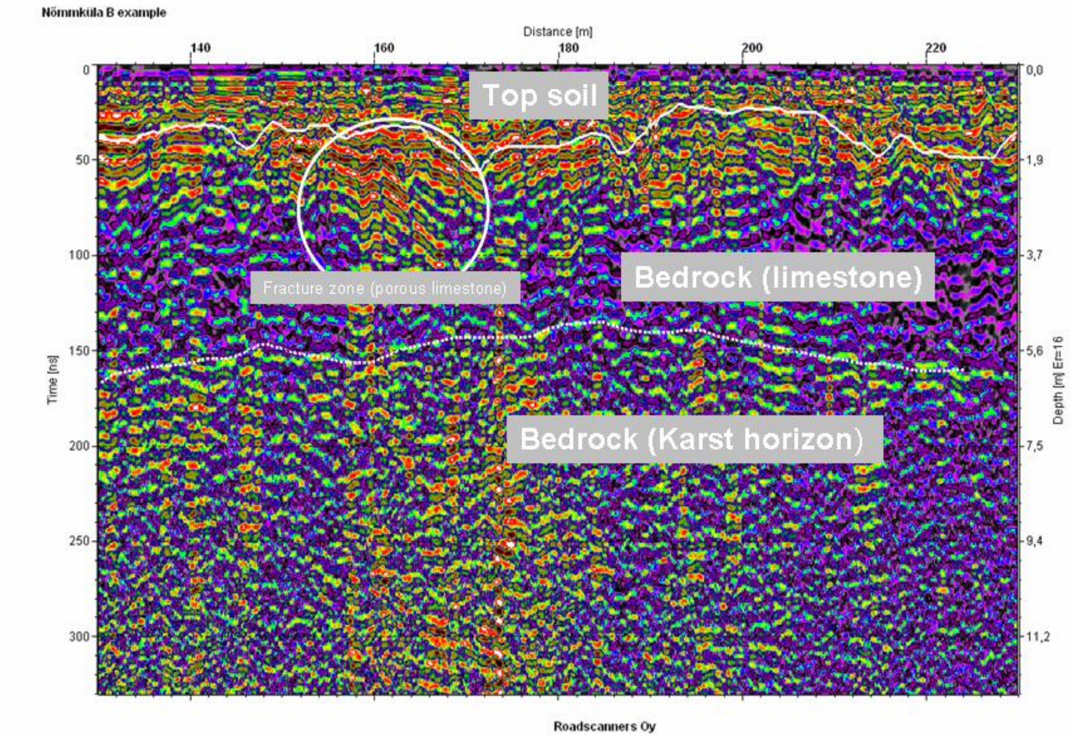


Figure 3. Sediment rock layers in the GPR profile. The layers continue from loose weathered rock into the firm bedrock deeper.

3. Bedrock and possibility of underground rivers

Based on the survey results, under the top soil there is a 3-4 m thick layer of mostly firm limestone bedrock. Locally there are fracture zones and cracks.

Below this firm bedrock there is a layer of porous rock, so called karst horizon. In this survey it was not possible to reliably tell the thickness of this layer, but learned from other studies, it is typically 2-4 m thick. The material is most probably gypsum. If there are undergound rivers, they would appear in this layer.

In general, the sediment structures in the area are quite horizontal, which supports the theory of generation of underground rivers.

5.2 Profile descriptions

5.2.1 File 260

Partially clear sediment layer structures. At few locations indications of fractured rock zones (analysis class 1).

5.2.2 File 261

No strong horizontal structures visible in bedrock. Indications of porous layers at few points.

5.2.3 File 262

For some reason more noisy data. No clear indications of porous structures.

5.2.4 File 263

Clear structures. At few locations indications of porous structure and most probably a sink hole at location 800-820. See Fig 4.

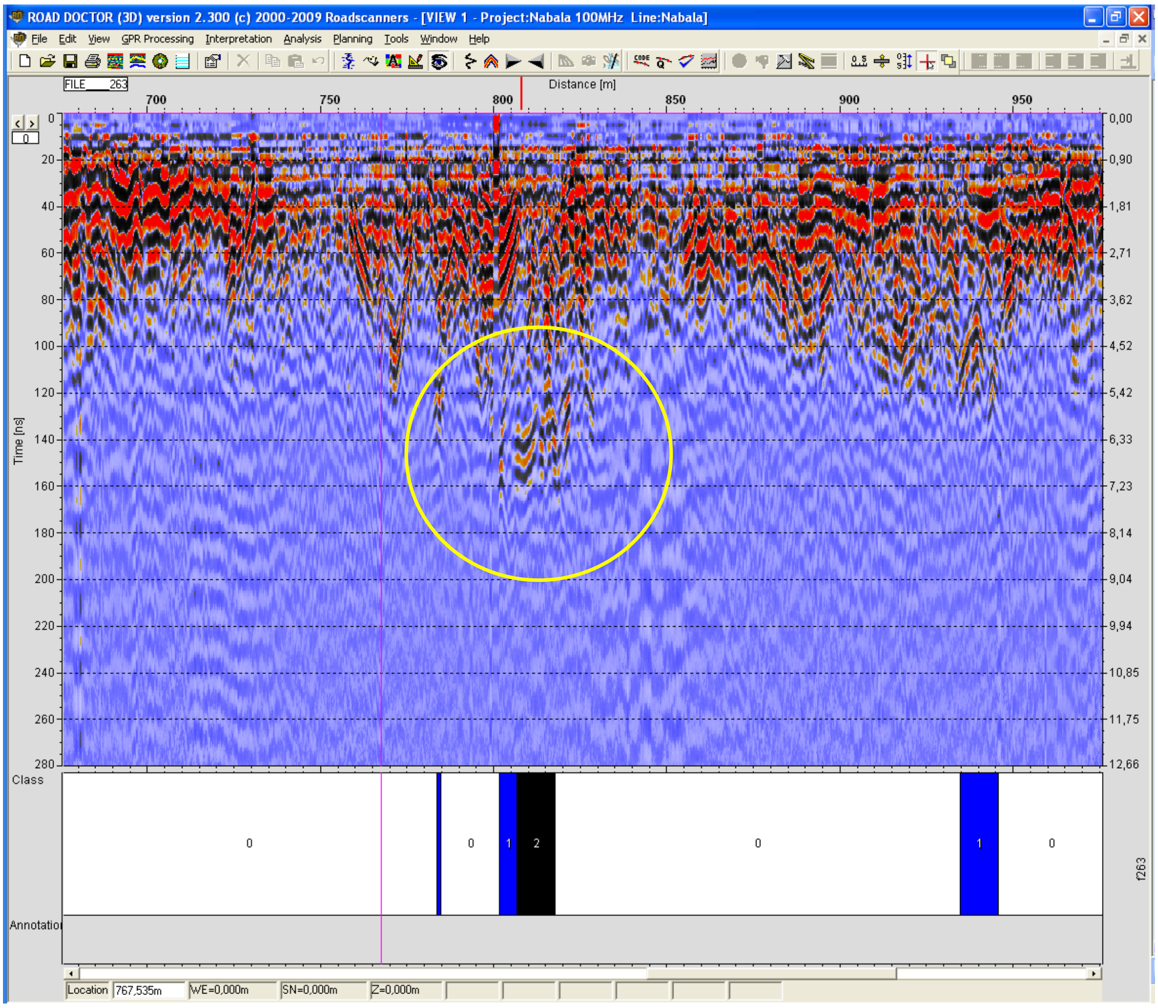


Figure 4. A sink hole on file 263 inside the yellow circle. Depth approximately 5,5 m (dielectric value 16).

5.2.5 File 264

Porous structures at few locations. Layer interfaces weak, no clear bedrock formations.

5.2.6 File 265

Porous structures at few locations. Layer structures quite visible.

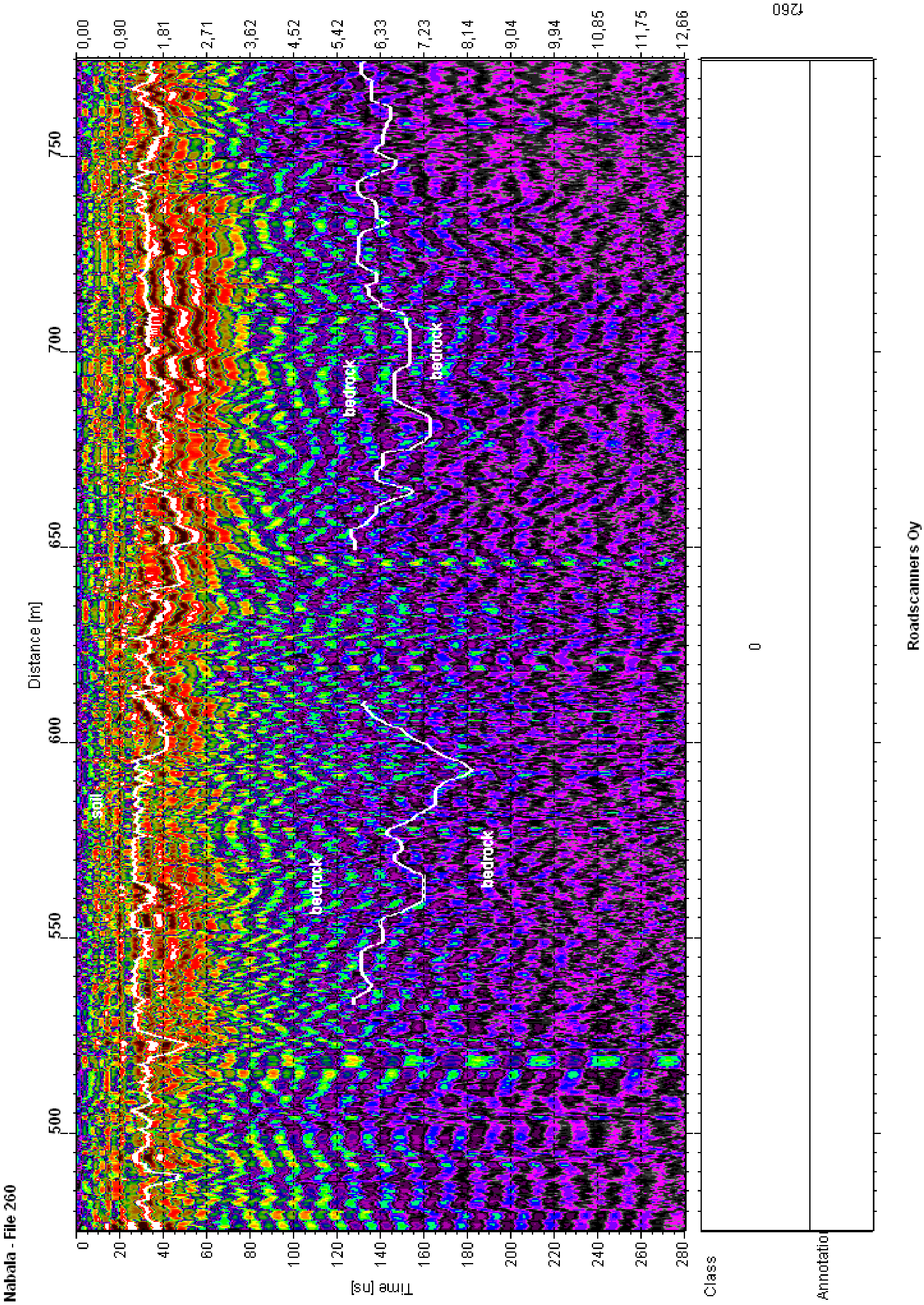
6. Conclusions

In the survey area, most probably at least a sink hole was found. Sink hole is a cavity or collapsed cavity in porous bedrock filled with water, soil or air. On survey profile number 263 a strong reflection at depth of approximately 5,5 meters can be spotted. The depth scale matches the geological description above (Chapter 5.1). The length of this reflection is about 20 m. It cannot be completely ruled out that this anomaly does not have a hydraulic connection in some direction, in other words an underground water route but according the surveys so far this has not been proved.

Other lines don't show same type of anomaly. Still the geological structures of the site, exposed by GPR, strongly support the possibility of underground tunnels with hydraulic connectivity. To map these connections a detailed and large scaled survey would be required.

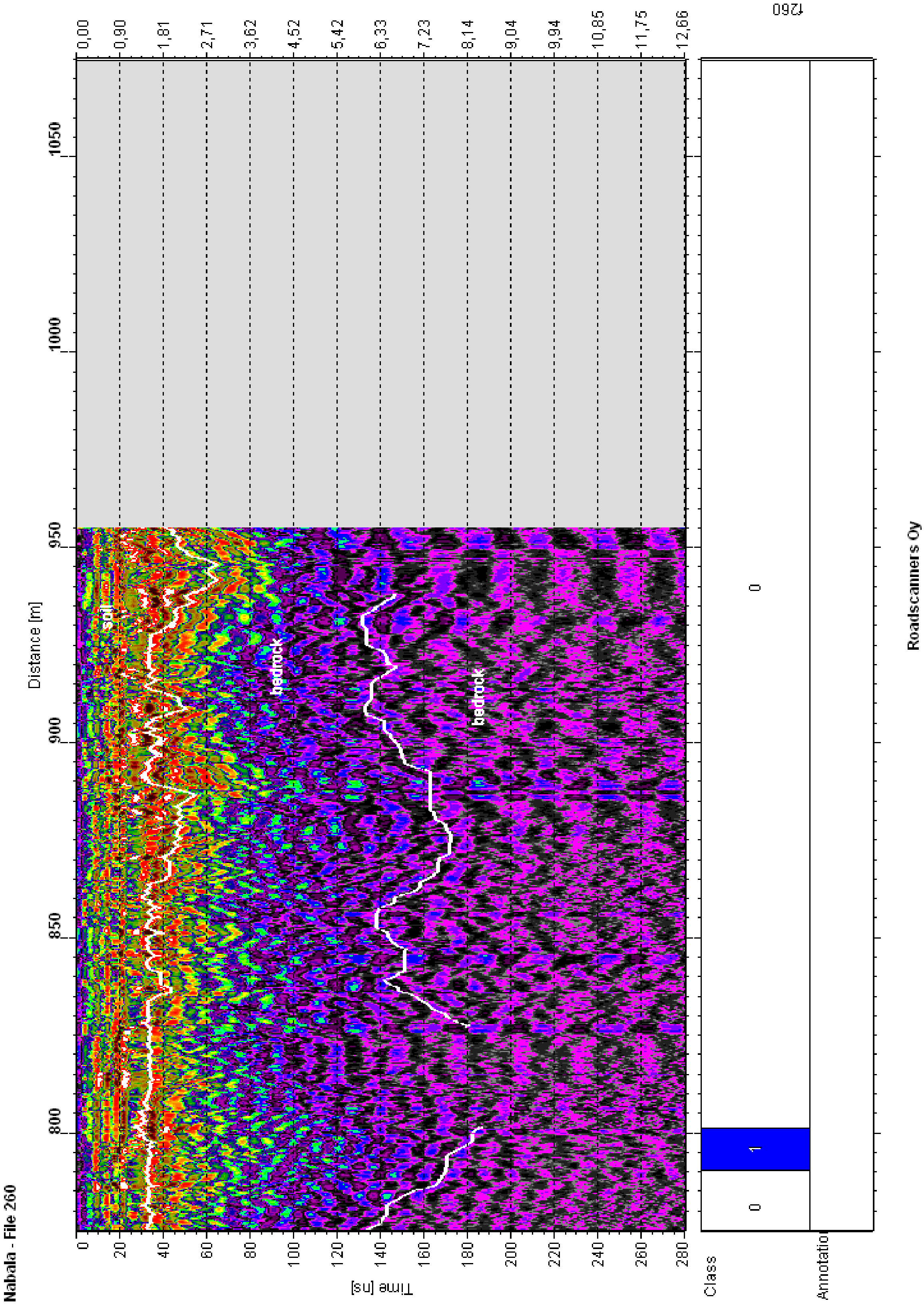
APPENDIXES:

Appendix 1

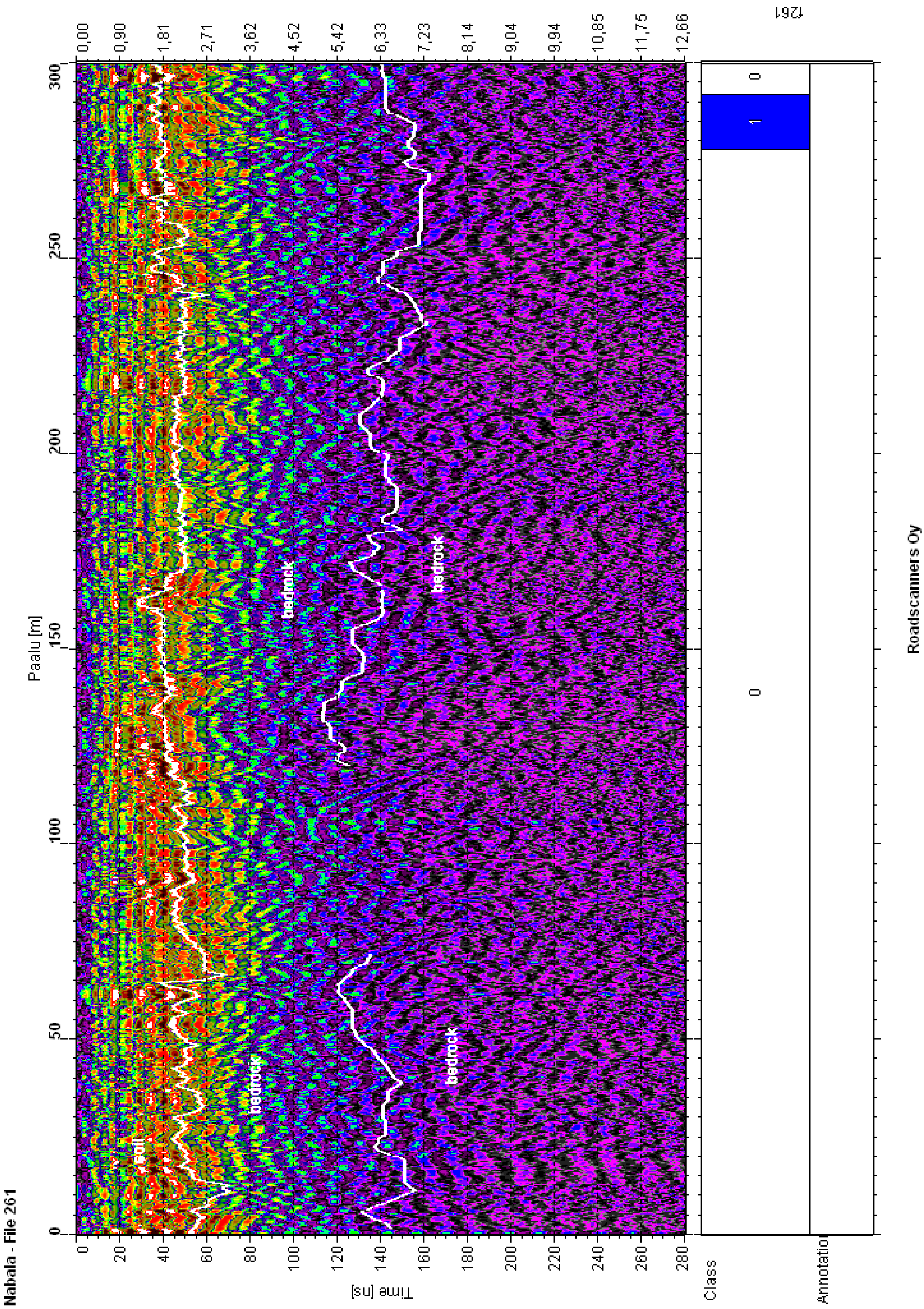


Nabala - File 260
Distance [m]
500
550
600
650
700
750
Time [ns]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
0,00
0,90
1,81
2,71
3,62
4,52
5,42
6,33
7,23
8,14
9,04
9,94
10,85
11,75
12,66
soil
bedrock
bedrock
bedrock
bedrock
Class
Annotatio
0
f260
Roadscanners Oy

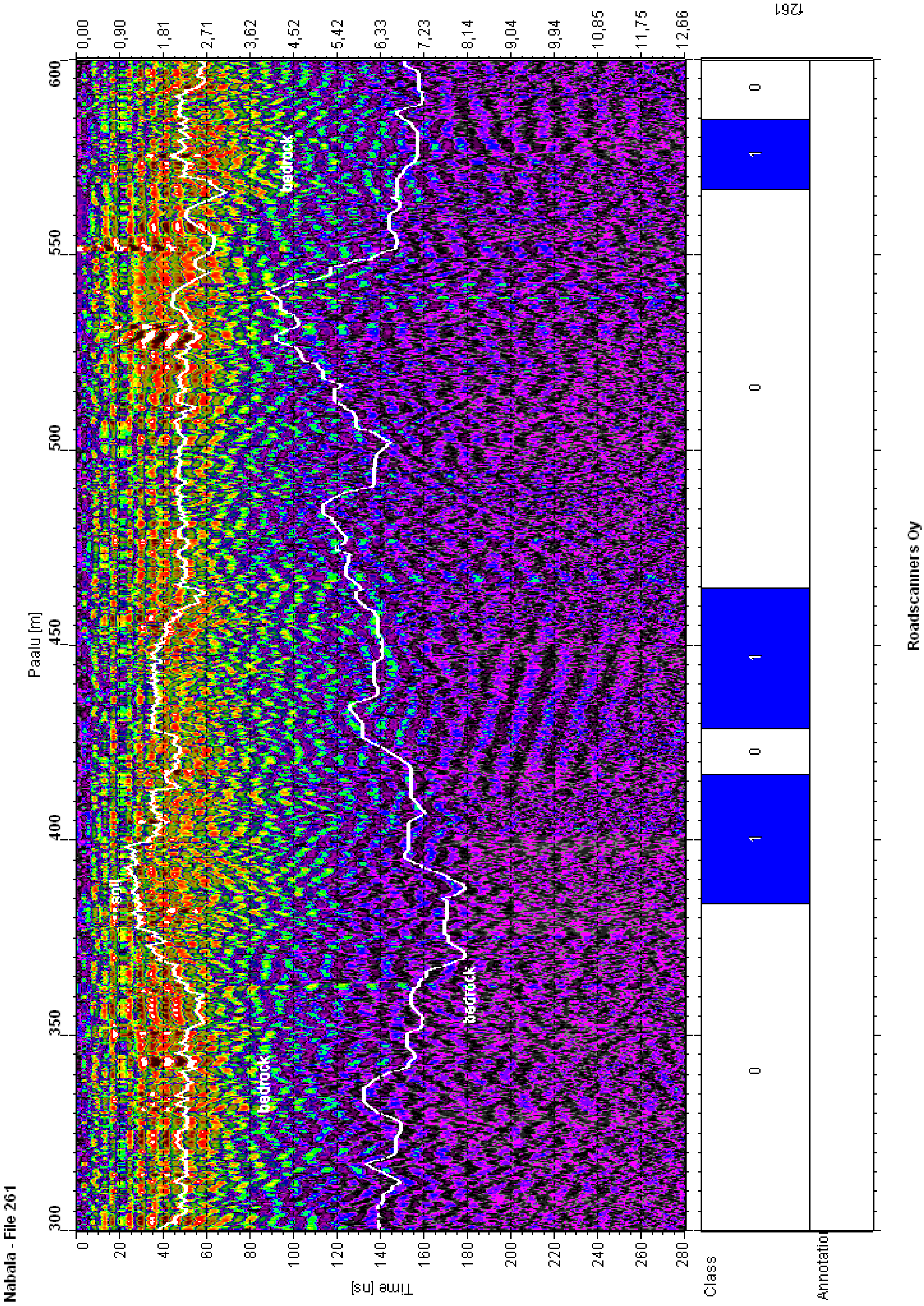
Appendix 1



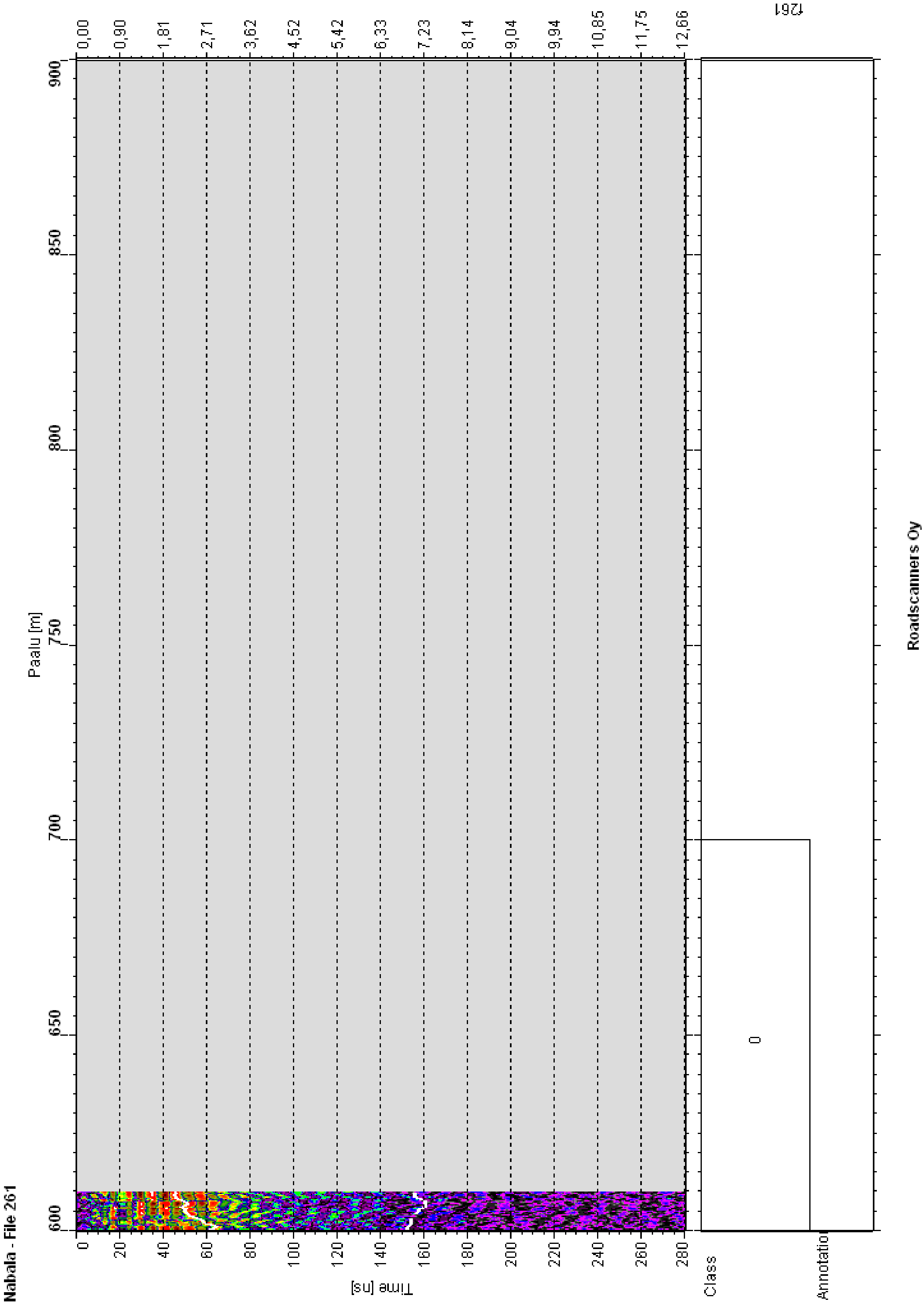
Nabala - File 260
Distance [m]
Time [ns]
soil
bedrock
bedrock
Class
Annotatio
Roadscanners Oy

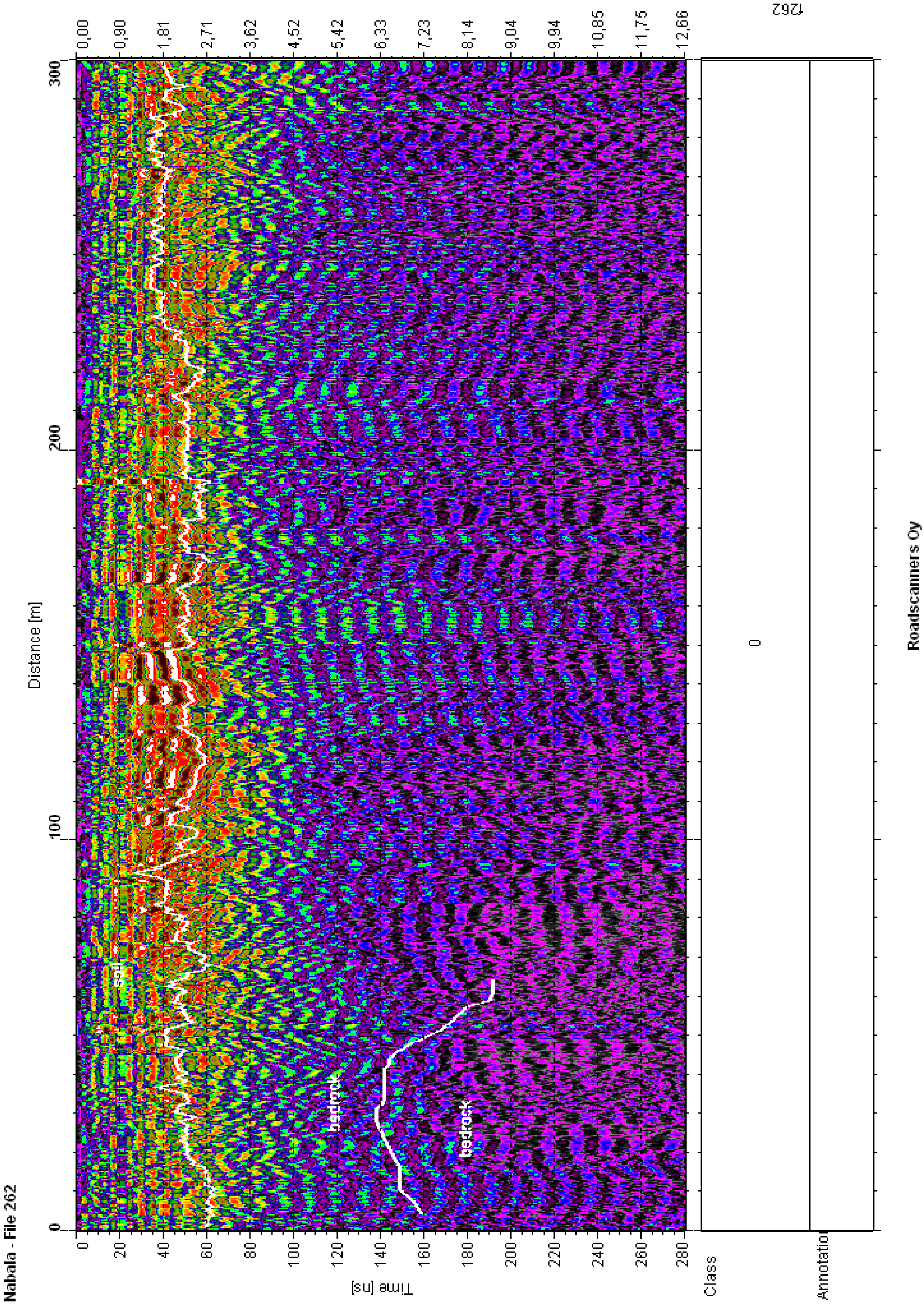


Nabala - File 261
Paalu [m]
Time [ns]
soil
bedrock
bedrock
bedrock
bedrock
Class
Annotatio
Roadscanners Oy
t261

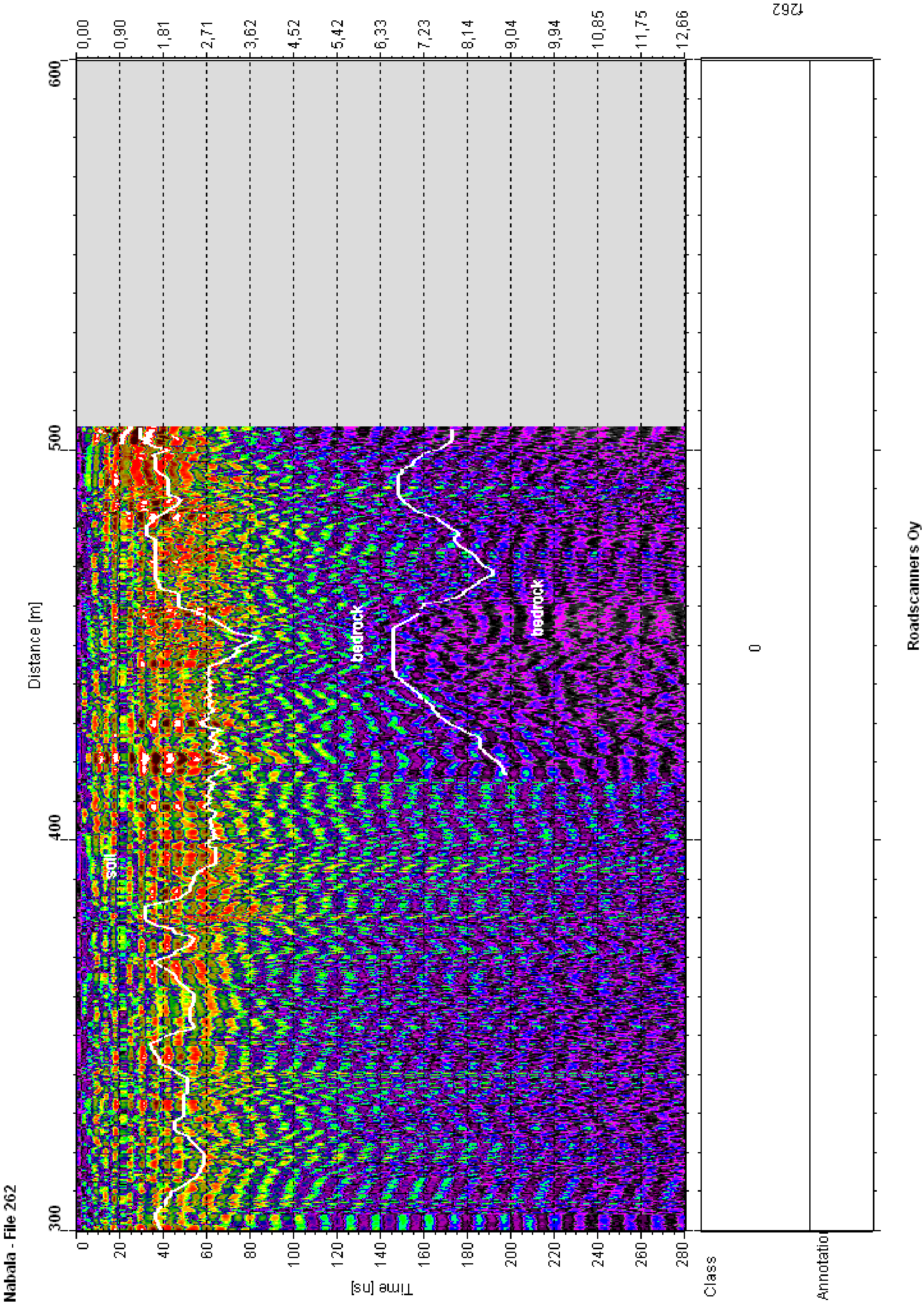

Nabala - File 261
Paalu [m]
Time [ns]
bedrock
soil
Class
Annotatio
Roadscanners Oy
t261

Appendix 2

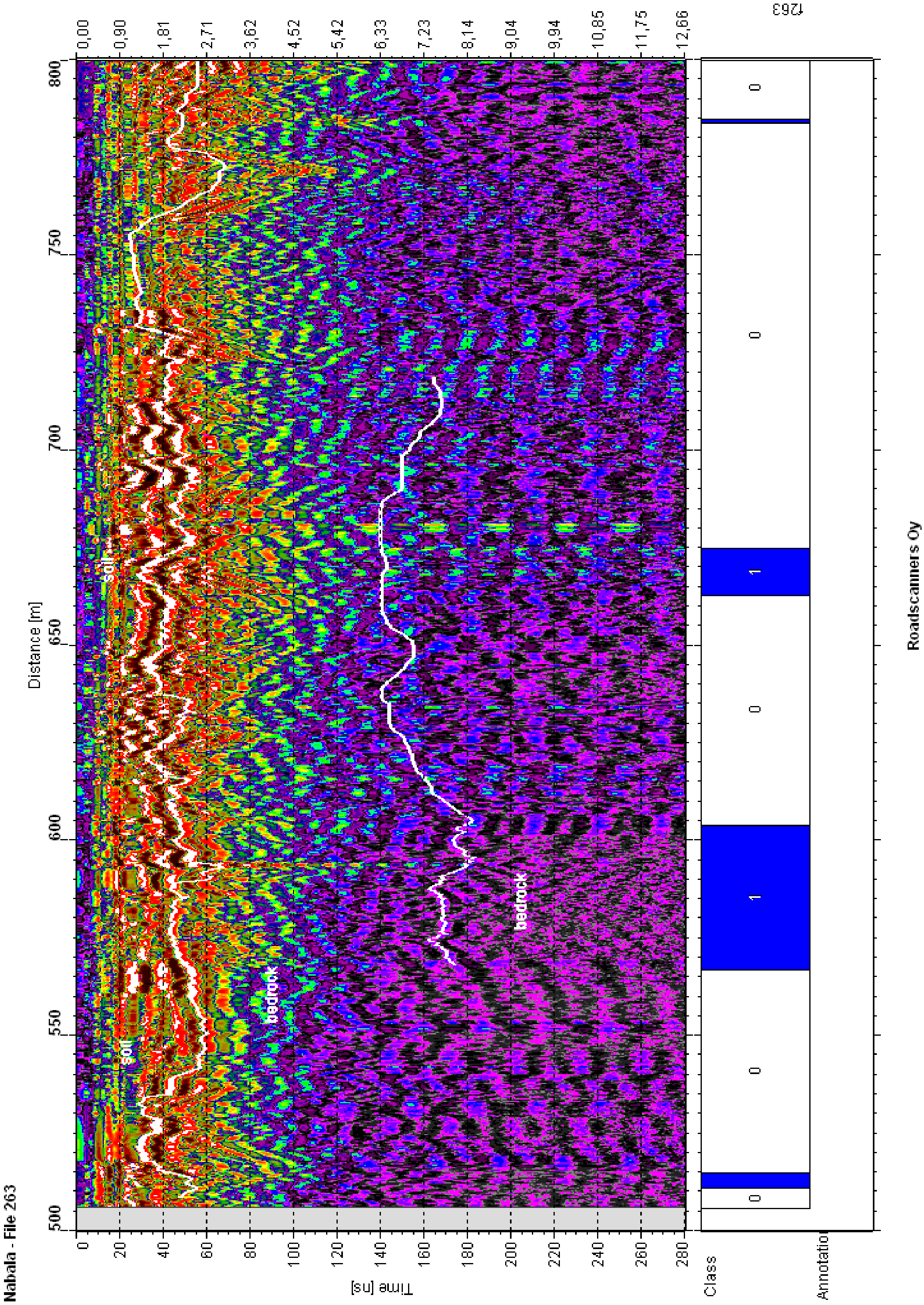

Nabala - File 261
Paalu [m]
600
650
700
750
800
850
900
Time [ns]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
0,00
0,90
1,81
2,71
3,62
4,52
5,42
6,33
7,23
8,14
9,04
9,94
10,85
11,75
12,66
Class
Annotatio
0
Roadscanners Oy

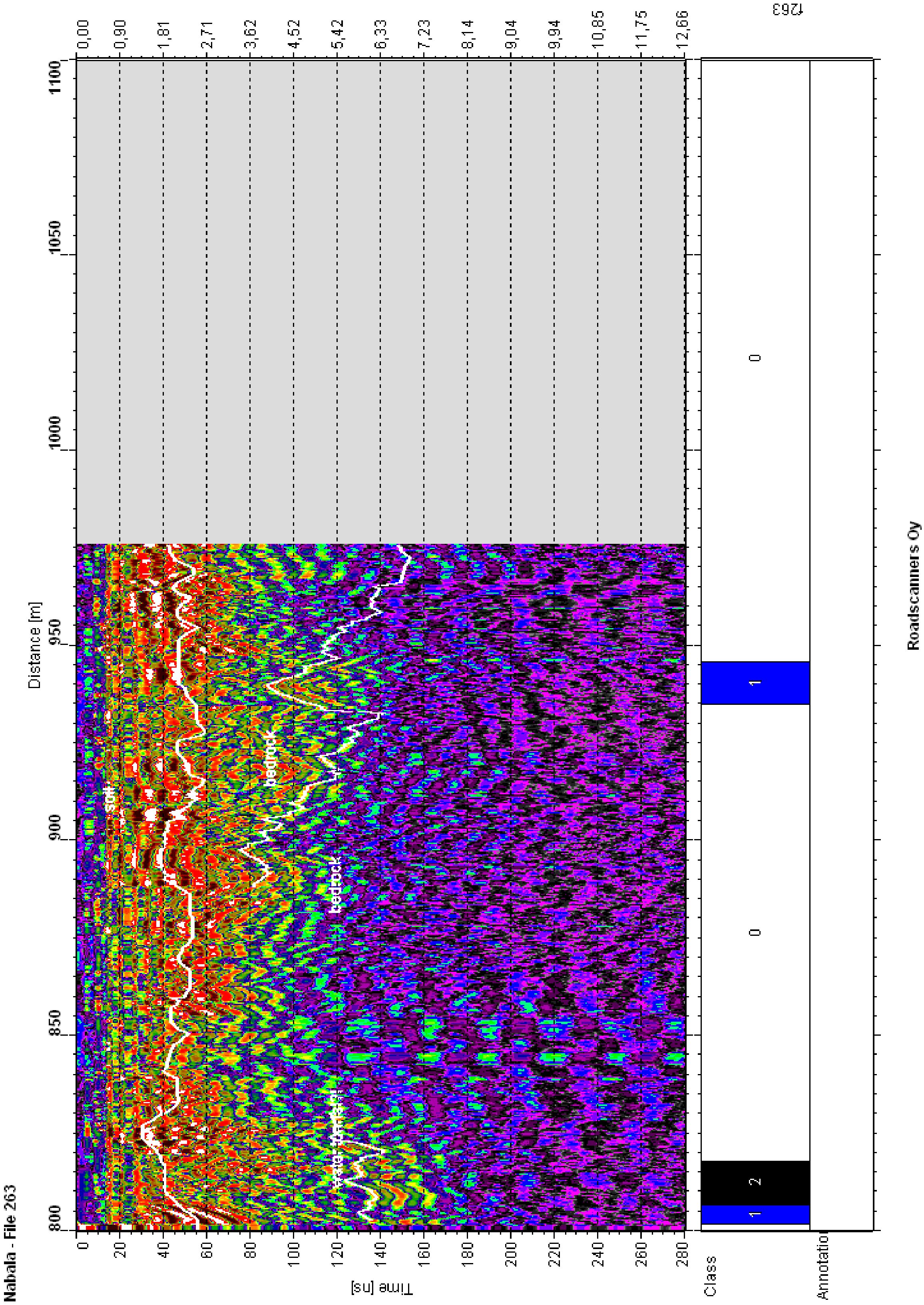

Nabala - File 262
Distance [m]
Time [ns]
soil
bedrock
bedrock
0
Class
Annotatio
Roadscanners Oy
t262

Appendix 3

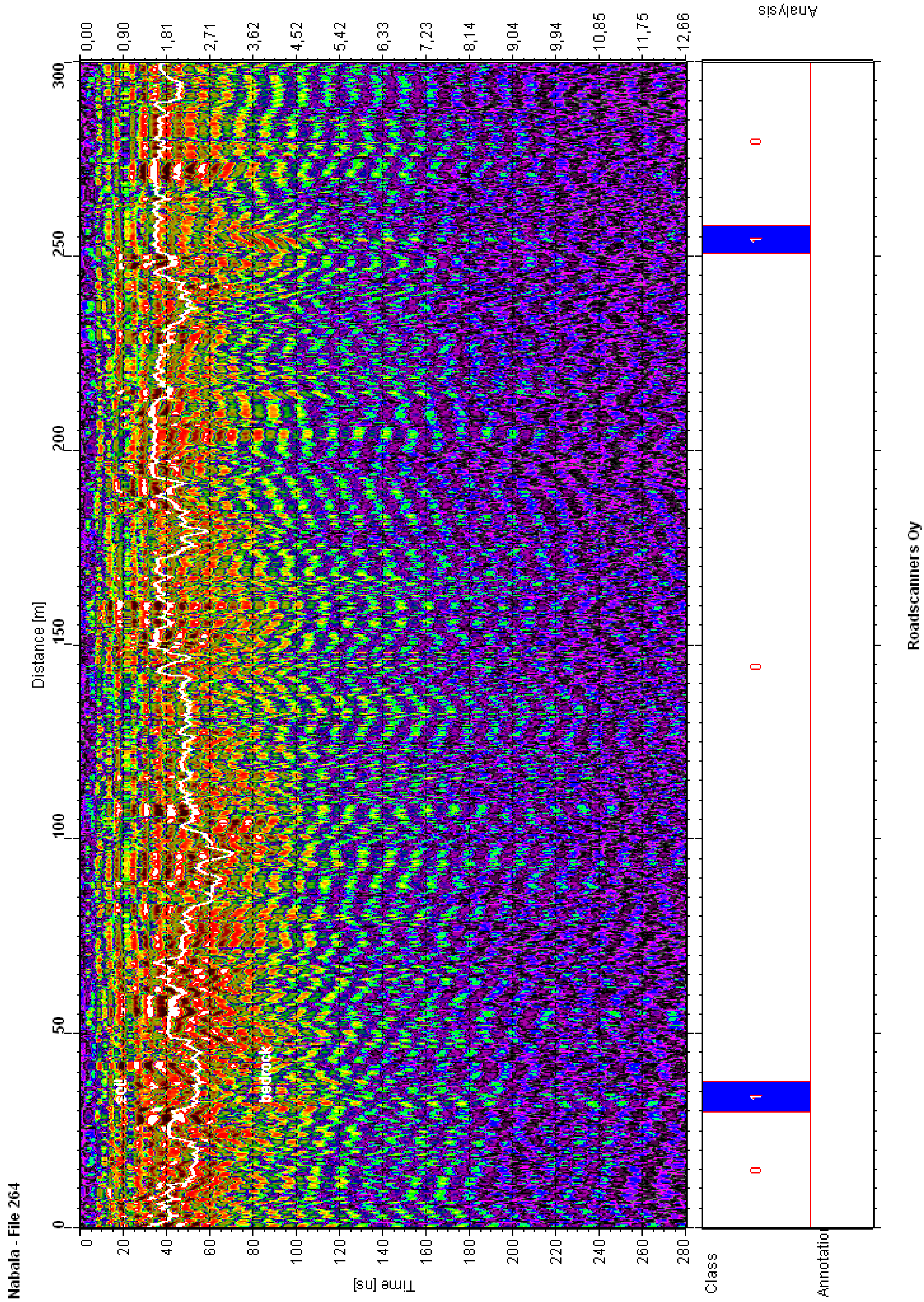


Nabala - File 262
Distance [m]
Time [ns]
soil
bedrock
bedrock
Class
Annotatio
0
Roadscanners Oy
t262


Nabala - File 263
Distance [m]
Time [ns]
soil
soil
bedrock
bedrock
Class
Annotation
Roadscanners Oy

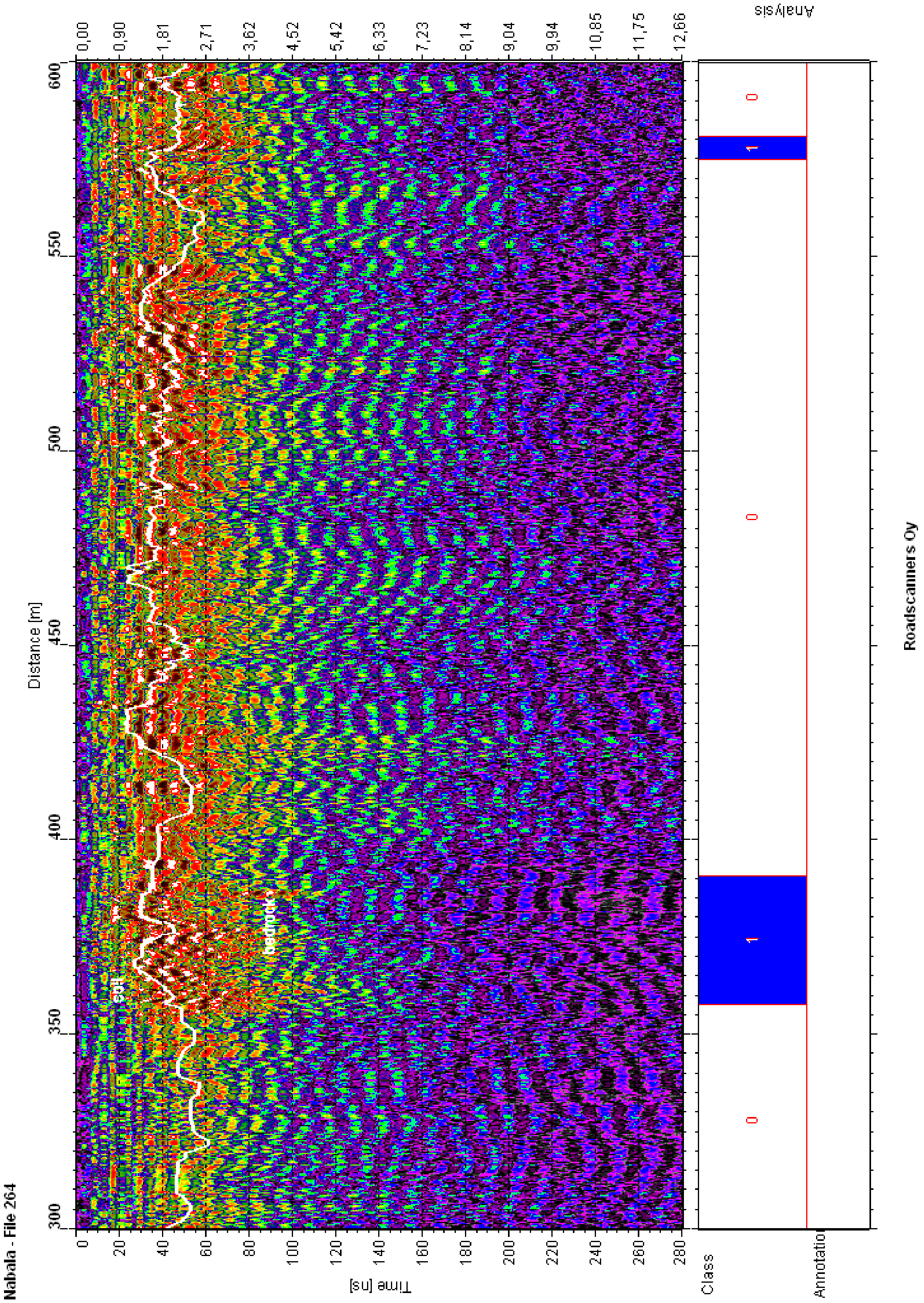

Nabala - File 263
Distance [m]
800
850
900
950
1000
1050
1100
Time [ns]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
0,00
0,90
1,81
2,71
3,62
4,52
5,42
6,33
7,23
8,14
9,04
9,94
10,85
11,75
12,66
soil
bedrock
bedrock
Class
Annotatio
1
2
0
1
0
f263
Roadscanners Oy

Appendix 5



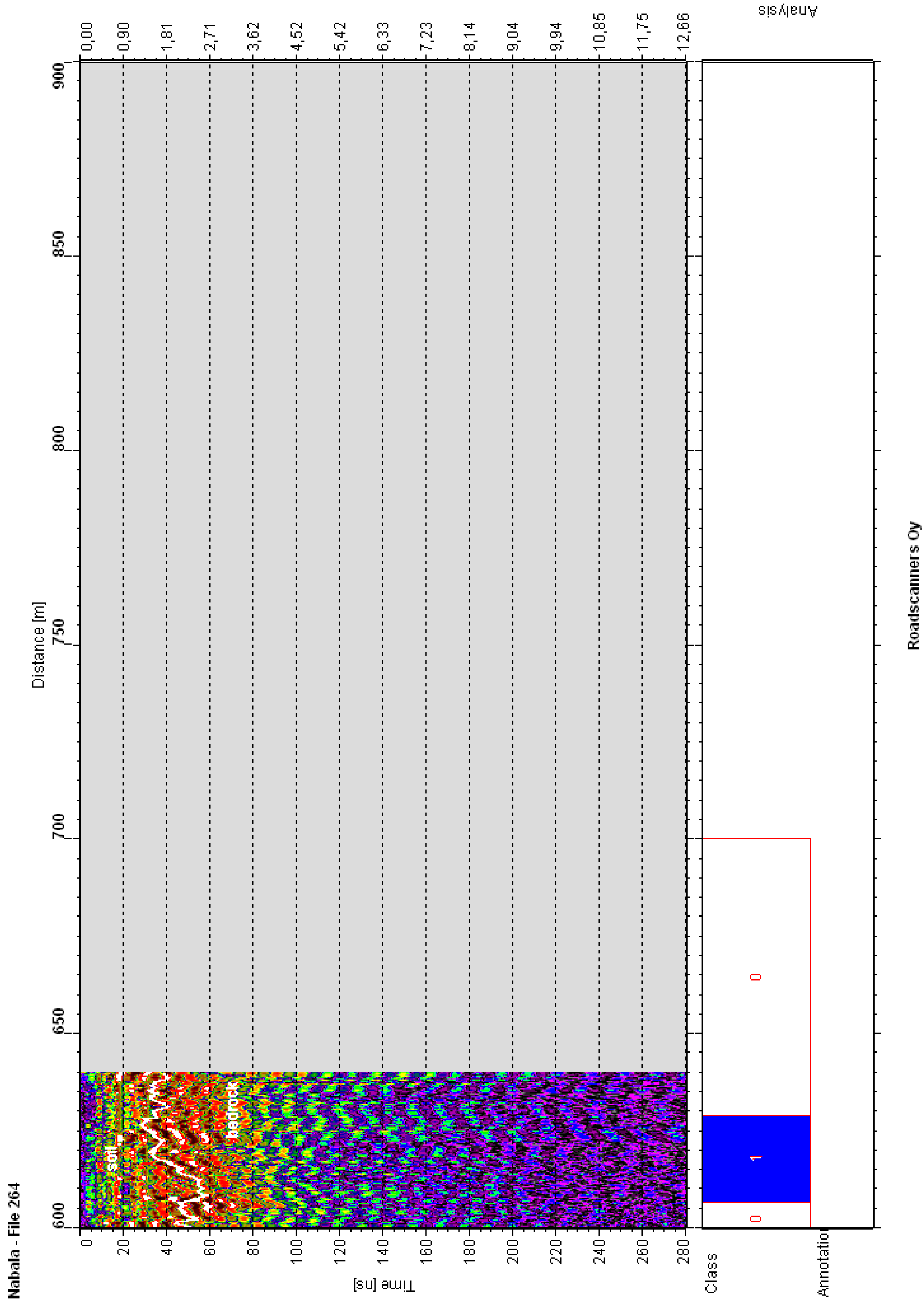
Nabala - File 264
Distance [m]
Time [ns]
Class
Annotatio
Analysis
Roadscanners Oy

Appendix 5

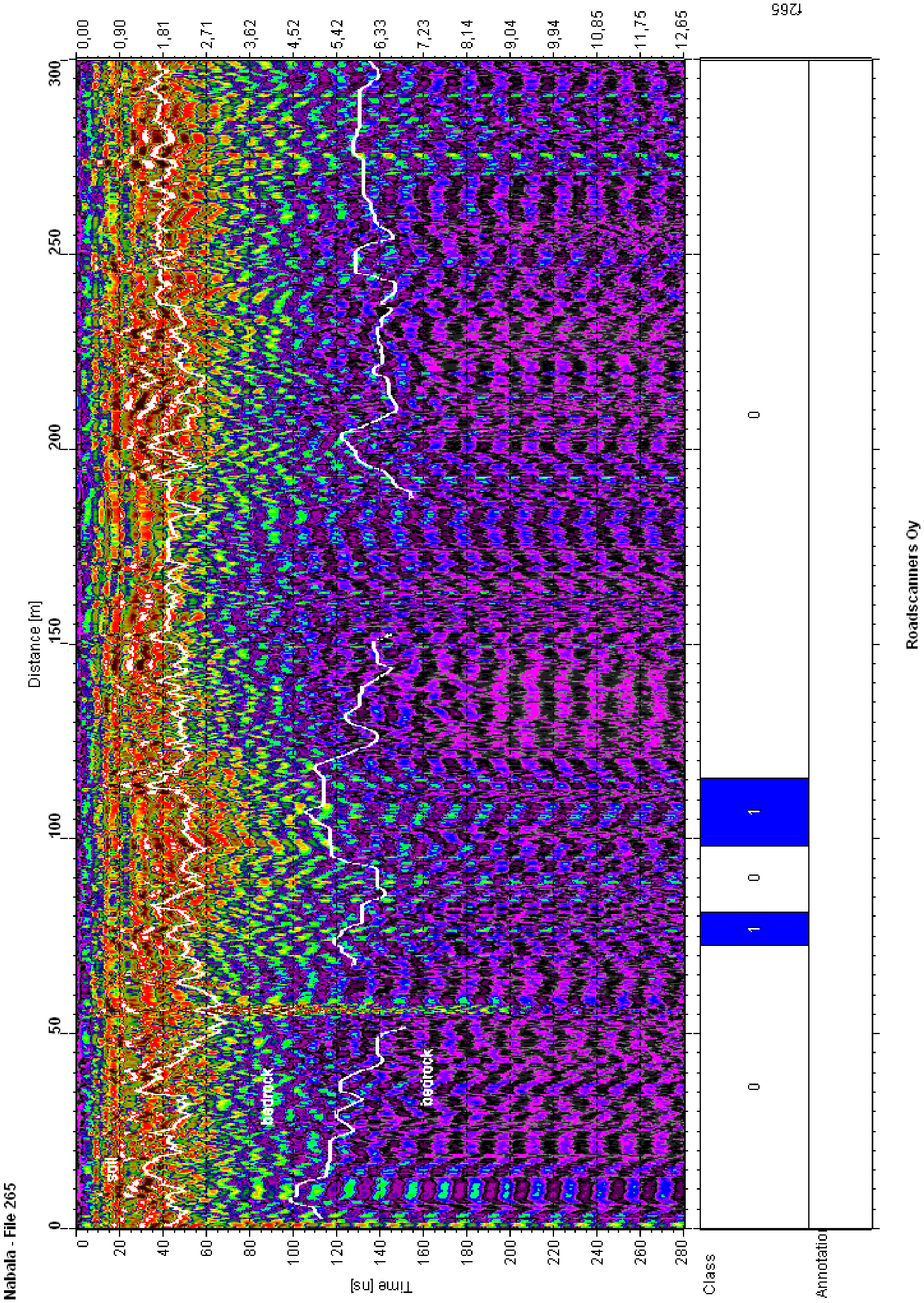


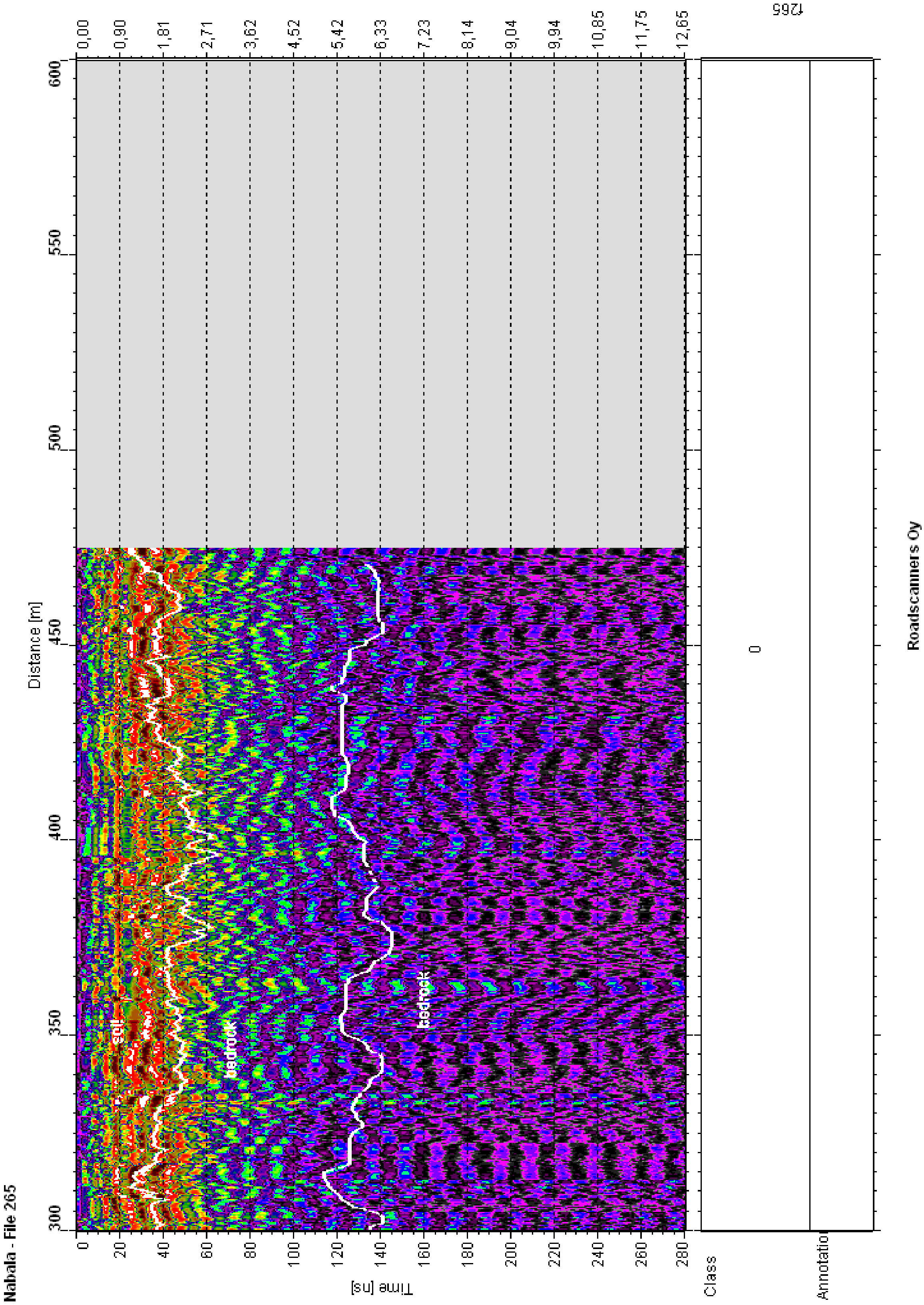
Nabala - File 264
Distance [m]
Time [ns]
soil
bedrock
Class
Annotatio
Analysis
Roadscanners Oy

Appendix 5

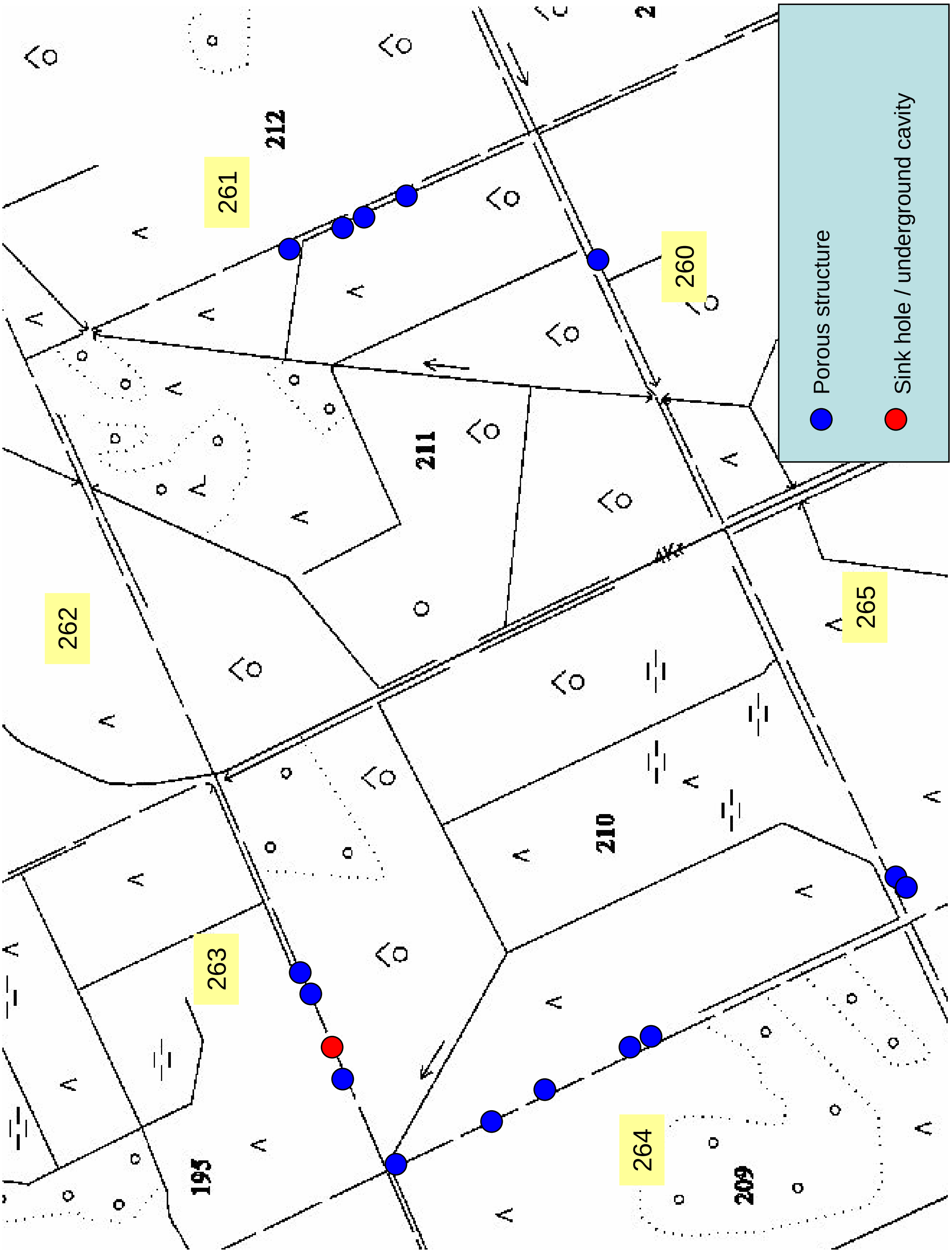


Nabala - File 264
Distance [m]
Time [ns]
Class
Annotatio
Analysis
Roadscanners Oy
soil
bedrock


Nabala - File 265
Distance [m]
Time [ns]
soil
bedrock
bedrock
Class
Annotatio
Roadscanners Oy


Nabala - File 265
Distance [m]
300
350
400
450
500
550
600
Time [ns]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
0,00
0,90
1,81
2,71
3,62
4,52
5,42
6,33
7,23
8,14
9,04
9,94
10,85
11,75
12,65
soil
bedrock
bedrock
Class
Annotation
0
Roadscanners Oy

Appendix 7



212
261
2
260
211
262
265
210
263
264
195
209
Porous structure
Sink hole / underground cavity