AGL13170_01

REPORT ON THE GEOPHYSICAL SURVEY AT RANHEIM VESTRE FOR MULTICONSULT

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1. EXECUTIVE SUMMARY

APEX Geoservices Limited was requested by Multiconsult Trondheim to carry out a geophysical survey prior to the construction of a new residential development in Ranheim, east of Trondheim.

The site is immediately north of the E6 motorway, and comprises mainly sloping crop fields which are north and south of a central area of houses, farm buildings and stables. These buildings are part of the survey area, although the western part of these buildings is designated as not for development.

The objectives of the survey were to map the thickness and variation of the soil layers, to identify the thickness and extent of the quick clay layer, to provide soil stiffness information (G_{max}) and to indicate the depth to bedrock.

The survey comprises ERT (Electrical Resistivity Tomography), Seismic Refraction Profiling and MASW (Multichannel Analysis of Surface Waves)

The results indicate that overburden ranges in thickness from 0.5-24.5m, with the zones of thickest overburden along the southern and eastern flanks of the site. Overburden is interpreted to comprise mainly sandy clay, with some clayey sand/sand mainly in the south of the site.

Sensitive clay is interpreted to be present in a zone in the east of the site (c.13m thick), with two further possible zones in the north-east of the site (c.6.5-9.5m). Zones of unleached marine clay have not been interpreted to be present on site.

The seismic refraction/MASW results indicate that overburden material is overall soft-very stiff/loose-very dense and diggable. The MASW results show that zones of soft/loose material are frequently present across the site.

Bedrock is interpreted as highly-moderately weathered greenschist which is c.3-5m thick, followed by slightly weathered-fresh greenschist. Interpreted bedrock elevation ranges from 10-47 mOD across the site, with the lowest bedrock elevations along the western and southern flanks of the site.

The site investigation results correlate well with the geophysical results.

2. INTRODUCTION

APEX Geoservices Limited was requested by Multiconsult Trondheim to carry out a geophysical survey prior to the construction of a new development at Ranheim Vestre, Trondheim.

2.1 Survey Objectives

The objectives of the survey were to:

1. Map the thickness and variation of the soil layers.
2. Identify the thickness and extent of the quick clay layer.
3. Provide soil stiffness information (G_{max}).
4. Provide information on the depth to bedrock.

2.2 Site Background

The site is located in Ranheim, which is approx. 4km to the east of Trondheim. The site is immediately north of the E6 motorway, and comprised mainly sloping crop fields which are north and south of a central area of houses, farm buildings and stables. These buildings are part of the survey area, although the western part of these buildings is designated as not for development.

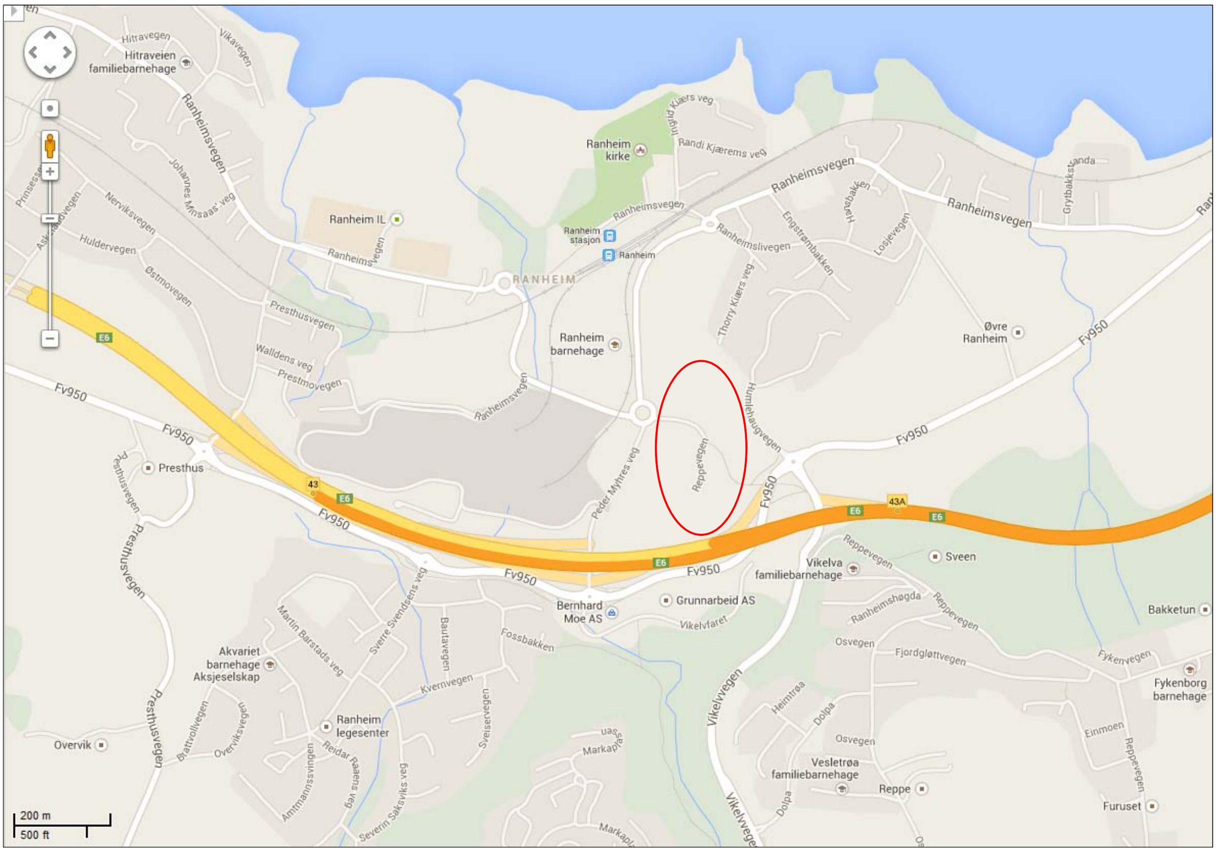

Figure 2.1 Site Location

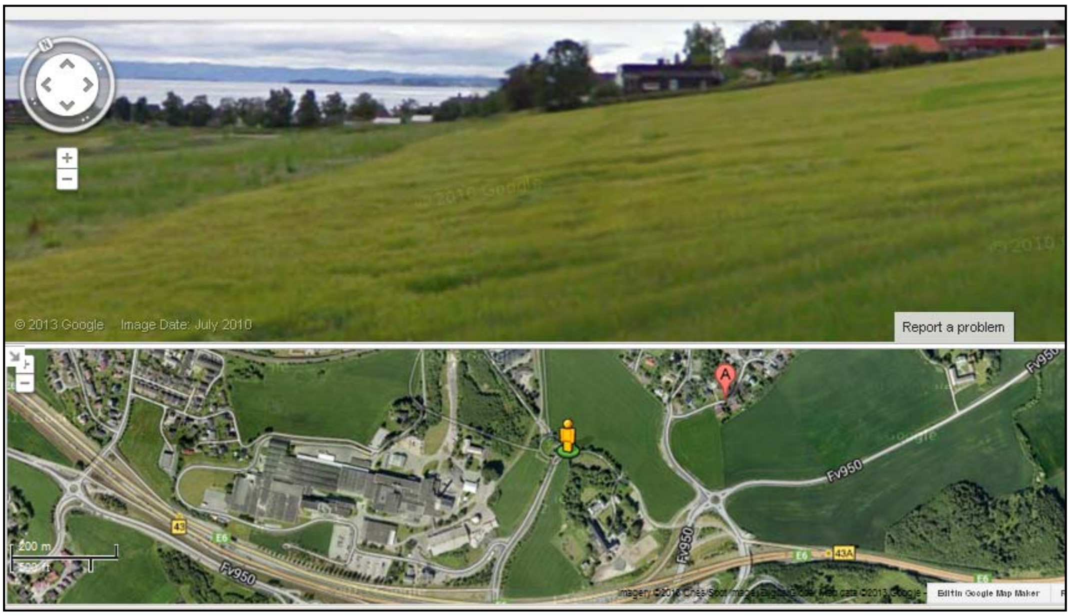

Figure 2.2 View of the site facing north.

The crop field to the north includes two elevated areas of levelled spoil, which is from the construction of a set of prefabricated service buildings in the north-west of the northern field. A road runs through the site from west to east.

2.2.1 Geology

The Geological Survey of Norway Geology Bedrock Map (Fig.2.3) indicates that the centre and west of the site area is mainly underlain by greenstone (meta-basalt) and undifferentiated green slate, with deformed pillow lavas. The east of the site comprises grey to green greywacke with layers of siltstone and phyllite.

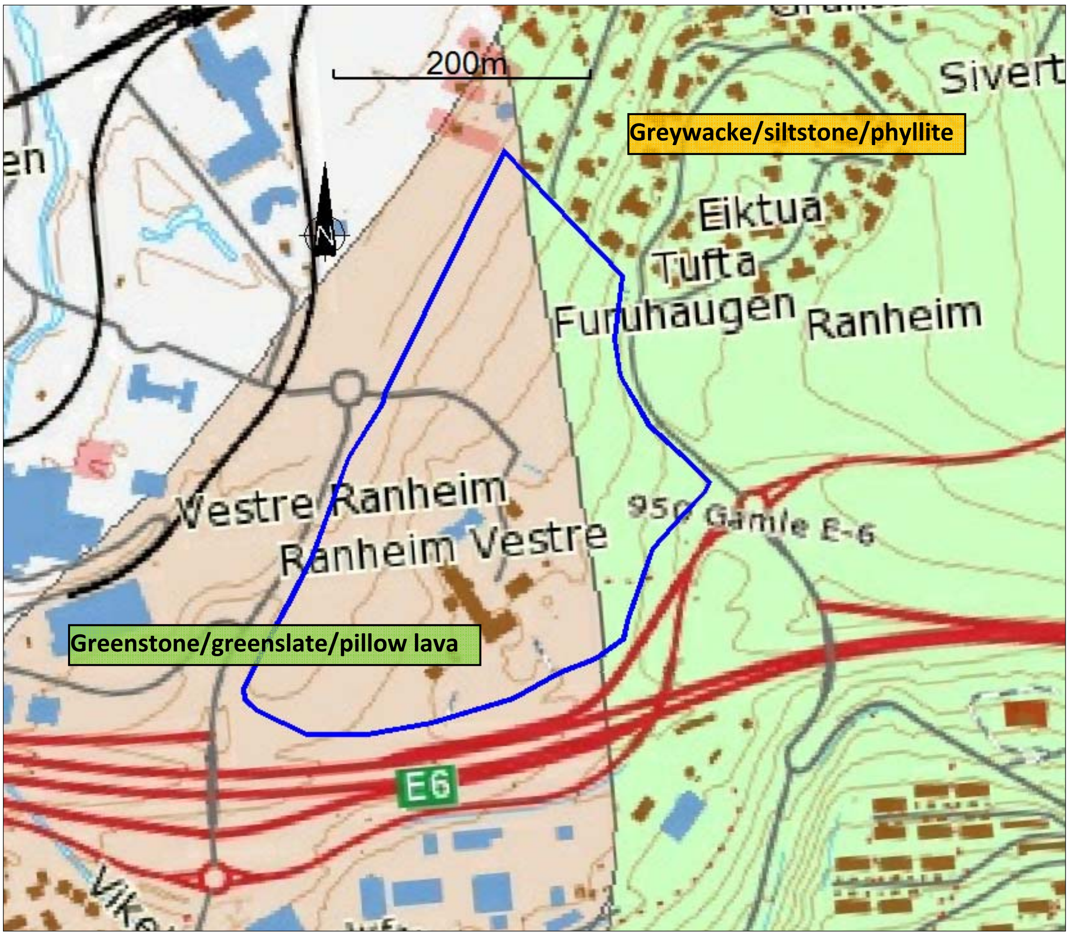

Figure 2.3: Geological map of the Ranheim area , showing the boundary between bedrock types in the east of the site (see description above). From http://www.ngu.no/en-gb/hm/Maps-and-data/

2.2.2 Soils

The Geological Survey of Norway Geology Superficial Deposits map for the survey area describes the northern four-fifths of the site as comprising beach deposits, with thick marine sediment in the south (Fig.2.4).

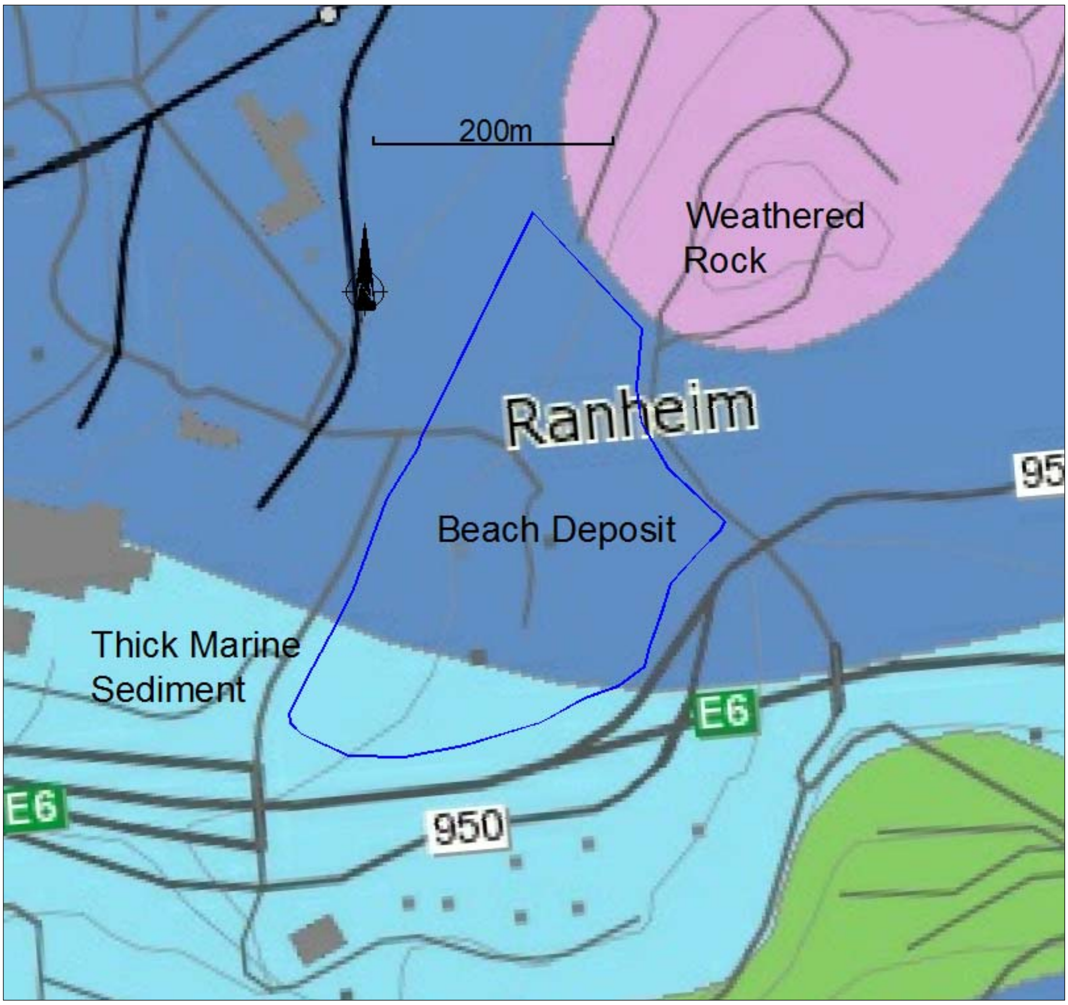

Figure 2.4: Superficial deposits for the Ranheim area (see description above). From http://www.ngu.no/en-gb/hm/Maps-and-data/

2.2.3 Site Investigation

A series of percussion soundings had been carried out throughout the site prior to the geophysical survey which ceased at 3.5-12.5m bgl. These results correlated well with the geophysical findings.

A further series of percussion soundings were then carried out after the geophysical survey and these were interpreted to cease at bedrock from 5.5-16.3m bgl for soundings E4, F3, G3 and I1. Soundings A2, B2A, C3, D5, E3 and E5 penetrated to 3.4-24.5 m bgl.

A series of borings to recover bedrock were also acquired, and these encountered bedrock at 1.4-13.6m bgl.

Sampling of the site investigation data recorded mainly clay in the northern part of the site, with clay and sand in the southern part of the site.

Sensitive clay is interpreted at 6.5m and from 7-18m bgl on sounding E5, and at 6.5m on F3.

Vertical resistivity soundings were carried out for B2, E4, E5 and I1, with resistivity ranging from mainly 50-200 ohm-m.

2.3 Survey Rationale

Electrical Resistivity Tomography (ERT) soundings will image the resistivity of the materials in the subsurface along a profile to produce a pseudo-section showing the variation in resistivity to a maximum of approx. 55m bgl, depending on the length of the profile. Each pseudo-section will be interpreted to determine the material type along the profile at increasing depth, based on the typical resistivities returned for ground materials. After initial testing on both Wenner and Gradient arrays, it was decided to acquire Wenner arrays for the Ranheim site.

Seismic Refraction Profiling measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via a multi-core cable to a seismograph. This method should allow us to profile the depth to the top of the bedrock, along profiles across the site.

The MASW method is used to estimate shear-wave (S-wave) velocities in the ground material to indicate possible soft zones. Materials with a S-wave velocity of <175 m/s are classified as soft/loose. MASW data was collected in 1D mode simultaneously with the seismic refraction data. MASW data is also a good indicator of bedrock depth.

3. RESULTS & INTERPRETATION

3.1 Resistivity Profiling

Resistivity Profiles R1-R21 were recorded across the survey area. The resistivity data has been interpreted on the following basis.

Resistivity (Ohm.m)	*Interpretation*
19 - 50	*SILT / CLAY / possible Sensitive CLAY*
50 - 139	*Sandy CLAY*
139 - 520	*Clayey SAND / SAND*
139 - 269	*Weathered GREENSCHIST*
269 - 2000	*GREENSCHIST*

3.2 Seismic Refraction Profiling

Seismic refraction Profiles S1-S20 were recorded across the survey area. The seismic data has outlined three-four P-wave velocity (Vp) layers and has been interpreted on the following basis:

Layer	Vp Velocity range (m/s)	Average Velocity (m/s)	Estimated Excavatability/ Rippability	Interpretation
1	152-513	308	Diggable	Soft/Loose Overburden
2	533-1300	881	Diggable	Firm-Stiff/Medium Dense-Dense Overburden
3	1201-2148	1613	Diggable	Stiff-Very Stiff/Dense-Very Dense Overburden
			Rippable-Break/Blast	Highly-Moderately Weathered BEDROCK
4	2107-6051	3883	Diggable	Very Stiff/Very Dense Overburden
			Break/Blast	Slightly Weathered-Fresh BEDROCK

Layer 2 has been interpreted as absent for Profiles S5, S9 and S17 and Layer 3 has been interpreted as absent for Profiles S1, S6 and S17.

3.3 MASW Profiling

MASW data was acquired in 1D mode. 1D Profiles were acquired at the locations of Profiles S1-S20, along the same profiles as the seismic refraction data. A 1D MASW profile was derived for each of S1-S20, with the exception of Profile S6 (data compromised due to proximity of bedrock to surface).

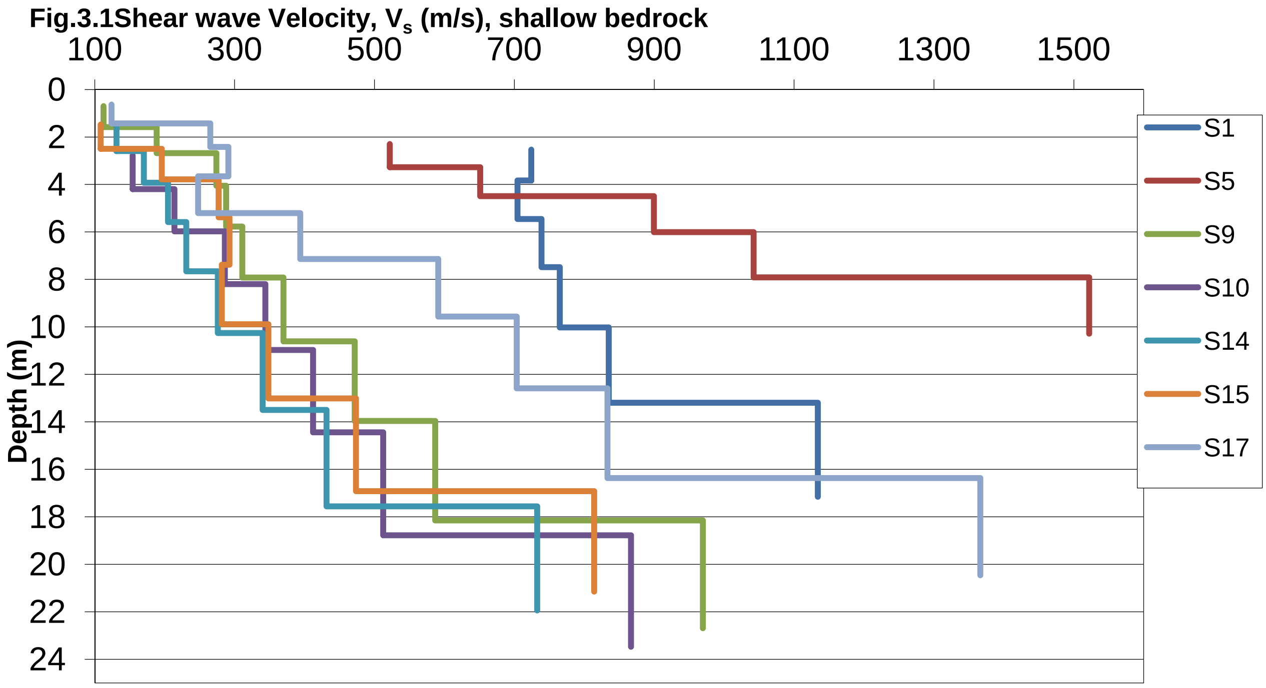
Fig.3.1Shear wave Velocity, Vs (m/s), shallow bedrock
100
300
500
700
900
1100
1300
1500
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S1
S5
S9
S10
S14
S15
S17

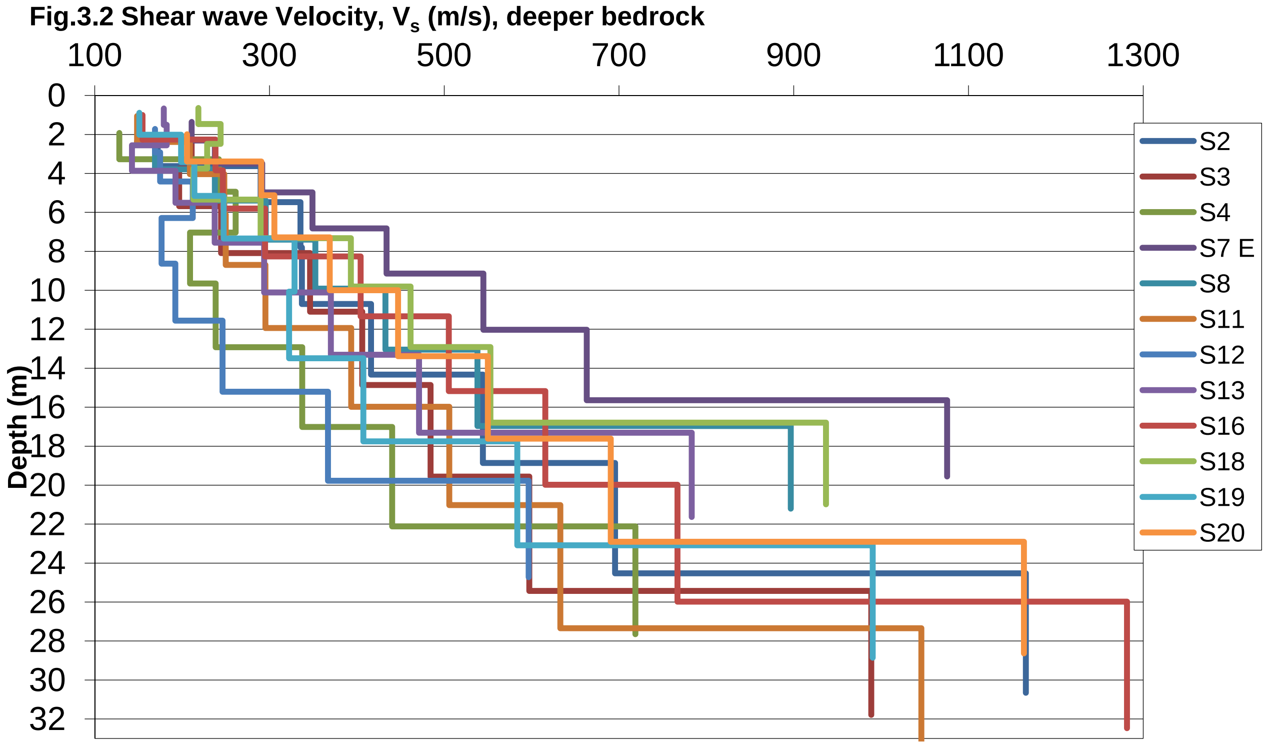
Fig.3.2 Shear wave Velocity, Vs (m/s), deeper bedrock
100
300
500
700
900
1100
1300
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Depth (m)
S2
S3
S4
S7 E
S8
S11
S12
S13
S16
S18
S19
S20

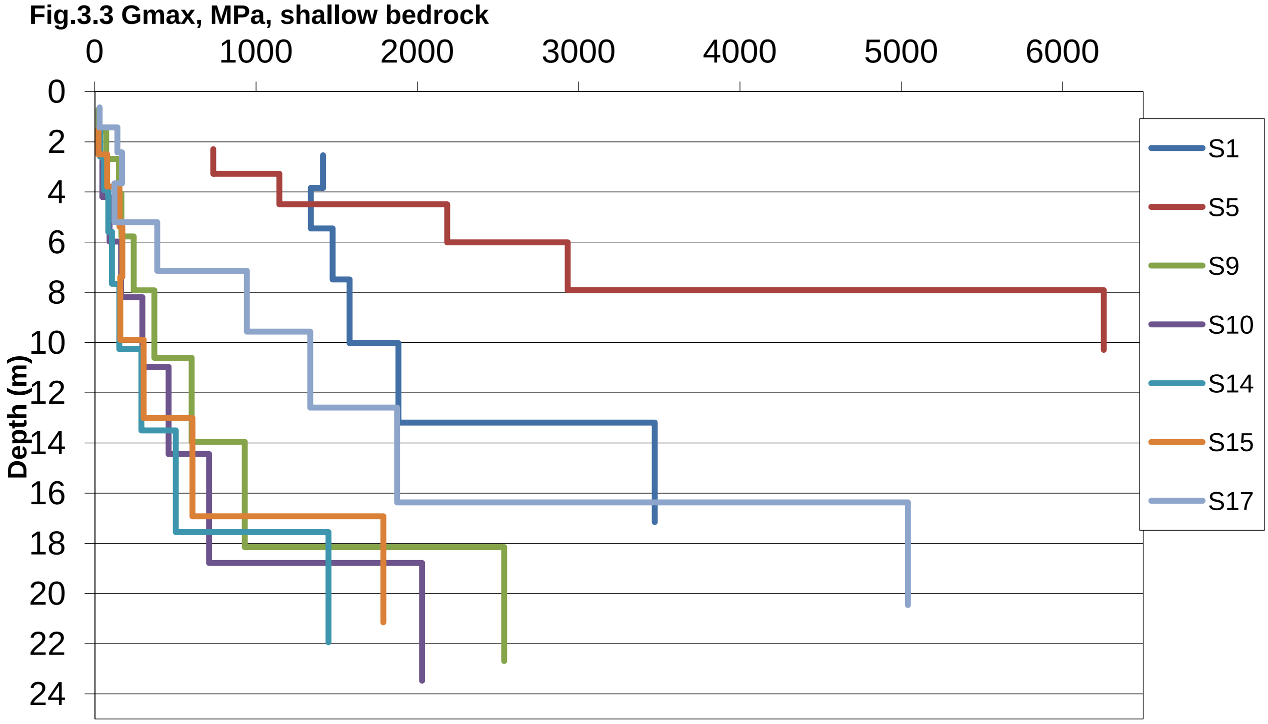
Fig.3.3 Gmax, MPa, shallow bedrock
0
1000
2000
3000
4000
5000
6000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
S1
S5
S9
S10
S14
S15
S17

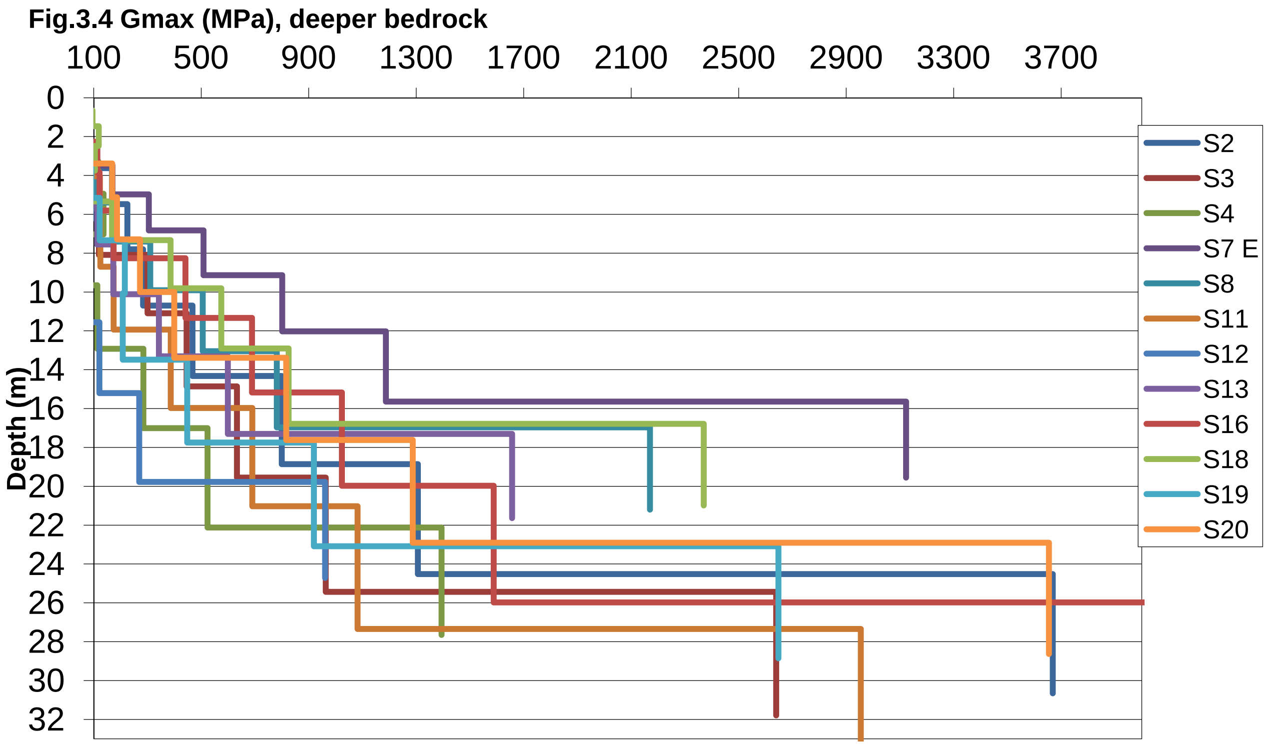
Fig.3.4 Gmax (MPa), deeper bedrock
100
500
900
1300
1700
2100
2500
2900
3300
3700
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
S2
S3
S4
S7 E
S8
S11
S12
S13
S16
S18
S19
S20

The 1D MASW Profiles show the variation in shear wave velocity with depth, at the centre of the profile location.

Figures 3.1 and 3.2 show the derived shear-wave velocity for the profiles acquired over shallow bedrock and deeper bedrock respectively. Figures 3.3 and 3.4 show the corresponding derived Gmax values (small strain shear modulus). The individual 1D plots are shown in Appendix C.

OVERBURDEN (SOIL)

The shear-wave velocity for material interpreted as overburden ranges from 109-447 m/s (average of 231 m/s) with a corresponding Gmax of 24-400 MPa (average of 115 MPa). These results indicate material which is generally soft–stiff (see table below). Soft material is interpreted as material from 100-175 m/s (Figure 3.5).

PROFILE	INTERPRETED SOFT ZONE (m bgl)	VELOCITY (m/s)
S2	2.1-3.6	172
S4	1.9-3.3	128
S8	1.5-3.8	150-169
S9	0.8-2.7	113
S10	2.8-4.2	154
S11	1.1-2.4	148
S12	2.9-4.4	175
S13	2.6-3.9	142
S14	1.5-3.9	131-170
S15	1.5-2.6	109
S16	1.0-2.3	155
S17	0.6-1.4	124
S19	0.9-2.0	151

Profile S12 is located upon sounding E5 (which has interpreted sensitive clay from 7-18m bgl.). Profile S12 shows a markedly lower velocity profile than the other 1D profiles, particularly from 2.9-8.6m bgl.

Profile S20 is acquired upon overburden which is interpreted to be c.16m thick. This profile shows markedly higher shear wave velocities for overburden (particularly from >10m bgl), which suggests than the material from >10m bgl comprises very stiff-hard overburden or highly-moderately weathered bedrock.

BEDROCK

The shear-wave velocity for material interpreted as bedrock ranges from 311-1522 m/s (average of 648 m/s) with a corresponding Gmax of 242-6255 MPa (average of 1332 MPa). These values are generally low, particularly for the material in the upper 3-6m of bedrock (in comparison to the Irish setting), which indicates a high degree of weathering/fracturing.

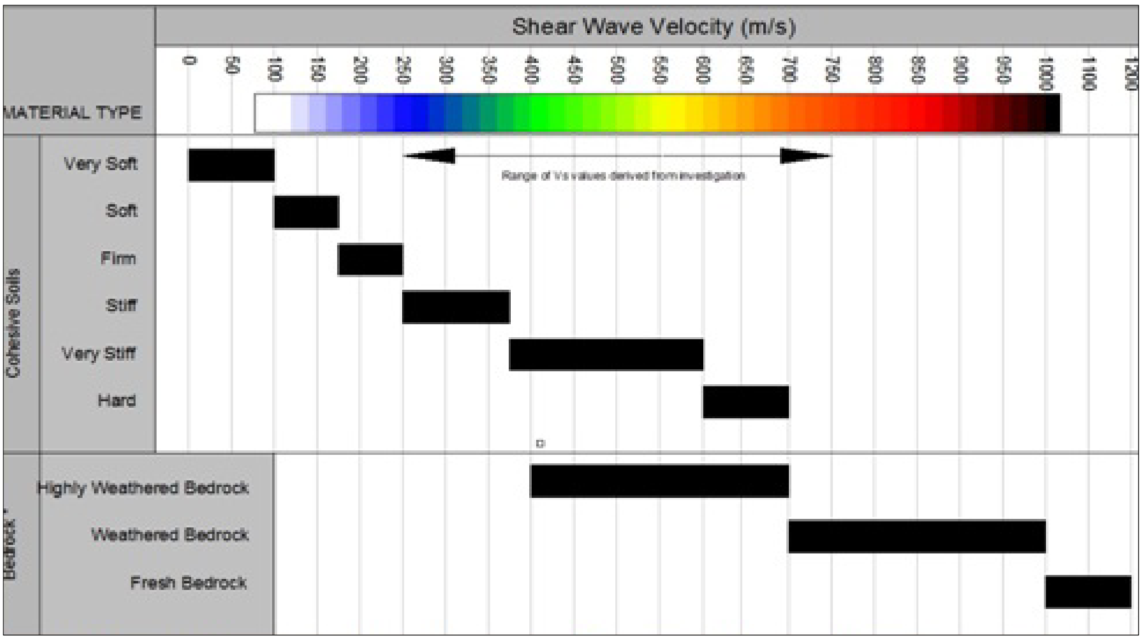

Fig.3.5 Shear wave velocity and corresponding soil stiffness.

3.4 Discussion

The Resistivity, Seismic Refraction, MASW, and site investigation results have been combined to produce the interpreted section on Drawings 13170_02 to 13170_08. The interpreted bedrock elevation and overburden thickness maps are shown in Drawings 13170_09 and 13170_10 respectively. Both of these incorporate the site investigation results. A summary map is shown on Drawing 13170_11.

3.4.1 Overburden

Material with a resistivity of 19-50, 50-139 and 139-520 ohm-m has been interpreted as silt/clay, sandy clay and clayey sand/sand respectively.

The results indicate that sandy clay is the most abundant soil type throughout the site, particularly on the northern side (overburden resistivities are generally lower in the north of the site). Pockets of silt/clay have been interpreted, and these are located in the north and east of the site.

Clayey sand/sand has mainly been interpreted in an area in the south of the site as shown on the summary map (Drawing 13170_11), comprising the southern parts of Profiles R10 and R14, and R13 and R12. This area comprises a sloped zone of lowest elevation in the southern part of the site. This increase in sandy material generally coincides with the zone depicted as thick marine sediment on the soils map for the area (Fig.2.4).

Overburden thickness has been contoured on Drawing 13170_10, and is interpreted to range from 0.5-24.5m, with the zones of thickest overburden along the southern and eastern flanks of the site, and in the far north-west.

The seismic refraction/MASW results indicate that overburden material is overall soft-very stiff/loose-very dense and diggable, and is generally soft-stiff/loose-dense with the exception of Profile S20 (see above). As detailed above, zones of soft/loose are frequently present within the MASW results.

The vertical resistivity soundings correlate very well with the ERT results with the exception of E4. E4 is carried out upon Profile R4 in the horse paddock, with lower resistivities recorded for R4 (<19 ohm-m) at the location on E4, suggesting interference due to underground services/effluent from animal waste for Profile R4.

Some further zones of very low resistivity (<19 ohm-m) are present within the ERT results, and these are all present for ERT profiles which span the inner buildings/stables. Further examination of the site investigation results, particularly C3, E3, E4, E5 and D5, indicates that the zones of very low resistivity are highly likely to be due to the presence of underground services/effluent from animal waste and are not due to natural ground materials.

Note that anisotrophy (slight variations in resistivity values due to the direction of travel of the electrical signal) may affect some of the ERT Profiles and will lead to slight variations at locations where ERT Profiles intersect.

3.4.2 Sensitive Clay

Sensitive clay is interpreted at 6.5m and from 7-18m bgl on sounding E5, and at 6.5m on F3. For E5, this corresponds with values of approx. 37-50 ohm-m for Profile R2, and a zone of sensitive clay has therefore been interpreted in the east of the site along Profile R2 (See Drawings 13170_02 and 13170_11), for overburden material of 37-50 ohm-m.

Published geotechnical papers indicate that sensitive clay is present within the range 10-100 ohm-m. However, since E5 is the only sounding which has resulted in an appreciable thickness of sensitive clay, and this corresponds with approx. 37-50 ohm-m, then for this site zones of sensitive clay have only been interpreted in areas of 37-50 ohm-m (some zones of 37-50 ohm-m are present on site which are not interpreted as sensitive clay; these are interpreted as mainly thin silt/clay near the surface). Two other areas of possible sensitive clay have therefore been interpreted, in the far north-east of the site (Drawing 13170_11).

Overall, low resistivities (<19 ohm-m) which would be indicative of unleached marine clay are not present on site (with the exception of profiles in the inner buildings/stables), and therefore this would limit the likelihood of substantial quantities of sensitive clay being present.

As shown in Section 3.3, 1D MASW Profile S12 shows a distinctive low velocity profile at the location of sounding E5. Profile S4, in the far north-west of the site, is the only other profile which gives a similar result. Profile S11 is located in the easternmost area of possible sensitive clay interpreted in the north-east of the site, however this profile shows a higher velocity profile from than S12, which may indicate a lower likelihood of sensitive clay in this area.

3.4.3 Bedrock

Bedrock with a resistivity of 139-269 and 269-2000 ohm-m has been interpreted as weathered greenschist and greenschist respectively.

The seismic refraction/MASW results indicate that highly-moderately weathered bedrock will be rippable to requiring breaking/blasting and that slightly weathered-fresh bedrock will require breaking/blasting. Highly-moderately weathered bedrock is generally interpreted as c.3-5m across the site.

The interpreted elevation of the top of the weathered bedrock is presented on Drawing 13170_09 and the results show that this bedrock elevation ranges from 10-47 mOD, with the lowest bedrock elevations along the western and southern flanks of the site.

Two possible faults have been interpreted to span the site, in the north and south of the site, as shown on Drawing 13170_11. These are interpreted from zones of near-vertical low resistivity within interpreted bedrock.

4. RECOMMENDATIONS

The geophysical report should be reviewed after the completion of any further direct investigation.

Suitable mitigation measures for construction in the presence of sensitive clay are recommended for any buildings located along the east of the site.

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6. APPENDIX A: DETAILED METHODOLOGY

6.1 Electrical Resistivity Tomography (ERT)

6.1.1 Principles

This surveying technique makes use of the Wenner or Gradient resistivity arrays. The 2D-resistivity profiling method records a large number of resistivity readings in order to map lateral and vertical changes in material types. The 2D-resistivity profiling method involves the use of 1-61 electrodes connected to a resistivity meter, using computer software to control the process of data collection and storage.

6.1.2 Data Collection

Profiles R1-R8 were recorded from 14-18th October 2013 using an ABEM resistivity meter, imaging software, two-three 20 takeout multicore cables and up to 61 stainless steel electrodes, with a 5m spacing between electrodes. Saline solution was used at the electrode\ground interface in order to gain a good electrical contact required for the technique to work effectively. The recorded data were processed and viewed immediately after the survey.

6.1.3 Data Processing

The field readings were stored in computer files and inverted using the RES2DINV package (ABEM, 2013) with up to 5 iterations of the measured data carried out for each profile to obtain a 2D-Depth model of the resistivities.

The inverted 2D-Resistivity models and corresponding interpreted geology are displayed on the accompanying drawings. Distance is indicated along the horizontal axis of the profiles. Profiles have been contoured using the same contour intervals and colour codes.

6.1.4 Relocation

All data were referenced using a Garmin GPS-60 with c.2m accuracy.

6.2 Seismic Refraction Profiling

6.2.1 Principles

The seismic refraction profiling method measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

6.2.2 Data Collection

Twenty seismic profiles were recorded from 14-18th October 2013 using a Geode high-resolution 24 channel digital seismograph with geophone spacings of 1.5-3m. The source of the seismic waves was a sledgehammer.

6.2.3 Data Processing

The recorded data was interpreted using the ray-tracing and intercept time methods, to acquire depths to layer boundaries and the P-wave velocities of these layers, using the FIRSTPIX and GREMIX programs.

GREMIX interprets seismic refraction data as a laterally varying layered earth structure. It incorporates the slope-intercept method, parts of the Plus-Minus Method of Hagedoorn (1959), Time-Delay Method, and features the Generalized Reciprocal Method (GRM) of Palmer (1980). Up to four layers can be mapped, one deduced from direct arrivals and three deduced from refractions. Phantoming of all possible travel time pairs can be carried out by adjusting reciprocal times of off shots.

6.2.4 Relocation

All data were referenced using a Garmin GPS-60 with c.2m accuracy.

6.3 MASW

6.3.1 Principles

The Multi-channel Analysis of Surface Waves (MASW) (Park et al., 1998, 1999) utilizes Surface waves (Rayleigh waves) to determine the elastic properties of the shallow subsurface. Surface waves carry up to two/thirds of the seismic energy but are usually considered as noise in conventional body wave reflection and refraction seismic surveys.

The penetration depth of surface waves changes with wavelength, i.e. longer wavelengths penetrate deeper. When the elastic properties of near surface materials vary with depth, surface waves then become dispersive, i.e. propagation velocity changes with frequency. The propagation (or phase) velocity is determined by the average elastic property of the medium within the penetration depth. Therefore the dispersive nature of surface waves may be used to investigate changes in elastic properties of the shallow subsurface.

The MASW method employs the multi-channel recording and processing techniques (Sheriff and Geldart, 1982) that have similarities to those used in a seismic reflection survey and which allow better waveform analysis and noise elimination. To produce a shear wave velocity (Vs) profile and a stiffness profile of the subsurface using Surface waves the following basic procedure is followed:

(i) A point source (eg. a sledgehammer) is used to generate vertical ground motions,

(ii) The ground motions are measured using low frequency geophones, which are disposed along a straight line directed toward the source,

(iii) the ground motions are recorded using either a conventional seismograph, oscilloscope or spectrum analyzer,

(iv) a dispersion curve is produced from a spectral analysis of the data showing the variation of Surface wave velocity with wavelength,

(v) the dispersion curve in inverted using a modeling and least squares minimization process to produce a subsurface profile of the variation of Surface wave and shear wave velocity with depth,

(vi) a stiffness-depth profile (shear modulus, G) can be derived from elastic theory.

6.3.2 Data Collection

The recording equipment consisted of a Geode 24 channel digital seismograph, 24 no. 10HZ vertical geophones, hammer energy source with mounted trigger and a 24 take-out cable. The data was recorded whilst the seismic refraction profiles S1-S20 were being acquired.

6.3.3 Data Processing

MASW processing was carried out using the SURFSEIS processing package developed by Kansas Geological Survey (KGS, 2010). SURFSEIS is designed to generate a shear wave (Vs) velocity profile.

SURFSEIS data processing involves three steps:

(i) Preparation of the acquired multichannel record. This involves converting the data file into the processing format.

(ii) Production of a dispersion curve from a spectral analysis of the data showing the variation of Raleigh wave phase velocity with wavelength. Confidence in the dispersion curve can be estimated through a measure of signal to noise ratio (S/N) which is obtained from a coherency analysis. Noise includes both body waves and higher mode surface waves. To obtain an accurate dispersion curve the spectral content and phase velocity characteristics are examined through an overtone analysis of the data.
(iii) Inversion of the dispersion curve is then carried out to produce a subsurface profile of the variation of shear wave velocity with depth.

The shear wave velocities were then converted into shear modulus values using the formulae:
(1) $G = V_s^2 * \rho/1000000$

Where	G	=	Shear Modulus (MPa)
	V_s	=	Shear Wave Velocity (m/s)
	ρ	=	Density (kg/m^3)

The Vp velocities were combined with the shear wave velocity data to calculate Poissons ratio, dynamic Bulk modulus and Youngs Modulus for each of the layers outlined by the P-wave data analysis using the formulae in Davies & Schulteiss, 1980 as follows:

(2)	$u=(Vp/Vs)^2-2 / 2((Vp/Vs)^2-2)$		
(3)	$E = 2V_s^2 \rho(1 +u)/1000$		
where	E	=	Youngs Modulus (GPa)
	V_s	=	Shear Wave Velocity (m/s)
	ρ	=	Density (kg/m^3)
	u	=	Poisson's ratio
and			
(4)	B	=	E/3(1-2 u)
where	B	=	Bulk Modulus (MPa)
	E	=	Youngs Modulus (MPa)
	u	=	Poisson's ratio

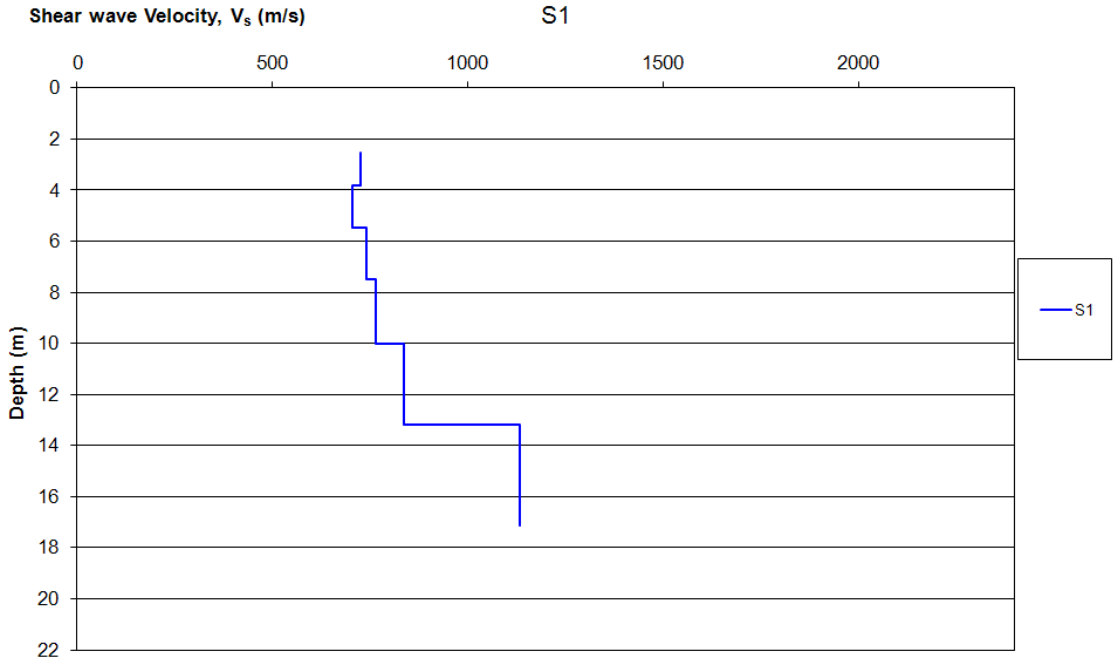
For the purpose of the calculation in this report an overburden density of 2000 kg/m^3 and a rock density of 2700 kg/m^3 has been assumed.

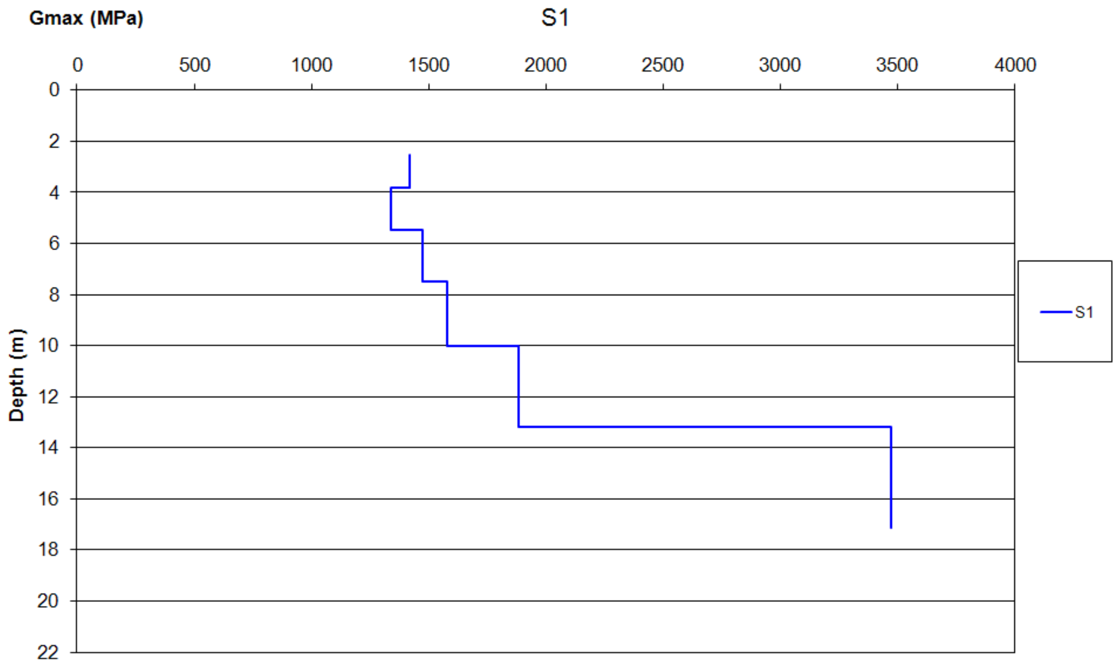
Each of the profiles S1-S20 were processed for 1D MASW profiles. The 1D profiles are located in the centre of the spreads S1-S20 as shown (with the exception of Profile S7). The surface waves for Profile S6 were insufficiently poor to produce a 1D profile. For profile S7m, traces 1-9 were rejected from processing, to improve the final result for S7.

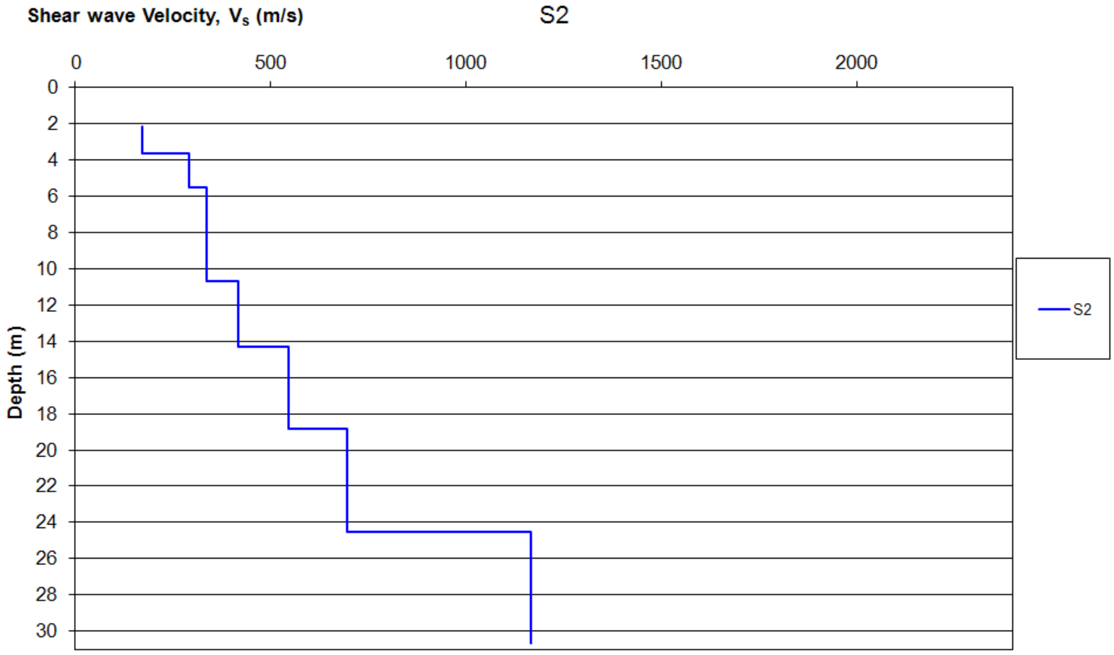
6.3.4 Relocation

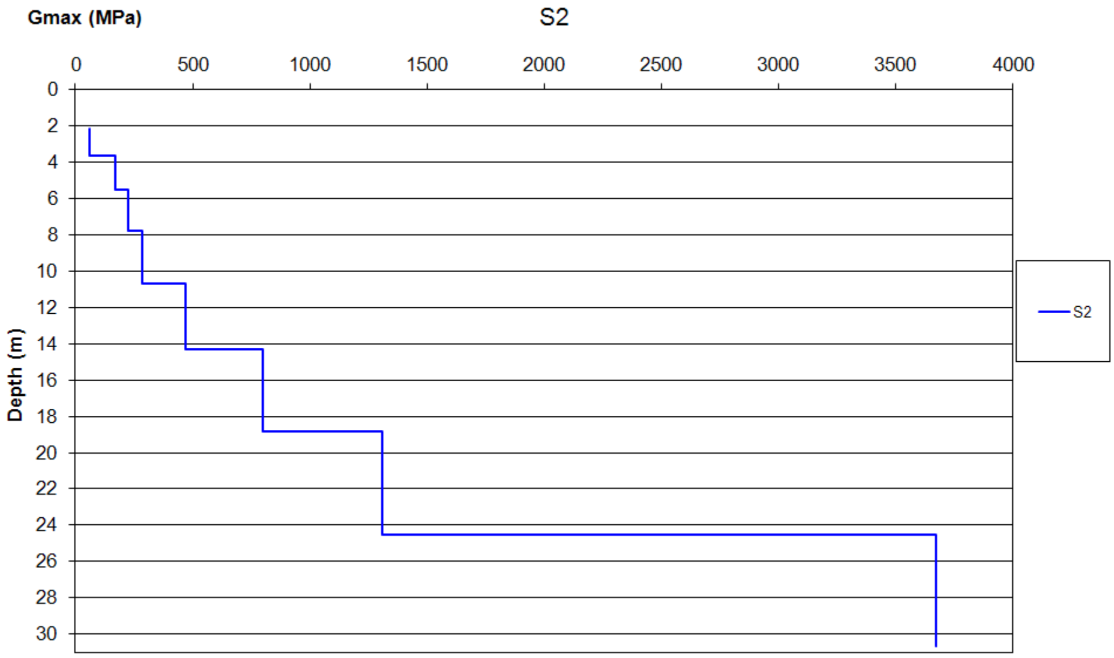
All data were referenced using a Garmin GPS-60 with c.2m accuracy.

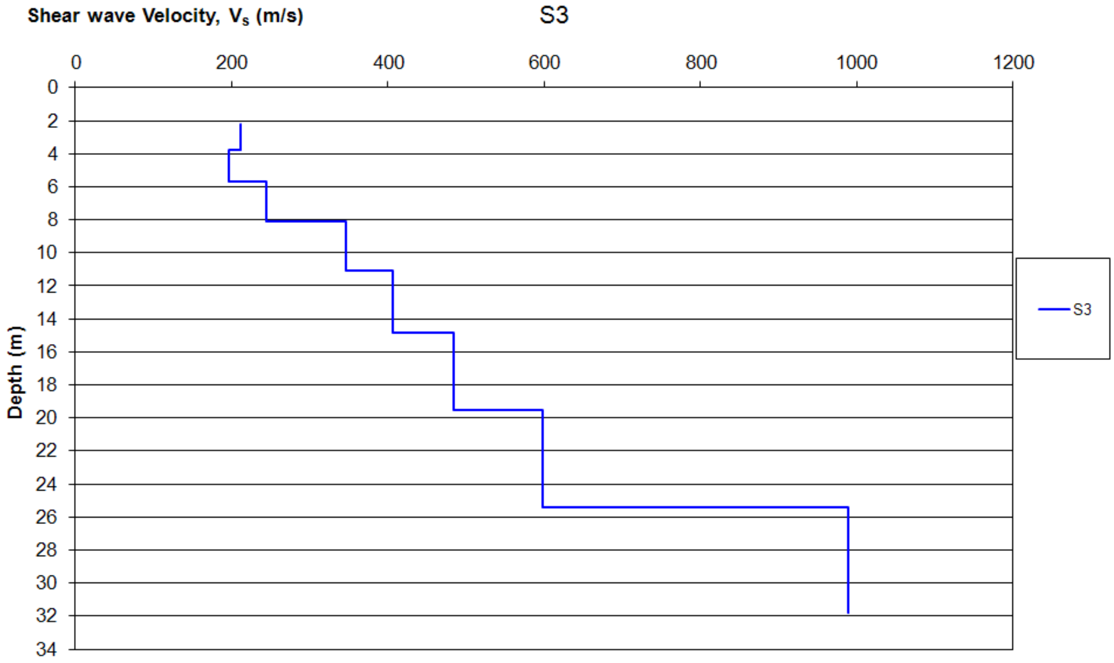
7. APPENDIX B: MASW RESULTS

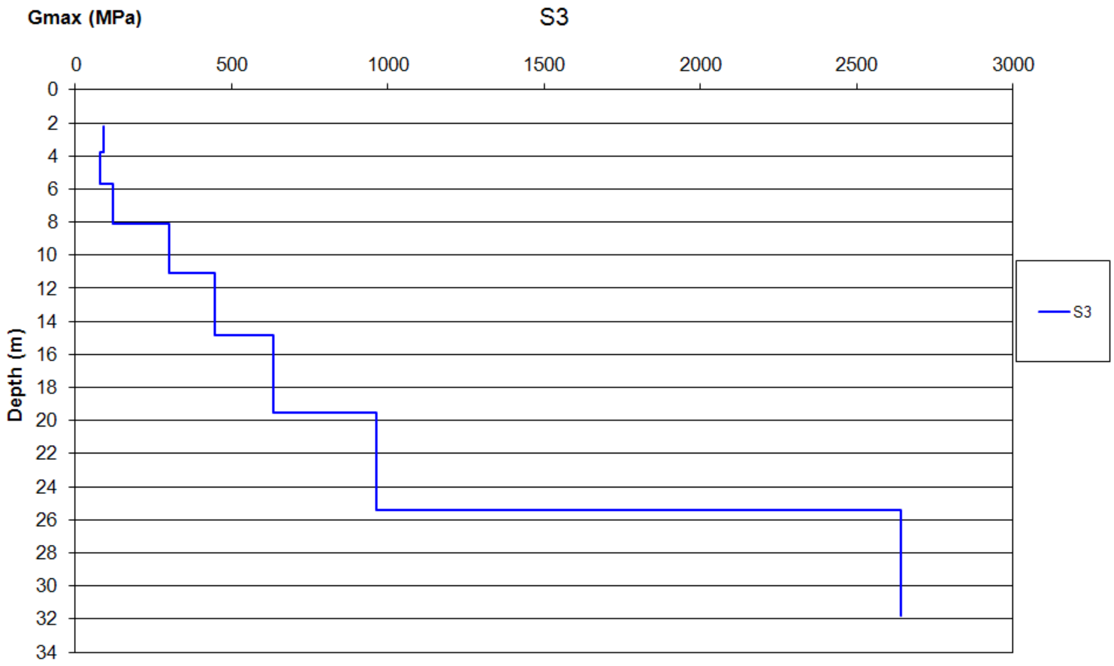


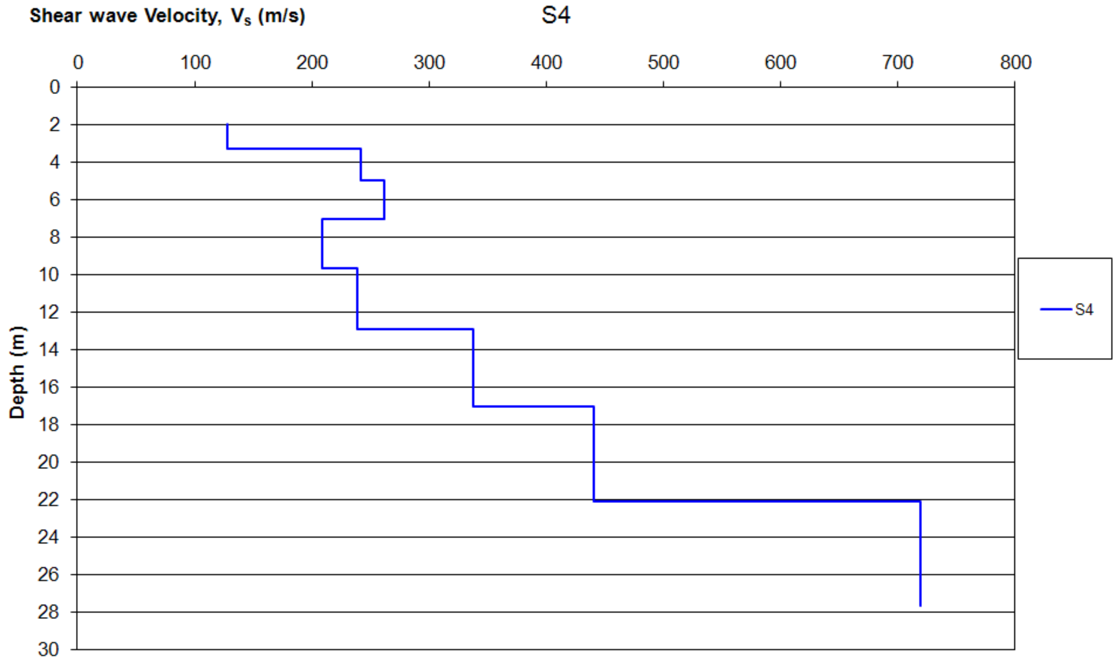


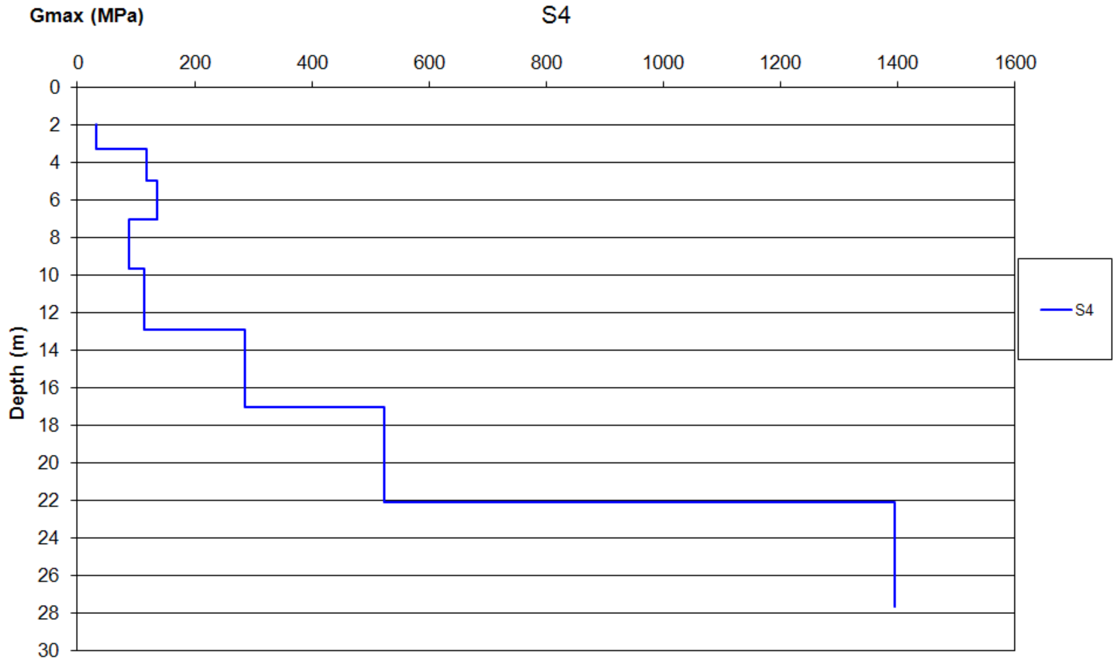

Shear wave Velocity, V_s (m/s)
S2
0
500
1000
1500
2000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
S2

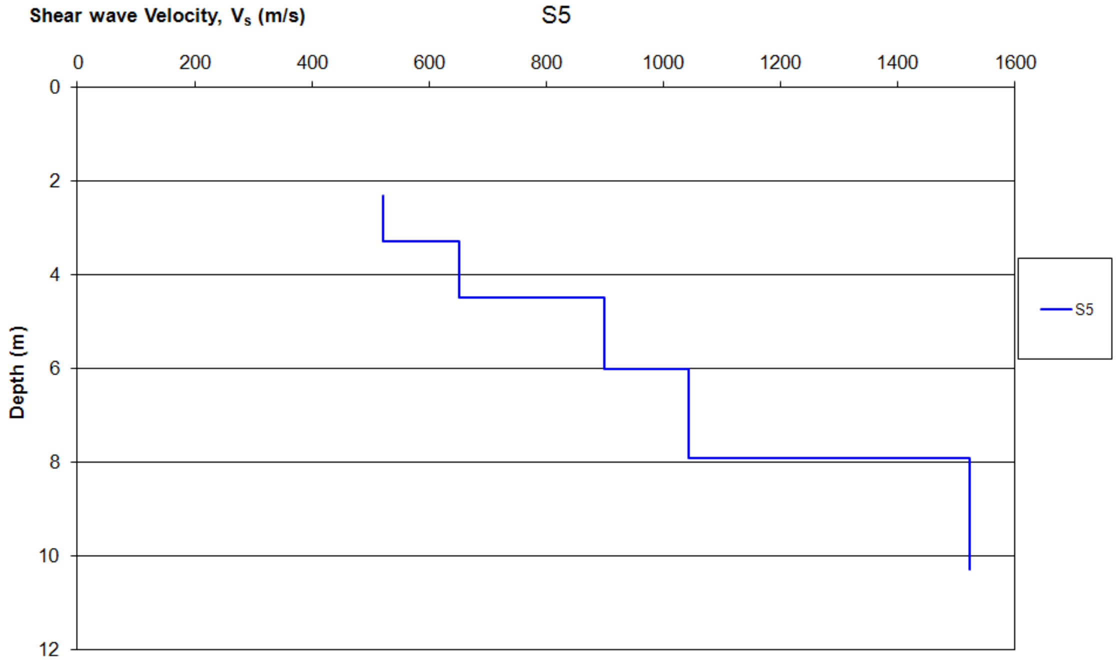

Gmax (MPa)
S2
0
500
1000
1500
2000
2500
3000
3500
4000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
S2

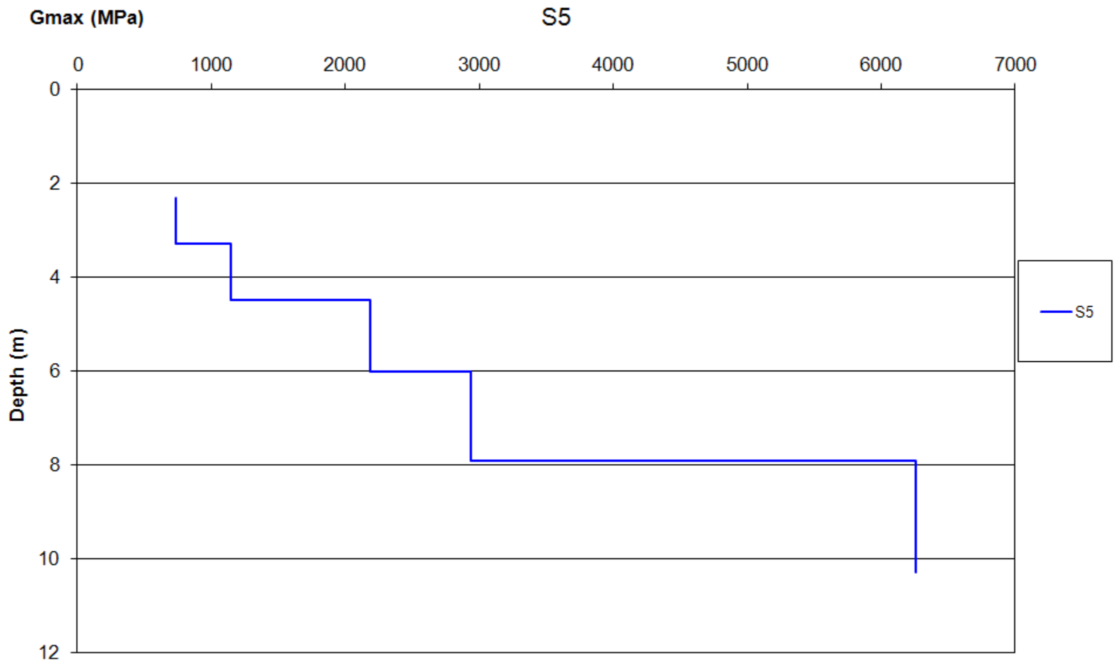

Shear wave Velocity, V_s (m/s)
S3
0
200
400
600
800
1000
1200
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
S3


Gmax (MPa)
S3
0
500
1000
1500
2000
2500
3000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
S3

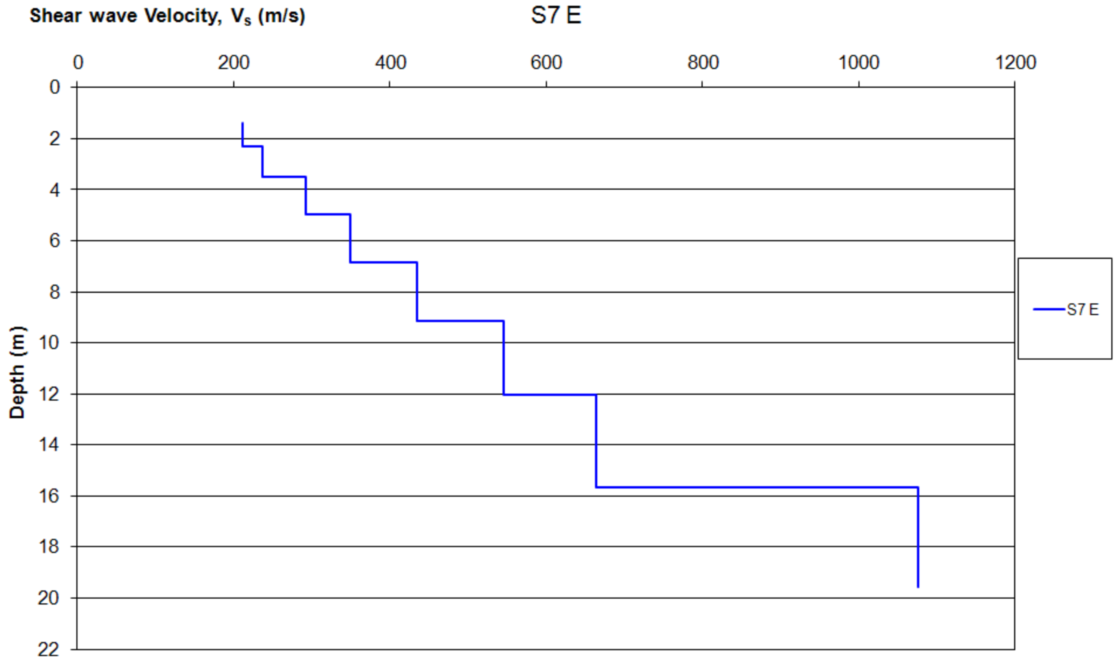

Shear wave Velocity, V_s (m/s)
S4
0 100 200 300 400 500 600 700 800
Depth (m)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
S4

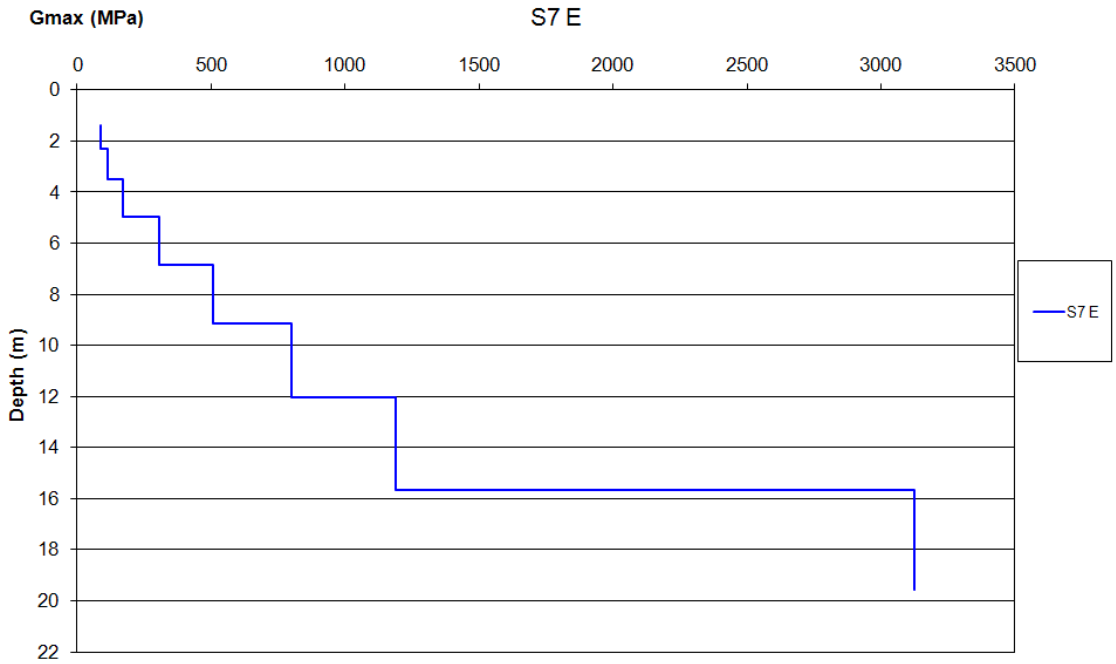

Gmax (MPa)
S4
0 200 400 600 800 1000 1200 1400 1600
Depth (m)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
S4

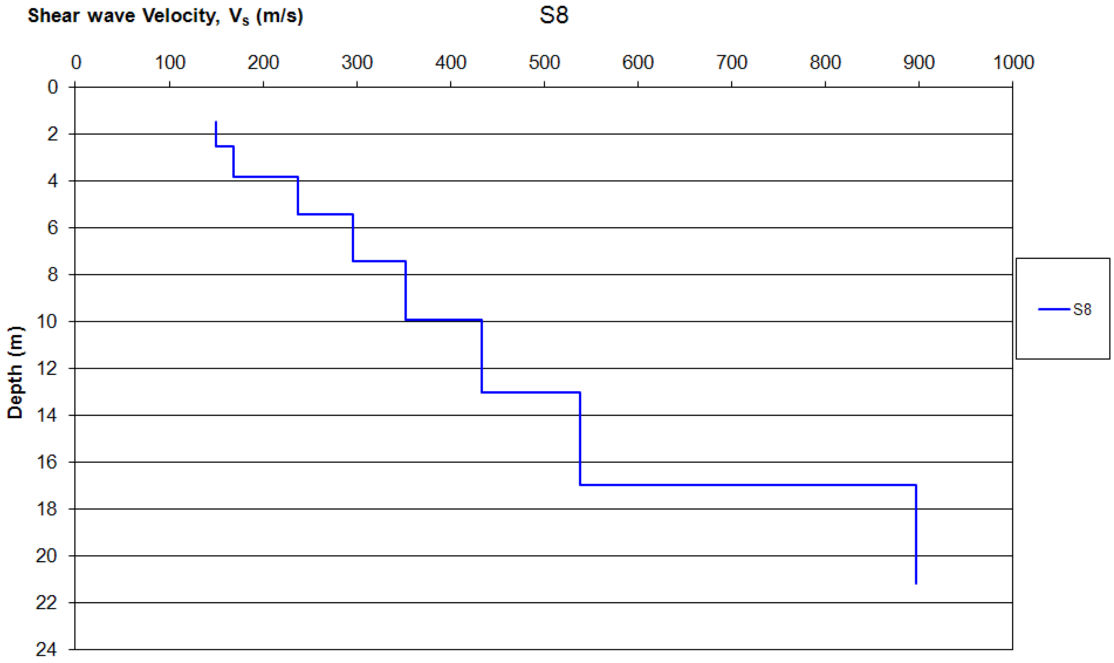


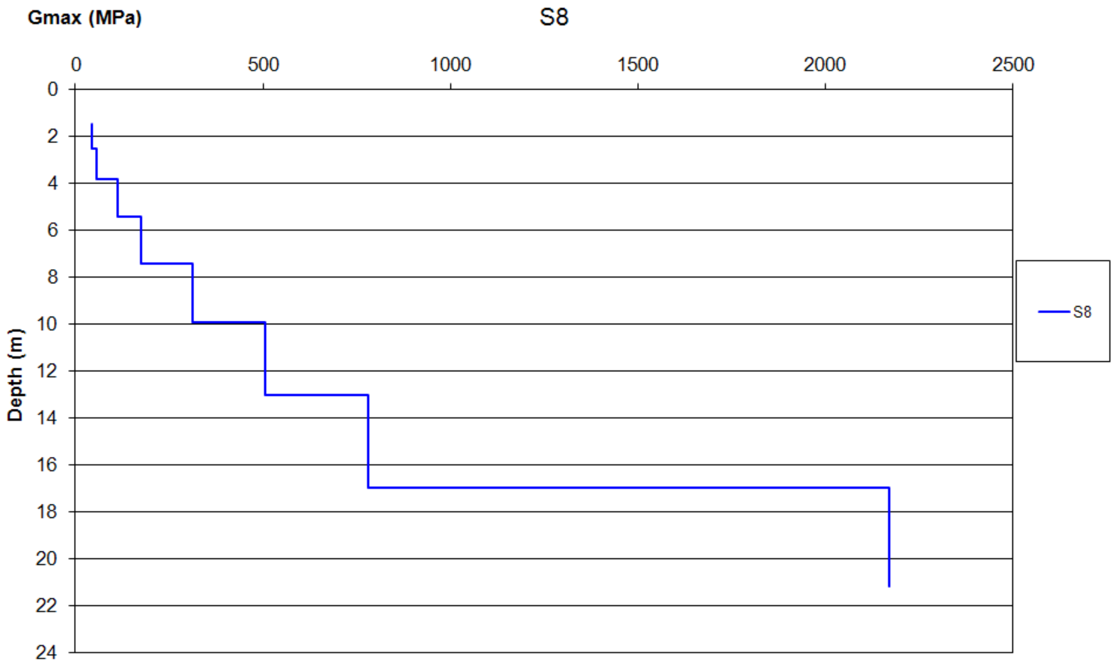


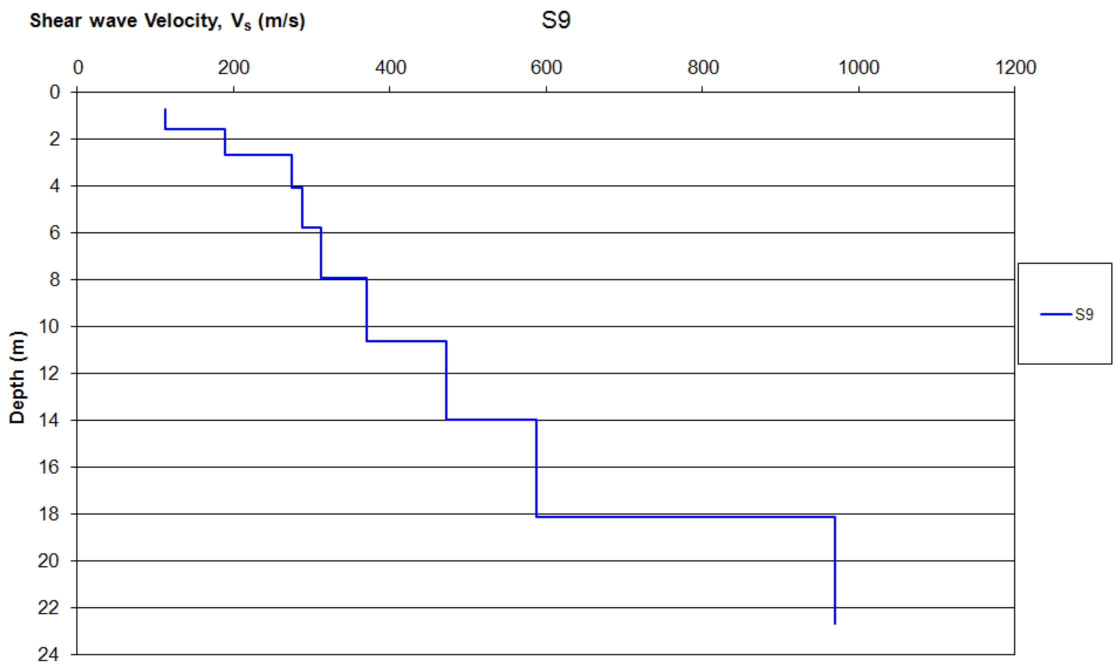
Note that a results has not been obtained for Profile S6, this data has been compromised due to the shallow bedrock.

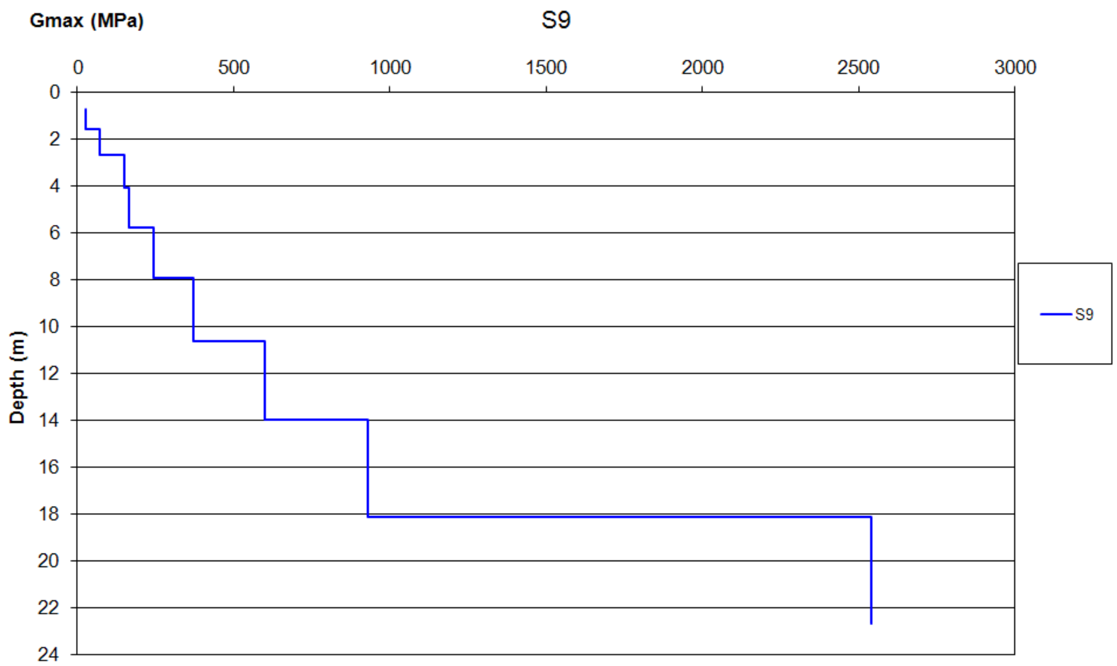

Shear wave Velocity, V_s (m/s)
S7 E
0
200
400
600
800
1000
1200
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
S7 E

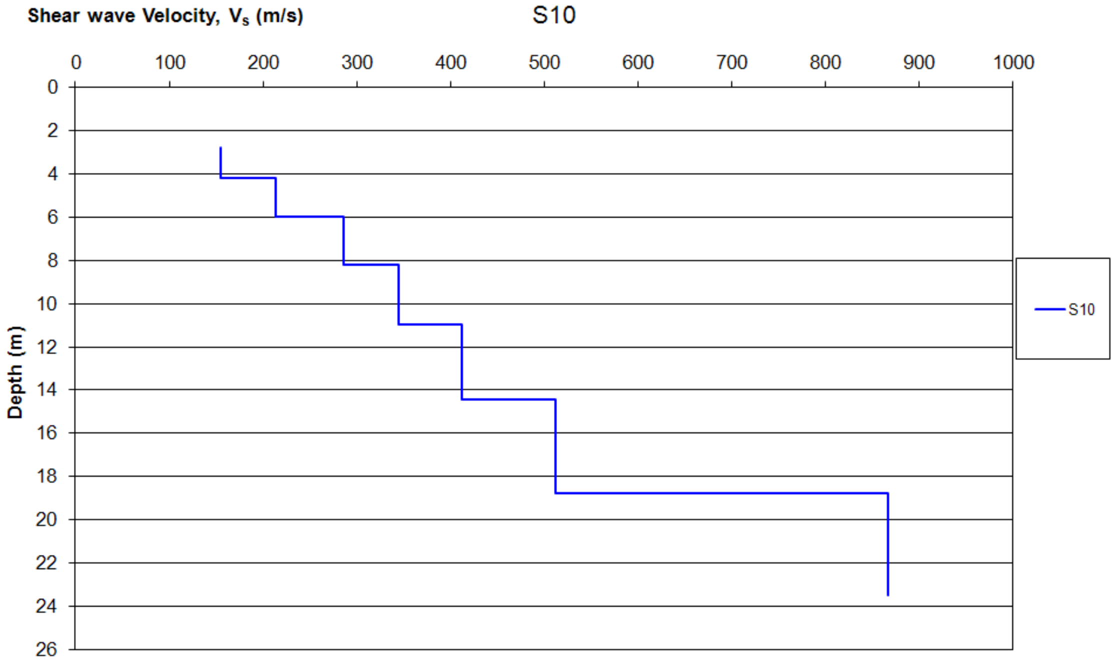

Gmax (MPa)
S7 E
0
500
1000
1500
2000
2500
3000
3500
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
S7 E

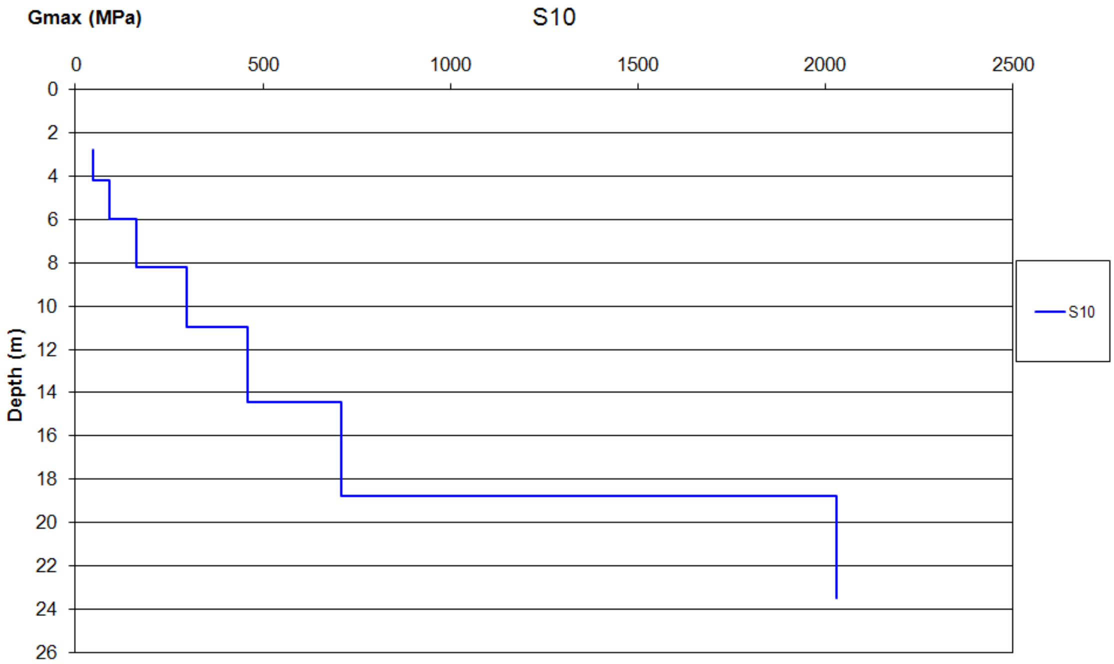

Shear wave Velocity, V_s (m/s)
S8
0
100
200
300
400
500
600
700
800
900
1000
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S8

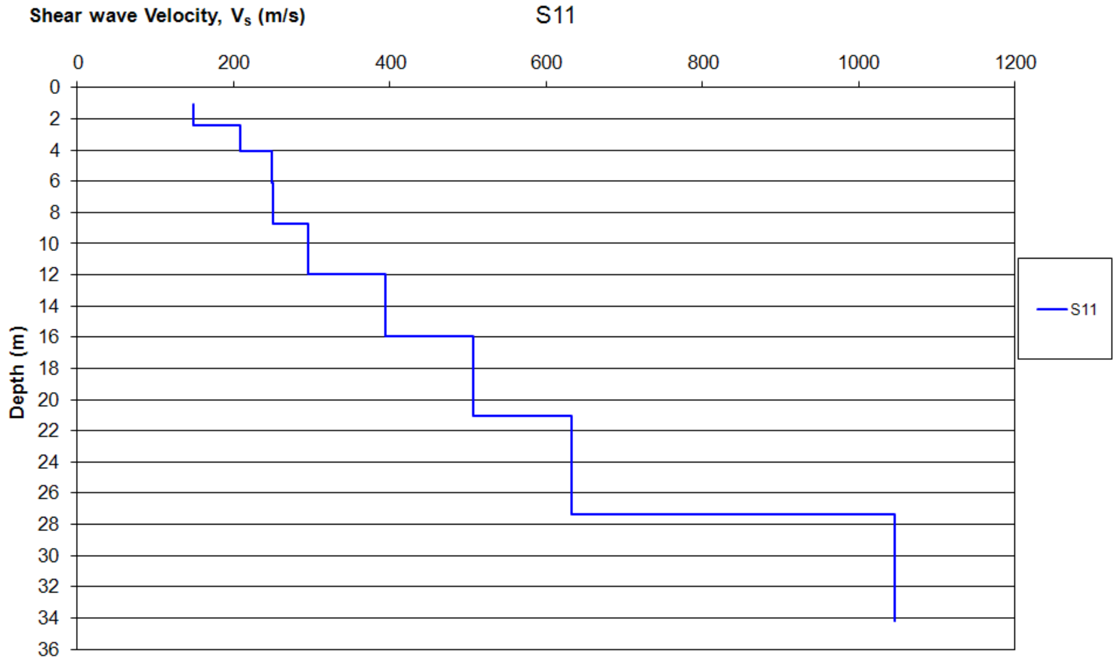

Gmax (MPa)
S8
0
500
1000
1500
2000
2500
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S8

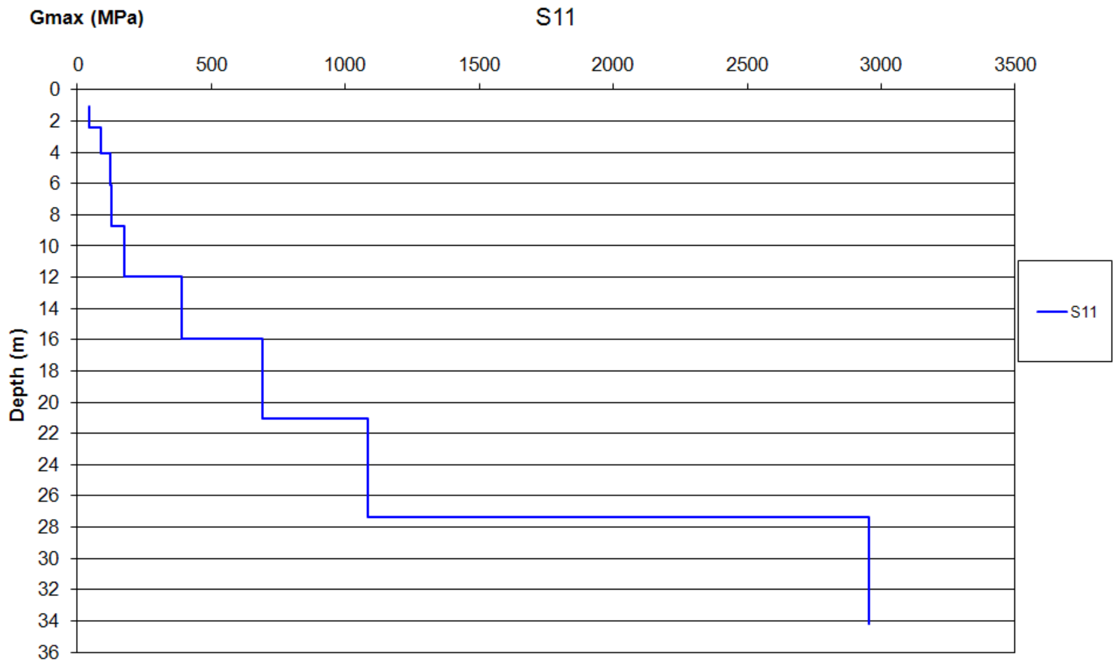

Shear wave Velocity, V_S (m/s)
S9
0
200
400
600
800
1000
1200
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
S9

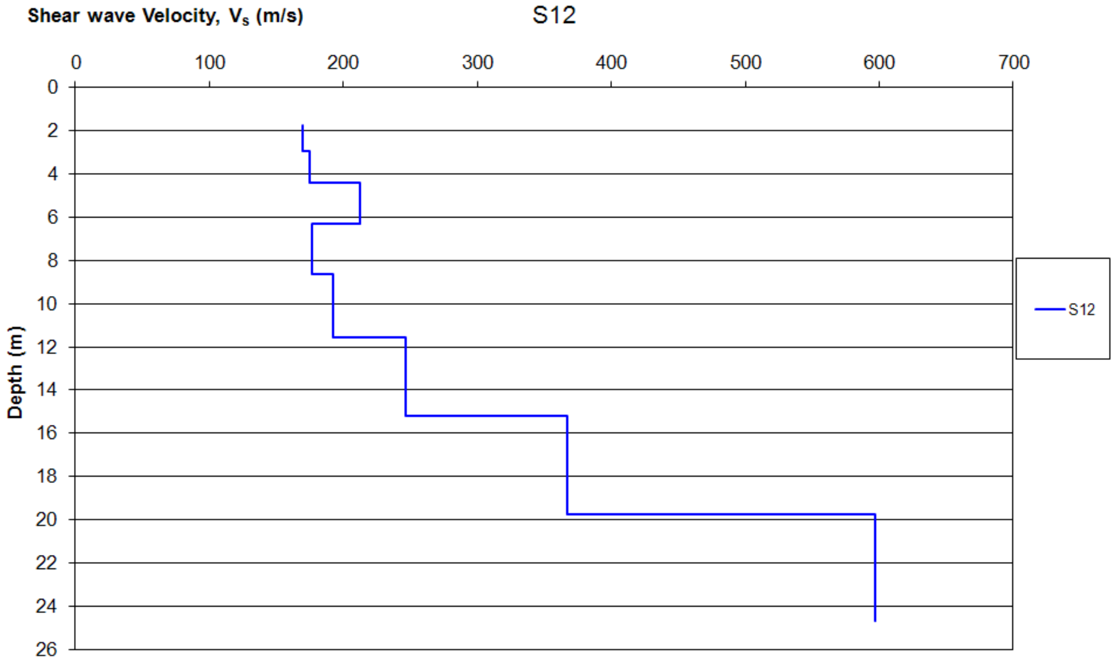

Gmax (MPa)
S9
0
500
1000
1500
2000
2500
3000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
S9

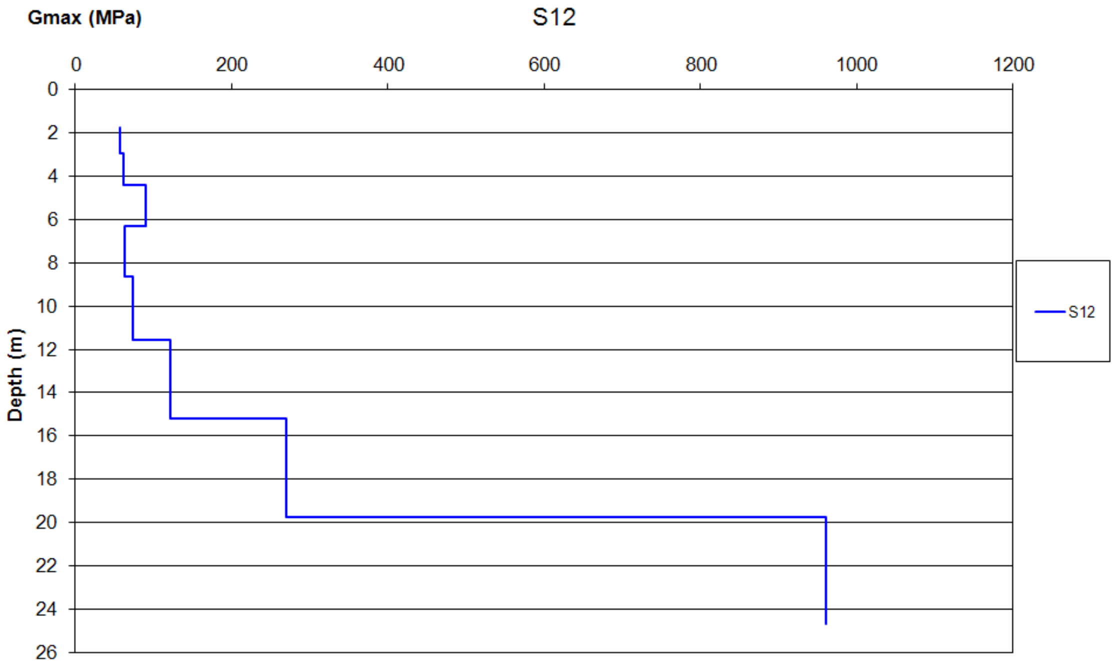

Shear wave Velocity, V_s (m/s)
S10
0 100 200 300 400 500 600 700 800 900 1000
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Depth (m)
S10

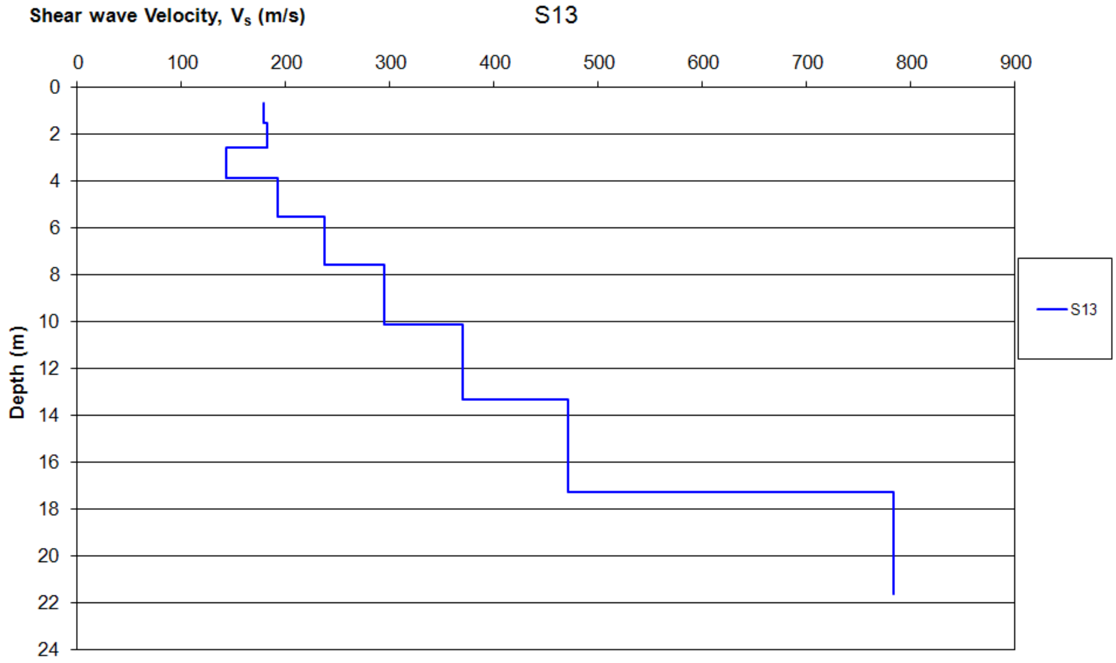

Gmax (MPa)
S10
0 500 1000 1500 2000 2500
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Depth (m)
S10

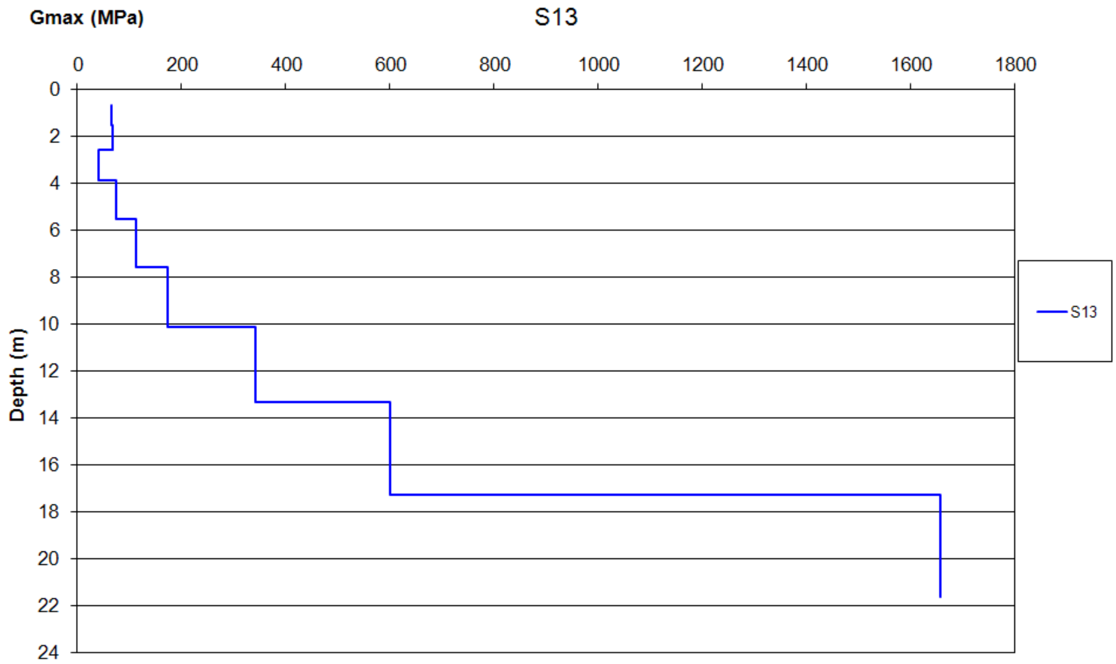

Shear wave Velocity, V_s (m/s)
S11
0
200
400
600
800
1000
1200
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
S11

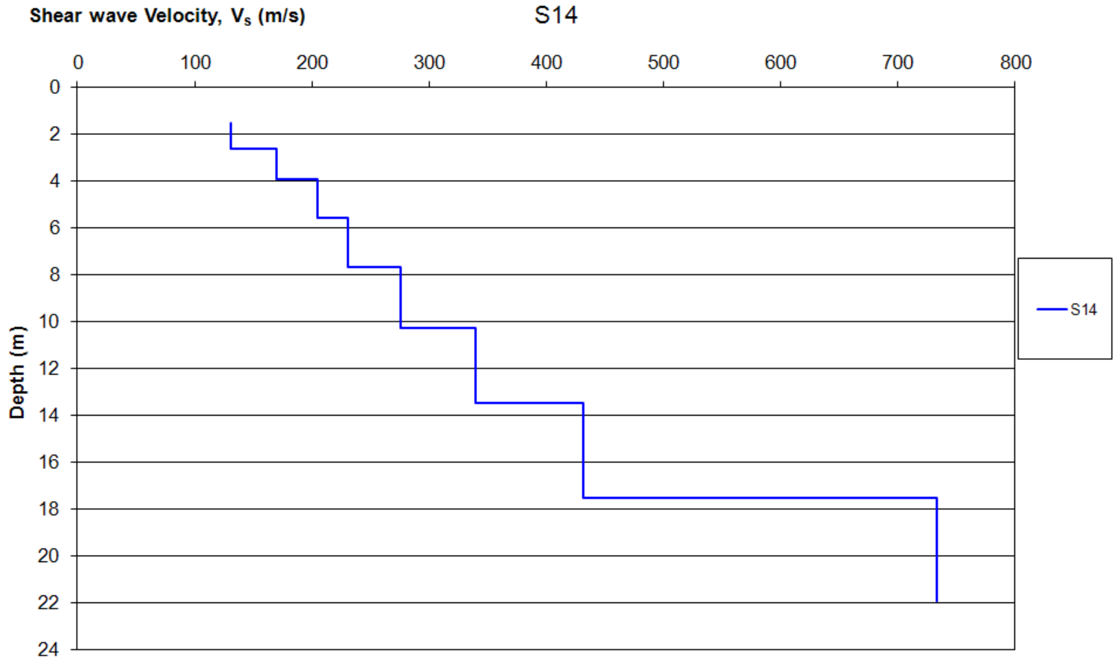

Gmax (MPa)
S11
0
500
1000
1500
2000
2500
3000
3500
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
S11

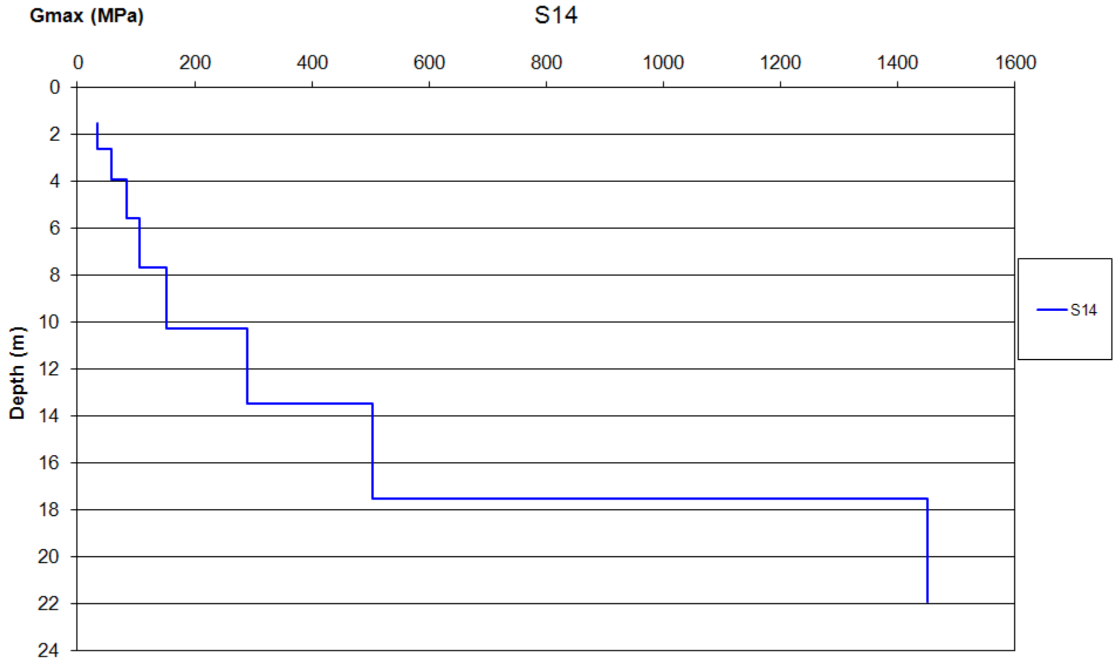

Shear wave Velocity, V_s (m/s)
S12
0
100
200
300
400
500
600
700
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
S12

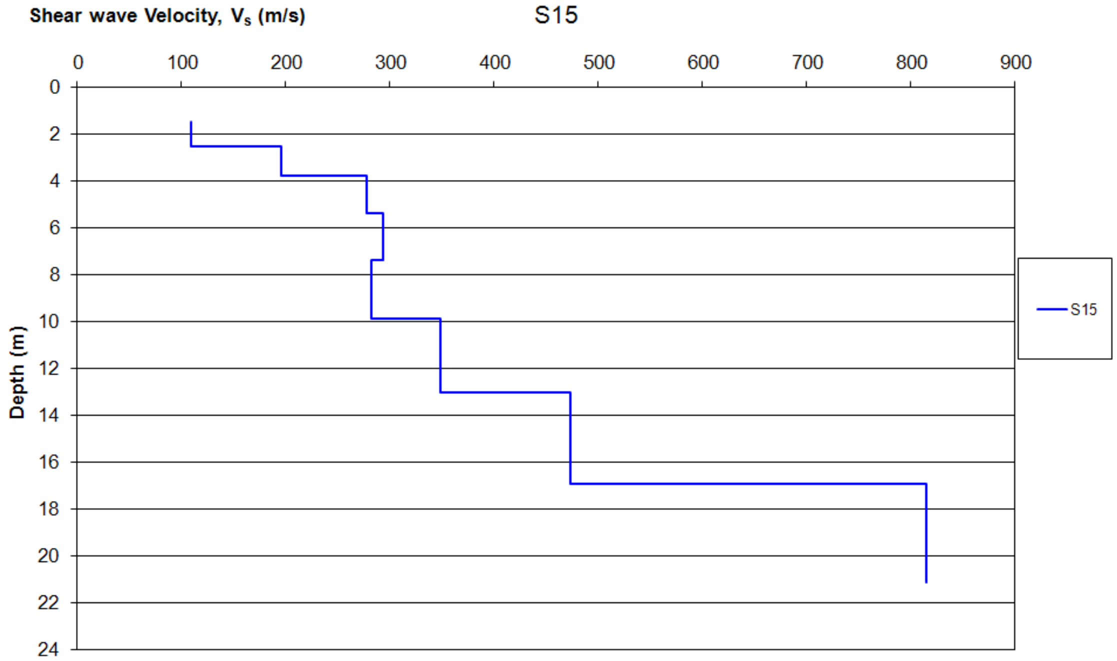

Gmax (MPa)
S12
0
200
400
600
800
1000
1200
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
S12

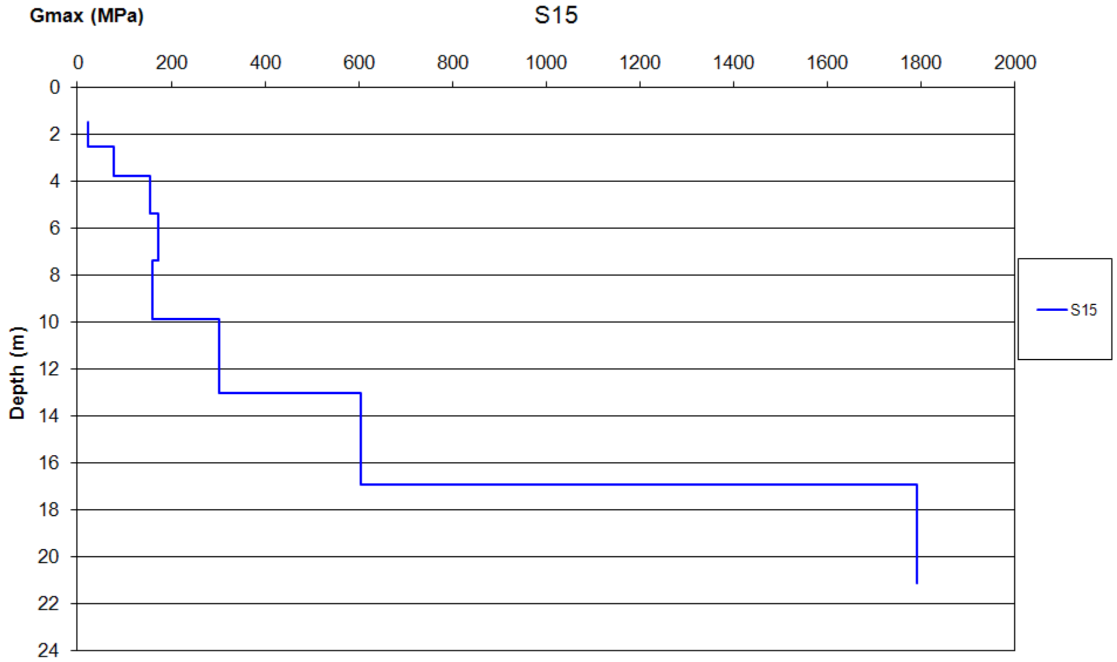

Shear wave Velocity, V_s (m/s)
S13
0
100
200
300
400
500
600
700
800
900
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
S13

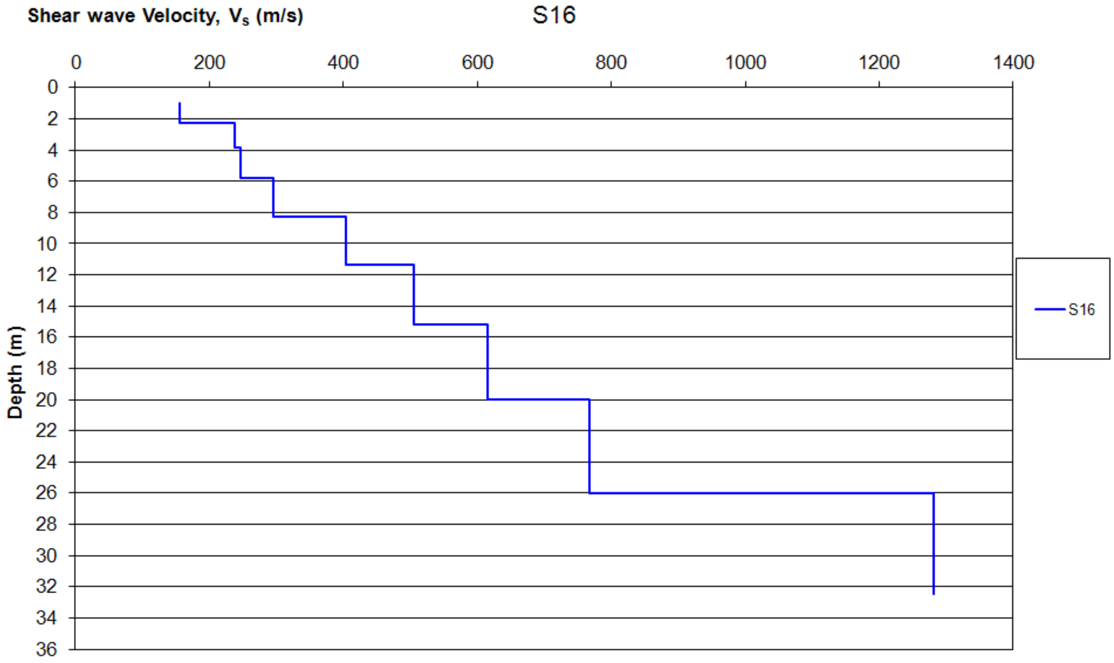

Gmax (MPa)
S13
0
200
400
600
800
1000
1200
1400
1600
1800
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
S13

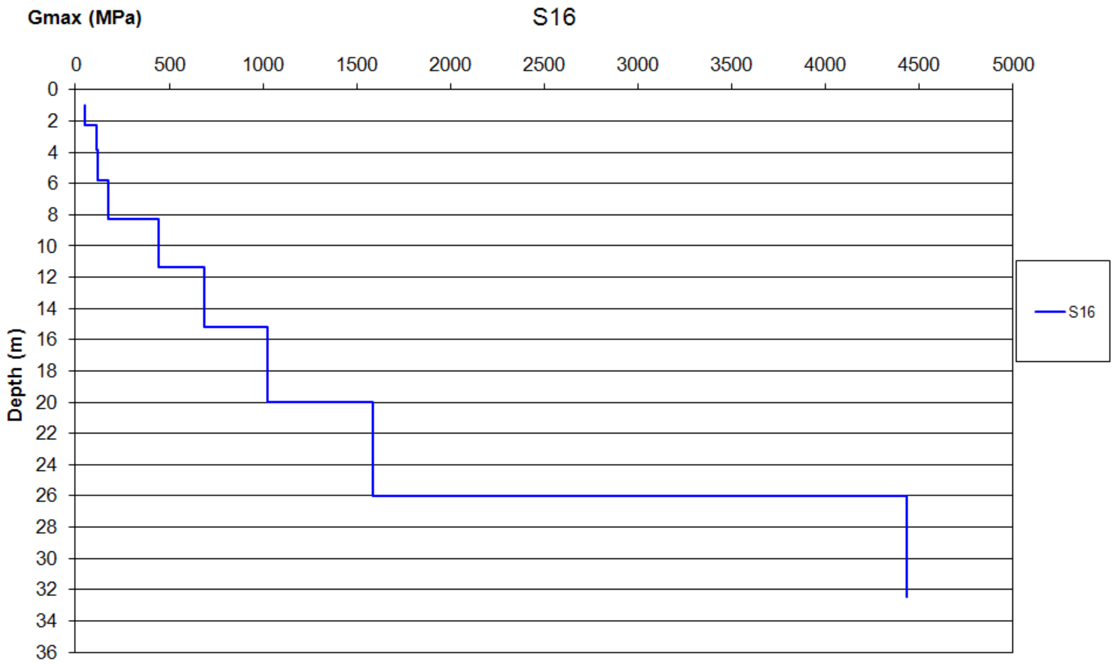

Shear wave Velocity, V_s (m/s)
S14
0
100
200
300
400
500
600
700
800
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S14

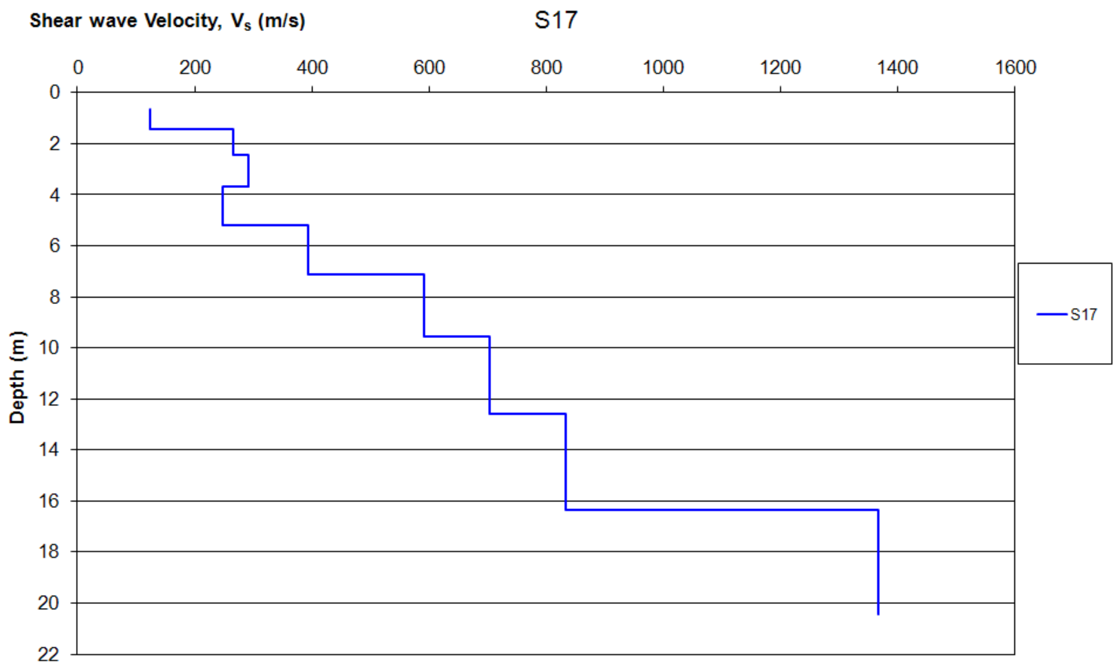

Gmax (MPa)
S14
0
200
400
600
800
1000
1200
1400
1600
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S14

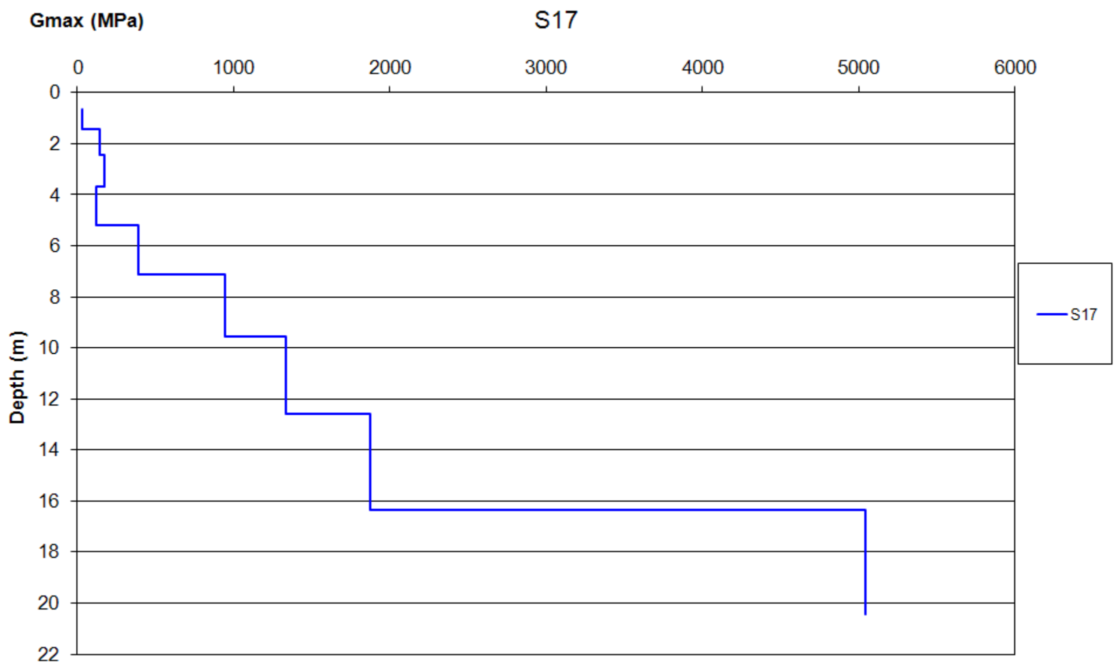

Shear wave Velocity, V_s (m/s)
S15
0
100
200
300
400
500
600
700
800
900
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S15

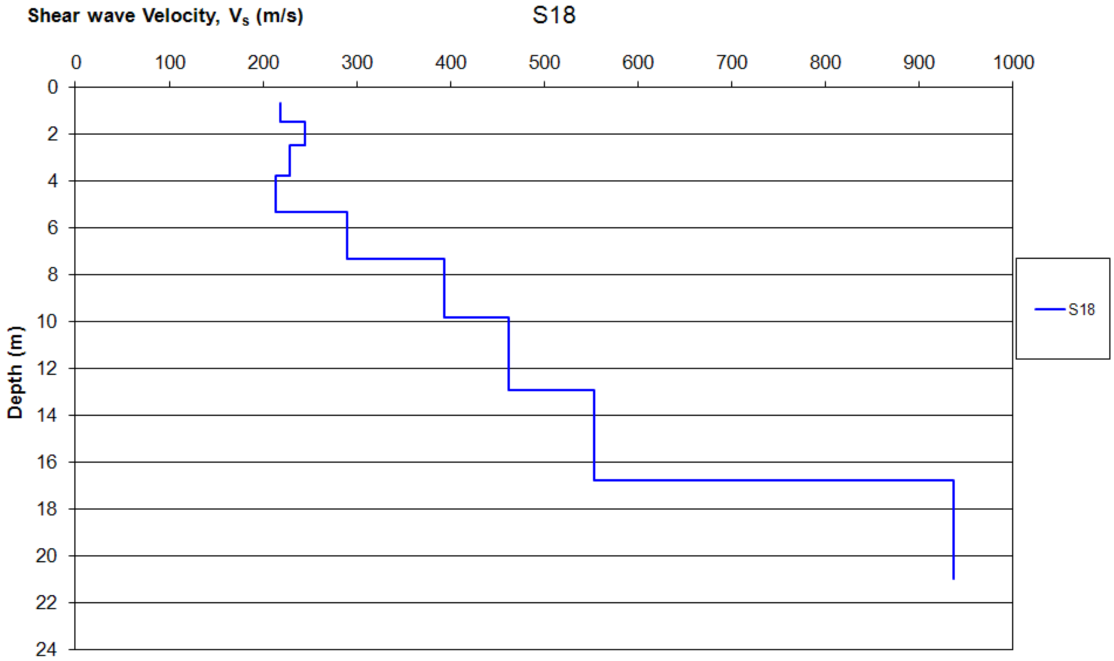

Gmax (MPa)
S15
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S15

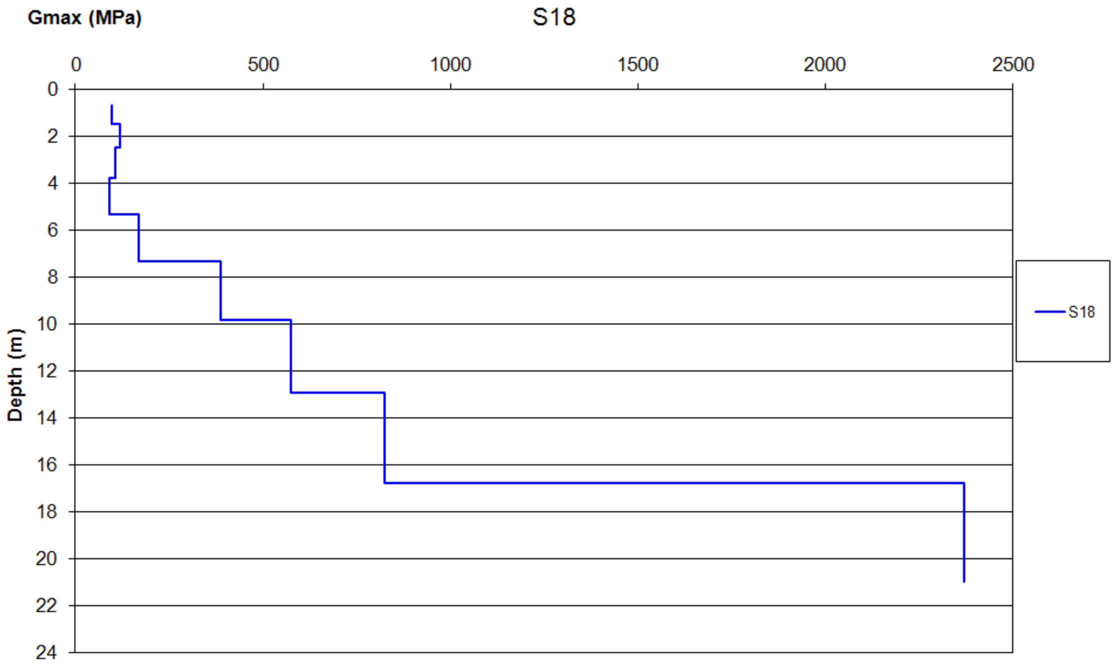

Shear wave Velocity, V_s (m/s)
S16
0
200
400
600
800
1000
1200
1400
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
S16

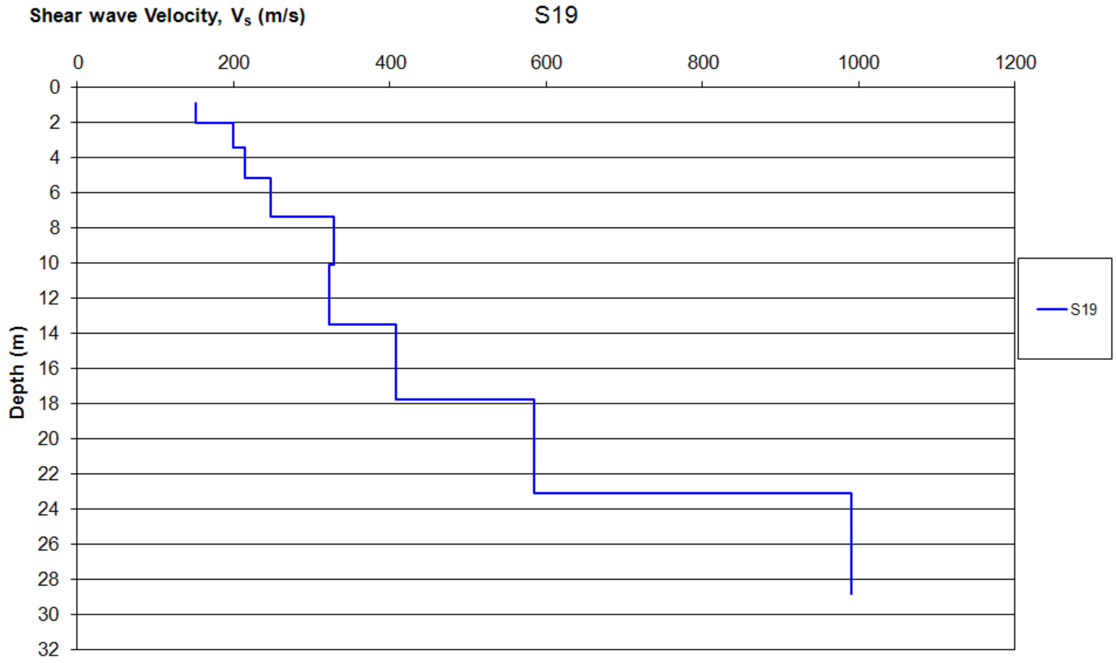

Gmax (MPa)
S16
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
S16

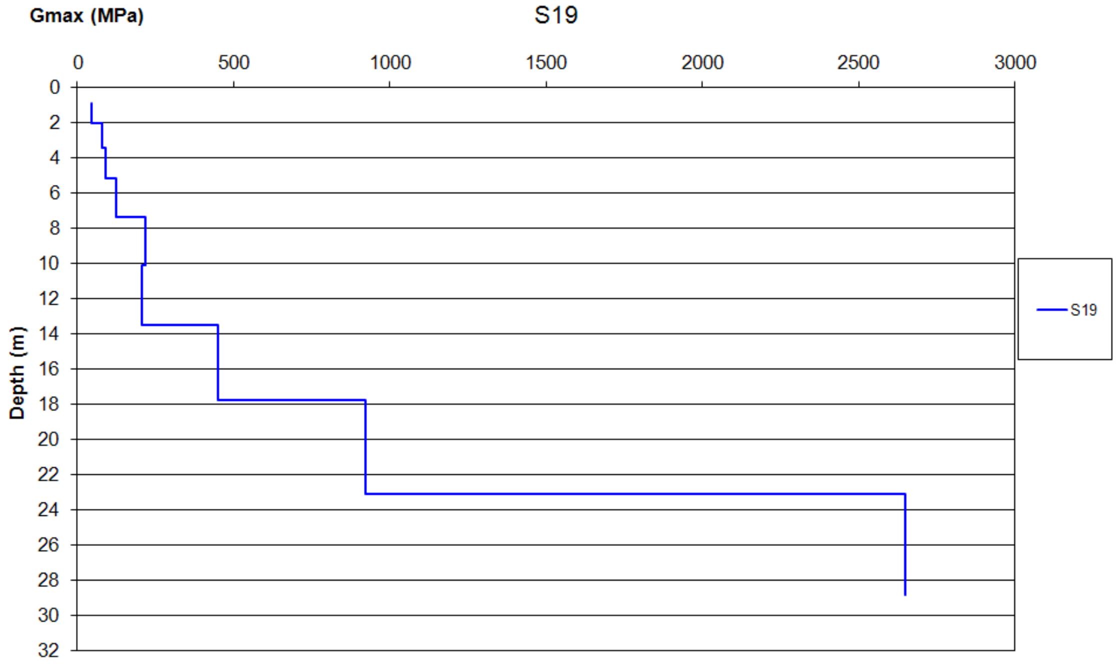

Shear wave Velocity, V_s (m/s)
S17
0
200
400
600
800
1000
1200
1400
1600
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
S17

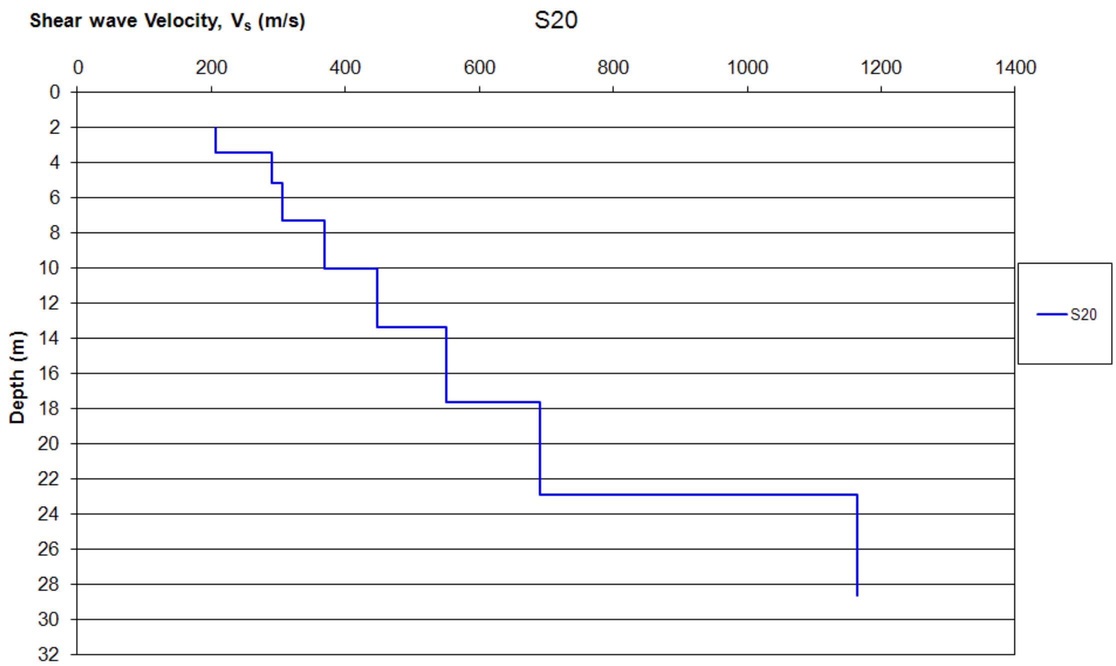

Gmax (MPa)
S17
0
1000
2000
3000
4000
5000
6000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
S17

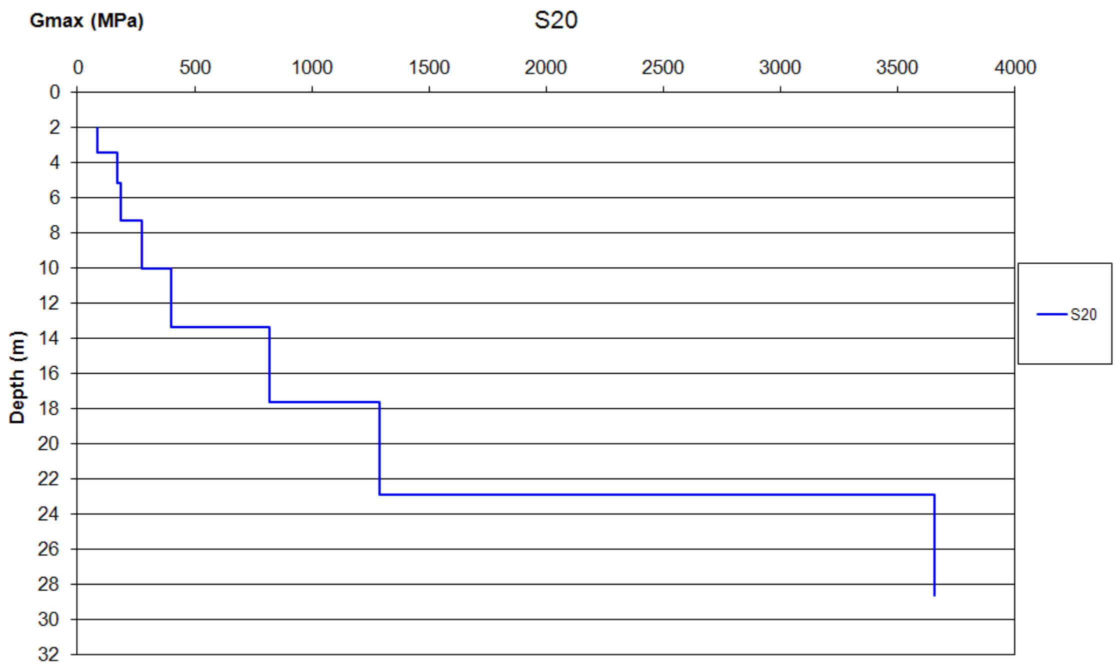

Shear wave Velocity, V_s (m/s)
S18
0
100
200
300
400
500
600
700
800
900
1000
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S18


Gmax (MPa)
S18
0
500
1000
1500
2000
2500
0
2
4
6
8
10
12
14
16
18
20
22
24
Depth (m)
S18


Shear wave Velocity, V_s (m/s)
S19
0
200
400
600
800
1000
1200
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
S19


Gmax (MPa)
S19
0
500
1000
1500
2000
2500
3000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
S19


Shear wave Velocity, V_s (m/s)
S20
0
200
400
600
800
1000
1200
1400
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
S20


Gmax (MPa)
S20
0
500
1000
1500
2000
2500
3000
3500
4000
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
S20

8. APPENDIX C: DYNAMIC MODULI

S1 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
2.535	724.209	1167	2700	0.187	1416.09	3.361	1.789	295.67
3.833	724.209	4366	2700	0.486	1416.09	4.208	49.579	428.37
3.833	704.573	4366	2700	0.487	1340.34	3.985	49.680	391.56
5.456	704.573	4366	2700	0.487	1340.34	3.985	49.680	391.56
5.456	738.94	4366	2700	0.485	1474.29	4.379	49.502	457.50
7.485	738.94	4366	2700	0.485	1474.29	4.379	49.502	457.50
7.485	764.933	4366	2700	0.484	1579.83	4.689	49.361	512.17
10.021	764.933	4366	2700	0.484	1579.83	4.689	49.361	512.17
10.021	835.065	4366	2700	0.481	1882.80	5.577	48.957	681.73
13.191	835.065	4366	2700	0.481	1882.80	5.577	48.957	681.73
13.191	1133.921	4366	2700	0.464	3471.60	10.164	46.838	1835.25
17.153	1133.921	4366	2700	0.464	3471.60	10.164	46.838	1835.25

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S2 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
2.138	172.1	847	2000	0.478	59.24	0.175	1.356	2.26
3.623	172.1	847	2000	0.478	59.24	0.175	1.356	2.26
3.623	289.923	847	2000	0.434	168.11	0.482	1.211	12.00
5.479	289.923	847	2000	0.434	168.11	0.482	1.211	12.00
5.479	335.543	1986	2000	0.485	225.18	0.669	7.588	20.60
7.8	335.543	1986	2000	0.485	225.18	0.669	7.588	20.60
7.8	337.06	4413	2500	0.497	284.02	0.850	48.308	30.62
10.701	337.06	4413	2500	0.497	284.02	0.850	48.308	30.62
10.701	416.25	4413	2700	0.496	467.81	1.399	51.958	69.63
14.327	416.25	4413	2700	0.496	467.81	1.399	51.958	69.63
14.327	544.152	4413	2700	0.492	799.47	2.386	51.515	167.97
18.859	544.152	4413	2700	0.492	799.47	2.386	51.515	167.97
18.859	695.556	4413	2700	0.487	1306.26	3.885	50.840	375.53
24.524	695.556	4413	2700	0.487	1306.26	3.885	50.840	375.53
24.524	1165.625	4413	2700	0.463	3668.44	10.730	47.690	2007.07
30.655	1165.625	4413	2700	0.463	3668.44	10.730	47.690	2007.07

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S3 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
2.218	210.947	1003	2000	0.477	89.00	0.263	1.893	4.41
3.758	210.947	1625	2000	0.491	89.00	0.265	5.163	4.48
3.758	196.613	1625	2000	0.493	77.31	0.231	5.178	3.56
5.683	196.613	1625	2000	0.493	77.31	0.231	5.178	3.56
5.683	244.675	1625	2000	0.488	119.73	0.356	5.122	7.29
8.089	244.675	1625	2000	0.488	119.73	0.356	5.122	7.29
8.089	346.489	5009	2500	0.498	300.14	0.899	62.325	33.55
11.097	346.489	5009	2500	0.498	300.14	0.899	62.325	33.55
11.097	406.174	5009	2700	0.497	445.44	1.333	67.149	64.30
14.857	406.174	5009	2700	0.497	445.44	1.333	67.149	64.30
14.857	484.267	5009	2700	0.495	633.19	1.894	66.899	114.71
19.557	484.267	5009	2700	0.495	633.19	1.894	66.899	114.71
19.557	597.354	5009	2700	0.493	963.45	2.876	66.459	228.65
25.432	597.354	5009	2700	0.493	963.45	2.876	66.459	228.65
25.432	988.723	5009	2700	0.480	2639.45	7.811	64.224	1188.66
31.79	988.723	5009	2700	0.480	2639.45	7.811	64.224	1188.66

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S4 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.929	128.263	1078	2000	0.493	32.90	0.098	2.280	0.87
3.269	128.263	1673	2000	0.497	32.90	0.099	5.554	0.87
3.269	242.129	1673	2000	0.489	117.25	0.349	5.442	7.05
4.943	242.129	1673	2000	0.489	117.25	0.349	5.442	7.05
4.943	261.315	1673	2000	0.487	136.57	0.406	5.416	9.05
7.036	261.315	1673	2000	0.487	136.57	0.406	5.416	9.05
7.036	209.101	1673	2000	0.492	87.45	0.261	5.481	4.36
9.652	209.101	1673	2000	0.492	87.45	0.261	5.481	4.36
9.652	238.458	1673	2000	0.490	113.72	0.339	5.446	6.71
12.922	238.458	1673	2000	0.490	113.72	0.339	5.446	6.71
12.922	337.561	3114	2500	0.494	284.87	0.851	23.863	30.66
17.01	337.561	3114	2500	0.494	284.87	0.851	23.863	30.66
17.01	440.44	3114	2700	0.490	523.77	1.561	25.484	83.37
22.12	440.44	3114	2700	0.490	523.77	1.561	25.484	83.37
22.12	718.683	3114	2700	0.472	1394.56	4.105	24.322	411.21
27.65	718.683	3114	2700	0.472	1394.56	4.105	24.322	411.21

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S5 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
2.299	522.01	3385	2700	0.488	735.73	2.189	29.956	145.73
3.272	522.01	3385	2700	0.488	735.73	2.189	29.956	145.73
3.272	651.122	3385	2700	0.481	1144.69	3.390	29.411	299.85
4.489	651.122	3385	2700	0.481	1144.69	3.390	29.411	299.85
4.489	899.641	3385	2700	0.462	2185.26	6.390	28.024	853.30
6.01	899.641	3385	2700	0.462	2185.26	6.390	28.024	853.30
6.01	1042.072	3385	2700	0.448	2931.97	8.489	27.028	1363.54
7.911	1042.072	3385	2700	0.448	2931.97	8.489	27.028	1363.54
7.911	1522.057	3385	2700	0.373	6254.98	17.180	22.597	4363.54
10.287	1522.057	3385	2700	0.373	6254.98	17.180	22.597	4363.54

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S7E	Calculation of static and dynamic moduli							
Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.364	211.063	827	2000	0.465	89.10	0.261	1.249	4.36
2.311	211.063	1441	2000	0.489	89.10	0.265	4.034	4.48
2.311	237.442	1441	2000	0.486	112.76	0.335	4.003	6.59
3.495	237.442	1441	2000	0.486	112.76	0.335	4.003	6.59
3.495	291.647	1441	2000	0.479	170.12	0.503	3.926	12.88
4.975	291.647	1441	2000	0.479	170.12	0.503	3.926	12.88
4.975	349.251	4592	2500	0.497	304.94	0.913	52.310	34.43
6.825	349.251	4592	2500	0.497	304.94	0.913	52.310	34.43
6.825	433.991	4592	2700	0.495	508.54	1.521	56.255	79.91
9.137	433.991	4592	2700	0.495	508.54	1.521	56.255	79.91
9.137	544.834	4592	2700	0.493	801.48	2.393	55.865	168.78
12.027	544.834	4592	2700	0.493	801.48	2.393	55.865	168.78
12.027	663.052	4592	2700	0.489	1187.02	3.536	55.351	321.41
15.64	663.052	4592	2700	0.489	1187.02	3.536	55.351	321.41
15.64	1075.414	4592	2700	0.471	3122.59	9.187	52.770	1553.33
19.55	1075.414	4592	2700	0.471	3122.59	9.187	52.770	1553.33

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S8 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.479	150.122	790	2000	0.481	45.07	0.134	1.188	1.44
2.506	150.122	790	2000	0.481	45.07	0.134	1.188	1.44
2.506	169.021	790	2000	0.476	57.14	0.169	1.172	2.12
3.79	169.021	790	2000	0.476	57.14	0.169	1.172	2.12
3.79	237.437	1568	2000	0.488	112.75	0.336	4.767	6.60
5.395	237.437	1568	2000	0.488	112.75	0.336	4.767	6.60
5.395	295.801	1568	2000	0.482	175.00	0.519	4.684	13.53
7.401	295.801	1568	2000	0.482	175.00	0.519	4.684	13.53
7.401	352.513	3185	2500	0.494	310.66	0.928	24.946	35.37
9.909	352.513	3185	2500	0.494	310.66	0.928	24.946	35.37
9.909	432.671	3185	2700	0.491	505.45	1.507	26.715	78.68
13.044	432.671	3185	2700	0.491	505.45	1.507	26.715	78.68
13.044	538.016	3185	2700	0.485	781.55	2.322	26.347	160.56
16.963	538.016	3185	2700	0.485	781.55	2.322	26.347	160.56
16.963	896.5	3185	2700	0.457	2170.02	6.323	24.496	838.73
21.204	896.5	3185	2700	0.457	2170.02	6.323	24.496	838.73

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S9 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
0.704	112.657	238	2000	0.356	25.38	0.069	0.079	0.48
1.583	112.657	238	2000	0.356	25.38	0.069	0.079	0.48
1.583	188.616	1365	2000	0.490	71.15	0.212	3.632	3.10
2.682	188.616	1365	2000	0.490	71.15	0.212	3.632	3.10
2.682	273.9	1365	2000	0.479	150.04	0.444	3.526	10.47
4.056	273.9	1365	2000	0.479	150.04	0.444	3.526	10.47
4.056	287.793	1365	2000	0.477	165.65	0.489	3.506	12.30
5.774	287.793	1365	2000	0.477	165.65	0.489	3.506	12.30
5.774	311.009	4880	2500	0.498	241.82	0.724	59.214	23.50
7.921	311.009	4880	2500	0.498	241.82	0.724	59.214	23.50
7.921	369.938	4880	2700	0.497	369.51	1.106	63.806	47.26
10.605	369.938	4880	2700	0.497	369.51	1.106	63.806	47.26
10.605	471.71	4880	2700	0.495	600.78	1.797	63.498	105.18
13.96	471.71	4880	2700	0.495	600.78	1.797	63.498	105.18
13.96	586.857	4880	2700	0.493	929.88	2.776	63.059	215.63
18.153	586.857	4880	2700	0.493	929.88	2.776	63.059	215.63
18.153	969.499	4880	2700	0.479	2537.81	7.509	60.915	1113.74
22.691	969.499	4880	2700	0.479	2537.81	7.509	60.915	1113.74

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S10 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
2.775	154.387	1141	2000	0.491	47.67	0.142	2.540	1.60
4.197	154.387	1141	2000	0.491	47.67	0.142	2.540	1.60
4.197	214.02	1141	2000	0.482	91.61	0.271	2.482	4.65
5.974	214.02	1141	2000	0.482	91.61	0.271	2.482	4.65
5.974	286.006	1141	2000	0.466	163.60	0.480	2.386	11.91
8.195	286.006	1141	2000	0.466	163.60	0.480	2.386	11.91
8.195	343.974	4368	2500	0.497	295.80	0.886	47.304	32.73
10.971	343.974	4368	2500	0.497	295.80	0.886	47.304	32.73
10.971	412.08	4368	2700	0.496	458.49	1.371	50.903	67.35
14.442	412.08	4368	2700	0.496	458.49	1.371	50.903	67.35
14.442	512.408	4368	2700	0.493	708.92	2.117	50.569	137.86
18.78	512.408	4368	2700	0.493	708.92	2.117	50.569	137.86
18.78	866.895	4368	2700	0.479	2029.07	6.004	48.809	770.00
23.475	866.895	4368	2700	0.479	2029.07	6.004	48.809	770.00

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S11 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.06	148.524	672	2000	0.474	44.12	0.130	0.844	1.38
2.385	148.524	672	2000	0.474	44.12	0.130	0.844	1.38
2.385	208.828	672	2000	0.447	87.22	0.252	0.787	4.12
4.041	208.828	672	2000	0.447	87.22	0.252	0.787	4.12
4.041	248.207	1493	2000	0.486	123.21	0.366	4.294	7.62
6.111	248.207	1493	2000	0.486	123.21	0.366	4.294	7.62
6.111	249.949	1493	2000	0.486	124.95	0.371	4.291	7.80
8.698	249.949	1493	2000	0.486	124.95	0.371	4.291	7.80
8.698	295.387	1493	2000	0.480	174.51	0.516	4.225	13.44
11.932	295.387	1493	2000	0.480	174.51	0.516	4.225	13.44
11.932	393.431	3437	2500	0.493	386.97	1.156	29.016	50.79
15.974	393.431	3437	2500	0.493	386.97	1.156	29.016	50.79
15.974	505.683	3437	2700	0.489	690.43	2.056	30.974	131.39
21.027	505.683	3437	2700	0.489	690.43	2.056	30.974	131.39
21.027	632.946	3437	2700	0.482	1081.68	3.207	30.453	273.61
27.343	632.946	3437	2700	0.482	1081.68	3.207	30.453	273.61
27.343	1046.011	3437	2700	0.449	2954.18	8.561	27.956	1382.69
34.179	1046.011	3437	2700	0.449	2954.18	8.561	27.956	1382.69

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S12 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.724	169.139	784	2000	0.476	57.22	0.169	1.153	2.13
2.922	169.139	784	2000	0.476	57.22	0.169	1.153	2.13
2.922	174.779	784	2000	0.474	61.10	0.180	1.148	2.36
4.419	174.779	784	2000	0.474	61.10	0.180	1.148	2.36
4.419	212.18	784	2000	0.460	90.04	0.263	1.109	4.42
6.29	212.18	784	2000	0.460	90.04	0.263	1.109	4.42
6.29	176.499	784	2000	0.473	62.30	0.184	1.146	2.44
8.629	176.499	784	2000	0.473	62.30	0.184	1.146	2.44
8.629	192.222	784	2000	0.468	73.90	0.217	1.131	3.21
11.553	192.222	784	2000	0.468	73.90	0.217	1.131	3.21
11.553	246.242	1535	2000	0.487	121.27	0.361	4.551	7.43
15.207	246.242	1535	2000	0.487	121.27	0.361	4.551	7.43
15.207	367.017	1535	2000	0.470	269.40	0.792	4.353	27.22
19.775	367.017	1535	2000	0.470	269.40	0.792	4.353	27.22
19.775	596.572	3982	2700	0.489	960.93	2.861	41.531	226.59
24.719	596.572	3982	2700	0.489	960.93	2.861	41.531	226.59

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S13 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
0.671	179.165	318	2000	0.267	64.20	0.163	0.117	2.00
1.509	179.165	318	2000	0.267	64.20	0.163	0.117	2.00
1.509	182.397	901	2000	0.479	66.54	0.197	1.535	2.74
2.557	182.397	901	2000	0.479	66.54	0.197	1.535	2.74
2.557	142.582	901	2000	0.487	40.66	0.121	1.569	1.23
3.867	142.582	901	2000	0.487	40.66	0.121	1.569	1.23
3.867	192.487	1634	2000	0.493	74.10	0.221	5.241	3.32
5.505	192.487	1634	2000	0.493	74.10	0.221	5.241	3.32
5.505	237.375	1634	2000	0.489	112.69	0.336	5.190	6.60
7.552	237.375	1634	2000	0.489	112.69	0.336	5.190	6.60
7.552	293.974	1634	2000	0.483	172.84	0.513	5.109	13.29
10.111	293.974	1634	2000	0.483	172.84	0.513	5.109	13.29
10.111	370.176	4324	2500	0.496	342.58	1.025	46.286	41.68
13.309	370.176	4324	2500	0.496	342.58	1.025	46.286	41.68
13.309	471.091	4324	2700	0.494	599.20	1.790	49.683	104.58
17.307	471.091	4324	2700	0.494	599.20	1.790	49.683	104.58
17.307	783.297	4324	2700	0.483	1656.60	4.914	48.273	553.18
21.634	783.297	4324	2700	0.483	1656.60	4.914	48.273	553.18

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S14 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.531	131.159	576	2000	0.473	34.41	0.101	0.618	0.92
2.594	131.159	576	2000	0.473	34.41	0.101	0.618	0.92
2.594	170.163	576	2000	0.452	57.91	0.168	0.586	2.11
3.923	170.163	576	2000	0.452	57.91	0.168	0.586	2.11
3.923	204.75	1623	2000	0.492	83.85	0.250	5.156	4.07
5.584	204.75	1623	2000	0.492	83.85	0.250	5.156	4.07
5.584	230.896	1623	2000	0.490	106.63	0.318	5.126	6.03
7.66	230.896	1623	2000	0.490	106.63	0.318	5.126	6.03
7.66	275.969	1623	2000	0.485	152.32	0.452	5.065	10.81
10.256	275.969	1623	2000	0.485	152.32	0.452	5.065	10.81
10.256	340.062	3259	2500	0.494	289.11	0.864	26.167	31.44
13.5	340.062	3259	2500	0.494	289.11	0.864	26.167	31.44
13.5	431.372	3259	2700	0.491	502.42	1.498	28.007	77.95
17.556	431.372	3259	2700	0.491	502.42	1.498	28.007	77.95
17.556	732.663	3259	2700	0.473	1449.35	4.271	26.744	438.95
21.945	732.663	3259	2700	0.473	1449.35	4.271	26.744	438.95

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S15 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.476	108.621	193	2000	0.268	23.60	0.060	0.043	0.38
2.501	108.621	193	2000	0.268	23.60	0.060	0.043	0.38
2.501	195.806	783	2000	0.467	76.68	0.225	1.124	3.41
3.782	195.806	783	2000	0.467	76.68	0.225	1.124	3.41
3.782	277.143	1677	2000	0.486	153.62	0.457	5.420	10.97
5.383	277.143	1677	2000	0.486	153.62	0.457	5.420	10.97
5.383	292.78	1677	2000	0.484	171.44	0.509	5.396	13.12
7.384	292.78	1677	2000	0.484	171.44	0.509	5.396	13.12
7.384	281.693	1677	2000	0.485	158.70	0.471	5.413	11.57
9.885	281.693	1677	2000	0.485	158.70	0.471	5.413	11.57
9.885	348.322	2555	2500	0.491	303.32	0.904	15.916	33.88
13.012	348.322	2555	2500	0.491	303.32	0.904	15.916	33.88
13.012	473.487	2555	2700	0.482	605.31	1.794	16.819	104.96
16.92	473.487	2555	2700	0.482	605.31	1.794	16.819	104.96
16.92	814.065	2555	2700	0.444	1789.29	5.166	15.240	600.79
21.15	814.065	2555	2700	0.444	1789.29	5.166	15.240	600.79

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S16 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.007	154.844	835	2000	0.482	47.95	0.142	1.331	1.60
2.265	154.844	835	2000	0.482	47.95	0.142	1.331	1.60
2.265	238.282	1728	2000	0.490	113.56	0.338	5.821	6.70
3.838	238.282	1728	2000	0.490	113.56	0.338	5.821	6.70
3.838	246.593	1728	2000	0.490	121.62	0.362	5.810	7.49
5.804	246.593	1728	2000	0.490	121.62	0.362	5.810	7.49
5.804	294.98	1728	2000	0.485	174.03	0.517	5.740	13.46
8.262	294.98	1728	2000	0.485	174.03	0.517	5.740	13.46
8.262	404.368	1677	2700	0.469	441.49	1.297	7.005	61.45
11.334	404.368	1677	2700	0.469	441.49	1.297	7.005	61.45
11.334	505.267	1677	2700	0.450	689.30	1.999	6.674	125.44
15.175	505.267	2555	2700	0.480	689.30	2.040	16.707	129.69
15.175	615.646	2555	2700	0.469	1023.35	3.007	16.261	246.02
19.976	615.646	2555	2700	0.469	1023.35	3.007	16.261	246.02
19.976	766.94	2555	2700	0.450	1588.13	4.607	15.508	497.42
25.977	766.94	2555	2700	0.450	1588.13	4.607	15.508	497.42
25.977	1281.288	2555	2700	0.332	4432.59	11.809	11.716	2350.62
32.471	1281.288	2555	2700	0.332	4432.59	11.809	11.716	2350.62

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S17 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
0.634	123.989	358	2000	0.432	30.75	0.088	0.215	0.73
1.427	123.989	358	2000	0.432	30.75	0.088	0.215	0.73
1.427	265.184	1379	2000	0.481	140.65	0.417	3.616	9.43
2.418	265.184	1379	2000	0.481	140.65	0.417	3.616	9.43
2.418	291.16	1379	2000	0.477	169.55	0.501	3.577	12.78
3.657	291.16	1379	2000	0.477	169.55	0.501	3.577	12.78
3.657	247.891	1379	2000	0.483	122.90	0.365	3.639	7.57
5.206	247.891	1379	2000	0.483	122.90	0.365	3.639	7.57
5.206	393.815	3773	2500	0.494	387.73	1.159	35.072	51.02
7.142	393.815	3773	2500	0.494	387.73	1.159	35.072	51.02
7.142	591.079	3773	2700	0.487	943.31	2.806	37.178	219.51
9.562	591.079	3773	2700	0.487	943.31	2.806	37.178	219.51
9.562	703.395	3773	2700	0.482	1335.86	3.959	36.655	387.40
12.587	703.395	3773	2700	0.482	1335.86	3.959	36.655	387.40
12.587	833.177	3773	2700	0.474	1874.30	5.527	35.937	671.65
16.368	833.177	3773	2700	0.474	1874.30	5.527	35.937	671.65
16.368	1366.382	3773	2700	0.425	5040.90	14.362	31.715	3246.79
20.46	1366.382	3773	2700	0.425	5040.90	14.362	31.715	3246.79

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S18 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
0.651	218.709	775	2000	0.457	95.67	0.279	1.074	4.86
1.464	218.709	775	2000	0.457	95.67	0.279	1.074	4.86
1.464	244.091	775	2000	0.445	119.16	0.344	1.042	6.89
2.481	244.091	775	2000	0.445	119.16	0.344	1.042	6.89
2.481	228.664	1891	2000	0.493	104.57	0.312	7.012	5.86
3.752	228.664	1891	2000	0.493	104.57	0.312	7.012	5.86
3.752	213.023	1891	2000	0.494	90.76	0.271	7.031	4.64
5.34	213.023	1891	2000	0.494	90.76	0.271	7.031	4.64
5.34	289.886	1891	2000	0.488	168.07	0.500	6.928	12.75
7.326	289.886	1891	2000	0.488	168.07	0.500	6.928	12.75
7.326	393.084	4016	2500	0.495	386.29	1.155	39.806	50.75
9.808	393.084	4016	2500	0.495	386.29	1.155	39.806	50.75
9.808	461.412	4016	2700	0.493	574.83	1.717	42.780	97.58
12.91	461.412	4016	2700	0.493	574.83	1.717	42.780	97.58
12.91	552.795	4016	2700	0.490	825.07	2.459	42.446	176.56
16.788	552.795	4016	2700	0.490	825.07	2.459	42.446	176.56
16.788	936.89	4016	2700	0.471	2369.96	6.973	40.386	985.71
20.985	936.89	4016	2700	0.471	2369.96	6.973	40.386	985.71

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S19 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
0.895	151.213	293	2000	0.318	45.73	0.121	0.111	1.22
2.013	151.213	293	2000	0.318	45.73	0.121	0.111	1.22
2.013	198.917	851	2000	0.471	79.14	0.233	1.343	3.61
3.411	198.917	851	2000	0.471	79.14	0.233	1.343	3.61
3.411	214.04	1862	2000	0.493	91.63	0.274	6.812	4.71
5.158	214.04	1862	2000	0.493	91.63	0.274	6.812	4.71
5.158	247.552	1862	2000	0.491	122.56	0.365	6.771	7.60
7.342	247.552	1862	2000	0.491	122.56	0.365	6.771	7.60
7.342	328.622	1862	2000	0.484	215.98	0.641	6.646	19.20
10.072	328.622	1862	2000	0.484	215.98	0.641	6.646	19.20
10.072	322.379	1862	2000	0.485	207.86	0.617	6.657	18.04
13.485	322.379	1862	2000	0.485	207.86	0.617	6.657	18.04
13.485	407.411	3220	2700	0.492	448.16	1.337	27.397	64.61
17.751	407.411	3220	2700	0.492	448.16	1.337	27.397	64.61
17.751	583.615	3220	2700	0.483	919.64	2.728	26.768	209.47
23.084	583.615	3220	2700	0.483	919.64	2.728	26.768	209.47
23.084	990.305	3220	2700	0.448	2647.90	7.667	24.464	1152.66
28.855	990.305	3220	2700	0.448	2647.90	7.667	24.464	1152.66

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

S20 Calculation of static and dynamic moduli

Depth (m bgl)	Vs m/sec	Vp m/sec	density kg/m^3	Poissons ratio	Shear* Mod. MPa Dynamic Gmax	Youngs * Mod. GPa Dynamic Emax	Bulk* Mod. GPa Dynamic	Youngs** Mod. MPa Static
1.998	205.708	785	2000	0.463	84.63	0.248	1.120	4.00
3.385	205.708	785	2000	0.463	84.63	0.248	1.120	4.00
3.385	290.672	1501	2000	0.481	168.98	0.500	4.281	12.76
5.119	290.672	1501	2000	0.481	168.98	0.500	4.281	12.76
5.119	305.648	1501	2000	0.478	186.84	0.552	4.257	15.03
7.286	305.648	1501	2000	0.478	186.84	0.552	4.257	15.03
7.286	369.023	1501	2000	0.468	272.36	0.800	4.143	27.65
9.995	369.023	1501	2000	0.468	272.36	0.800	4.143	27.65
9.995	447.248	1501	2000	0.451	400.06	1.161	3.973	51.19
13.381	447.248	1501	2000	0.451	400.06	1.161	3.973	51.19
13.381	549.951	4268	2700	0.492	816.60	2.436	48.094	173.81
17.614	549.951	4268	2700	0.492	816.60	2.436	48.094	173.81
17.614	690.48	4268	2700	0.487	1287.26	3.827	47.466	366.28
22.905	690.48	4268	2700	0.487	1287.26	3.827	47.466	366.28
22.905	1163.372	4268	2700	0.460	3654.27	10.670	44.310	1988.38
28.631	1163.372	4268	2700	0.460	3654.27	10.670	44.310	1988.38

** converted to static equivalent using empirical correlation from Heerden, 1987.

Soil density taken as 2000 kg/m^3
& 2500 kg/m^3 for Weathered Bedrock & 2700 kg/m^3 for Fresh Bedrock

9. APPENDIX D: SEISMIC REFRACTION PLATES

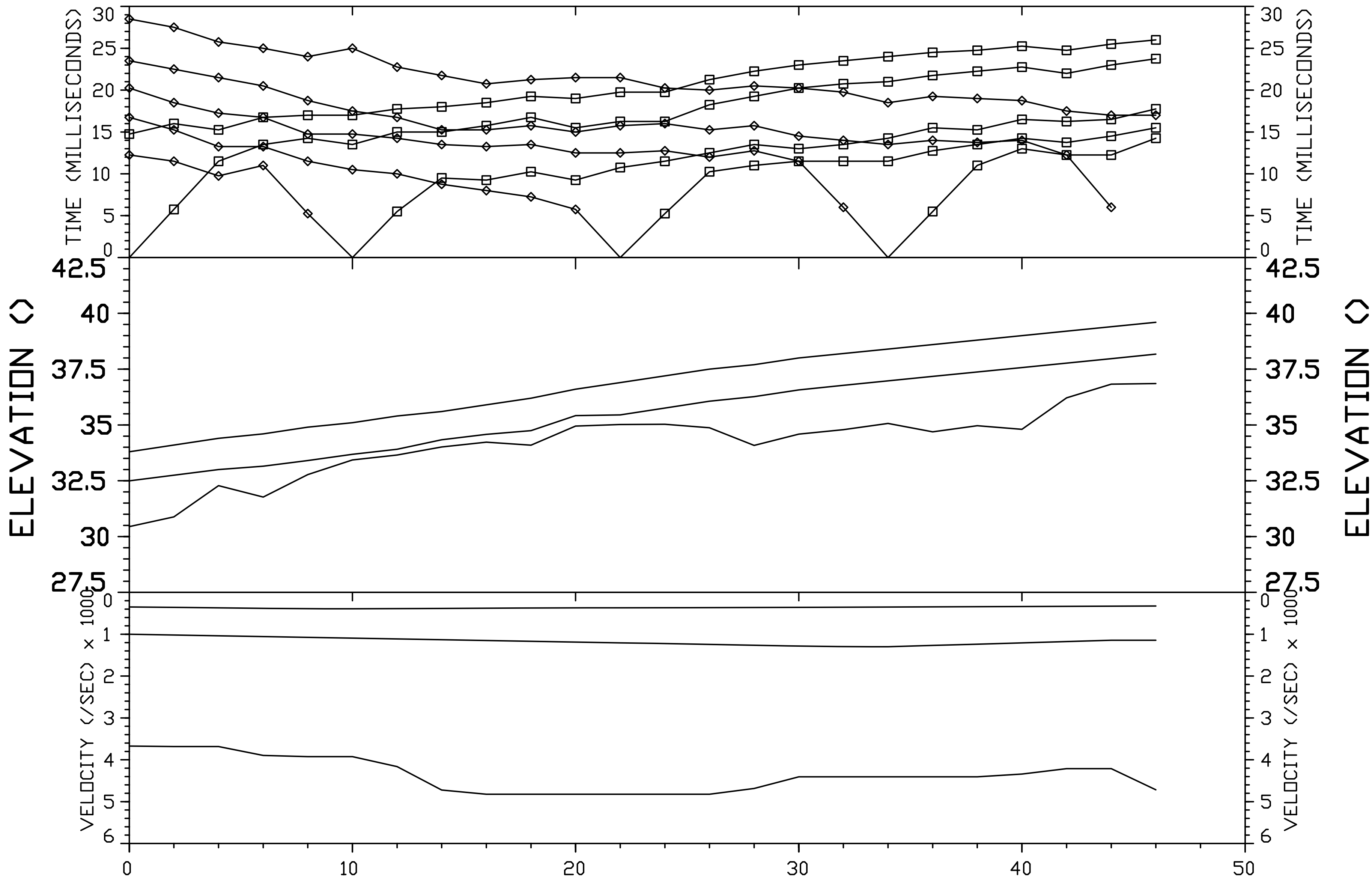


Plate: 10a

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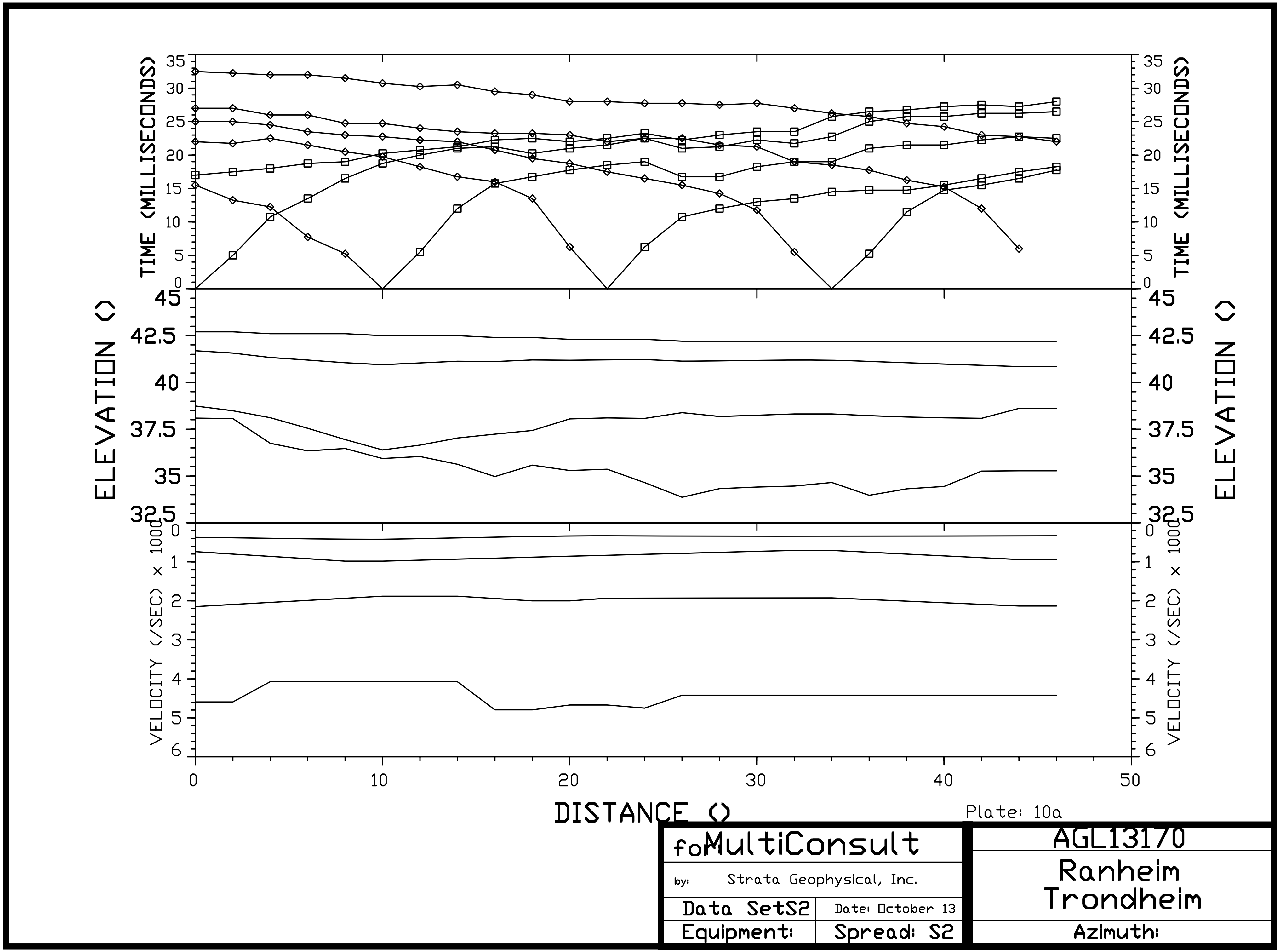
by: Strata Geophysical, Inc.		Ranheim Trondheim
Data SetS1	Date: October 13	
Equipment:	Spread: S1	Azimuth: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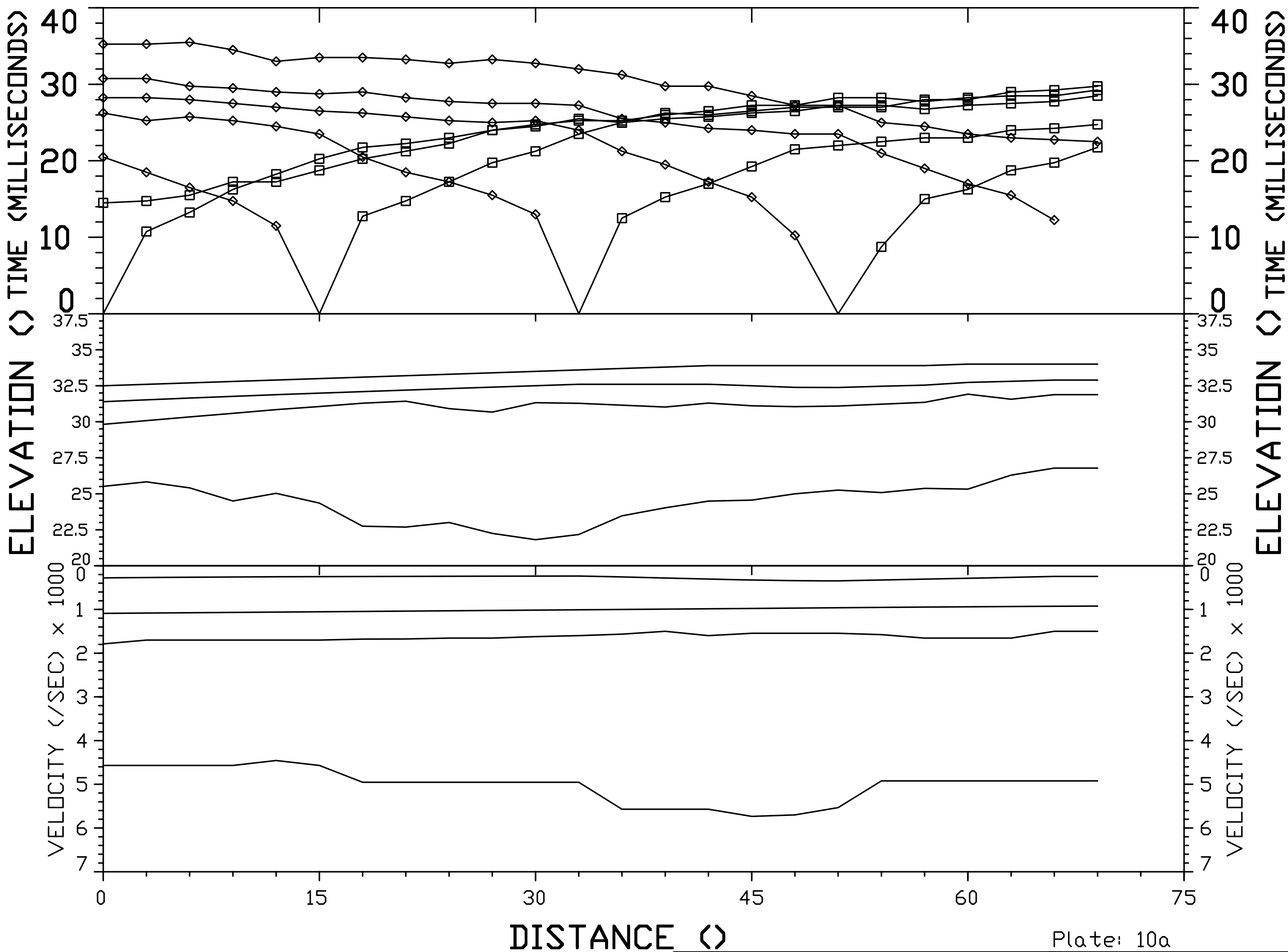
ELEVATION ()
VELOCITY (/SEC) x 1000
DISTANCE ()
Plate: 10a
for MultiConsult
by: Strata Geophysical, Inc.
Data SetS2
Date: October 13
Equipment:
Spread: S2
AGL13170
Ranheim
Trondheim
Azimuth:



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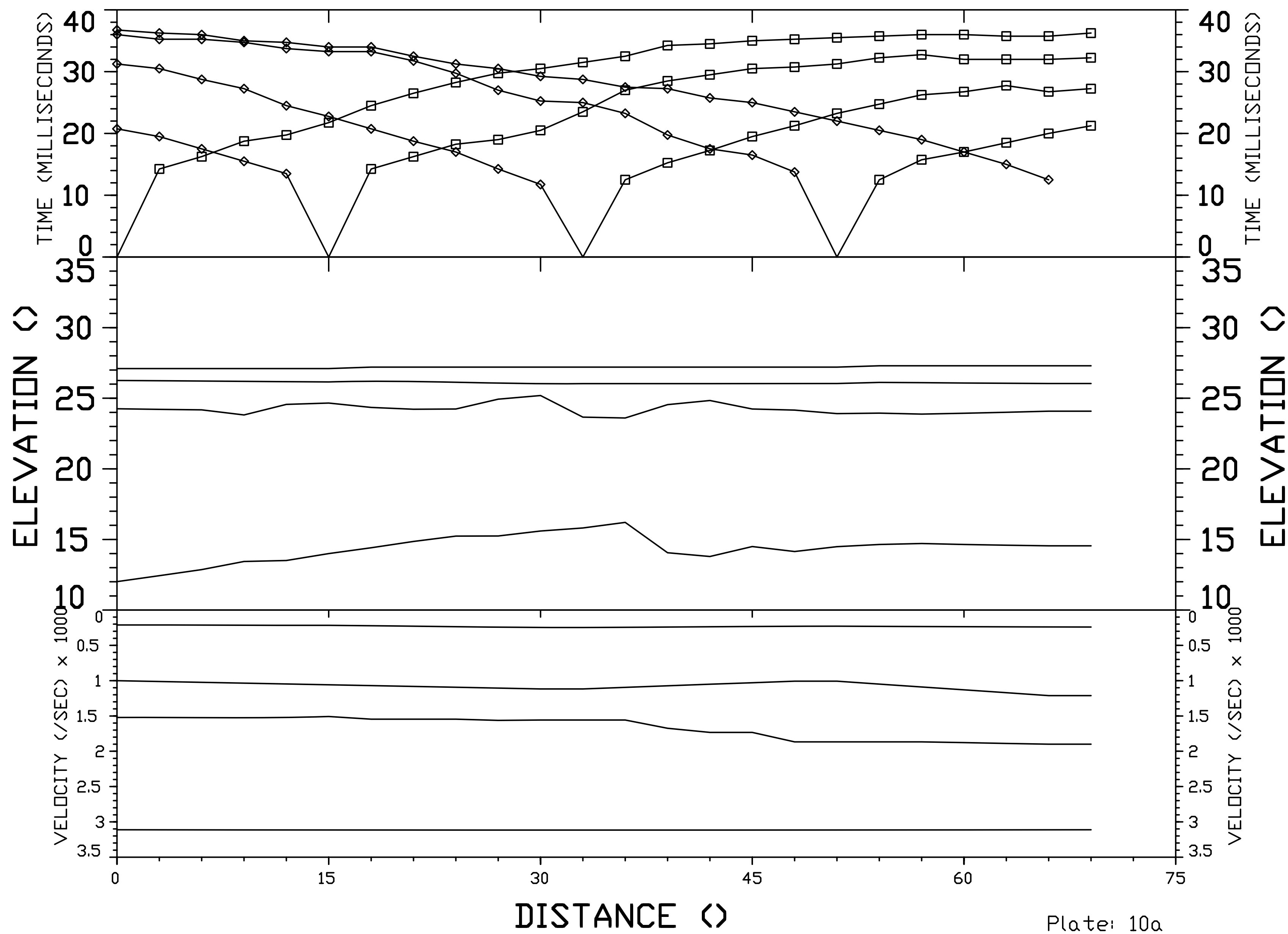

Plate: 10a

for MultiConsult		AGL13170
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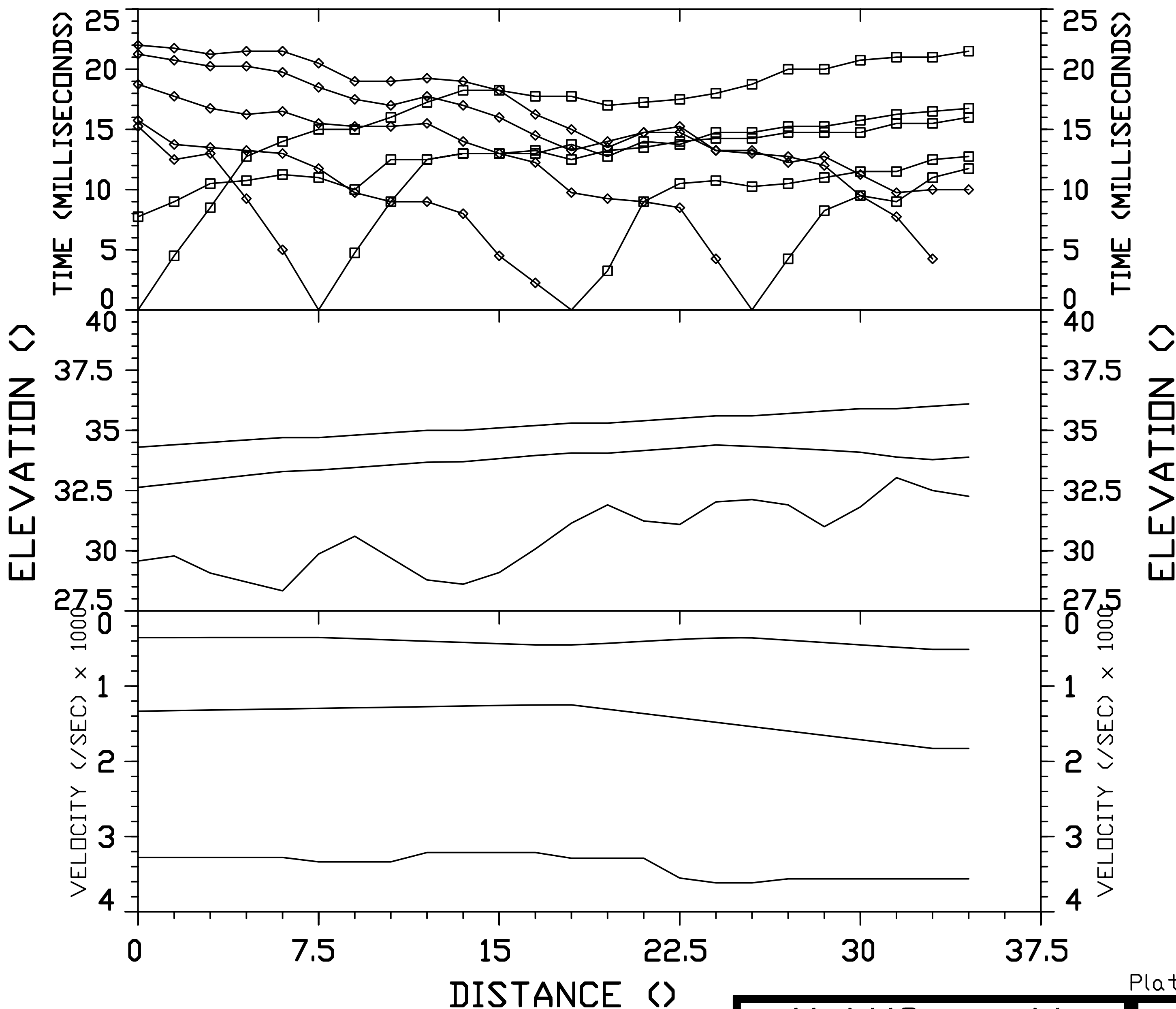
Data Set S4	Date: October 13	
Equipment:	Spread: S4	Azimuth:



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by: Strata Geophysical, Inc.	Ranheim Trondheim
Data SetS5 / Date: October 13	
Equipment: / Spread: S5	Azimuth:

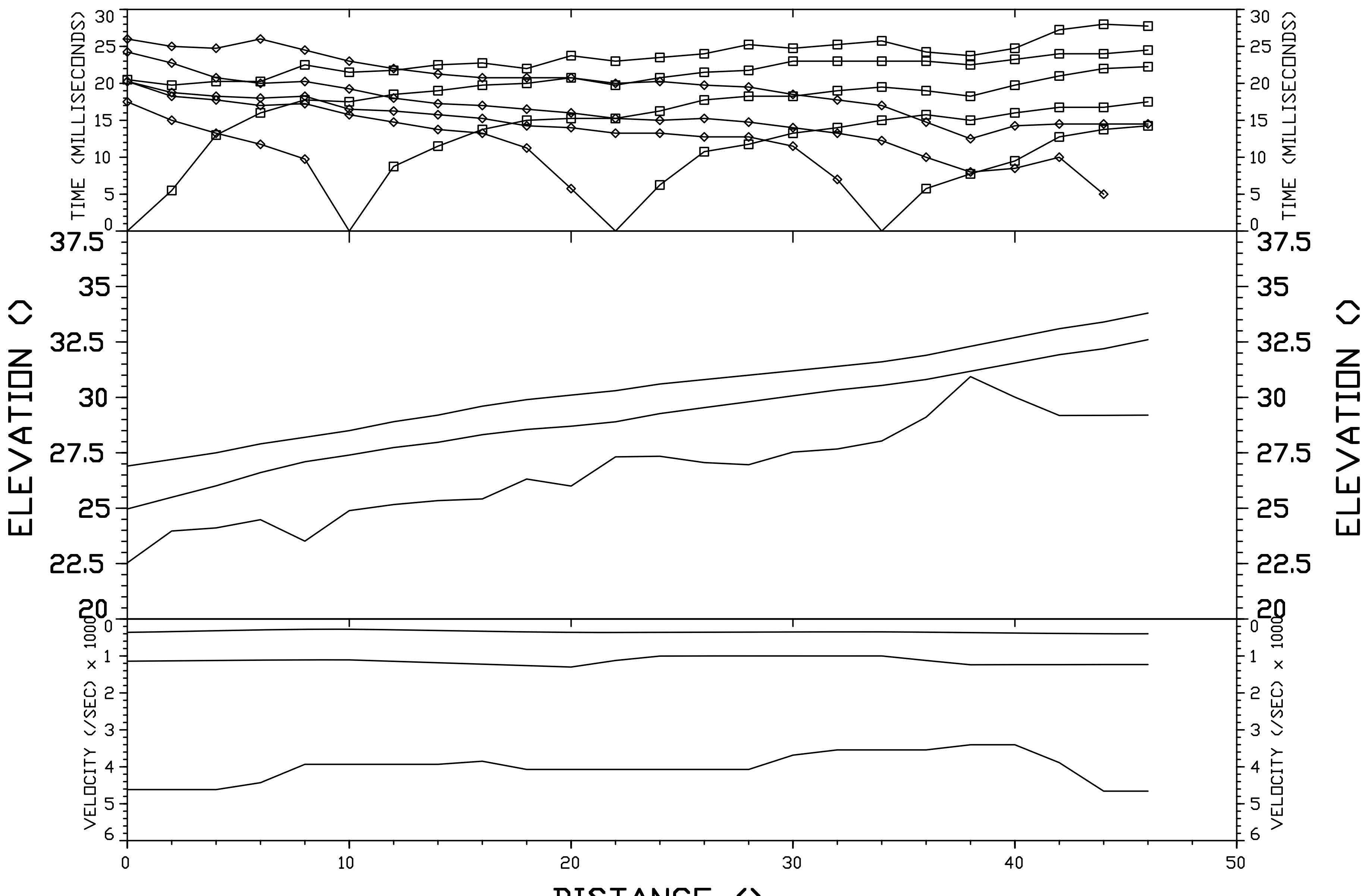

Plate: 10a

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Data SetS6	Date: October 13	
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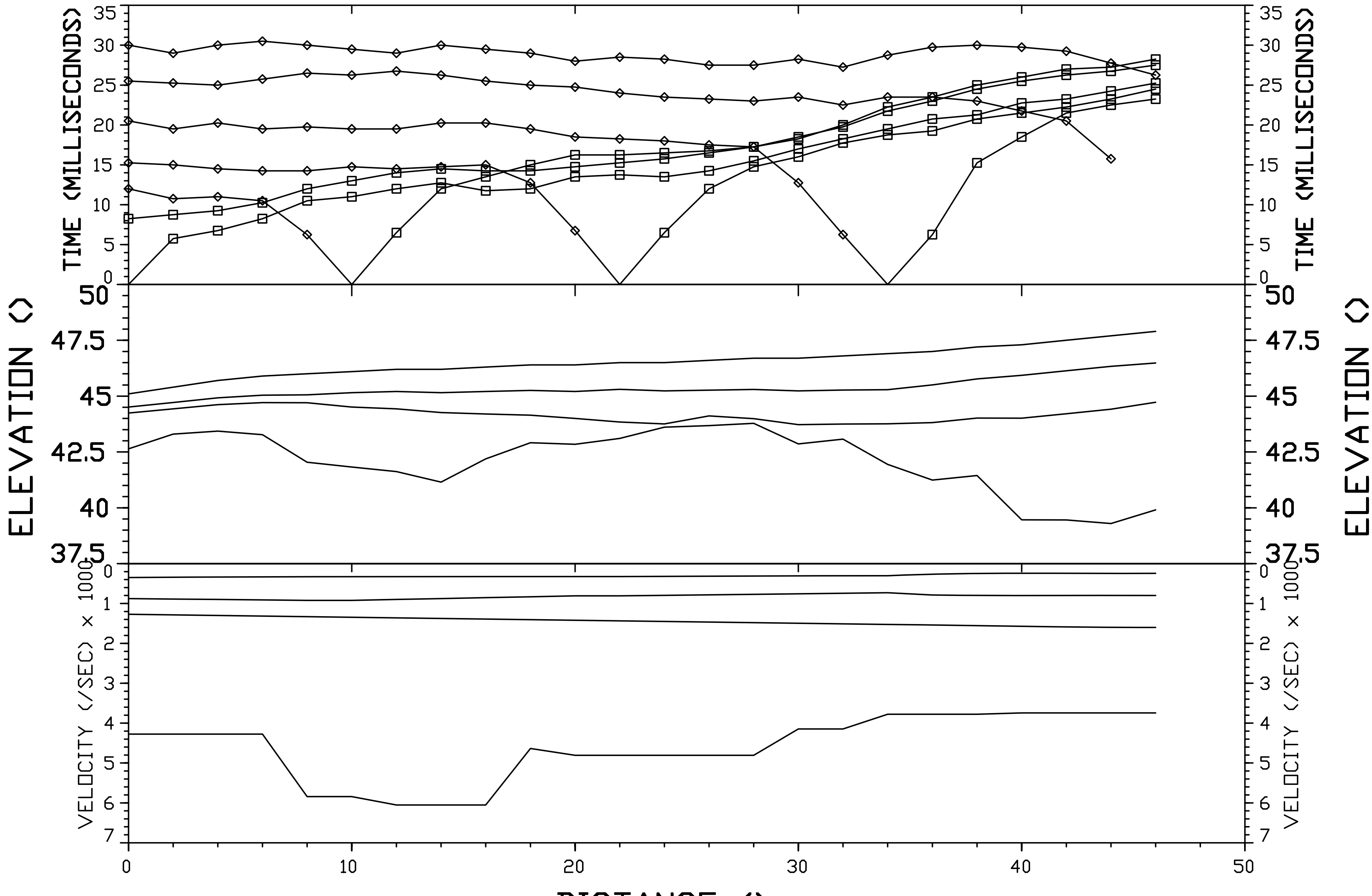

Plate: 10a

for MultiConsult	AGL13170
by: Strata Geophysical, Inc.	Ranheim Trondheim
Data Set S7 — Date: October 13	
Equipment: — Spread: S7	Azimuth:

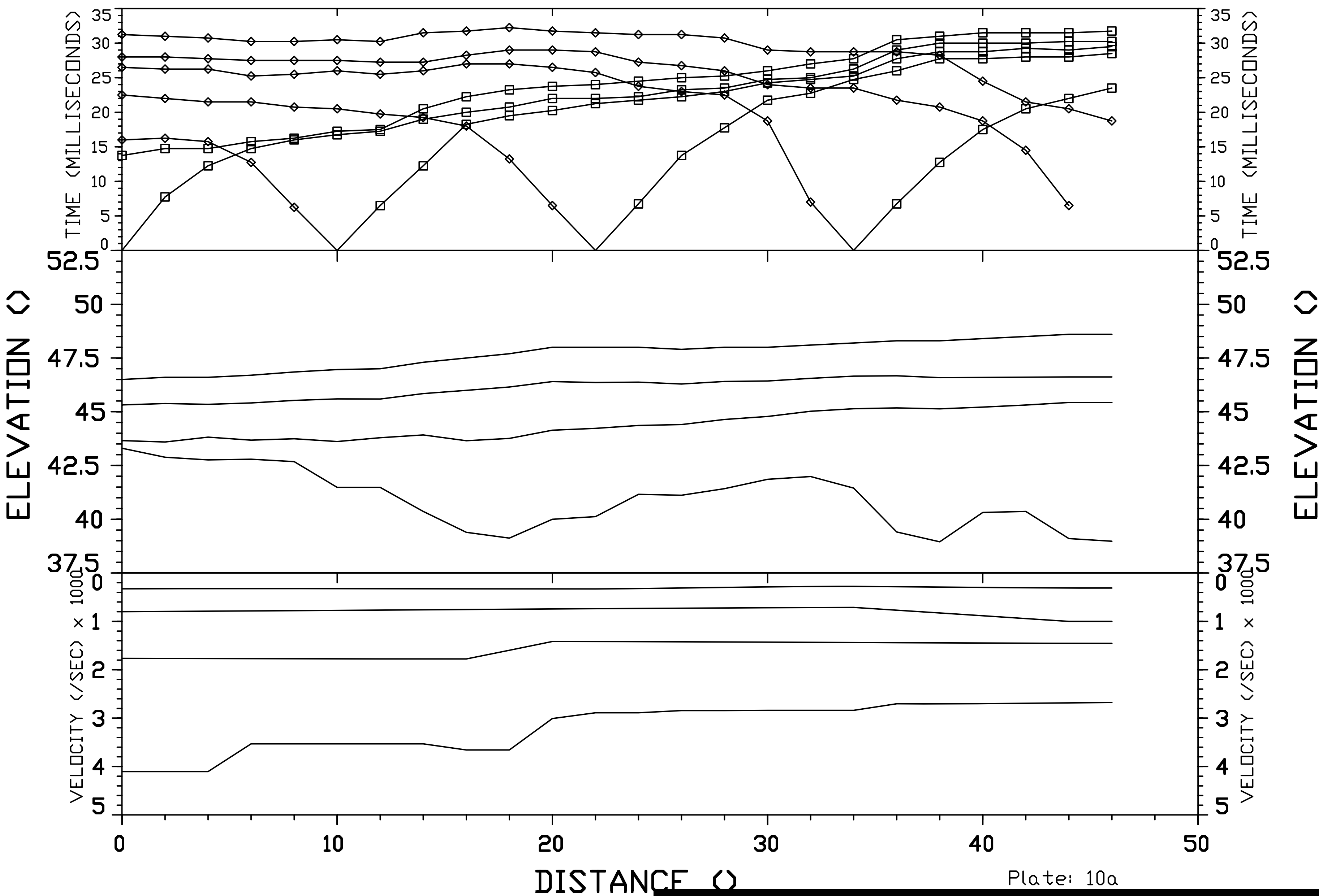

Plate: 10a

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by: Strata Geophysical, Inc.	Ranheim Trondheim
Data Set S8 / Date: October 13	
Equipment: / Spread: S8	Azimuth:

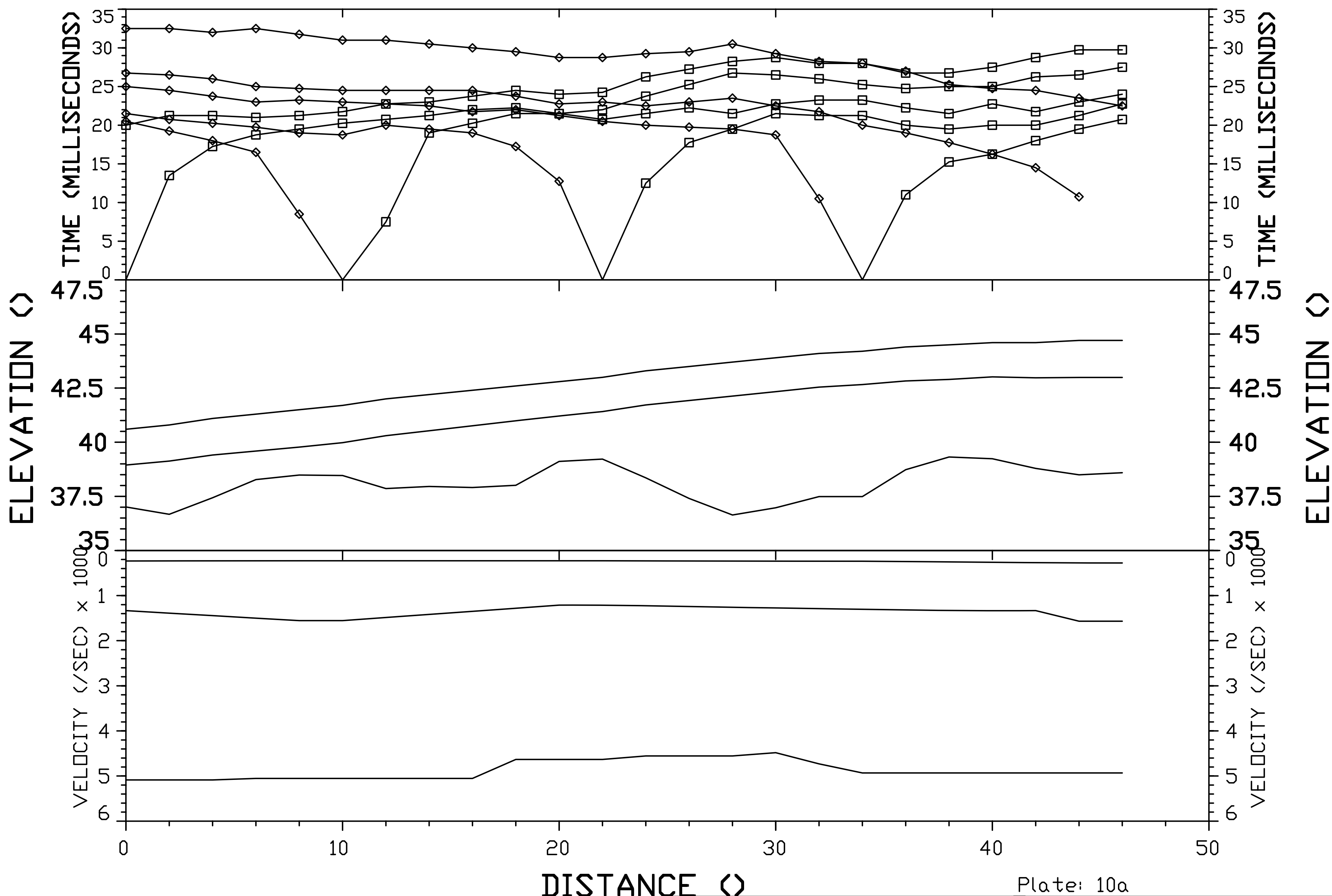

Plate: 10a

for MultiConsult	AGL13170
by: Strata Geophysical, Inc.	Ranheim Trondheim
Data SetS9 — Date: October 13	
Equipment: — Spread: S9	Azimuth:

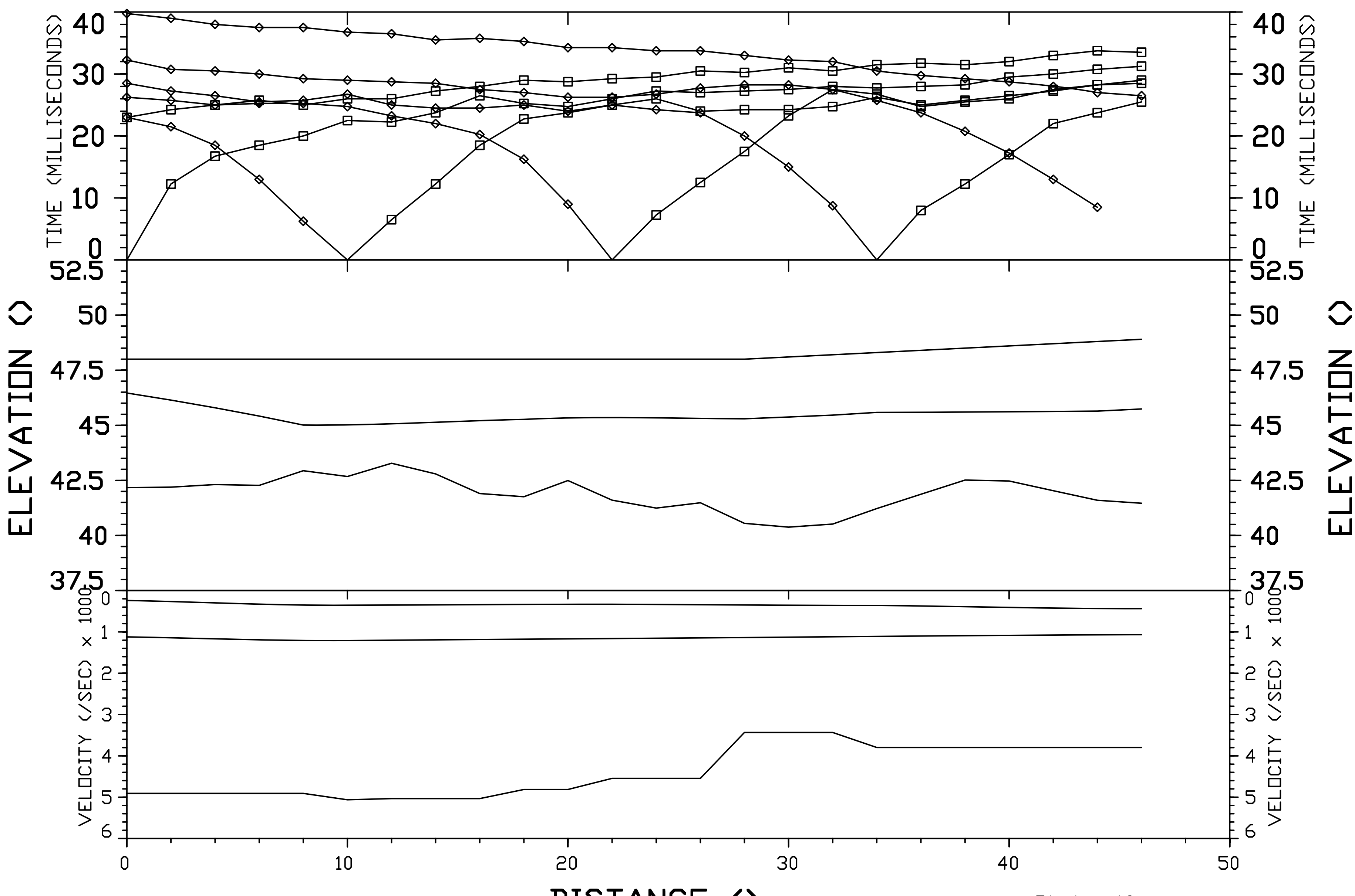

Plate: 10a

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by: Strata Geophysical, Inc.		Ranheim Trondheim	
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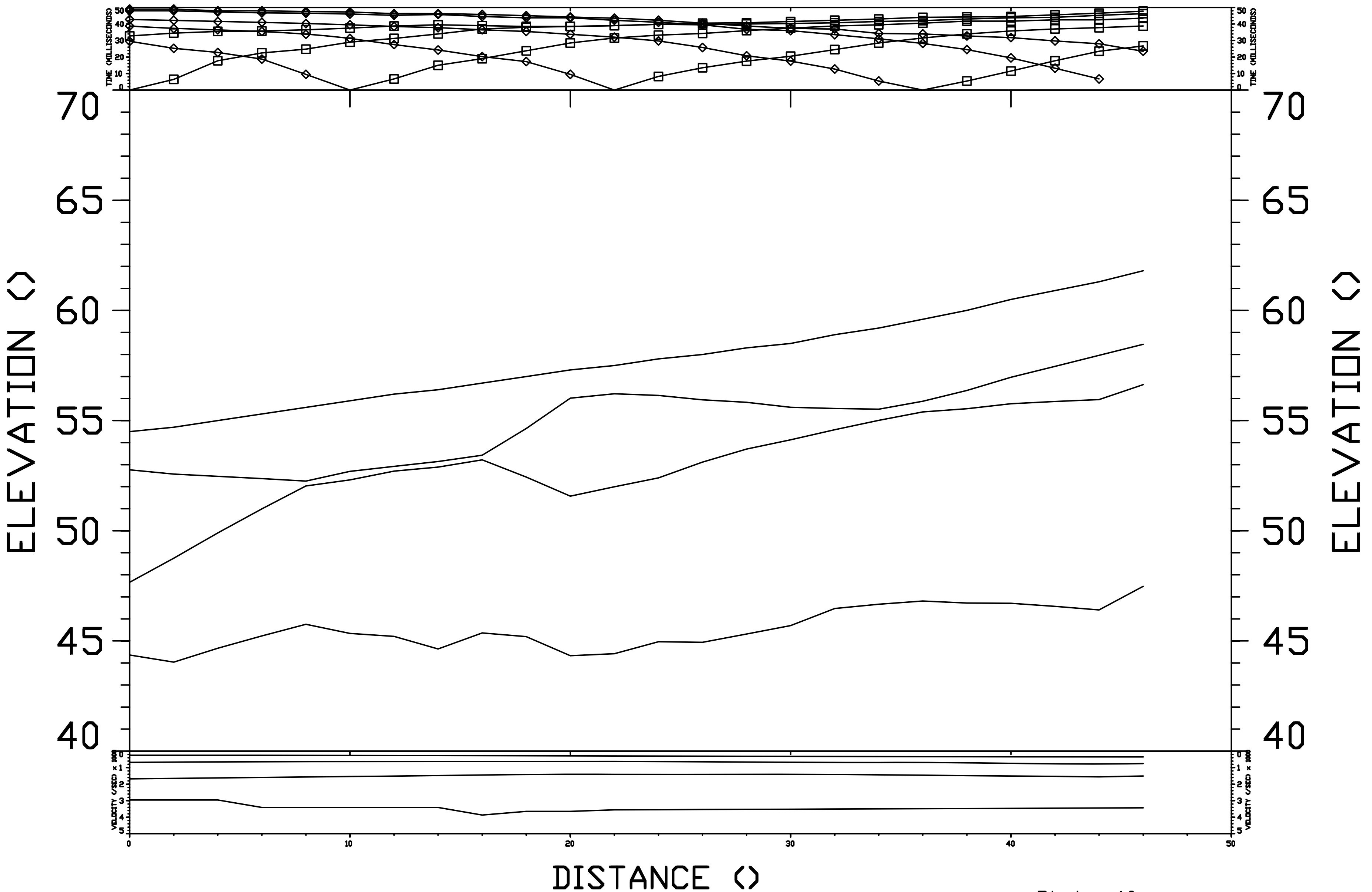

Plate: 10a

for MultiConsult	AGL13170
by: Strata Geophysical, Inc.	Ranheim Trondheim
Data Set S11 — Date: Oct 2013	
Equipment: — Spread: S11	Azimuth:

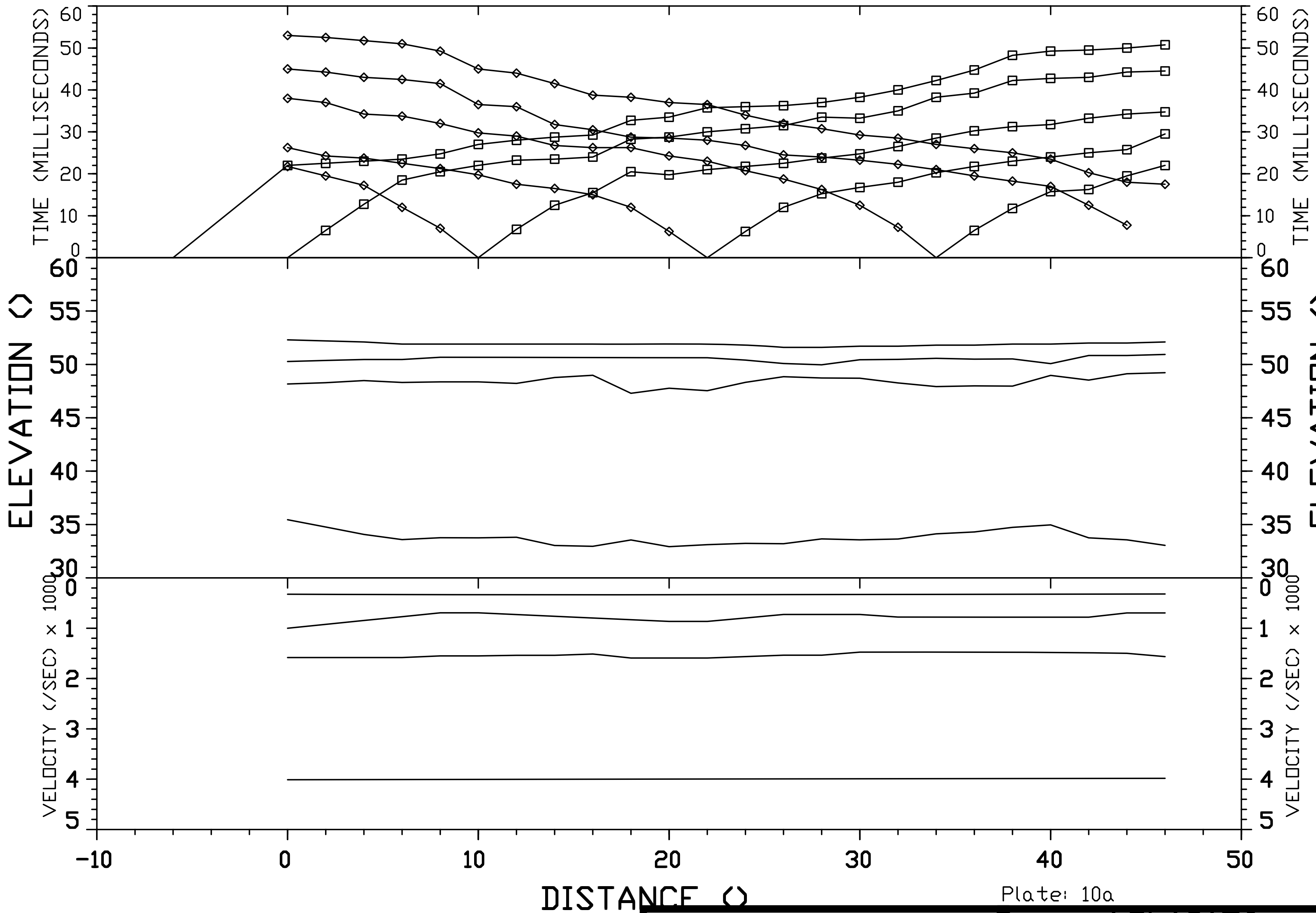

Plate: 10a

for MultiConsult		AGL13170	
by: Strata Geophysical, Inc.		Ranheim Trondheim	
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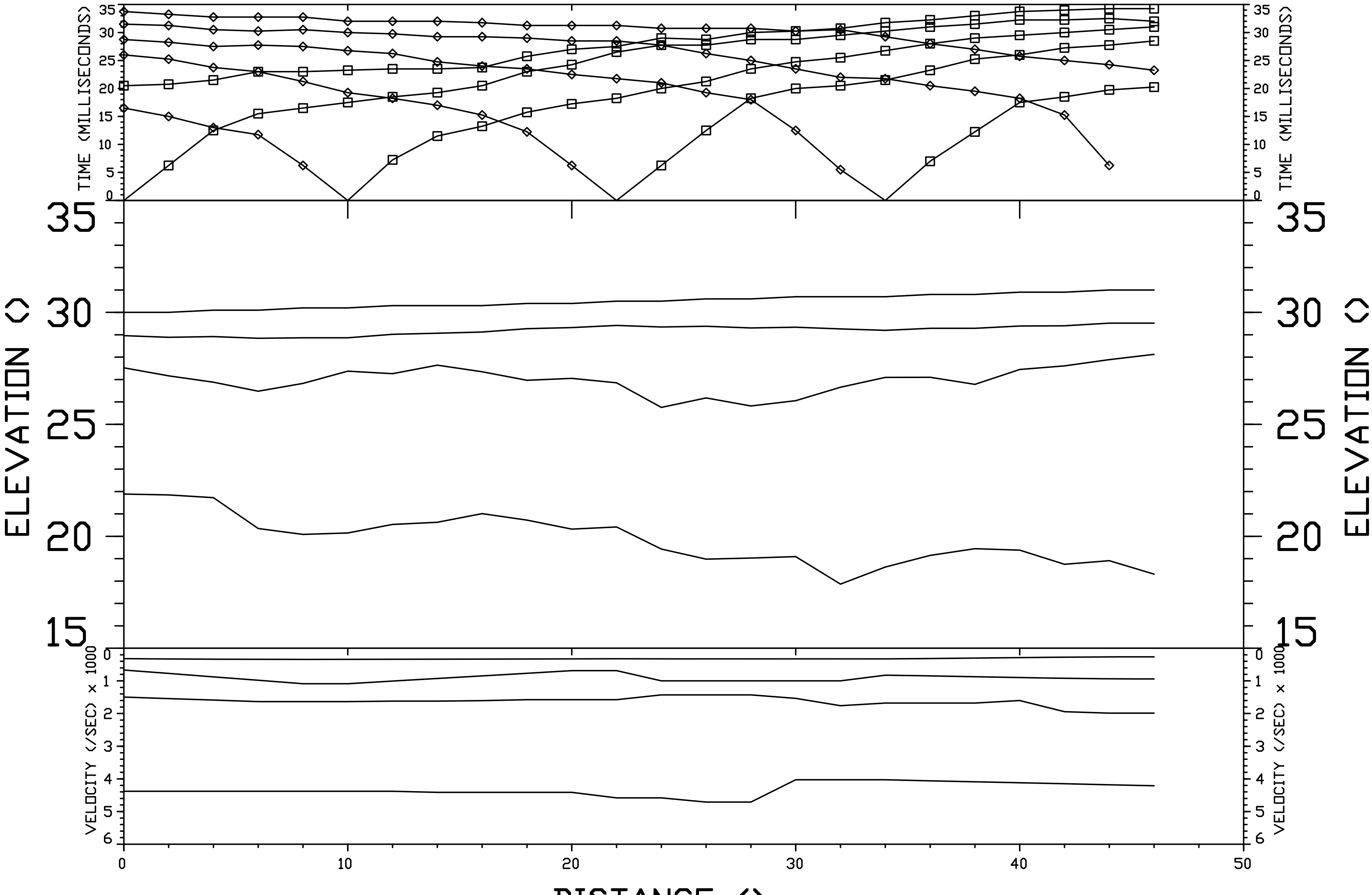

Plate: 10a

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by: Strata Geophysical, Inc.	Ranheim Trondheim
Data Set S13 / Date: Oct 2013	
Equipment: / Spread: S13	Azimuth:

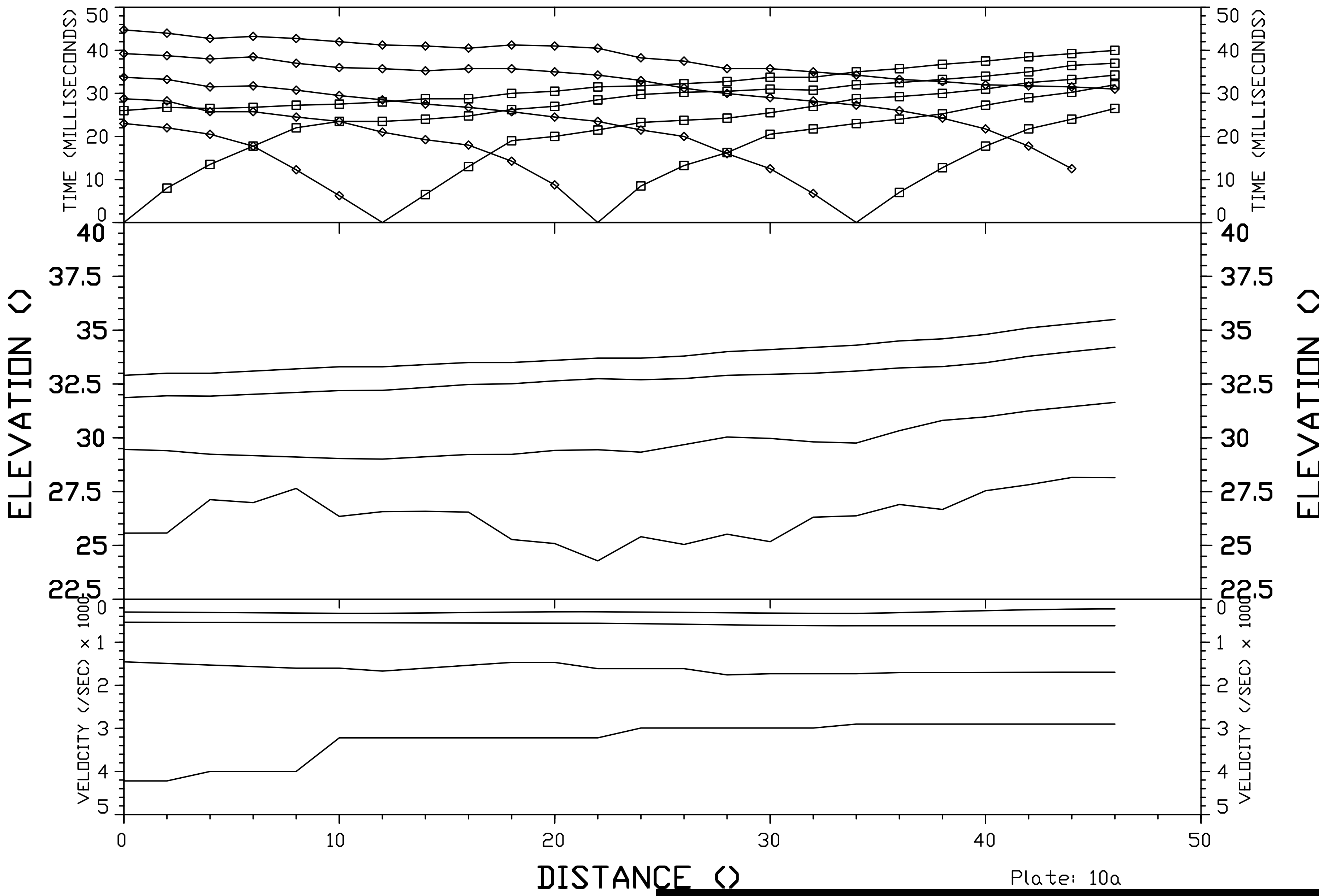

Plate: 10a

for MultiConsult	AGL13170
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Data Set S14 — Date: Oct 2013	
Equipment: — Spread: S14	Azimuth:

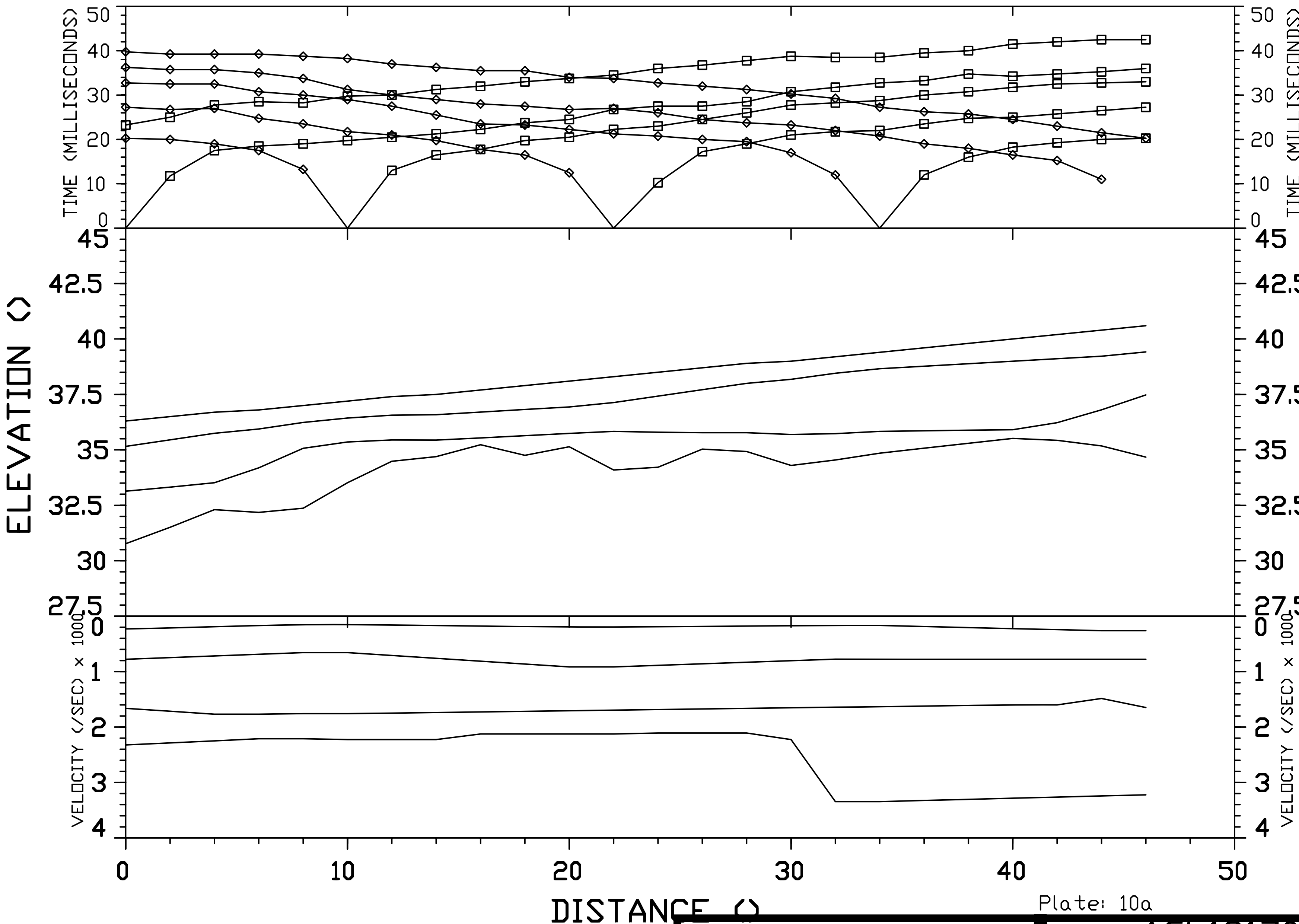

Plate: 10a

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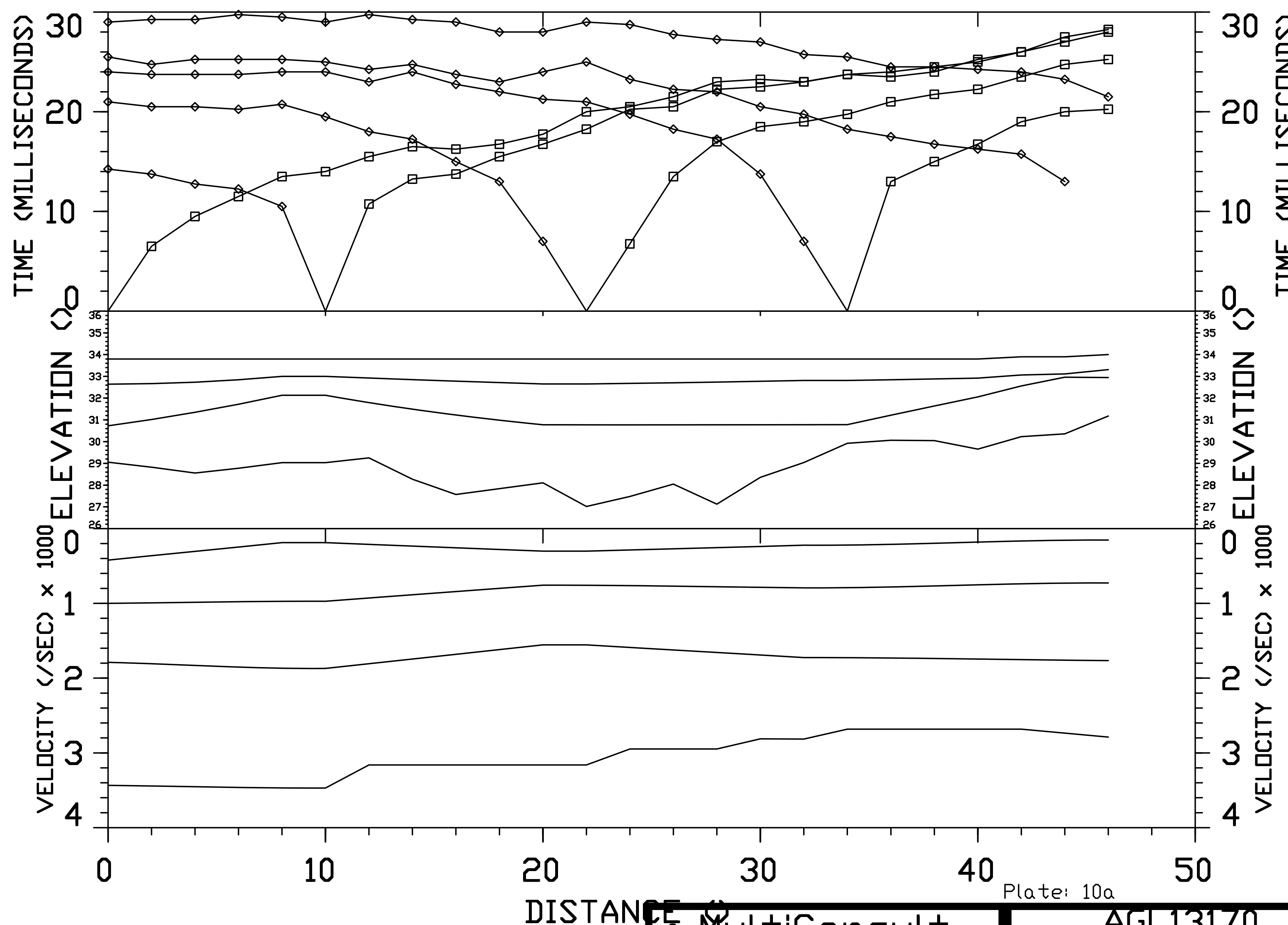

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Data Set S16 / Date: Oct 2013	
Equipment: / Spread: S16	Azimuth:

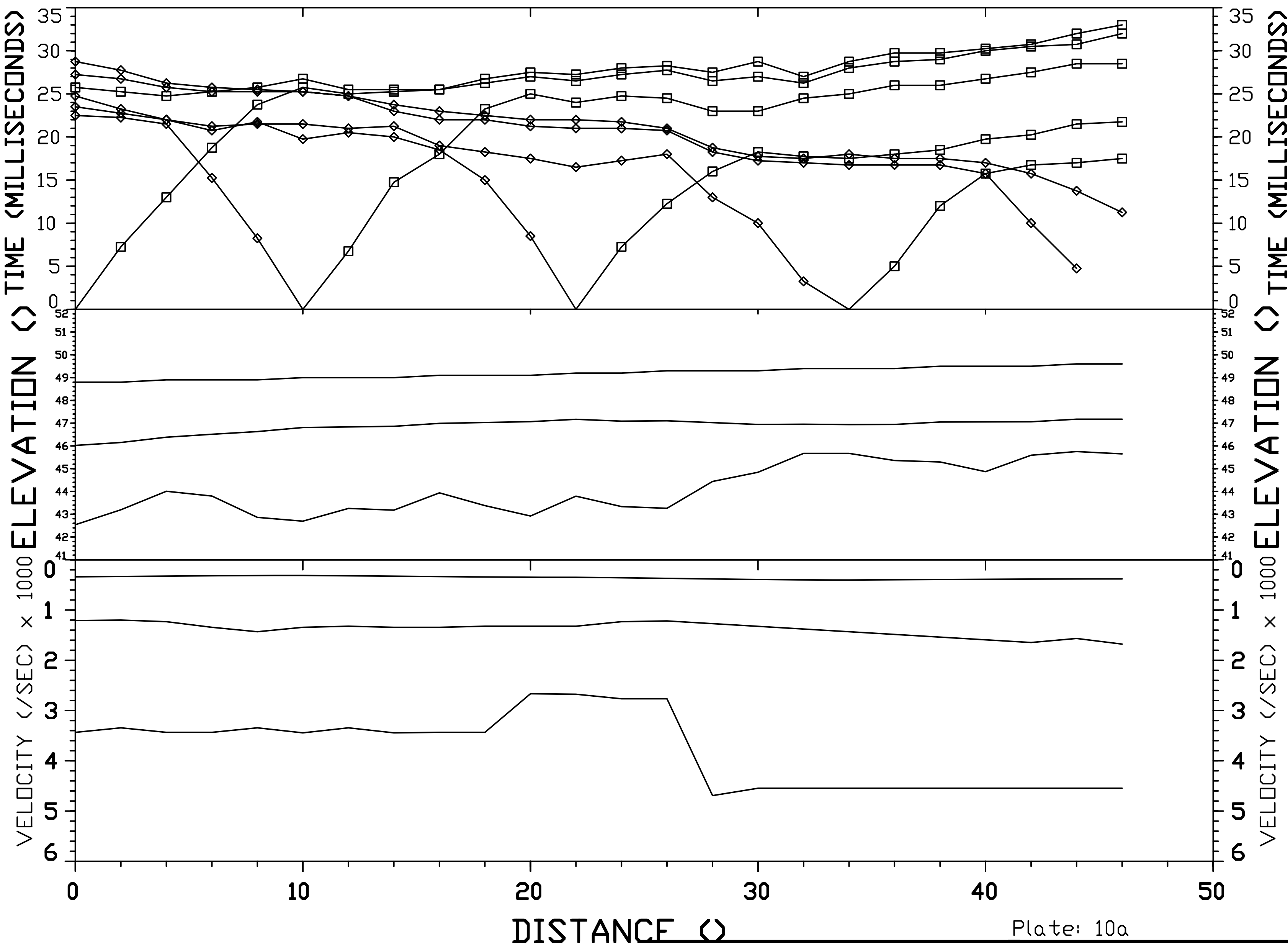

Plate: 10a

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Data Set S17	Date: Oct 2013	
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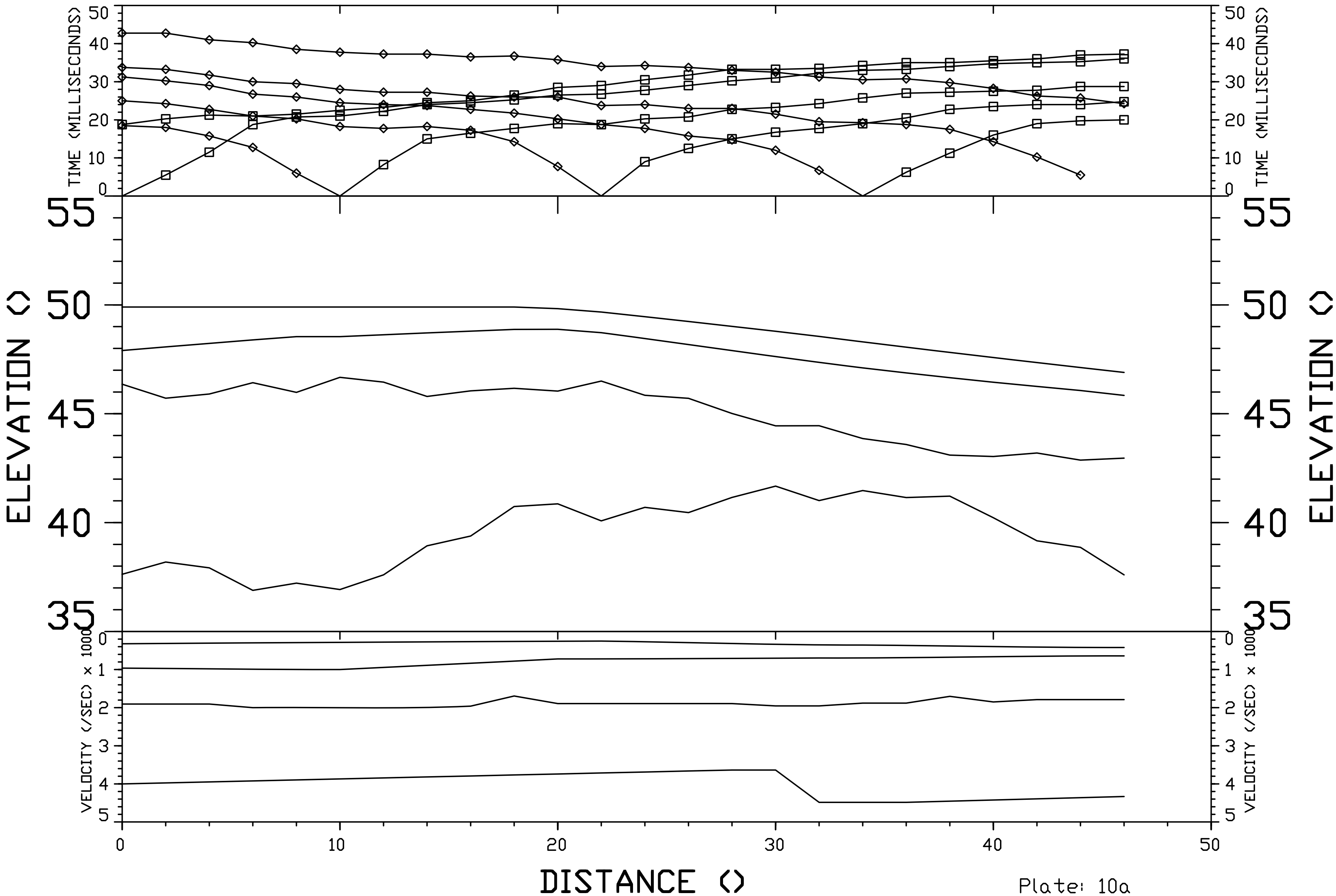

Plate: 10a

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Data SetS18	Date: October 13	
Equipment:	Spread: S18	Azimuth:

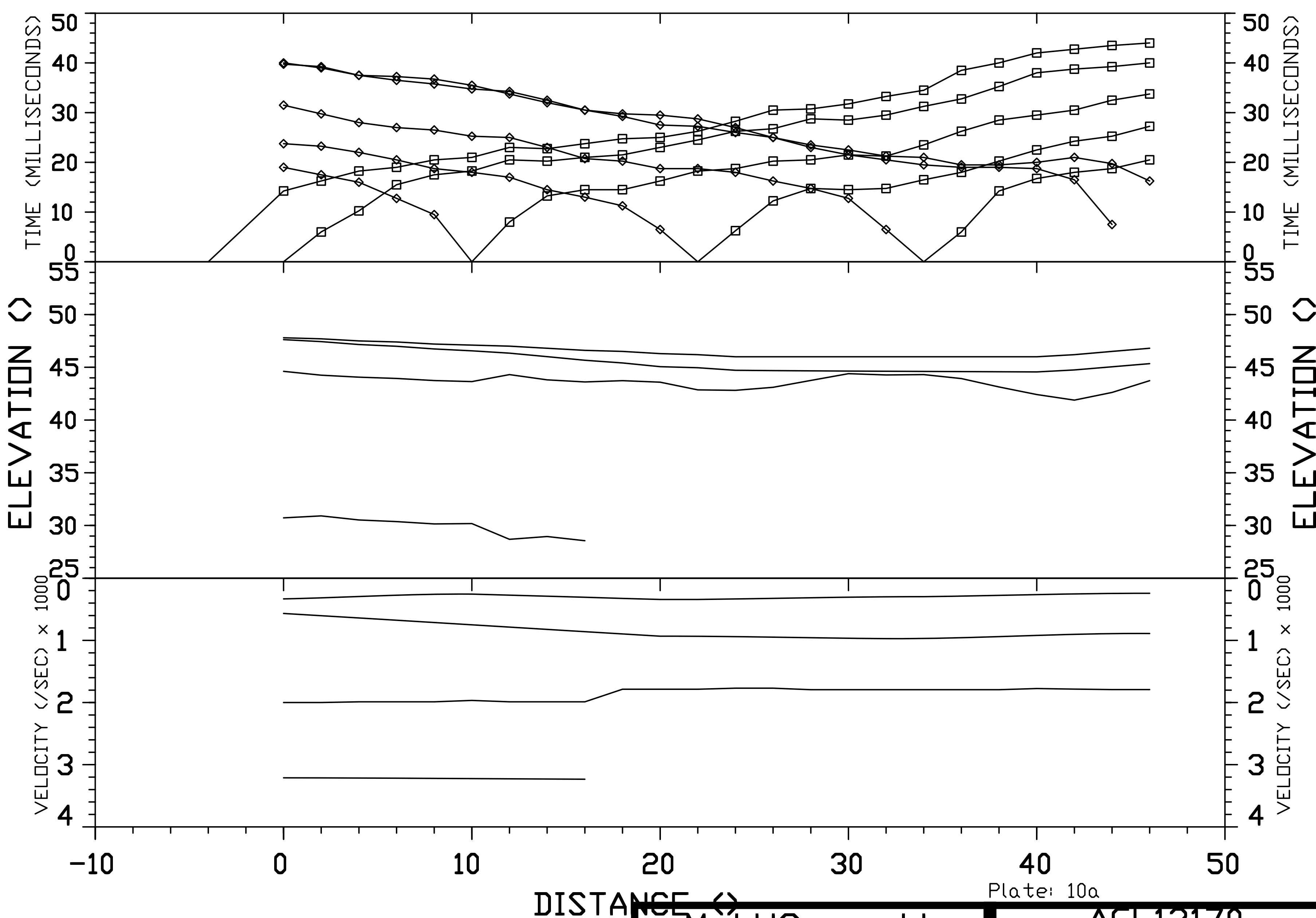

Plate: 10a

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Data Set S19 / Date: October 13	
Equipment: / Spread: S19	Azimuth:

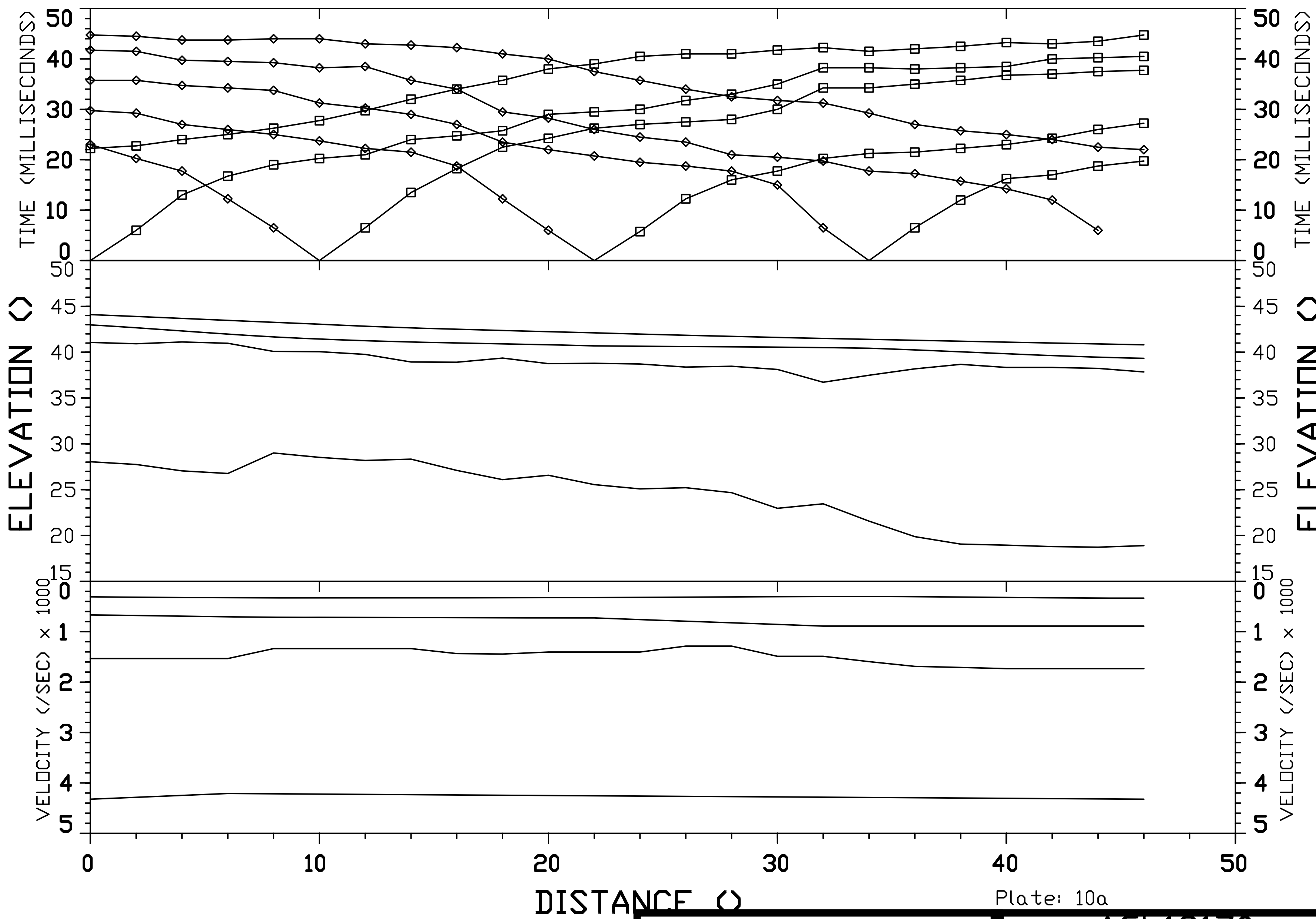


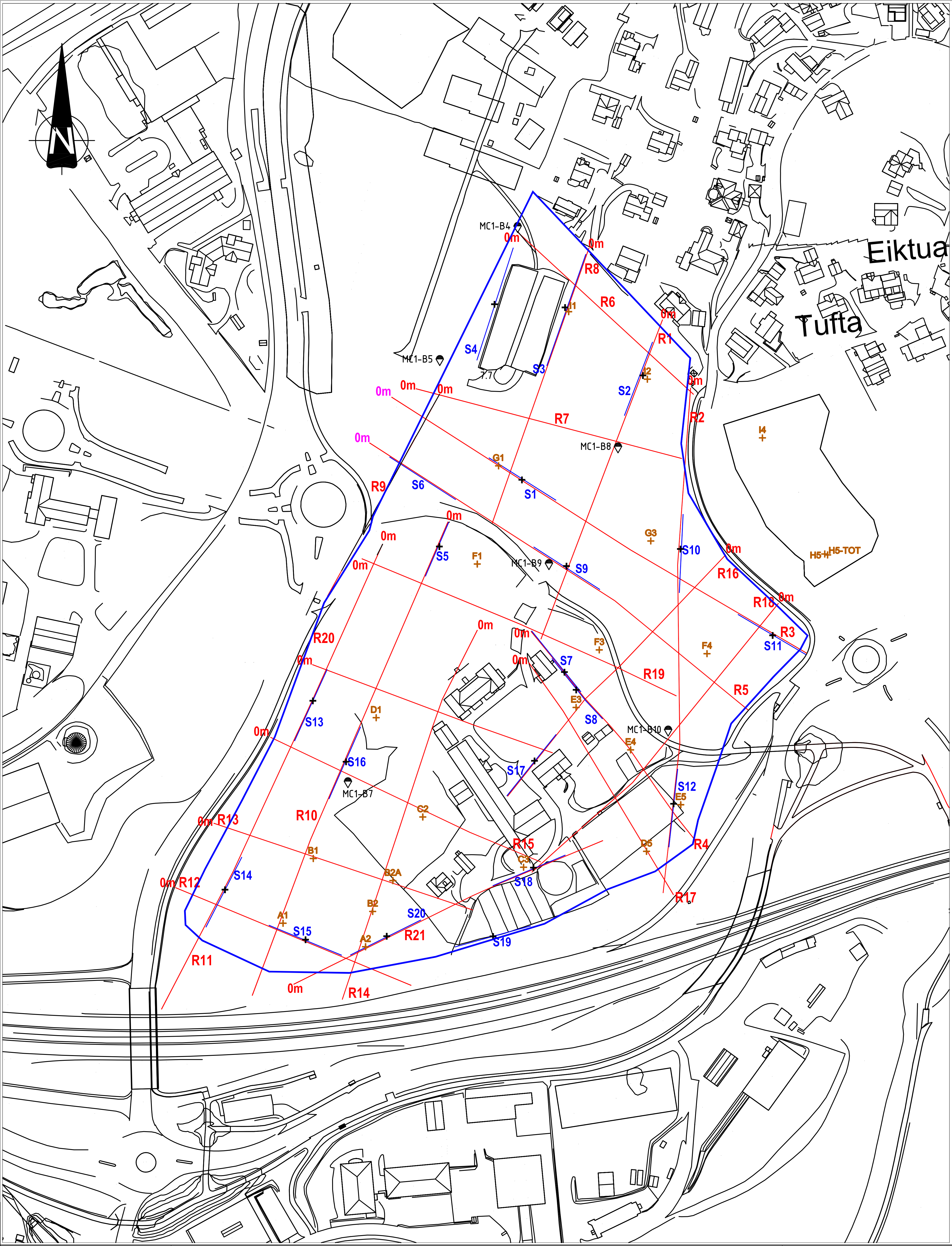
Plate: 10a

forMultiConsult		AGL13170
by: Strata Geophysical, Inc.		Ranheim Trondheim
Data SetS20	Date: Oct 2013	
Equipment:	Spread: S20	Azimuth:

10. APPENDIX E: DRAWINGS

The information derived from the geophysical investigation is presented in the following drawings:

13170_01	Geophysical Survey Location	1:2000	@ A3
13170_02	ERT Profiles R18, R16 & R2	1:1250	@A3
13170_03	ERT Profiles R1 & R6-R8	1:1250	@A3
13170_04	ERT Profiles R3 & R5	1:1250	@A3
13170_05	ERT Profiles R11 & R10	1:1250	@A3
13170_06	ERT Profiles R14, R21 & R9	1:1250	@A3
13170_07	ERT Profiles R20, R15, R13 & R12	1:1250	@A3
13170_08	ERT Profiles R19, R4 & R17 & Seismic Refraction Profiles S4 and S19	1:1250	@A3
13170_09	Interpreted Bedrock Elevation	1:2000	@A3
13170_10	Interpreted Overburden Thickness	1:2000	@A3
13170_11	Summary Map	1:2000	@A3



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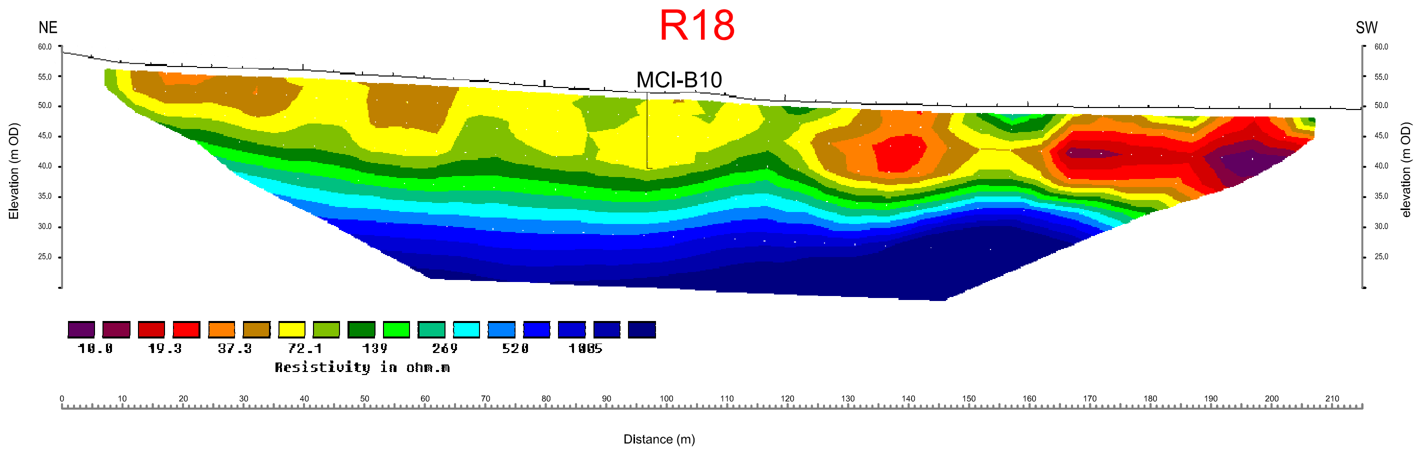
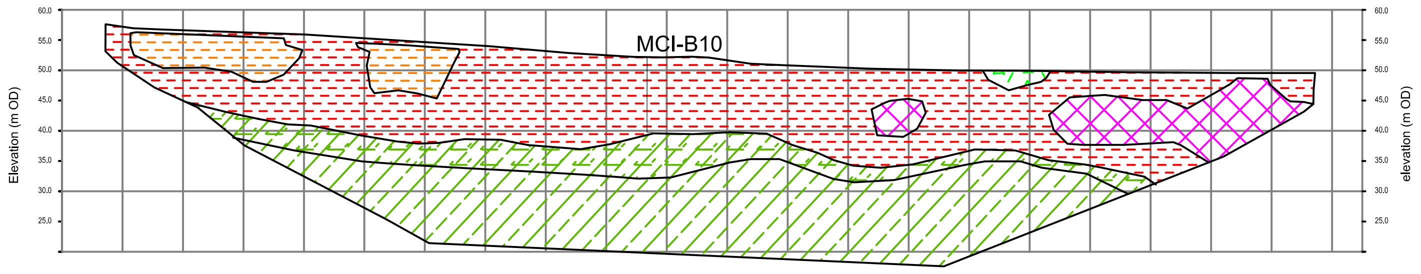
LEGEND:

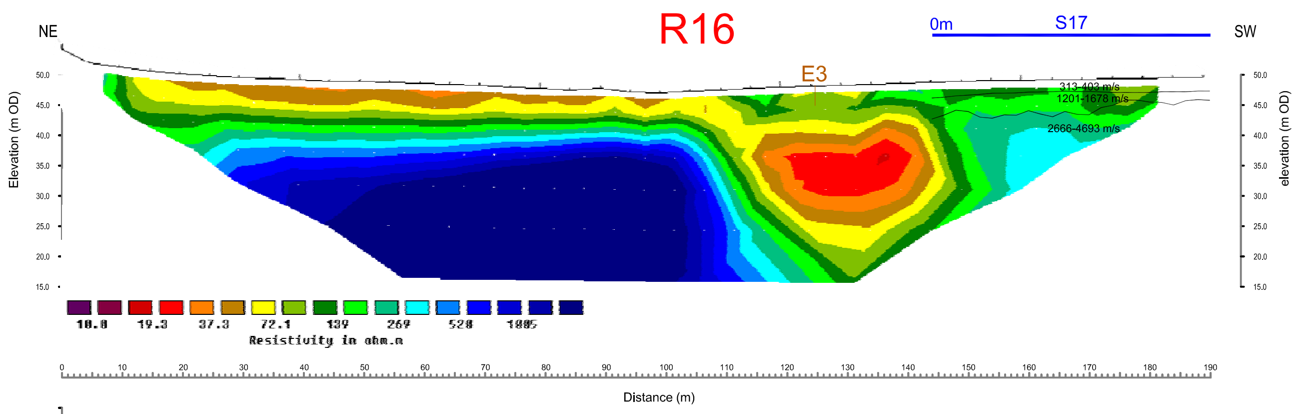
- Electrical Resistivity Profile
- Seismic Refraction Profile
- ✚ 1D MASW Profile

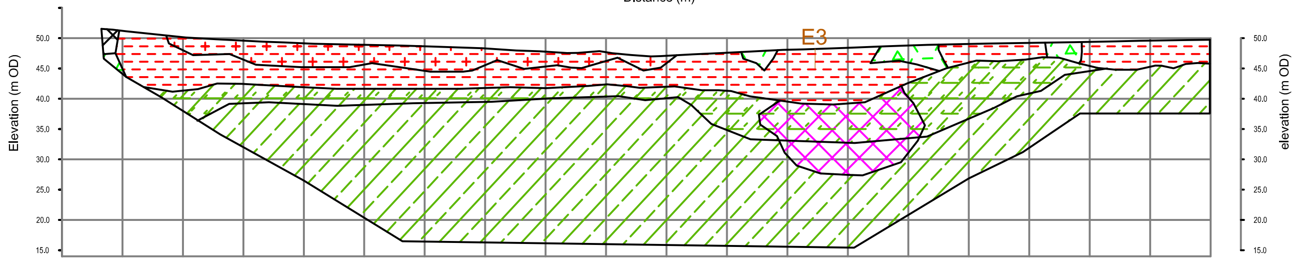
PROJECT:	RANHEIM VESTRE
DRAWING No.:	13170_01 GEOPHYSICAL LOCATION
DATE:	25-02-14
CLIENT:	MULTICONSULT
SCALE:	1:2000 @A3

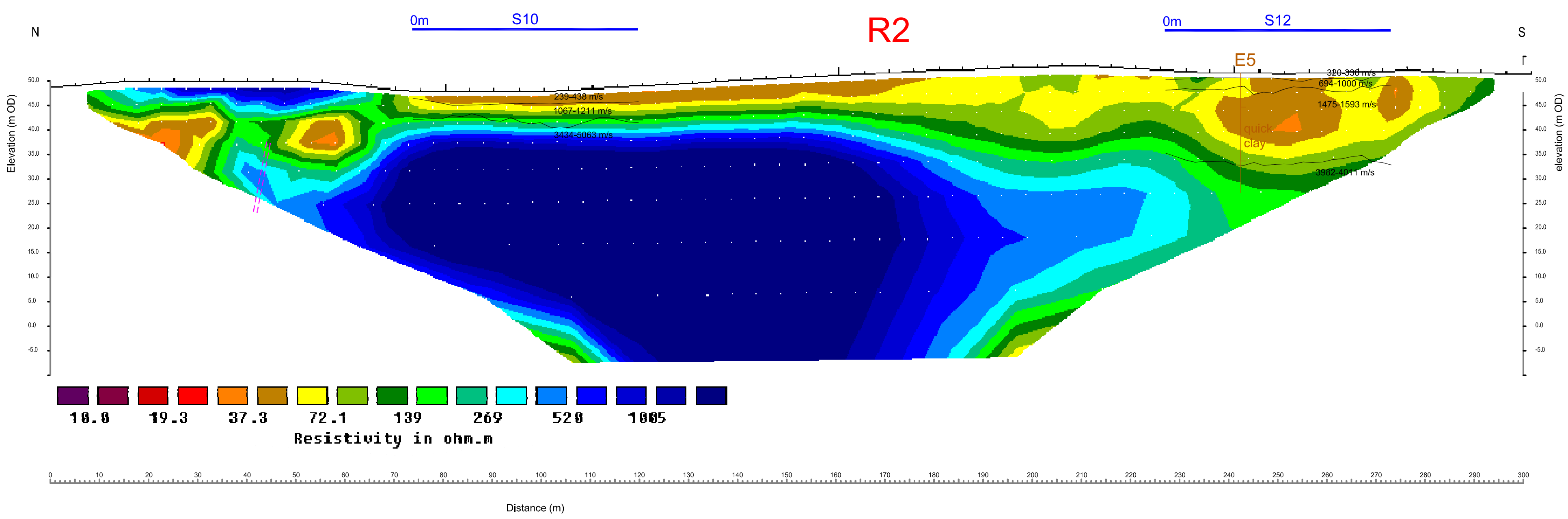
Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC

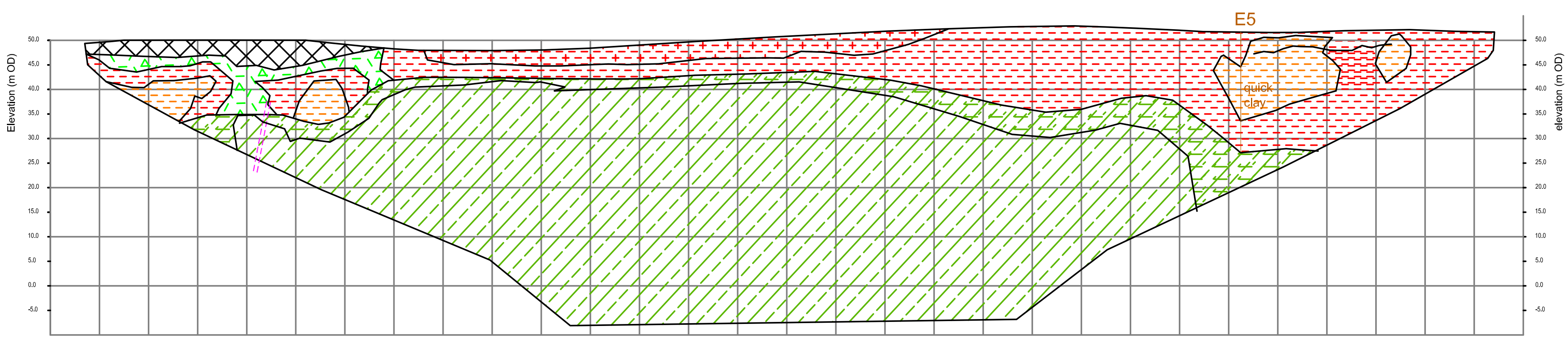












LEGEND:

- SILT/CLAY
- sandy CLAY
- possible sensitive CLAY
- clayey SAND / SAND
- MADE GROUND
- Possible effect of underground services/effluent from animal waste
- Highly-Moderately Weathered GREENSCHIST
- Slightly Weathered-Fresh GREENSCHIST
- GREENSCHIST with possible saline intrusion
- Possible FAULT
- 694-1000 m/s — Seismic Refraction Layer with interpreted P-wave velocity

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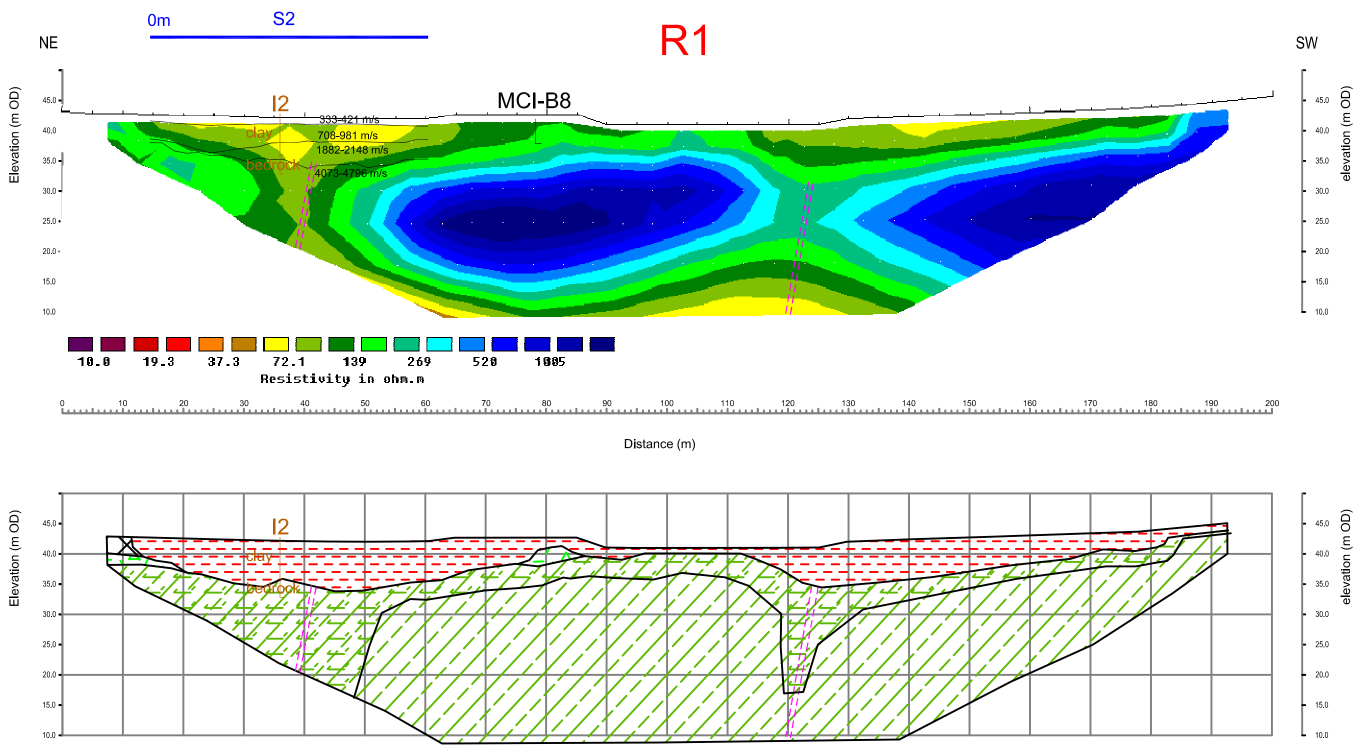
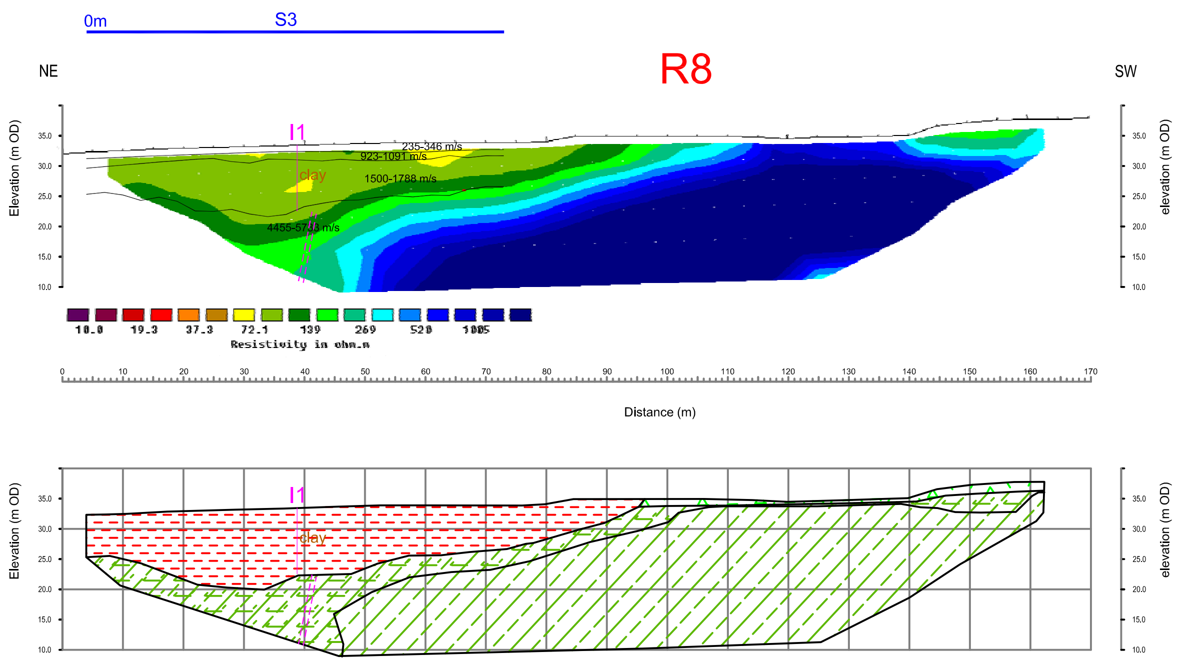
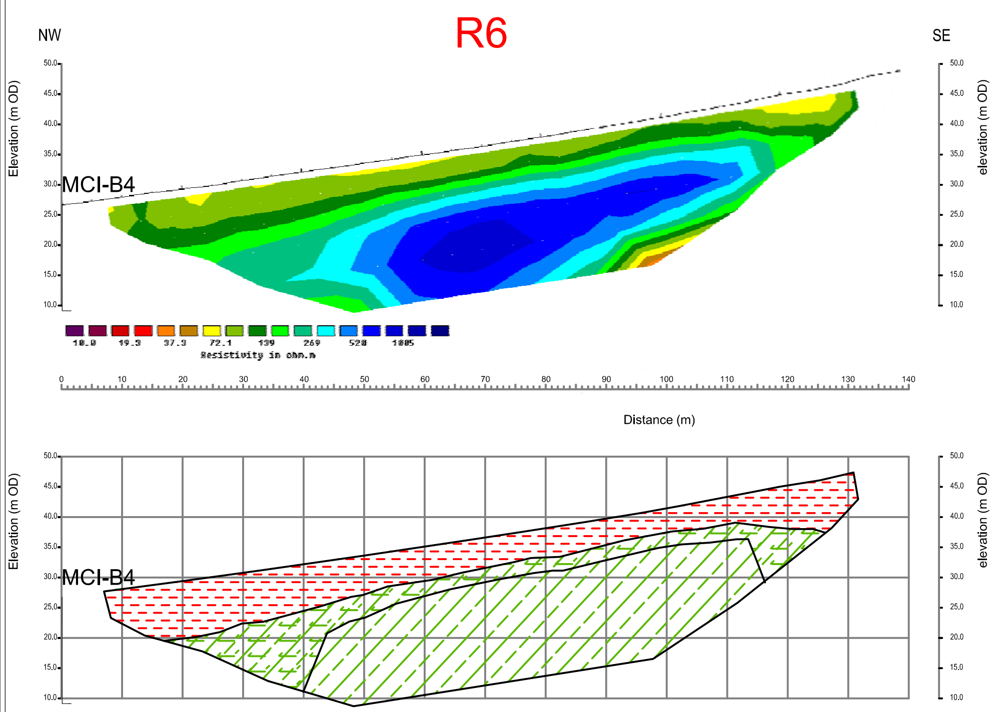
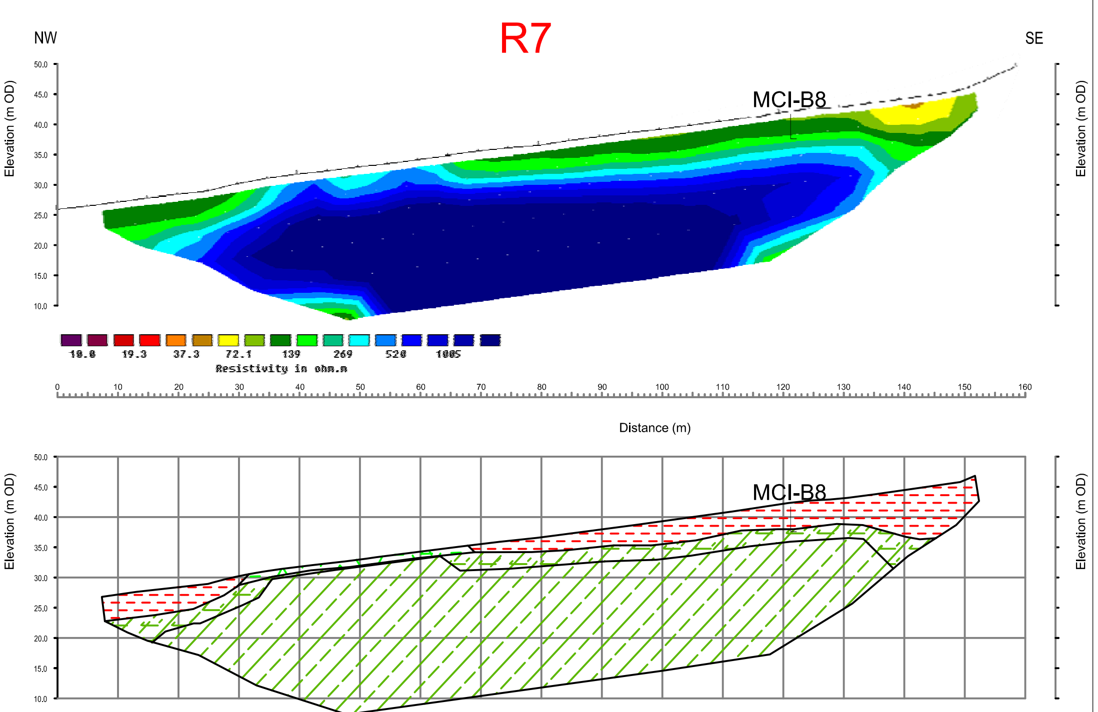
PROJECT:	RANHEIM VESTRE
DRAWING No.:	13170_02 ERT PROFILES R18,R16 & R2
DATE:	25-02-14
CLIENT:	MULTICONSULT
SCALE:	1:1250 @A3

Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC









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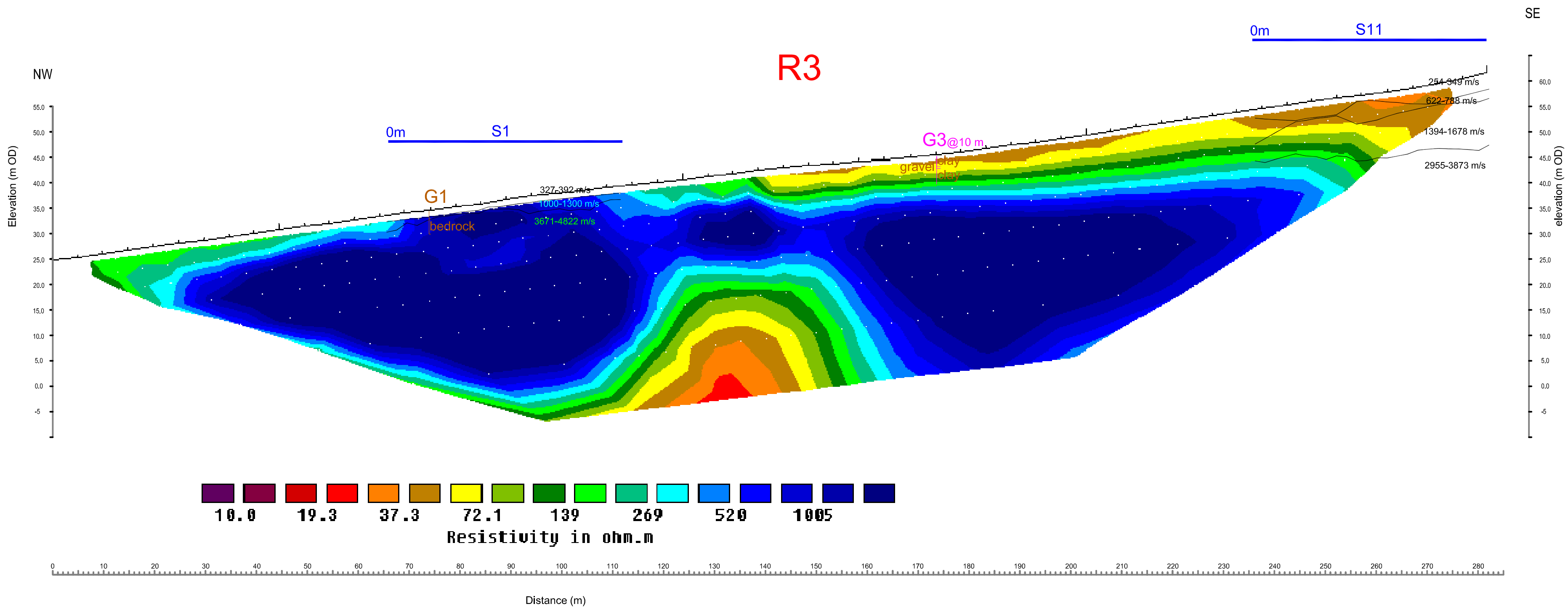
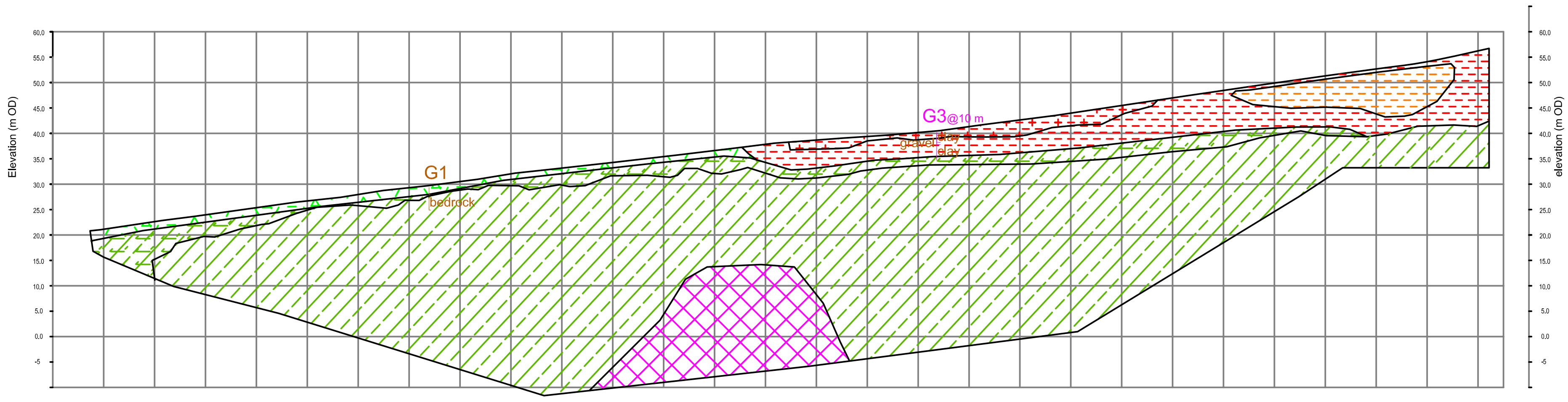
LEGEND:

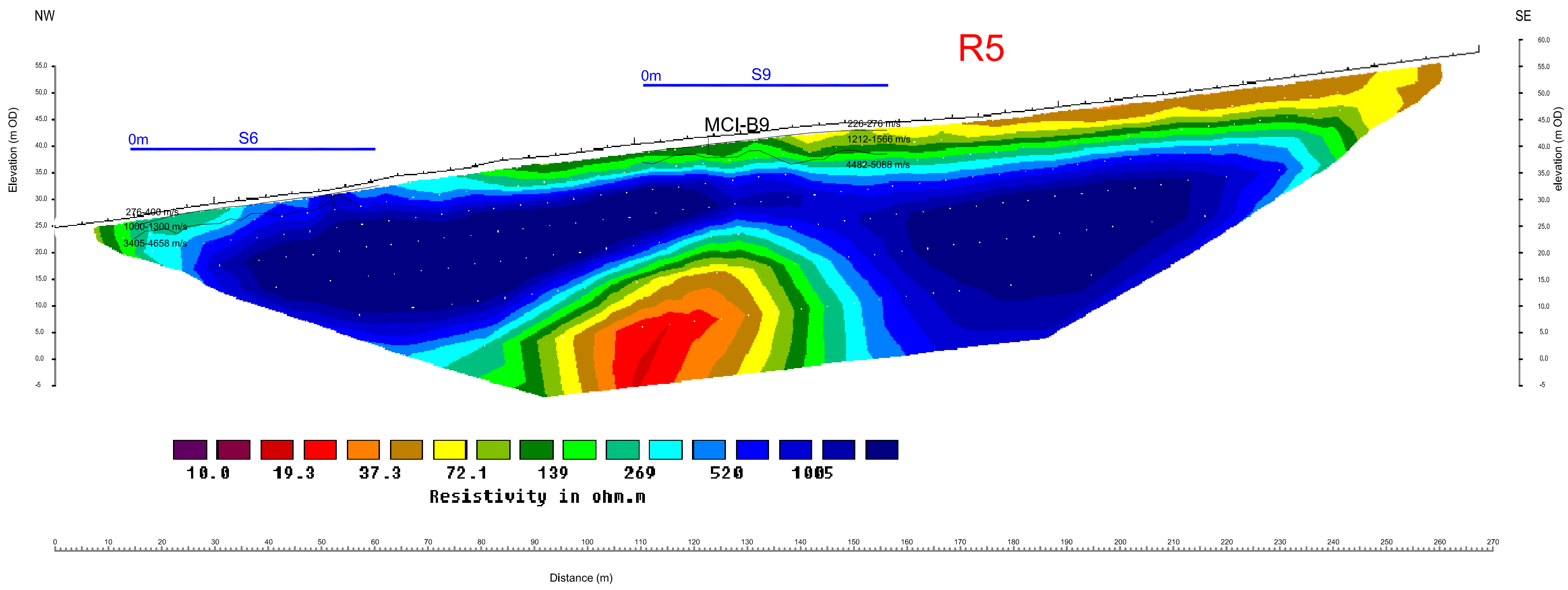
- SILT/CLAY
- sandy CLAY
- possible sensitive CLAY
- clayey SAND / SAND
- MADE GROUND
- Possible effect of underground services/effluent from animal waste
- Highly-Moderately Weathered GREENSCHIST
- Slightly Weathered-Fresh GREENSCHIST
- GREENSCHIST with possible saline intrusion
- Possible FAULT
- 694-1000 m/s — Seismic Refraction Layer with interpreted P-wave velocity

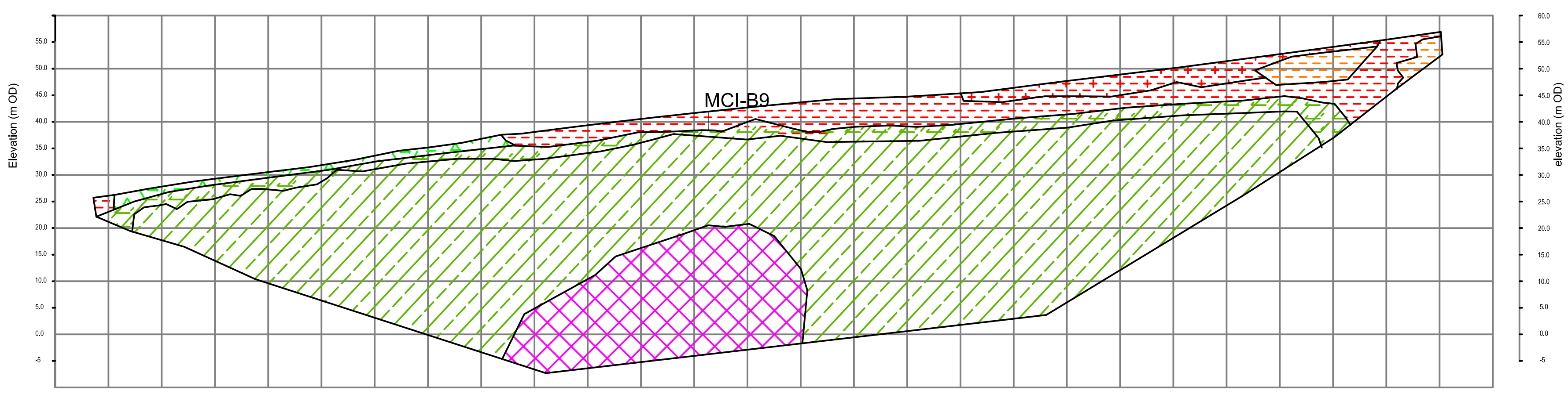
PROJECT:	RANHEIM VESTRE
DRAWING No.:	13170_03 ERT PROFILES R1 & R6-R8
DATE:	25-02-14
CLIENT:	MULTICONSULT
SCALE:	1:1250 @A3

Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC









LEGEND:

- SILT/CLAY
- sandy CLAY
- possible sensitive CLAY
- clayey SAND / SAND
- MADE GROUND
- Possible effect of underground services/effluent from animal waste
- Highly-Moderately Weathered GREENSCHIST
- Slightly Weathered-Fresh GREENSCHIST
- GREENSCHIST with possible saline intrusion
- Possible FAULT
- 694-1000 m/s — Seismic Refraction Layer with interpreted P-wave velocity

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PROJECT:	RANHEIM VESTRE
DRAWING No.:	13170_04 ERT PROFILES R3 & R5
DATE:	25-02-14
CLIENT:	MULTICONSULT
SCALE:	1:1250 @A3

Version:	Date:	Drawn By:	Checked:
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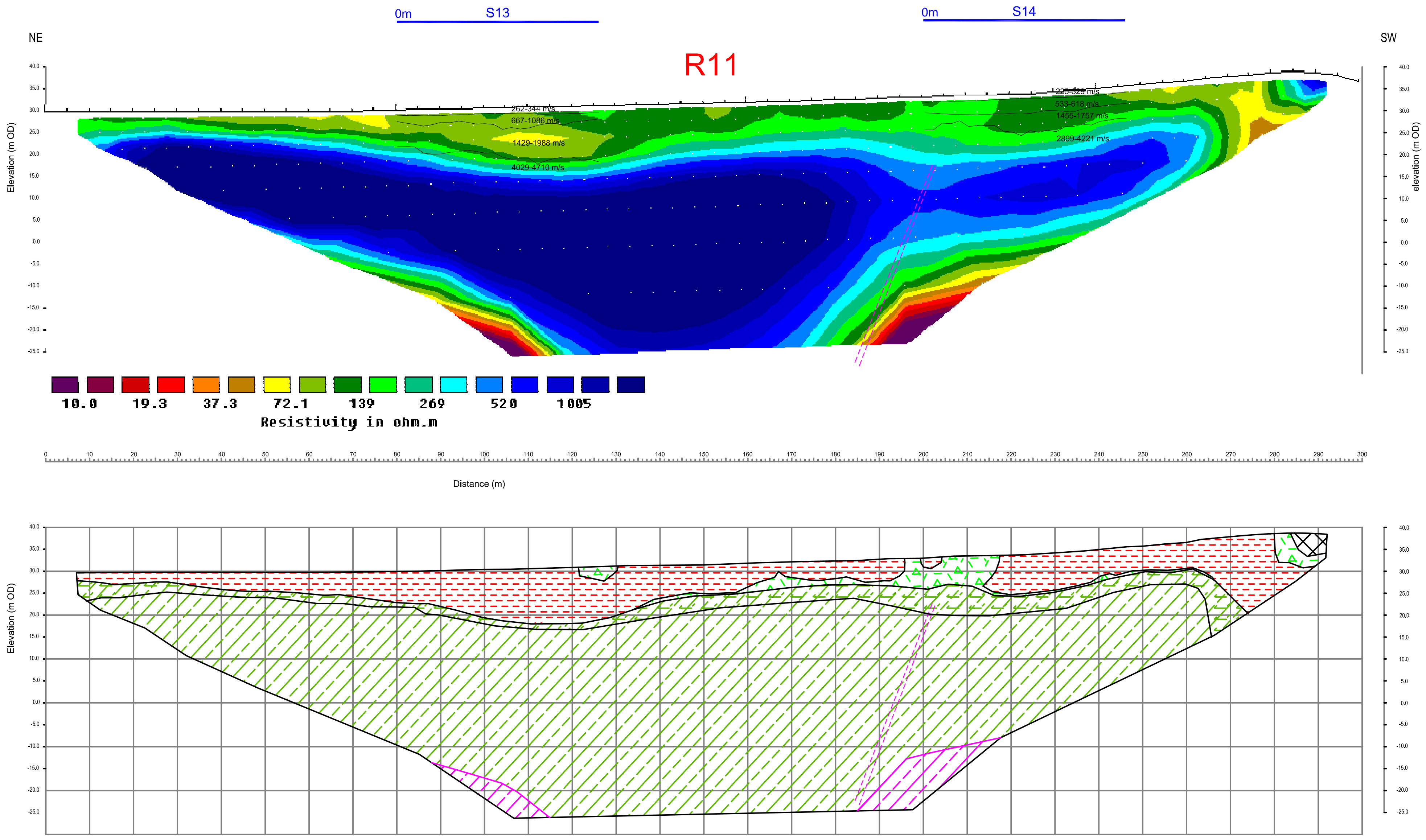

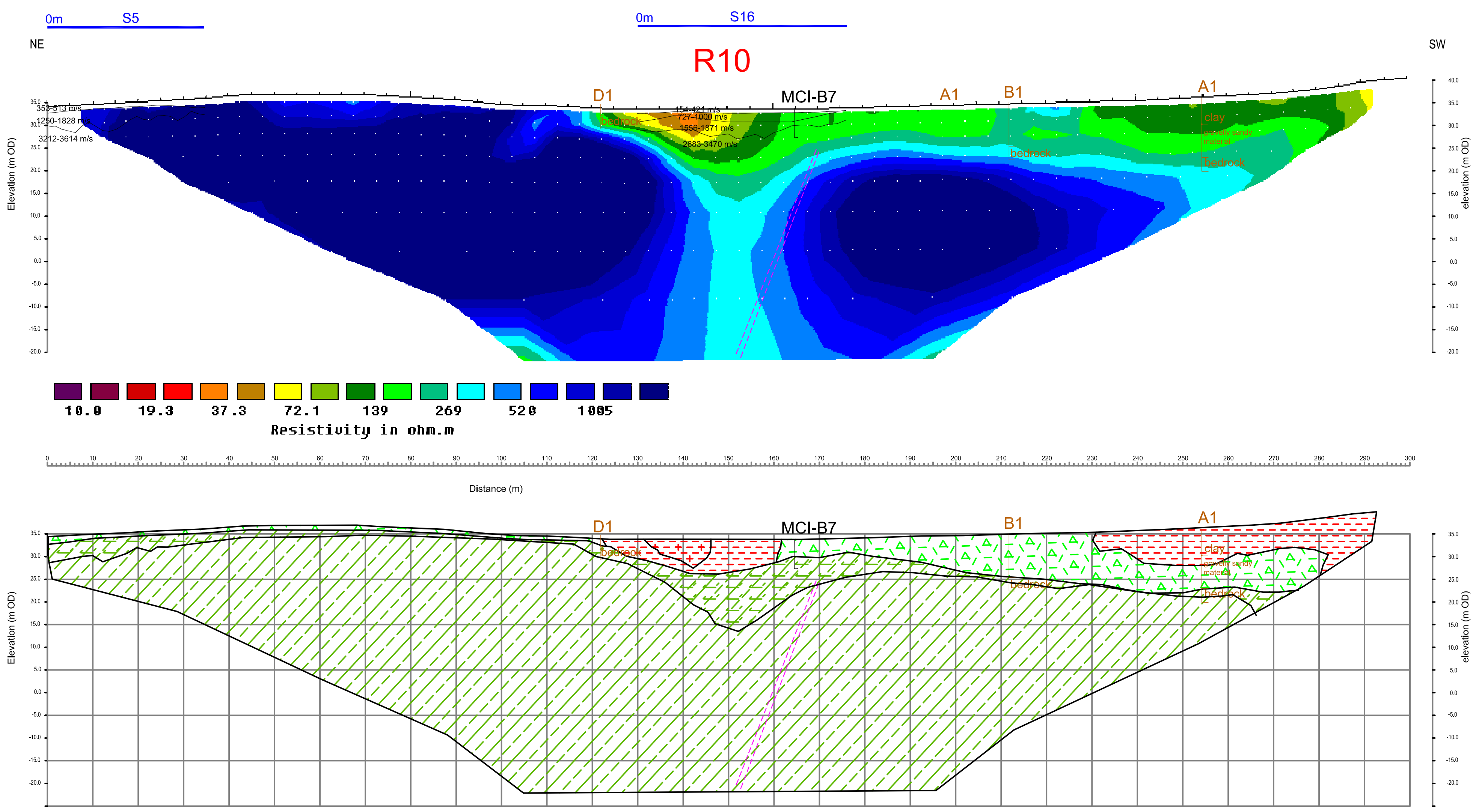

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LEGEND:

- SILT/CLAY
- sandy CLAY
- possible sensitive CLAY
- clayey SAND / SAND
- MADE GROUND
- Possible effect of underground services/effluent from animal waste
- Highly-Moderately Weathered GREENSCHIST
- Slightly Weathered-Fresh GREENSCHIST
- GREENSCHIST with possible saline intrusion
- Possible FAULT
- 694-1000 m/s — Seismic Refraction Layer with interpreted P-wave velocity

PROJECT:	RANHEIM VESTRE
DRAWING No.:	13170_05 ERT PROFILES R11 & R10
DATE:	25-02-14
CLIENT:	MULTICONSULT
SCALE:	1:1250 @A3

Version:	Date:	Drawn By:	Checked:
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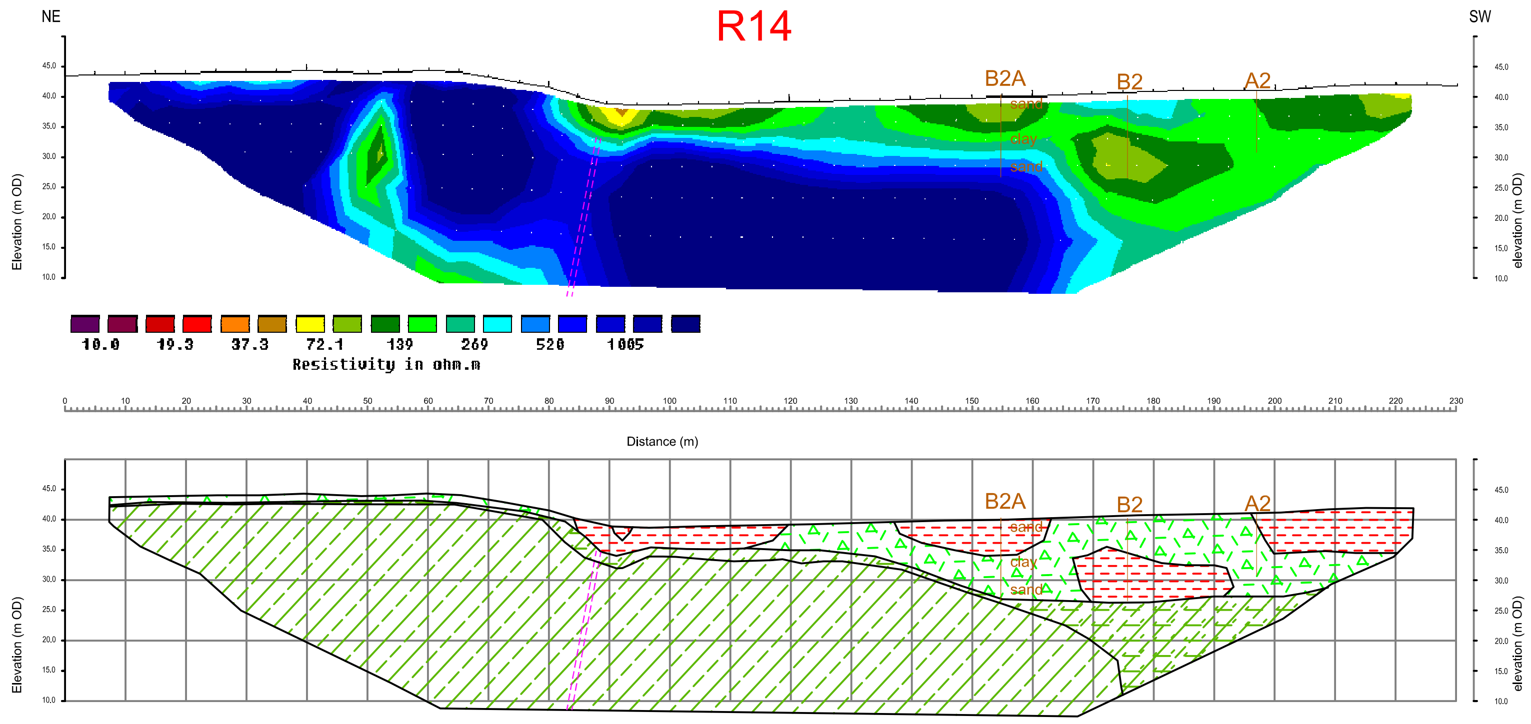

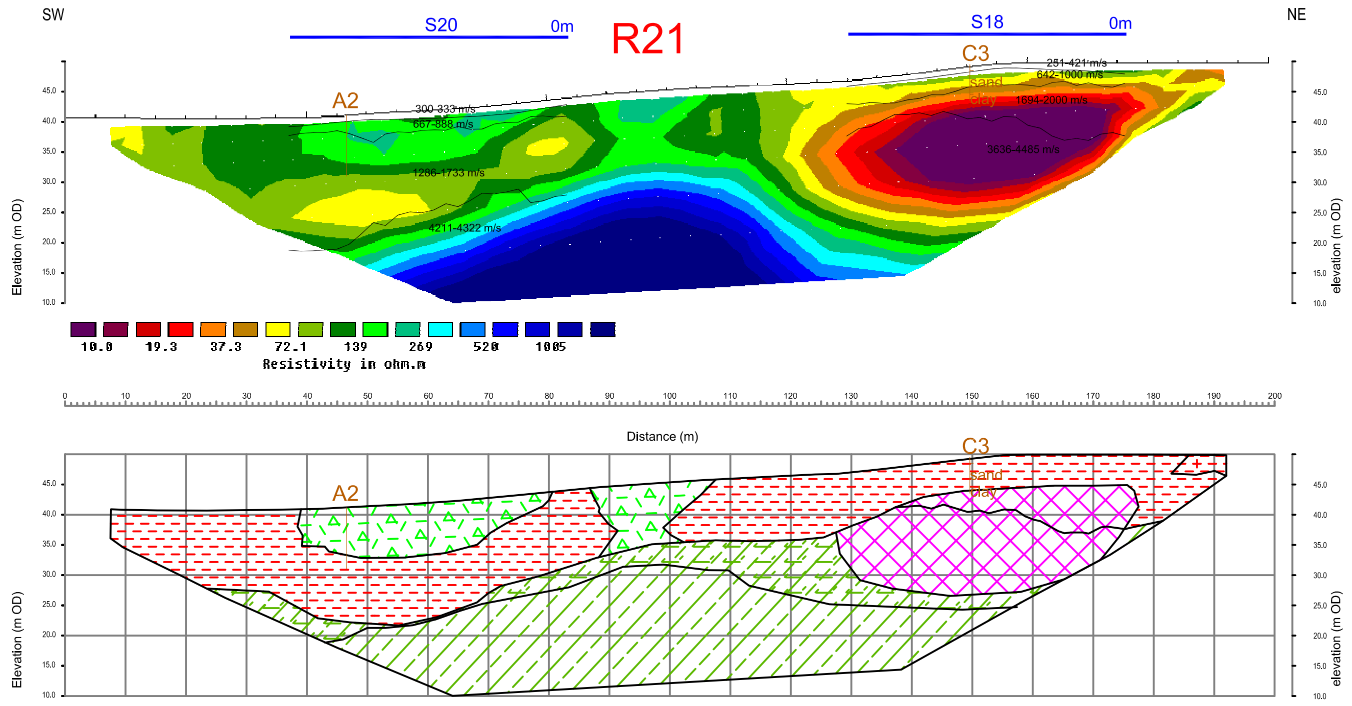

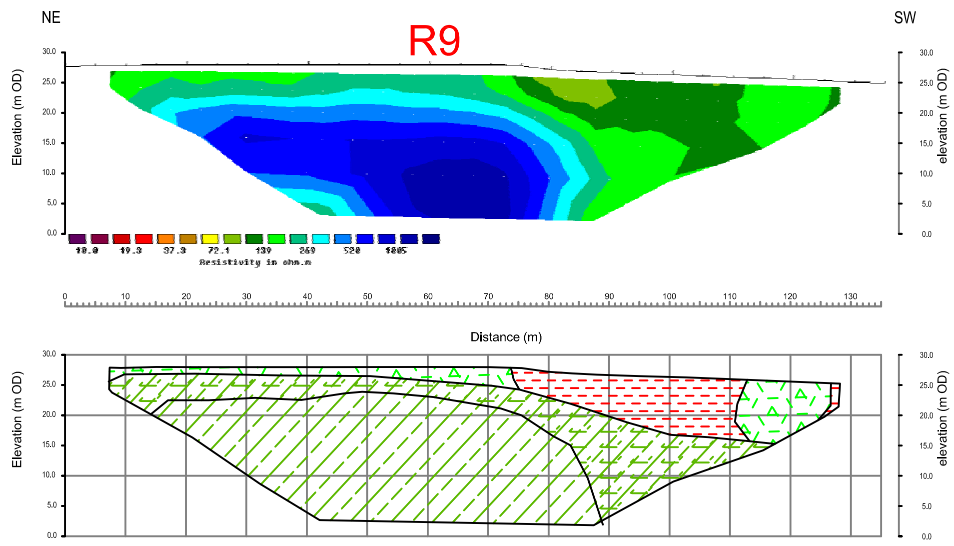

LEGEND:

- SILT/CLAY
- sandy CLAY
- possible sensitive CLAY
- clayey SAND / SAND
- MADE GROUND
- Possible effect of underground services/effluent from animal waste
- Highly-Moderately Weathered GREENSCHIST
- Slightly Weathered-Fresh GREENSCHIST
- GREENSCHIST with possible saline intrusion
- Possible FAULT
- 694-1000 m/s — Seismic Refraction Layer with interpreted P-wave velocity

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PROJECT: RANHEIM VESTRE

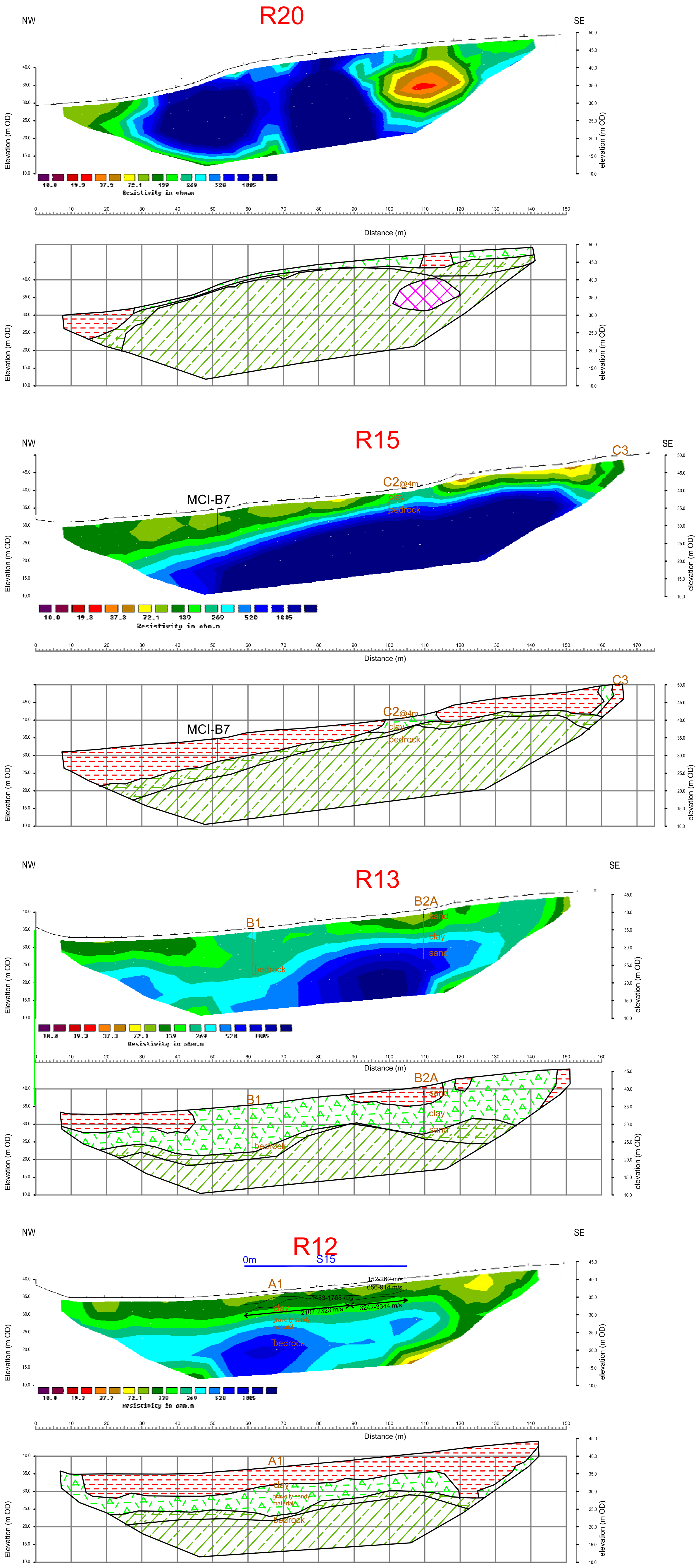
DRAWING No.: 13170_06 ERT PROFILES R14, R21 & R9

DATE: 25-02-14

CLIENT: MULTICONSULT

SCALE: 1:1250 @A3

Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC



LEGEND:

- SILT/CLAY
- sandy CLAY
- possible sensitive CLAY
- clayey SAND / SAND
- MADE GROUND
- Possible effect of underground services/effluent from animal waste
- Highly-Moderately Weathered GREENSCHIST
- Slightly Weathered-Fresh GREENSCHIST
- GREENSCHIST with possible saline intrusion
- Possible FAULT
- 694-1000 m/s — Seismic Refraction Layer with interpreted P-wave velocity

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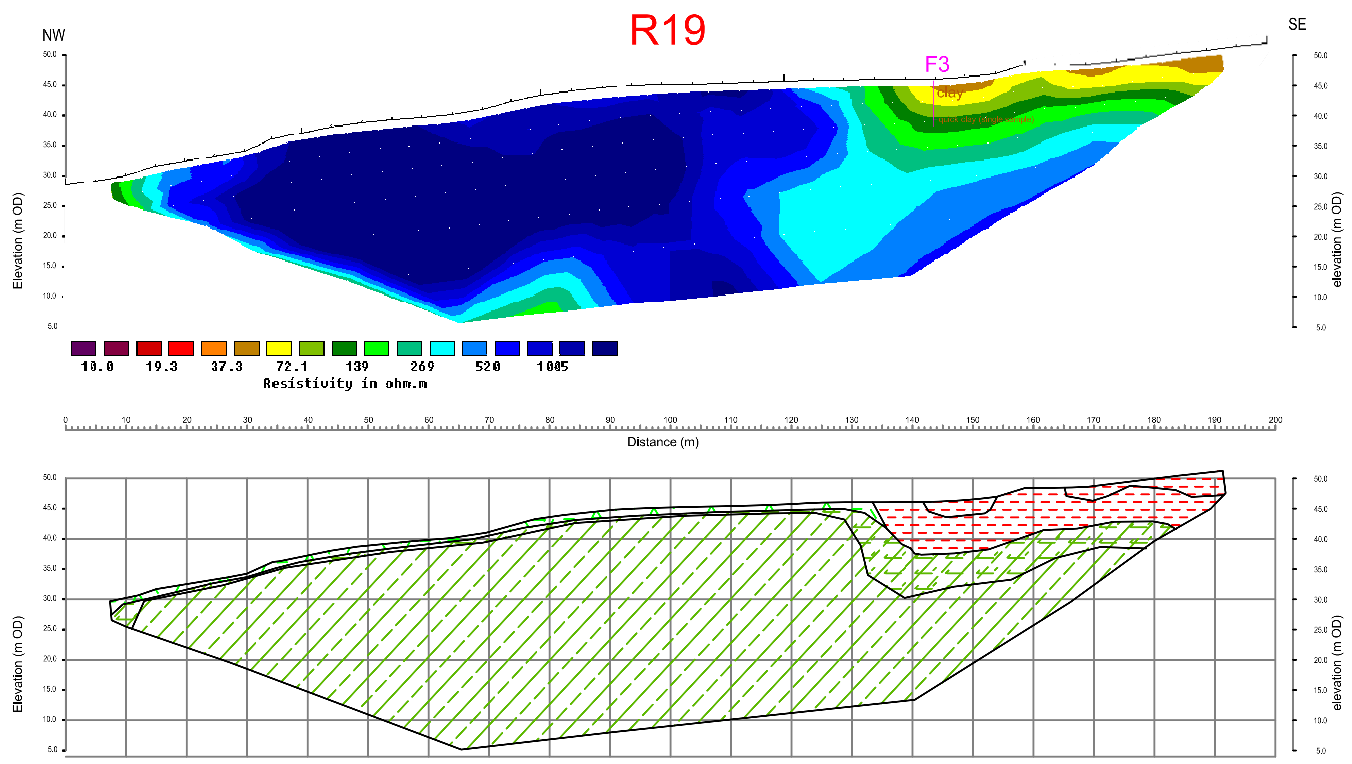
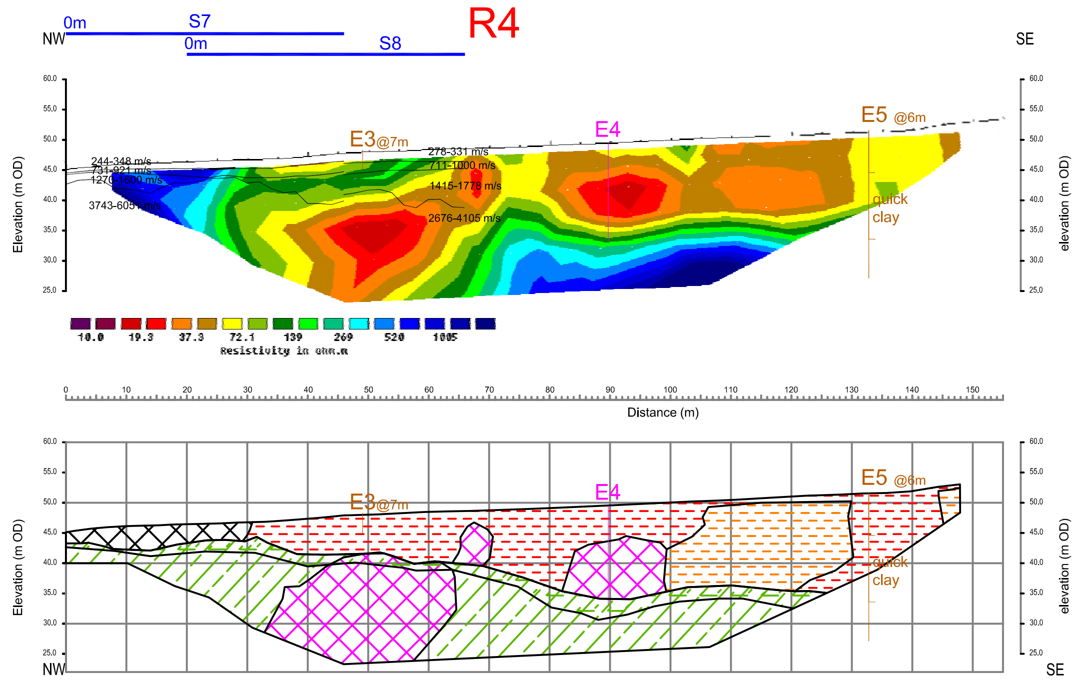
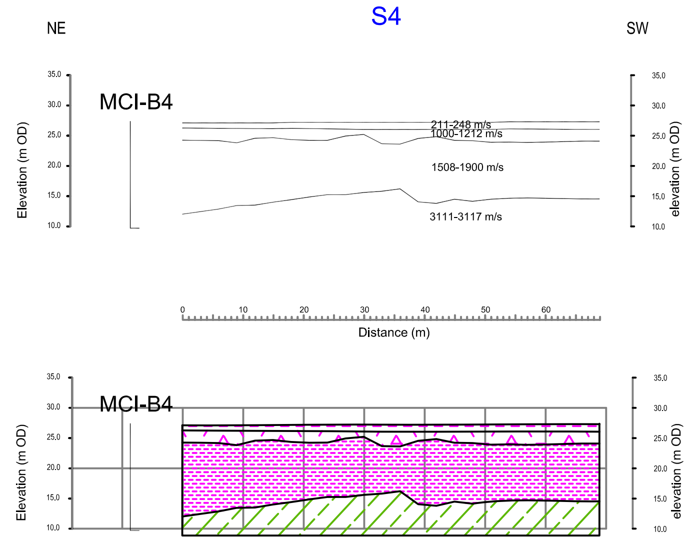
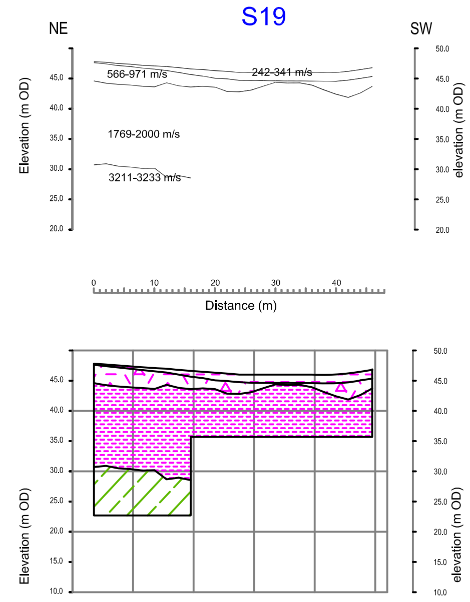
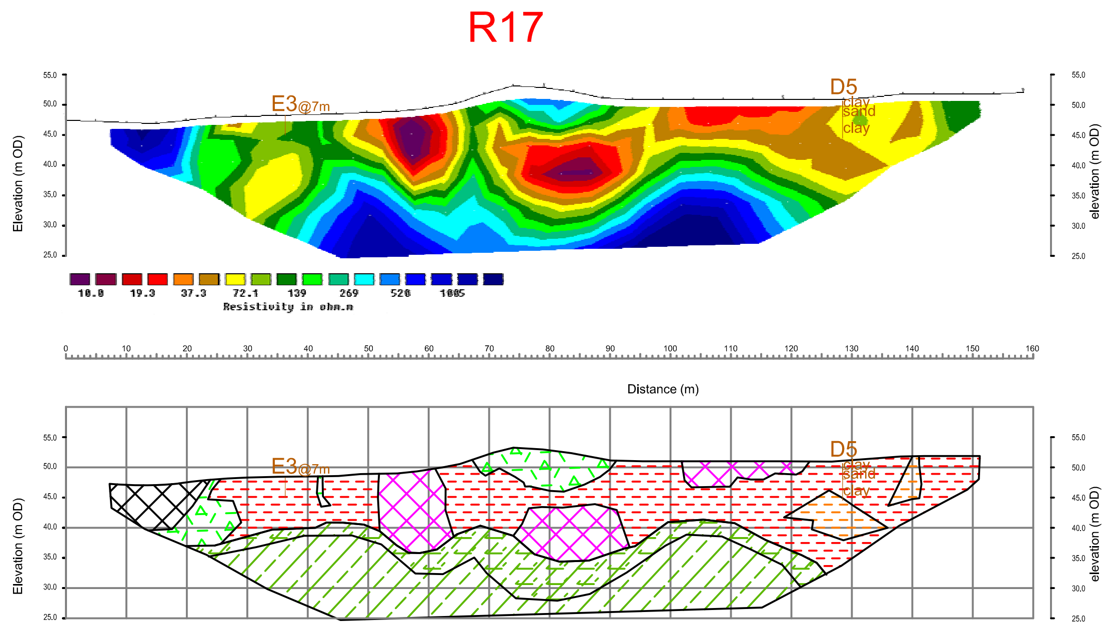
PROJECT: RANHEIM VESTRE			
DRAWING No.: 13170_07 ERT PROFILES R20,R15,R13 & R12			
DATE: 25-02-14			
CLIENT: MULTICONSULT			
SCALE: 1:1250 @A3			
Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC











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LEGEND:

- SILT/CLAY
- sandy CLAY
- possible sensitive CLAY
- clayey SAND / SAND
- MADE GROUND
- Possible effect of underground services/effluent from animal waste
- Highly-Moderately Weathered GREENSCHIST
- Slightly Weathered-Fresh GREENSCHIST
- GREENSCHIST with possible saline intrusion
- Possible FAULT
- 694-1000 m/s — Seismic Refraction Layer with interpreted P-wave velocity
- Soft/Loose Overburden
- Firm-Stiff/Medium Dense-Dense Overburden
- Stiff-very Stiff/Dense-very Dense Overburden
- Moderately weathered-Fresh Bedrock

PROJECT: RANHEIM VESTRE

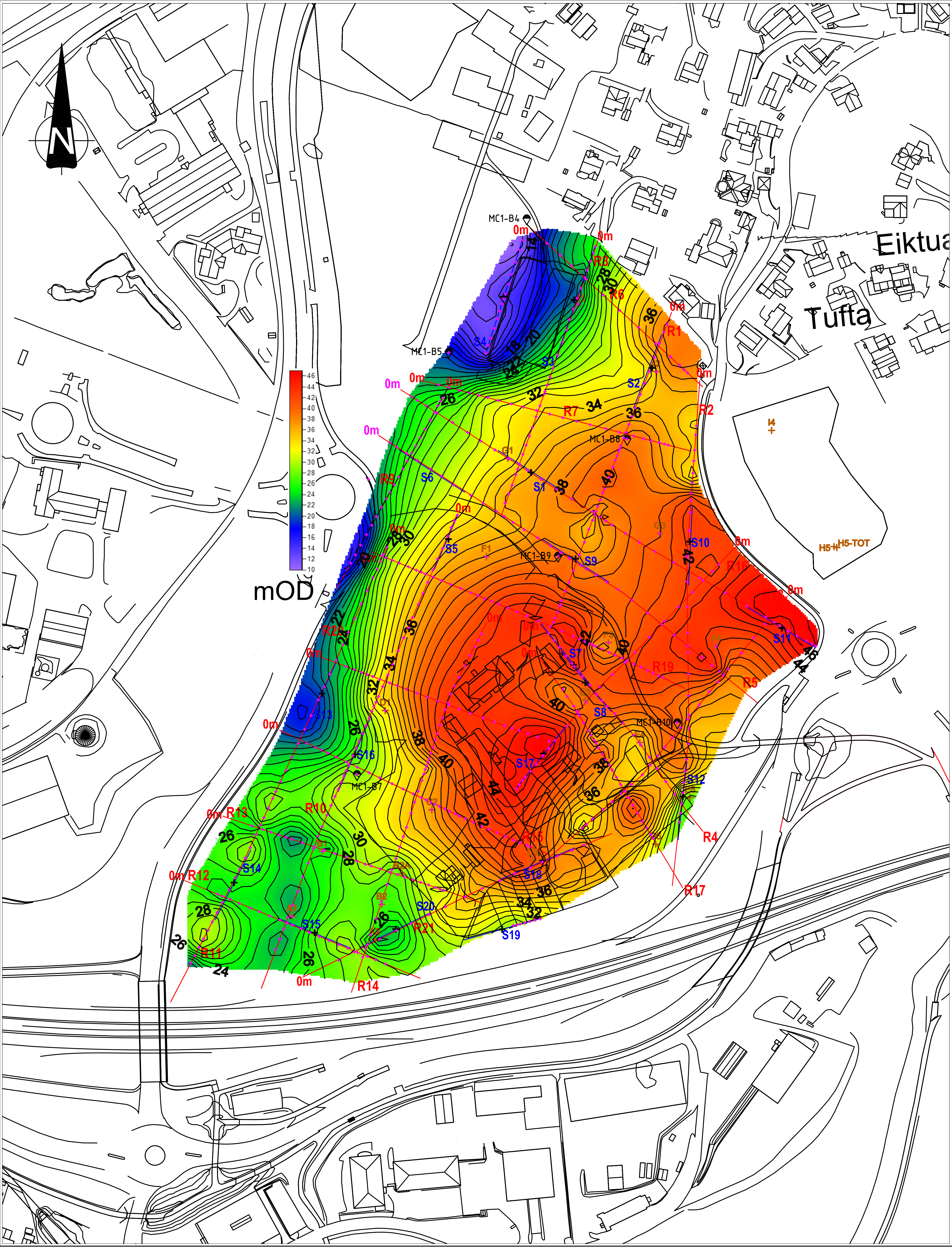
DRAWING No.: 13170_08 PROFILES R19,R4,R17,S4,S19

DATE: 25-02-14

CLIENT: MULTICONSULT

SCALE: 1:1250 @A3

Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC



LEGEND:

24	Interpreted Bedrock Elevation (mOD)
+	Data Point

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PROJECT:
RANHEIM VESTRE

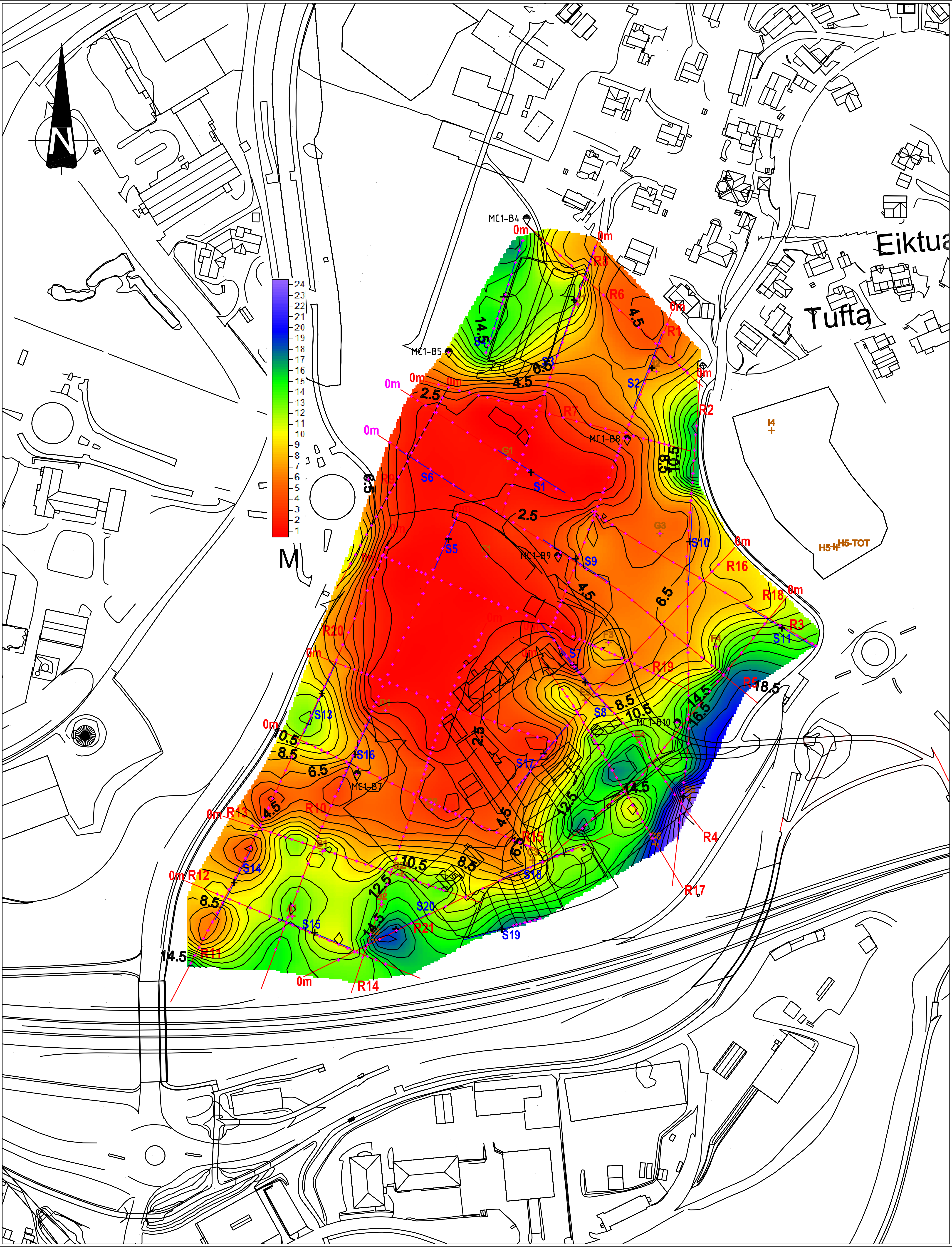
DRAWING No.:
13170_09 INTERPRETED BEDROCK ELEVATION

DATE:
25-02-14

CLIENT:
MULTICONSULT

SCALE:
1:2000 @A3

Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC



PROJECT:	RANHEIM VESTRE
DRAWING No.:	13170_10 INTERPRETED OVERBURDEN THICKNESS
DATE:	25-02-14
CLIENT:	MULTICONSULT
SCALE:	1:2000 @A3

Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC

LEGEND:

3.5 Interpreted Overburden Thickness (m)

+ Data Point

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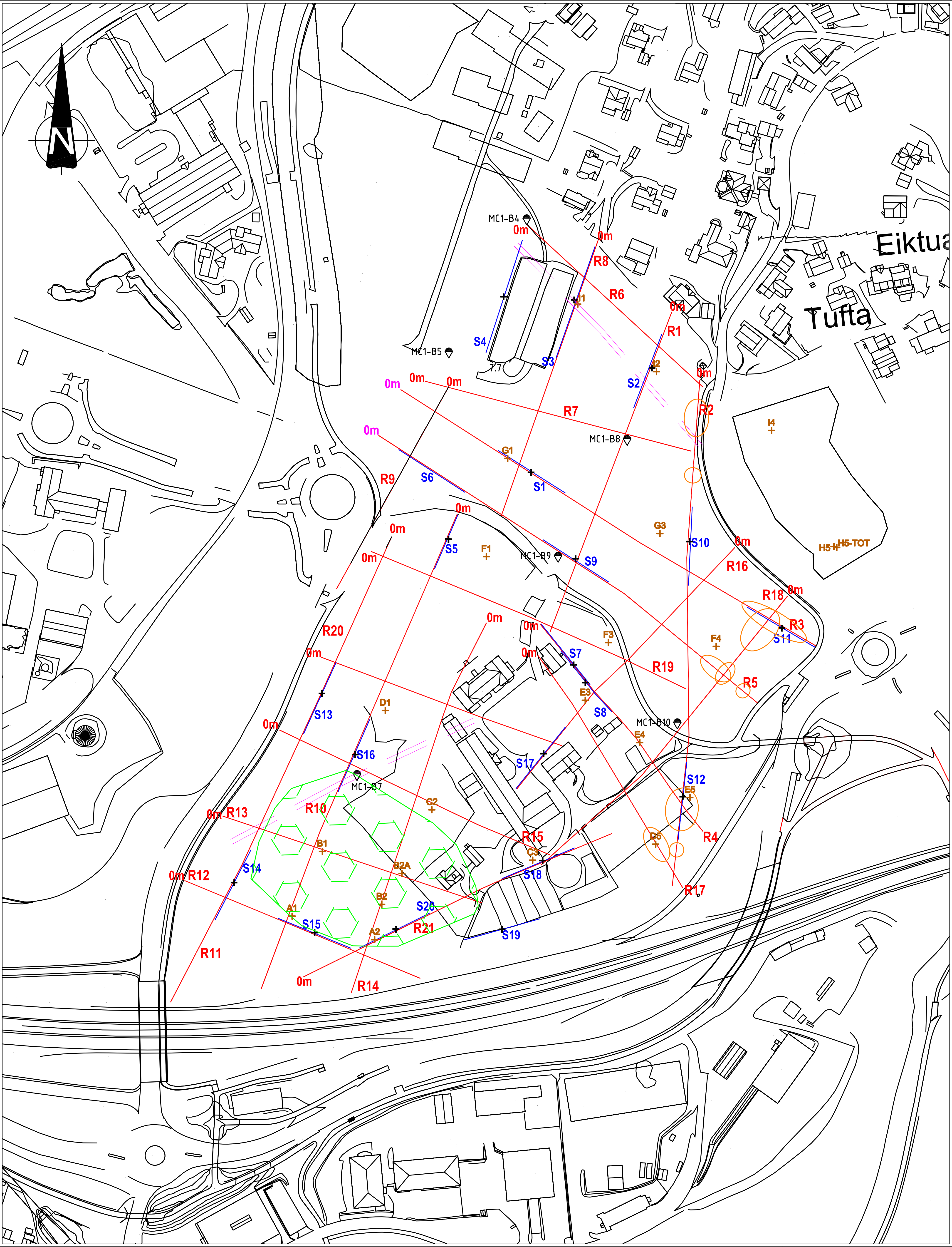

LEGEND:

Possible Quick CLAY zone

Interpreted as mainly thick Sandy overburden

Possible FAULT

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PROJECT: RANHEIM VESTRE

DRAWING No.: 13170_11 SUMMARY MAP

DATE: 25-02-14

CLIENT: MULTICONSULT

SCALE: 1:2000 @A3

Version:	Date:	Drawn By:	Checked:
1	25-02-14	SOR	POC