Percussion Borehole PH04

Depth From (m)	Depth To (m)	Material Description	Comments
0	1.5	Silty Clay with basalt fragments	
1.5	2.2	Basalt	
2.2	6.9	Basalt – fresh, high strength	
6.9	9.0	Basalt – moderately weathered	
9.0	10.0	Basalt – trace of clay fines	
10.0	13.8	Basalt – fresh, very high strength	
13.8	13.9	Becoming low strength agglomerate	Borehole terminated at 13.80m

Percussion Borehole PH05

Depth From (m)	Depth To (m)	Material Description	Comments
0	3.0	Silty Clay with basalt fragments	
3.0	11.3	Basalt, fresh, fractured	At 8.9m basalt is moderately weathered with pale brown fines. At 10.0m larger clasts encountered.
11.3	11.5	Brown fines	11.5m – hole blocked

Percussion Borehole PH06

Depth From (m)	Depth To (m)	Material Description	Comments
0	3.0	Silty Clay with basalt fragments	
3.0	4.0	Basalt fragments with dark brown fines	
4.0	7.1	Basalt – slightly weathered to fresh, very high strength	Driller noted a fractured zones
7.1	8.0	Basalt – moderately weathered, pale brown fines	
8.0	11.2	Basalt – fresh, very high strength, fractured	8.0m – high penetration rate
11.2	11.8	Brown fines – possibly agglomerate	Borehole terminated at 11.80m

Percussion Borehole PH07

Depth From (m)	Depth To (m)	Material Description	Comments
0	2.8	Silty Clay with basalt fragments	
2.8	5.6	Basalt, slightly weathered to fresh	
5.6	11.2	Basalt – fresh, very high strength	5.6m – very hard drilling
11.2	13.2	Possible fracture zone	
13.2	14.0	Brown fines – possibly agglomerate	Borehole terminated at 14.0m, bit blocked

Percussion Borehole PH08

Depth From (m)	Depth To (m)	Material Description	Comments
0	1.4	Gravelly silt, gravel is basalt	
1.4	2.4	Dark brown fines with basalt fragments	
2.4	6.6	Basalt – moderately weathered to slightly weathered with brown fines	
6.6	8.1	Basalt – moderately weathered to slightly weathered	
8.1	14.5	Basalt – fresh	8.1m – very hard drilling
14.5	14.7	Brown fines – possibly agglomerate	Borehole terminated at 14.7m, bit blocked

Percussion Borehole PH09

Depth From (m)	Depth To (m)	Material Description	Comments
0	3.5	Silty Clay	
3.5	5.5	Silty Clay with basalt fragments	Possibly fractured basalt
5.5	10	Basalt	
10	11	Basalt	
11	11.10	Silty Clay, possibly low strength agglomerate	Borehole blocking up

APPENDIX FSEISMIC REFRACTION SURVEY

IMPORTANT NOTE

All reduced levels in the attached seismic report need to be lowered by 37.306 metres to bring levels to AHD.

The survey data provided was carried out using GPS survey equipment that "ground adjusts" and produces GPS levels based on the Corsnet local antennae which has a Lipsoid level, NOT an AHD level.

ET458.SMEC.WattleVale.GlenInnes.Seismic

Report prepared for
SMEC Australia

On behalf of
Glen Innes Severn Council

SEISMIC REFRACTION TESTING

WATTLE VALE SITE,
GLEN INNES, NSW

April 2016 Job No ET458
Report ET458.01

Report Prepared By:
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Eastwood NSW 2122
Tel: 612 9804 1752

TABLE OF CONTENTS

1.0 INTRODUCTION

At the request of SMEC Australia on behalf of Glen Innes Severn Council, seismic refraction testing was completed as part of the geotechnical assessment of potential quarry sites at the Wattle Vale property at Glen Innes, NSW.

The objective of the seismic study was to provide lateral coverage of the shallow bedrock conditions across a number of identified sites to identify relatively shallow areas of high seismic velocity material consistent with high strength rock to maximise the effectiveness of a proposed borehole program.

Eight lines were completed at 4 selected sites as shown on the aerial photo site plan Drawing 458-1.

The seismic fieldwork was carried out between 14th and 17th March, 2016 and preliminary seismic results were provided from site.

The data acquisition was undertaken in accordance with detailed engineering seismic refraction practice as described below.

2.0 EQUIPMENT & FIELD PROCEDURES

2.1 Seismograph

A Geometrics Strataview 48 channel engineering seismograph was used. This unit has internal calibration, paper printer and hard and floppy disc drive capability. A sampling interval of 0.064 millisecs was used. Typically a record length of 128 millisecs was required.

2.2 Geophones and Source-Point Configurations

The geophones used for the survey were Geospace GS11D, with a natural resonant frequency of 8Hz. A rigid coupling with the ground was obtained with 75mm tapered spikes on the geophone base.

The seismic refraction testing was completed using a linear array of 48 geophones, connected via 24 channel multi-core cables to the seismograph.

A geophone spacing of 2m was used with a source-point spacing of 10m within each spread. Typically 3 to 4 offset shot points were used for each spread, positioned up to 50m from the end geophone where possible.

Generally 18 seismic source positions were used for each spread resulting in reversed coverage seismic data with source - receiver offsets of up to

150m, in accordance with accepted practice.

2.3 Seismic Source

A triggered sledge hammer impacting a steel plate was used as the seismic source. The hammer is connected via trigger cable to the seismograph.

A number of impacts were summed to improve the signal to noise ratio until adequate quality data was achieved. The number of stacks depending on the position of the source within the spread, with typically six or seven impacts in the middle of the spreads and an increasing number of stacked impacts towards the offset source-points.

There was a intermittent moderate level of background seismic noise from trains, however there was minimum vehicle traffic at the site.

2.4 Positioning

A site plan/aerial photo was provided with the recommended locations of the seismic lines indicated. A walkover with the SMEC & Glen Innes Severn Council representative was also conducted confirming each of the seismic line locations.

Positioning along the seismic line was maintained using 100m tapes laid along the ground surface. Coordinates of the start and end of each seismic line were taken by the seismic crew using hand held DGPS, and pegs were placed. Surface survey of the seismic lines was provided by the project surveyor base on the pegs and GPS coordinates provided for the seismic lines by ETS.

2.5 Records and Documentation

All seismic data were recorded on hard drive and backed up at the end of each field day. Field records were maintained on ETS Form ET1.1 Seismic Refraction Field Sheet on which the geophone and source-point configurations, filename and equipment details were recorded. The filenames contain the seismic line number, spread number and source-point number.

A complete set of the seismic data and field records has been archived in ETS seismic database.

3.0 INTERPRETATION PROCEDURES

The digital seismic records were examined on computer, and the first arrival times were determined using REFRACT2006 software. Generally the data was considered of very good quality.

The seismic data were interpreted using the interpretation program REFRACT2006, which is based on the Intercept Time Method and the Reciprocal Method in accordance with engineering seismic refraction practice (Walker et al, 1991) as described briefly below.

The interpretation begins with segmentation of the T-X graph to identify individual layers.

Reciprocal time checks are determined automatically and are edited manually to reduce any reciprocal time errors. Velocity analysis follows using the computed Minus-Time Graph, derived from the reversed overlapping phantomed data for each layer. Least squares fitted lines are manually selected from each refractor, allowing lateral velocity changes along the profile and the velocities are computed. The time depths and layer thickness, which are computed automatically, are checked and edited to eliminate minor errors.

The final output of the seismic refraction method is an interpreted seismic section, which is a 2 dimensional representation of the earth beneath the survey line.

Up to four discrete layers of differing seismic velocity were interpreted, with any measured lateral velocity variations indicated within each layer.

4.0 RESULTS

The interpreted seismic sections are provided in Drawing 2 to 9 presented generally at a scale of 1:400. Due to the lengths of Lines 1 & 8 (Drawings 2 & 9) these sections are presented at a horizontal scale of 1:800.

4 layers of differing seismic velocity were interpreted, with a range of seismic velocities (350m/s to 440m/s) consistent with a range of material from SOIL through to very high strength ROCK.

A general summary of typical seismic velocity ranges is provided below in table format, which are based on the observed seismic velocity range.

The seismic layers should be correlated with the borehole information where available.

Velocity Range (m/s)	Interpretative Comments (based on seismic velocities range)
350 – 1000	Seismic velocities consistent with SOIL with increase in seismic velocity indicative of increasing content of cobbles & boulders.
1100 – 2200	Seismic velocity range consistent with low to moderate strength ROCK.
2200 – 3300	Seismic velocity consistent with Moderate to High Strength ROCK.
3300 - 4400	Seismic velocity range consistent with Very High strength ROCK

Generally an increase in seismic velocity within an intact rock layer indicates a decrease in weathering, fracturing and/or higher strength material. The degree of fracturing can have a significant effect on the bulk seismic velocity measured.

As with all seismic methods, seismic refraction has some inherent limitations in effectively representing subsurface conditions in all geological environments. Some of these issues are presented in Appendix A – Guide to the Use of Interpreted Seismic Sections. This offers some general information on the seismic refraction method including the precision and accuracy of results and the possible effects of violations of the assumptions on which the method and interpretation procedure is based. The presence of thin layers beyond the limits of detection and anisotropy are potential factors, which may lead to minor variations between the measured and actual velocities.

Some general summary comments on the seismic results for each site are provided below:

Site #3 – Seismic Lines 1, 2 & 5

Line 1 (longitudinal) indicates a relatively shallow (less than 3m depth) high velocity of greater than 2500m/s (Seismic Layer 3) consistent with high strength rock from about distance 80m to 300m. The underlying higher velocity layer 4 (2800 to 4400m/s) is seen to vary from approximately 5m to 8m depth along this region of the line.

Line 2 (transverse) indicates quite narrow zone of high velocity material (greater than 2500m/s within Seismic Layer 3) approximately 25m wide from distance 40m to 65m. The very velocity Seismic Layer 4 is relatively deep (approximately 12m to 20m depth) along this transverse profile.

Line 5 (transverse) indicates a slightly wider zone (approximately 50m wide) of relatively shallow high velocity material.

Note there is some evidence of seismic velocity anisotropy (ie. variation in seismic velocity in a North South orientation, Line 1, compared to the East West direction, Lines 2 & 5) which is most likely related to the predominant fracture orientation – and possibly to some extent less continuity of these units in a transverse direction.

There is some evidence in the travel time data of the transverse lines at this site, of a significant drop off in time for the data from offsets shots at either end of the seismic lines, which may indicate a high strength rock unit of limited thickness.

Correlation of the seismic sections with the Boreholes at Site # 3 is provided below.

Correlation: Seismic Line 1 & BH 01

Line 1 @ 102m				**BH 01 (365264mE, 6711927mN)**		
Seismic Layer	**RL (m)**	**Depth (m)**	**Velocity (m/s)**	**RL (m)**	**Depth (m)**	**Soil/Rock Material Description**
1	1162.6	0	330	1162.4	0	TOPSOIL & Residual SOIL with cobbles & boulders
2	1162.0	0.6	2150	1161.7	1.0	SW, H Strength BASALT
3	1159.9	2.7	3600	1160.9	1.5	SW to FR, VH strength BASALT
4	1153	9.4	4400	1149.8	9.7	XW to HW, L to H strength BASALT
				1147.6	14.8	Fr, VH strength BASALT

Generally a good correlation is observed however the XW, L-H strength BASALT unit is not identified in the seismic interpretation due to the velocity inversion ie higher strength material overlying a lower strength unit.

The transverse seismic Line 2 does indicate a deeper weathering profile and seismic layer 4 of 4500m/s at approximately 15m depth correlates well with the VH strength Fresh BASALT unit encountered at this depth at BH01.

Some considerable variability is indicated in the upper H to VH strength BASALT unit by the comparison of transverse to longitudinal seismic lines

Correlation: Seismic Line 1 & BH 02

Line 1 @ 160m				**BH 02 (365278mE, 6711980mN)**		
Seismic Layer	**RL (m)**	**Depth (m)**	**Velocity (m/s)**	**RL (m)**	**Depth (m)**	**Soil/Rock Material Description**
1	1163.0	0	360	1163.0	0	Residual SOIL – Clay with cobbles & boulders
2	1162.4	0.6	1800	1162.4	0.6	SW VH strength BASALT
3	1161.6	1.4	2800	1161.0	2.0	XW-HW, VL - H strength BASALT & BASALT BRECCIA
4	1159.4	3.6	3700	1159.7	3.3	SW-Fr, V High strength BASALT
				1156.7	6.3	HW, L – M strength LAPILLI TUFF

A generally good correlation is observed above, however once again the underlying lower strength units are not identified by the seismic refraction method.

Correlation: Seismic Line 1 & BH 03

Line 1 @ 198m				**BH 03 (365289mE, 6712024mN)**		
Seismic Layer	**RL (m)**	**Depth (m)**	**Velocity (m/s)**	**RL (m)**	**Depth (m)**	**Soil/Rock Material Description**
1	1162.7	0	350	1162.3	0	Residual SOIL – Silty CLAY
2	1162.1	0.6	1400	1161.7	0.6	SW VH Strength BASALT
3	1160.2	2.5	3100	1156.3	6.0	HW, L - M strength LAPILLI TUFF & AGGLOMERATE
4	1157	5.7	4000	1149.7	12.6	Fr, H- V High strength BASALT

Similarly the L-M strength LAPILLI TUFF / AGGLOMERATE at 6m depth is not identified with the seismic method

Site #1 – Seismic Lines 3 & 5

Seismic Lines 3 & 4 show more uniform subsurface conditions than at Site #3, however a relatively deeper weathering is indicated with Seismic Layer 4 (>3000m/s seismic velocity) observed at over 10m depth across the site.

The overlying intermediate layer (Seismic Layer 3 - 1350 to 2050m/s) the top of which varies from approximately 2m to 5m depth across the site may contain highly fractured rock of moderate to high strength.

Site #4 – Seismic Line 6

Seismic Line 6 indicates very deep a weathering profile across the top of the steep hilltop. Seismic Layer 2 of relatively low seismic velocity (550 to 1150m/s) extends to approximately 12m depth in the central region.

The basal Seismic Layer 4 (seismic velocity 2450 to 3200m/s) is observed at over 20m depth in the middle of the seismic line.

Site #5 – Seismic Lines 7 & 8

Seismic Line 8 (Longitudinal) indicates a very high velocity layer (Seismic Layer 4 - 2500 to 3500m/s) at less than 5m depth in the south and increasing in depth to approx 15m at the northern end of the seismic line.

Seismic Line 7 (Transverse) indicates the basal Seismic Layer 4 (>3000m/s) typically at a relatively uniform depth of 10m to 12m – consistent with the intersection of Line 8 at that location.

Correlation: Seismic Line 8 & BH 09

Line 8 @ 30m				BH 09 (365372mE, 6710619mN)		
Seismic Layer	**RL (m)**	**Depth (m)**	**Velocity (m/s)**	**RL (m)**	**Depth (m)**	**Soil/Rock Material Description**
1	1219.3	0	400	1219.4	0	TOPSOIL & Residual SOIL – Clayey SILT & Silty CLAY
2	1218.1	1.2	1000	1217.7	1.7	EW, EL – L strength BASALT
3	1216.4	2.9	2500	1217.4	2.0	MW - SW, H strength BASALT
					2.8	MW- SW, VH strength BASALT
4	1212.7	6.6	3200		6.8	SW–Fr, V High strength BASALT

Generally a good correlation is observed between the seismic Line 8 interpretation and BH09. Seismic Layer 3 correlates with the range of MW to SW BASALT of H to VH strength.

Correlation: Seismic Line 8 & BH 10

Line 8 @ 75m				**BH 10 (365367mE, 6710665mN)**		
Seismic Layer	**RL (m)**	**Depth (m)**	**Velocity (m/s)**	**RL (m)**	**Depth (m)**	**Soil/Rock Material Description**
1	1218.6	0	350	1218.6	0.0	TOPSOIL & Residual SOIL – Silty CLAY
2	1217.9	0.8	850	1217.6	1.0	EW, EL to L Strength BASALT
3	1215.3	3.3	1750	1216.4	2.2	MW-HW, H strength BASALT
				1214.6	4.0	MW- SW, H to V High strength BASALT
4	1211.4	7.2	3100	1211.9	6.7	SW, VH Strength BASALT

Generally a good correlation is observed with some variability is indicated with Seismic Layer 3. Lower velocity regions are most likely indicative of increased fracturing ie smaller defect spacing.

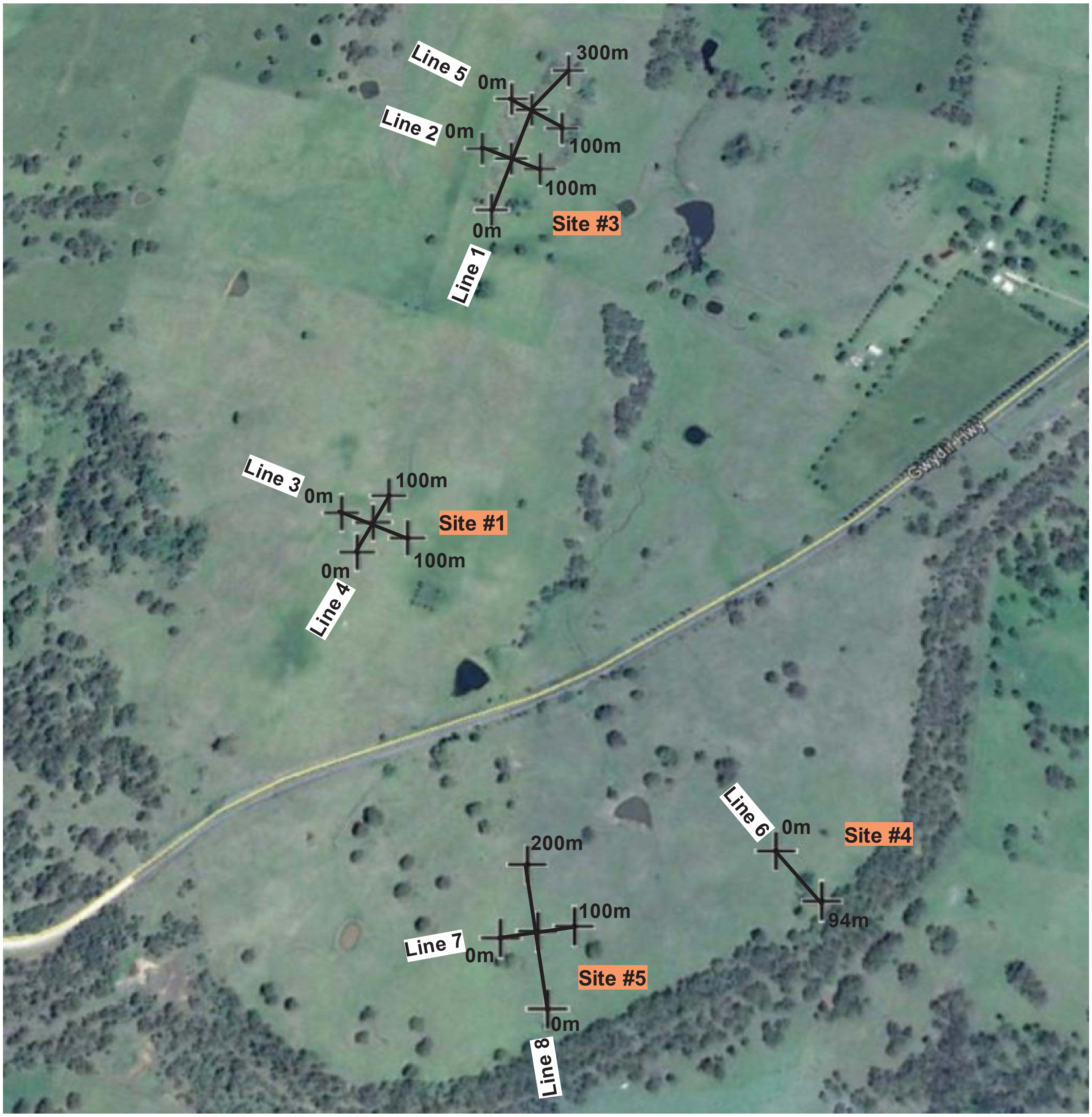
5.0 CONCLUSIONS

Seismic refraction testing was successfully completed along the 8 selected profiles. This seismic study has delineated 4 layers of differing seismic velocity within the shallow subsurface in these areas and indicated a considerable variation in depth of weathering across the sites tested.

Some general interpretative comments have been provided within this report and a correlation of the relevant borehole information with the seismic layers has been undertaken at site # 3 and Site #5.

The seismic refraction method has shown generally a good correlation with the borehole results. However at Site #3 the boreholes indicated a layer of lower strength rock (TUFF & AGGLOMERATE) underlying a unit of very high strength BASALT which was not defined by the seismic method which requires layers of increasing velocity with depth.

Appendix A – Guide to the use of Interpreted Seismic Sections, is provided as background material on the seismic refraction method and some of the potential limits of seismic interpretations.



SMEC / Glen Innes Severn Council
Seismic Refraction Survey
"Wattle Vale" Property, Glen Innes
Aerial Photo Site Plan - Seismic Lines

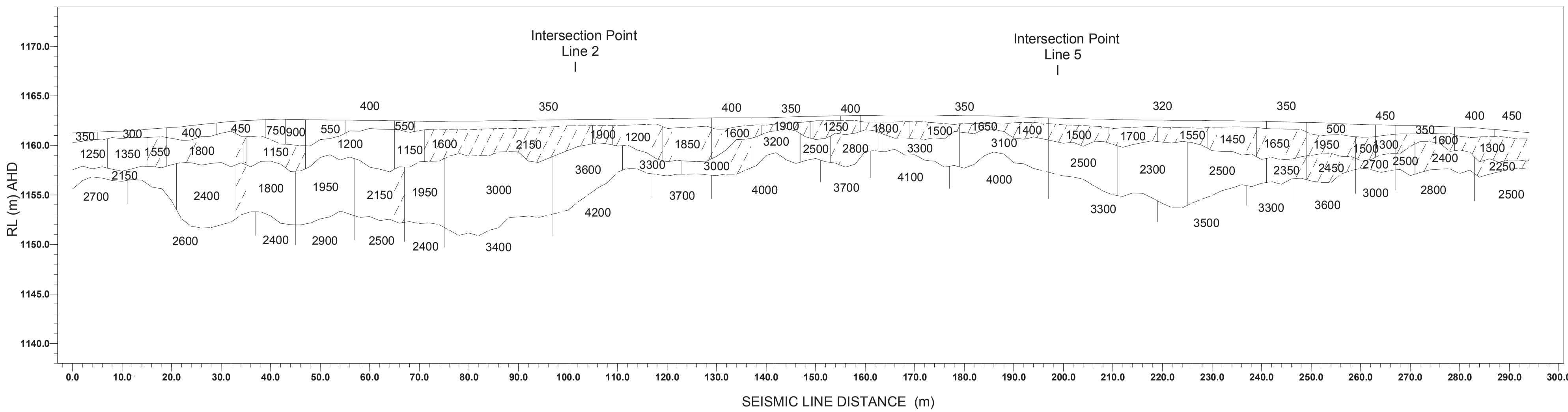
Earth Technology Solutions Pty Ltd
ABN 12 078 325 628

Job No.: ET458.1
Date : 14/04/16

ETS

Drawing ET458-1

INTERPRETED SEISMIC SECTION : LINE 1 (Longitudinal Line - Site #3)



South
Line 1 - 0m Start
E: 365237mE
N: 6711833mN
RL: 1161.3

North
Line 1 - 300m End
E: 365347mE
N: 6712105mN
RL: 1161.1

Scale H 1:800 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD
ABN 12 078 325 658

ETS

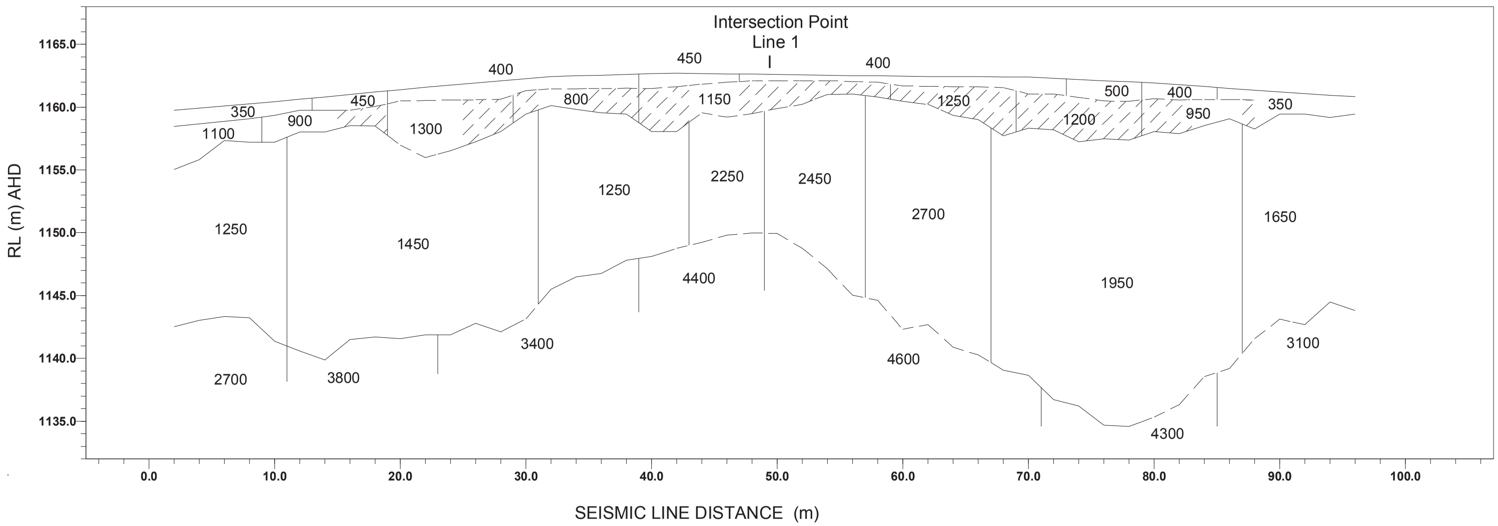
AUTHORISED :
PF

DATE :
19 Apr 2016

SMEC / GLEN INNES COUNCIL
"WATTLE VALE" SITE INVESTIGATION
SEISMIC REFRACTION SURVEY
INTERPRETED SEISMIC SECTION
LINE 1

DRAWN BY PF	FOR ETS	REPORT ET458/ 1	SCALE H 1: 800 @ A3	Figure No. 458-2

INTERPRETED SEISMIC SECTION : LINE 2 (Transverse Line - Site #3)



West (10m off fence)
Line 2 - 0m Start
E: 365216mE
N: 6711947mN
RL: 1159.6

East
Line 2 - 100m End
E: 365309mE
N: 6711913mN
RL: 1160.6

Scale H 1:400 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

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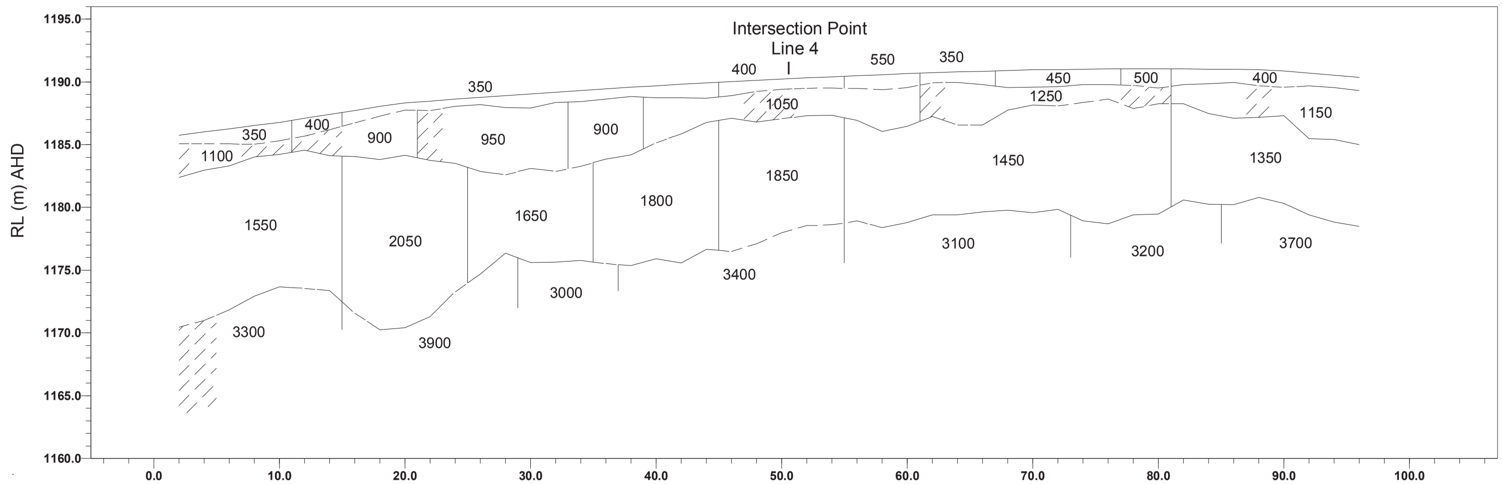
SEISMIC REFRACTION SURVEY
INTERPRETED SEISMIC SECTION
LINE 2

DRAWN BY PF FOR ETS	REPORT ET458/ 1	SCALE H 1: 400 @ A3	Figure No. 458-3

INTERPRETED SEISMIC SECTION : LINE 3 (Transverse Line - Site #1)



West (10m off fence)
Line 3 - 0m Start
E: 365047mE
N: 6711296mN
RL: 1185.5

East
Line 3 - 100m End
E: 365146mE
N: 6711260mN
RL: 1190.1

Scale H 1:400 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

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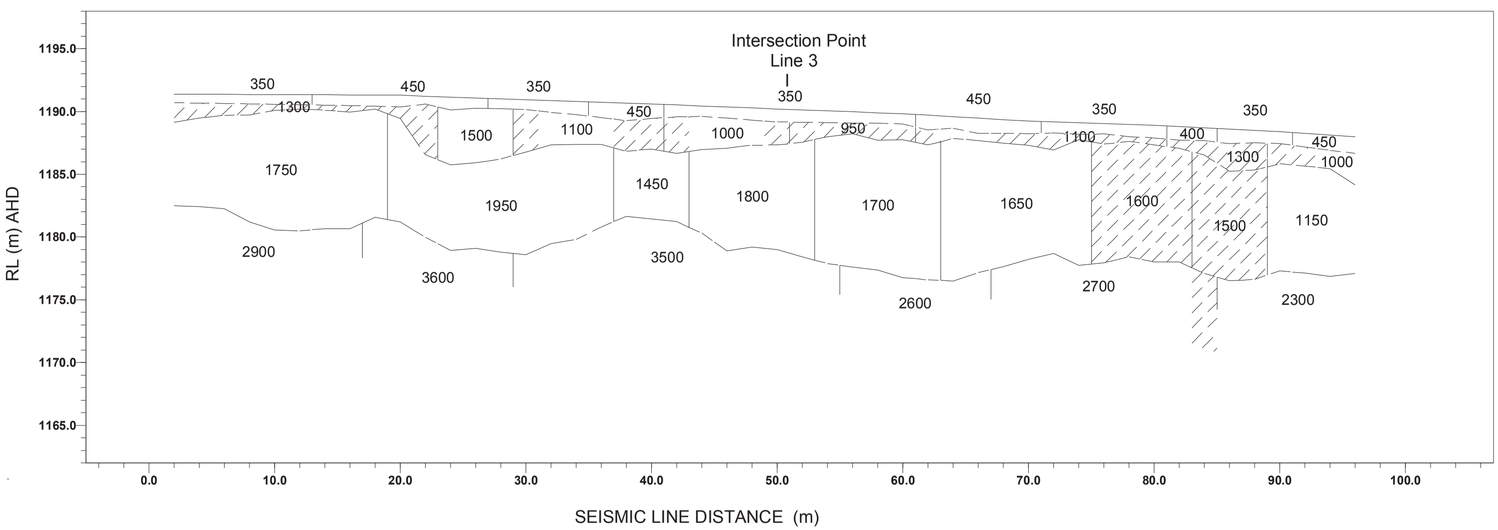
"WATTLE VALE" SITE INVESTIGATION
SEISMIC REFRACTION SURVEY
INTERPRETED SEISMIC SECTION
LINE 3

DRAWN BY PF FOR ETS	REPORT ET458/ 1	SCALE H 1: 400 @ A3	Figure No. 458-4

INTERPRETED SEISMIC SECTION : LINE 4 (Longitudinal Line - Site #1)



South
Line 4 - 0m Start
E: 365075mE
N: 6711234mN
RL: 1191.4

North
Line 4 - 100m End
E: 365114mE
N: 6711326mN
RL: 1187.7

Scale H 1:400 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

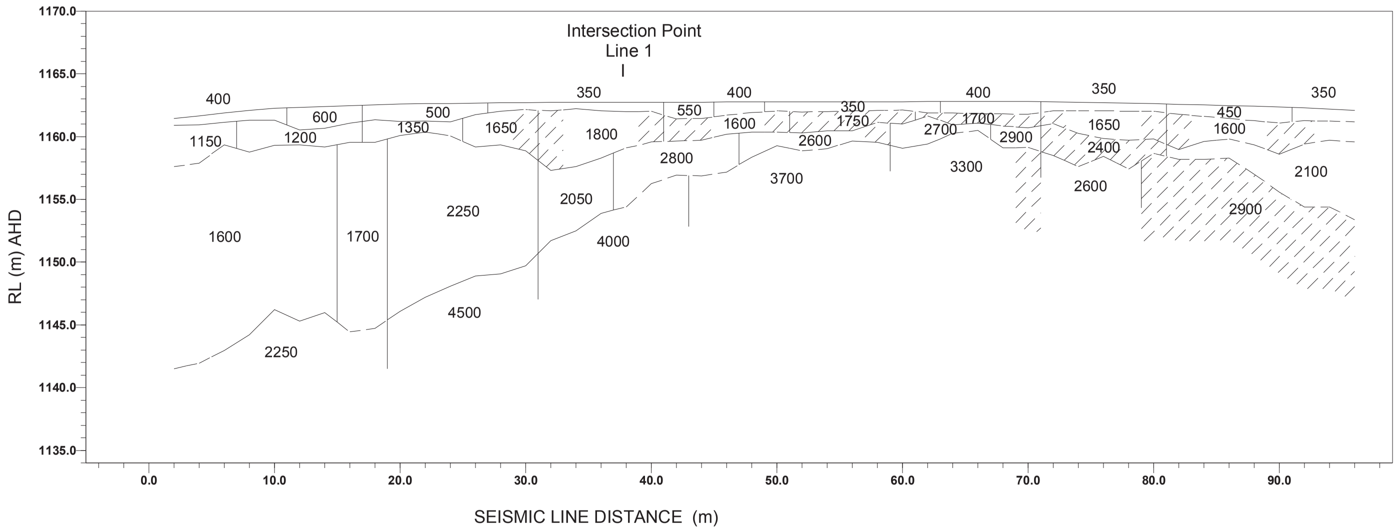
Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658			ETS
AUTHORISED : PF DATE : 19 Apr 2016	SMEC / GLEN INNES COUNCIL "WATTLE VALE" SITE INVESTIGATION SEISMIC REFRACTION SURVEY INTERPRETED SEISMIC SECTION LINE 4		
DRAWN BY PF FOR ETS	REPORT ET458/ 1	SCALE H 1: 400 @ A3	Figure No. 458-5

INTERPRETED SEISMIC SECTION : LINE 5 (Transverse Line - Site #3)



West (10m off fence)
Line 5 - 0m Start
E: 365258mE
N: 6712045mN
RL: 1161.2

East
Line 5 - 100m End
E: 365341mE
N: 6711992mN
RL: 1161.9

Scale H 1:400 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

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DATE : 19 Apr 2016

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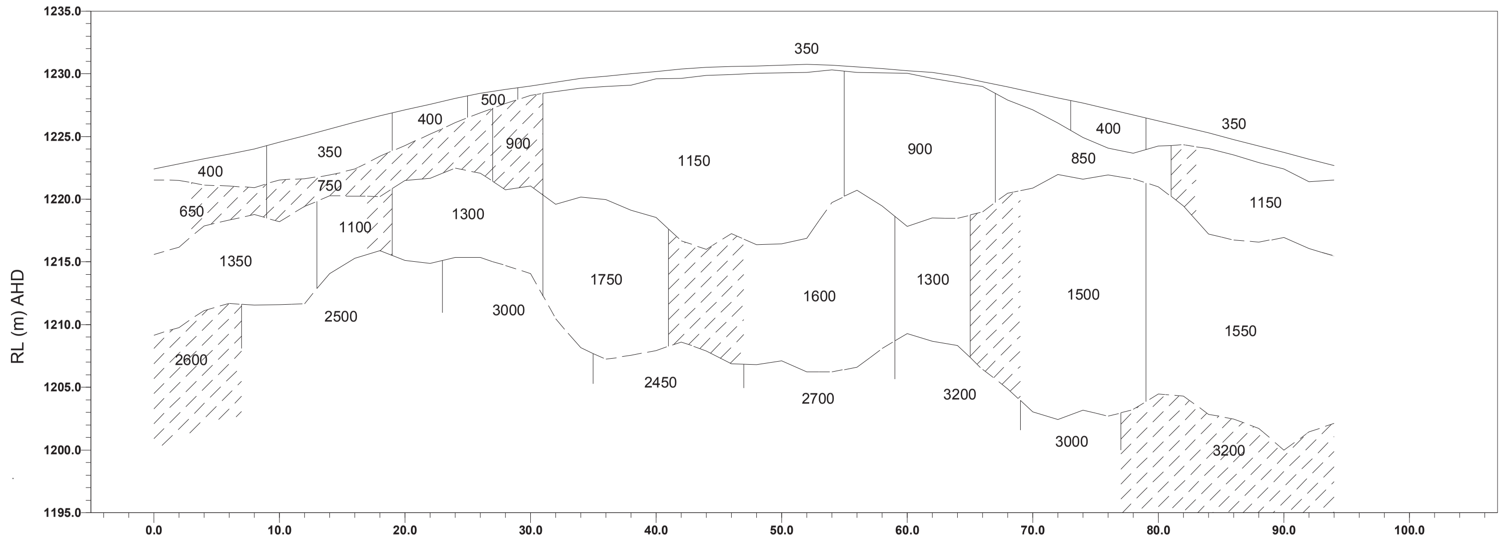
"WATTLE VALE" SITE INVESTIGATION
SEISMIC REFRACTION SURVEY
INTERPRETED SEISMIC SECTION
LINE 5

DRAWN BY PF FOR ETS	REPORT ET458/ 1	SCALE H 1: 400 @ A3	Figure No. 458-6

INTERPRETED SEISMIC SECTION : LINE 6 (Transverse Line - Site #4)



North
Line 6 - 0m Start
E: 365673mE
N: 6710815mN
RL: 1222.4

SEISMIC LINE DISTANCE (m)

South
Line 6 - 94m End
E: 365733mE
N: 6710749mN
RL: 1222.6

Scale H 1:400 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

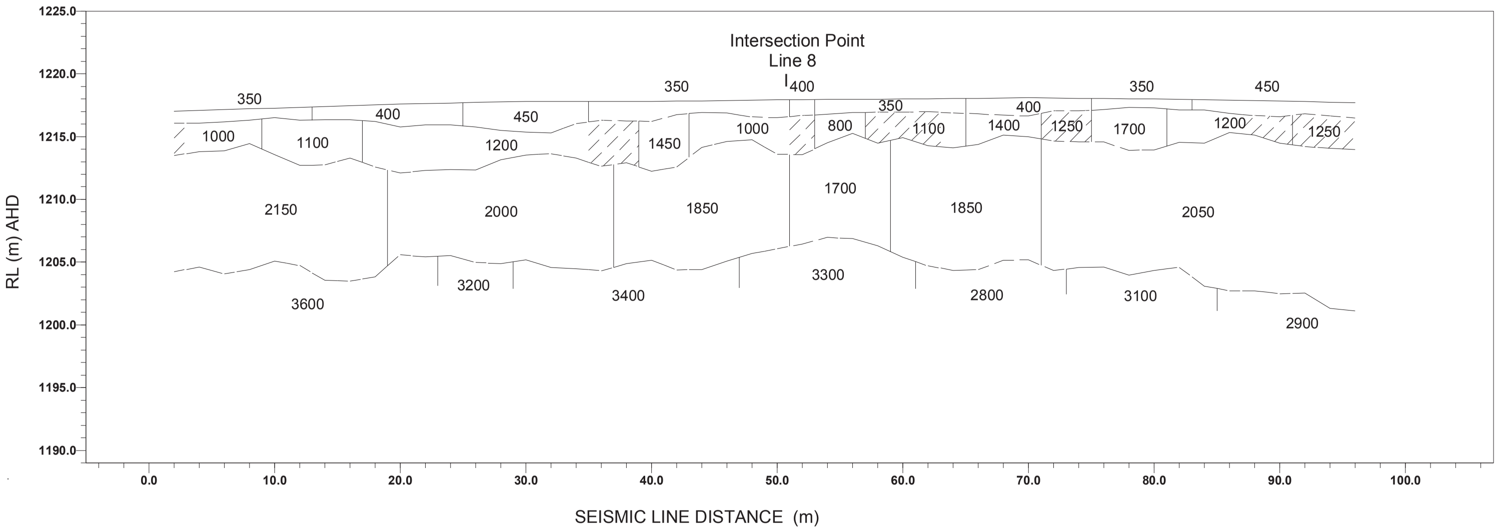
Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658			ETS
AUTHORISED : PF	SMEC / GLEN INNES COUNCIL "WATTLE VALE" SITE INVESTIGATION SEISMIC REFRACTION SURVEY INTERPRETED SEISMIC SECTION LINE 6		
DATE : 19 Apr 2016			
DRAWN BY PF FOR ETS	REPORT ET458/ 1	SCALE H 1: 400 @ A3	Figure No. 458-7

INTERPRETED SEISMIC SECTION : LINE 7 (Transverse Line - Site #4)



West
Line 7 - 0m Start
E: 365310mE
N: 6710681mN
RL: 1216.9

East
Line 7 - 100m End
E: 365407mE
N: 6710701mN
RL: 1217.6

Scale H 1:400 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

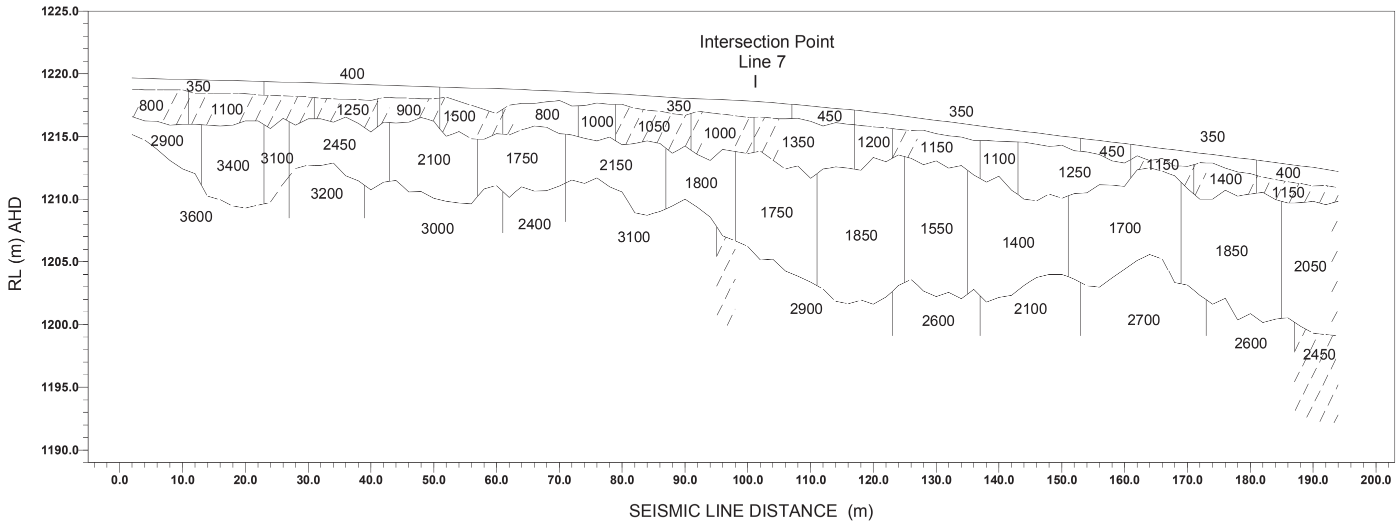
Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658			ETS
AUTHORISED : PF DATE : 19 Apr 2016	SMEC / GLEN INNES COUNCIL "WATTLE VALE" SITE INVESTIGATION SEISMIC REFRACTION SURVEY INTERPRETED SEISMIC SECTION LINE 7		
DRAWN BY PF FOR ETS	REPORT ET458/ 1	SCALE H 1: 400 @ A3	Figure No. 458-8

INTERPRETED SEISMIC SECTION : LINE 8 (Longitudinal Line - Site #4)



South
Line 8 - 0m Start
E: 365376mE
N: 6710590mN
RL: 1219.7

North
Line 8 - 200m End
E: 365341mE
N: 6710783mN
RL: 199.8

Scale H 1:800 (@ A3)
V 1:400

LEGEND

Seismic velocity (m/s) and interpreted refractor boundary based on reciprocal method minus time and time depths 1800

Seismic velocity (m/s) based on reciprocal method minus times, interpreted refractor boundary based on reciprocal method time depths (solid line) or limited data* [(2), (3)] (dashed line) 1800

Seismic velocity based on limited data* [(1), (3)] (hatched area) and the value of the hatched area is the same as the adjacement minus times velocity 1800

Seismic velocity (m/s) based on limited data* [(1), (3)] (hatched area) and interpreted refractor boundary based on limited data* [(1), (2) & (3)] (dashed line) 1800

Lateral seismic velocity boundary ....

* NB - Limited data includes harmonic mean velocity (1), interpolated time depth (2) or edited data (3)

EARTH TECHNOLOGY SOLUTIONS PTY LTD ABN 12 078 325 658	ETS
AUTHORISED : PF DATE : 19 Apr 2016	SMEC / GLEN INNES COUNCIL "WATTLE VALE" SITE INVESTIGATION SEISMIC REFRACTION SURVEY INTERPRETED SEISMIC SECTION LINE 8

DRAWN BY PF FOR ETS	REPORT ET458/ 1	SCALE H 1: 800 @ A3	Figure No. 458-9

APPENDIX A

GUIDE TO THE USE OF INTERPRETED SEISMIC SECTIONS

The results of seismic refraction surveys are presented as vertical sections beneath the line of traverse. These sections show a two-dimensional distribution of seismic velocities, which have been interpreted from first arrival travel time data obtained in the field.

The following general summary is intended to assist in the understanding of the interpreted seismic sections provided.

A1 Methods Of Interpretation

First arrival travel times obtained for individual source locations representing the arrival at individual detectors of seismic waves which have travelled through the earth via least-time paths are determined interactively from the digital seismic field records. These times are plotted against distance from the source, as travel-time curves. These times are examined, reviewed and edited as necessary.

Further quantitative seismic interpretation, aimed at providing subsurface depth and velocity information, is carried out using the intercept time or reciprocal methods as appropriate. The interpretation method applied is determined by the field procedure used, the nature of the subsurface at the site, and by the objectives of the seismic study.

The interpretation provides a simplified seismic picture of the subsurface and depends on a number of assumptions about its nature. The major assumptions are:

i) the subsurface essentially consists of a series of discrete uniform layers which may vary laterally in velocity,
ii) the boundaries between these layers are distinct. For the simpler methods of interpretation, these boundaries are also assumed to be planar, but can be highly irregular,
iii) The seismic velocities of successive layers increase with depth,
iv) Each layer is of sufficient thickness to critically refract energy, and to produce a refracted wave arrival at the surface of sufficient energy to be detected as a first arrival.

These assumptions demonstrate requirements of the interpretation procedure for ideal conditions of which all of the requirements are unlikely to be fulfilled in reality. The extent to which each assumption is valid may vary from site to site and within a site. Consequently, at all sites, interpreted seismic sections are a simplification of the actual subsurface velocity distribution. The degree of simplification depends on the interpretative method used, the amount of data available for analysis and the extent to which the basic assumptions are violated at a site.

Some violations of the basic assumptions, such as diffractions from large irregularities, and non-critical refractions, may be observed in the seismic data or may be undetectable. Consequently the interpretation process is partly subjective; other interpretations of the data are possible and may differ considerably from the interpretation presented.

The effects of common violations of the assumptions are discussed in Section A3, below. Other effects, which may be relevant to the understanding of the seismic sections, are discussed in Section A4.

It should be noted that, at a given site, these effects can occur in virtually any combination and that, as a result, even highly complex subsurface conditions may give rise to relatively simple-looking seismic sections.

A2 Precision And Accuracy Of Results

A given seismic velocity does not necessarily uniquely determine the engineering properties of an earth material, even for the one rock type. For example a medium strength rock may have the same seismic velocity as a mixture of extremely low strength rock, and boulders or zones of very high strength rock.

Moreover a relatively small proportion of extremely low strength material can dramatically lower the composite seismic velocity. For example a material composed of 50% rock or boulders with seismic velocity 4000 m/s, and 50% of material with seismic velocity 800 m/s, then the composite velocity is lowered to 1333 m/s.

Interpreted velocities are usually shown on the seismic sections to the nearest 20 or 100 m/s. Interpreted velocities, as a measure of the actual field velocities, are not regarded as being accurate to better than ± 10%, but can be independently calibrated using drilling or excavation.

Calculated layer thickness' are subject to a similar level of experimental error. This has a cumulative effect on interpreted depths to deeper interfaces. For example, the interpreted depth to the base of the first layer defined is often considered accurate to better than ± 10%, however depths to deeper layers may not be accurate to better than ± 30% (Dampney and Whiteley, 1978).

These experimental errors are inherent in the procedure and must be taken into account in any use which is made of the seismic sections e.g., in estimating the volume of material represented by each layer in a proposed excavation.

A3 Effects Of Violation Of Assumptions

A3.1 Assumption of Discrete, Uniform Layers.

The most common problems are:

i) continuous increase in velocity with depth.
ii) inhomogeneity below the scale of resolution of the survey.

The first of these occurs in many geological settings, particularly in sediments, or highly weathered sedimentary rocks. It can be allowed for in a number of ways but contributes to the uncertainty in depth calculations based on constant layer velocity. Often the seismic sections show the “average” velocity of the layer.

For the second type of problem, under ideal conditions a refraction study can resolve features as small as 1.5-2 times the geophone spacing. In general, however, the practical limit of resolution is 2-3 times this spacing although the presence of inhomogeneity may be observable from the travel time curves, without more detailed interpretation being possible.

Calculated seismic velocities are averages which represent the bulk properties of the interpreted layers. It is possible for this averaging to conceal local variations in velocity on a scale up to at least twice the geophone spacing.

A3.2 Assumptions of Distinct Boundaries

Real geological boundaries, especially those related to weathering, are often gradational and/or irregular. The seismic method inevitably disguises gradation and smoothes irregularity. The importance of this varies from site to site, but it is common for interpreted seismic boundaries to appear at an intermediate level somewhere between the limits of gradation. For example, if there is an irregular boundary between fresh and highly weathered rock, the interpreted boundary frequently appears at a level some metres below the highest points at which fresh rock is found.

A3.3 Assumption of Increasing Velocity with Depth

This assumption may be violated for a number of different reasons and such violations (termed velocity reversals, or velocity inversions) often cannot be detected from the travel time data alone. It may be possible (in some, but not all cases) to infer them from the geological setting, from borehole information, or from surface-to-borehole seismic. If the inversion layers do not persist laterally their effect may also be observable on the travel-time data.

In general, it is not possible to allow for a velocity inversion in the interpretation unless there is an independent means of estimating both the thickness and the velocity of the layer. If an undetected velocity reversal is present, all calculated depths below the reversal will be in error. In particular, depths to underlying high velocity layers may be significantly over-estimated. Areas where strong layers overlay weaker layers, for example, a basalt flow overlying sediments or weathered rock, or cementation of surface layers, are sites where these problems sometimes occur.

A3.4 Assumption of Detectability

Two main types of violation occur:

i) When a layer is too thin to transmit the seismic wave.
ii) When a layer transmits the wave but is not detected because waves from a deeper, higher velocity layer reach the detector first.

The first type of problem may occur in many geological settings and means that relatively thin, higher velocity layers may occur undetected within lower velocity materials. “Thin” in this context is defined in terms of seismic detectability and can imply thickness of the order of 0.1-0.2m. The effect cannot be detected from the surface seismic refraction data alone, but may be inferred from borehole or ripping information, surface mapping or surface-to-borehole seismic. If such a layer were thick enough to be detected, it would form a velocity reversal (see Section A3.3).

The second type of problem (termed a hidden layer or blind zone) may be inferred from the geological setting, borehole data or sometimes from the seismic refraction data. If it is not detected, it also results in erroneous depth calculations in the interpreted section; normally the calculated depth to deeper interfaces is underestimated. In theory, between every pair of layers there could be a hidden layer (or blind zone), whose maximum thickness may be calculated for a range of intermediate velocities.

A4 Other Factors

Other common factors may lead to differences between the surface seismic refraction model and reality. While not strictly due to assumptions made in interpretation, they should still be taken into account, if the site conditions dictate, in any further use of the interpreted sections. These factors are:

i) Three-dimensional effects
ii) Effect of water
iii) Anisotropy

A4.1 Three-dimensional effects

The interpreted sections are two-dimensional representations and only apply to a narrow zone below the line of traverse typically 2 - 4m either side of the seismic line. However, the real subsurface is three-dimensional and as a result significant lateral variations in conditions can occur without being detected, even within a short distance to the side of a traverse. If seismic signals originating from such features are obtained, they may result in the interpreted sections containing features, which are non-existent, displaced from their true position or shown with incorrect velocities. This problem is most common in sites with irregular topography, boulders and highly irregular rock masses.

In some cases three-dimensional effects may be observed by using cross seismic spreads at right angles to the main profile, or additional parallel seismic lines, or from other information.

A4.2 Effect of Water

The presence of water can greatly increase the field velocity of materials which have low velocities in the dry condition. The effect is most pronounced in soils or unconsolidated materials and is due to the difference in seismic velocity between air and water (340 m/s and 1470 m/s, respectively). It may however occur to a significant degree in materials with dry velocities as high as 2000-2500m/s.

Less frequently, it is possible for water saturation to cause a decrease in field velocity, most commonly in low velocity materials where highly expansive clay minerals are present and the material is unconfined. In the marine environment the presence of gas derived generally from organic matter, in otherwise water-saturated sediments can actually lower velocities below that of water.