Appendix B

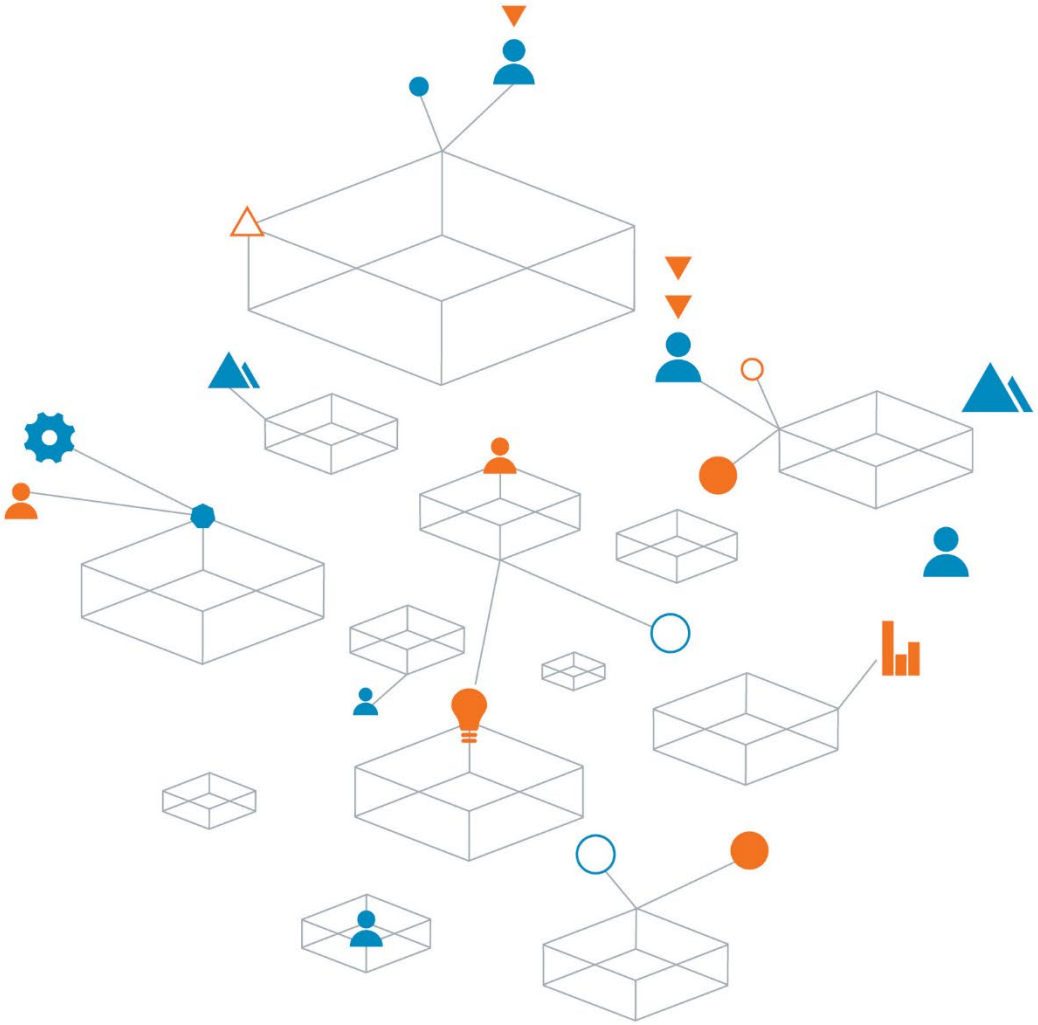
Geotechnical Assessment

Rolleston Industrial Developments Ltd
1491 Springs Road, Lincoln

773-CHCGE280252

Geotechnical Assessment Report – Rev 1

20 October 2020



Trust is the cornerstone of all our projects

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20 October 2020

Our ref: 773-CHCGE280252

Rolleston Industrial Developments Ltd
ASB House, 166 Cashel Street
Christchurch Central

Attention: Tim Carter / Bruce Van Duyn

Executive Summary: 1491 Springs Road, Lincoln – Geotechnical Assessment to support a Plan Change application

Rolleston Industrial Developments Ltd has engaged Coffey Services (NZ) Limited to carry out a geotechnical investigation and assessment of suitability for the proposed Plan Change and future subdivision at 1491 Springs Road, Lincoln, Canterbury. The purpose of this report is to support a Plan Change application for the construction of approximately 2,000 new residential Lots at the site.

The site investigations and preliminary liquefaction assessment indicates that the site is predominantly TC1-like. Other geotechnical hazards (erosion, slippage and inundation) are considered low risk with appropriate future engineering design.

Our assessment has considered the items required by Section 106 of the RMA and in our opinion the site is considered geotechnically suitable for Plan Change and future subdivision. Further investigations and design will be carried out at the subdivision consent stage.

If you have any queries, please contact he undersigned.

For and on behalf of Coffey

Chris Thompson
BSc (Tech)
Associate Engineering Geologist

1491 Springs Road, Lincoln

Prepared for
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20 October 2020

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Quality information

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V0	GAR	15/10/2020	CT	RB	CT

Distribution

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1. Introduction

Rolleston Industrial Developments Ltd has engaged Coffey Services (NZ) Limited to carry out a geotechnical investigation and assessment of suitability for a proposed Plan Change and future subdivision at 1491 Springs Road, Lincoln, Canterbury. The purpose of this report is to support a Plan Change application for the construction of approximately 2,000 new residential Lots at the site.

Our assessment has considered the items required by Section 106 of the RMA. In our opinion the site is considered geotechnically suitable for subdivision subject to further investigation and design at the subdivision consent stage.

2. Scope

An investigation methodology for the 178 Ha site was developed and carried out by Coffey, as outlined below:

- Review of previous geotechnical investigations including previous work on the site and surrounding area.
- Site walkover to assess geotechnical hazards.
- Completion of 20 piezocone penetration tests (CPTs). The CPT tests were the primary investigation tool used to develop the preliminary ground model at the site.
- Three multi-channel analysis of surface waves (MASW) geophysical investigation lines with a total length of 2.6km were measured to supplement the CPTs and provide continuous profiles of information about soils below CPT refusal depths.
- Assessment of the geotechnical hazards at the site per Section 106 of the RMA.
- Geotechnical analyses and reporting.

Coffey have considered the following in the preparation of this report:

- Existing geotechnical investigation data available from the New Zealand Geotechnical Database (NZGD).
- New geotechnical investigation data.
- Project correspondence with the wider Plan Change consultants engaged by Rolleston Industrial Developments Ltd.

Reference has also been made to the MBIE Guidance Part D: Subdivisions, to confirm that the requirements outlined in these documents have been incorporated in this report.

3. Proposed development

The proposed Plan Change area comprises a series of land parcels totalling 178 Ha located to the south of Lincoln, bordering the existing Te Whariki and Verdeco Park subdivisions. The overall site has a gentle downslope east from Springs Road towards the “L II” River. It also slopes gently down to the west from a high point just west of Springs Road.

There are a number of springs and associated drains / waterways located within the Plan Change area that will be incorporated into the overall development plan. The site is predominantly used for grazing and some cropping. To the west of Springs Road, a small area has been used as a borrow area for sourcing gravel and was backfilled in the past 5 to 10 years.

4. Site investigation

The location of the geotechnical investigations carried out on the site to develop the ground model, along with the location of the MASW lines, are provided in Figure 1 (in Appendix A). The CPT results are summarised below. Investigation results are presented in Appendix B.

Table 1: CPT investigation summary

Reference	Depth of test (metres below ground level) – 1 DP	Depth to groundwater (as measured in CPT hole)	Termination criteria
CPT 01	7.5	2.78	Effective refusal
CPT 02	5.21	1.96	Effective refusal
CPT 03	5.83	2.17	Effective refusal
CPT 04	6.24	1.25	Effective refusal
CPT 05	4.37	1.37	Effective refusal
CPT 06	12.02	1.26	Effective refusal
CPT 07	4.15	0.90	Effective refusal
CPT 08	5.24	1.50	Effective refusal
CPT 09	4.94	1.52	Effective refusal
CPT 10	6.34	1.48	Effective refusal
CPT 11	5.91	2.58	Effective refusal
CPT 12	6.65	1.75	Effective refusal
CPT 13	7.82	1.50	Effective refusal
CPT 14	4.36	0.61	Effective refusal
CPT 15	4.91	0.46	Effective refusal
CPT 16	2.28	Not encountered	Effective refusal
CPT 17	5.60	2.50	Effective refusal
CPT 18	2.22	Not encountered	Effective refusal
CPT 19	7.62	3.40	Effective refusal
CPT 20	1.53	Not encountered	Effective refusal

Note: CPT20 was carried out through a previously remediated fill area so is not indicative of the general area.

4.1. MASW profiles results

The MASW geophysical survey was measured in three profiles totalling 2.6 km in length, two east-west across the site and one north-south as shown in Figure 1 (Appendix A) and in Figure 1 of the geophysics report (Appendix C). The MASW profiles are considered to be good data that captures the ground profile and soil conditions below the generally shallow depth of refusal of the CPTs above. The MASW profiles show that non-liquefying gravels are consistently present over the site below the weaker upper soil layers whose properties have been measured in more detail by the CPTs, and that these gravels increase in density with depth.

5. Site performance

5.1. Ground motion

The site is not in an area mapped for ground damage effects as part of the Canterbury Earthquake Sequence response, however the nearby Lincoln University strong motion sensor recorded the following peak ground accelerations (PGA):

- 4 September 2010: 0.437g
- 22 February 2011: 0.12g
- Later 2011 earthquakes: <0.1g

Based on the above, we consider that the site was "sufficiently tested" to the serviceability limit state (SLS) level of earthquake demand during the 4 September 2010 earthquake of the Canterbury earthquake sequence (CES) using the MBIE[1] and Bradley & Hughes (2012)[2] procedures.

An assessment has been made regarding predicted earthquake-induced deformation that may occur in a design earthquake based on geological setting, site terrain, and the level of "test" previously experienced. It is considered that:

- An SLS earthquake event is likely to cause less damage to that experienced in the 4 September 2010 earthquake and to be similar to the February 2011 earthquake.
- Under ultimate limit state (ULS) conditions, the nature of land and building damage is likely to be similar to that already experienced in the 4 September 2010 earthquake of the CES.

6. Ground model

6.1. Geology

The geological map[3] of the area indicates that the site is near the geological boundary of "Grey to brown alluvium, comprising silty sub-angular gravel and sand forming alluvial fans (Q1a)" (also known as colluvium) and "Grey river alluvium, comprising gravel, sand and silt, in active floodplains (Q1a)." of the Springston Formation.

6.2. Groundwater

Based on the observed groundwater levels recorded from the CPTs, the groundwater appears to be shallower in the eastern portions of the site and gradually deepens to the west. Conservatively, for the initial liquefaction assessment, we have used a groundwater level of 1.0mbgl for the eastern portion and 2.0m to 2.5mbgl for the western portion of the site. This can be refined later.

[1] Ministry of Business, Innovation and Employment (MBIE), December 2012: Repairing and rebuilding houses affected by the Canterbury earthquakes
[2] Bradley & Hughes (2012) Conditional Peak Ground Accelerations in the Canterbury Earthquakes for Conventional Liquefaction Assessment. Report for DBH (MBIE), April 2012.
[3] Forsyth, P.J.; Barrell, D.J.A.; Jongens, R. (compilers) 2008: Geology of the Christchurch area: scale 1:250,000. Lower Hutt: GNS Science. Institute of Geological & Nuclear Sciences 1:250,000 geological map 16. 67 p. + 1 folded map

6.3. Investigation findings

Twenty CPTs and the MASW geophysical investigation have been used to develop the ground model for the 1491 Springs Road subdivision. A summary of the ground model is provided below:

Table 2: Ground profile

Description		Strength/ consistency	Thickness (m)	Depth to top of layer (mbgl)
Springston Formation	Sandy silt and organic silt (topsoil)		0.3 to 0.4	0.0
	Interbedded alluvium: Silt, sandy silt and silty sand	Soft to very stiff	West of Springs Road – 1.0 to 2.2 East of Springs Road – 3.5 to 5.5	0.3 to 0.4
	Interbedded alluvium: typically sand and gravel deposits with some layers of silt, sandy silt and silty sand	Medium dense to dense, non-liquefiable	>20m	West of Springs Road – 1.0 to 2.2 East of Springs Road – 3.5 to 5.5

The above ground profile is simplified as an illustration; however, the actual ground profile includes a highly interbedded (interfingered) layering of silty alluvium and sandy / gravel alluvium. These layers have different geotechnical properties (strength) and are present in various thicknesses across the site, as shown in the CPT investigations. The eastern edge of the site has potentially organic deposits in the low-lying area, however, this will be further investigated during the subdivision consent stage once the overall development plan is confirmed.

The MASW geophysical investigation has confirmed that relatively dense non-liquefiable deposits are present below the termination depth of the CPTs conducted. The assessment of these deposits as being non-liquefiable is based on the shear wave velocities recorded being greater than 200m/s and increasing with depth.

6.4. Site sub-soil class

In accordance with NZS1170.5, Section 3.1.3, a subsoil classification of “Class D – Deep or soft soil sites” can be assumed for the site.

7. Geotechnical hazard assessment

7.1. Erosion

The site has relatively flat topography and is bounded by newly developed residential areas as well as grassed paddock land. Provided appropriate stormwater systems are installed as part of the development, there will be few viable sources of erosion at this site.

7.2. Falling debris

As there are no slopes or exposed hills or rock faces surrounding the site, there are no sources of falling debris at the site, or for the surrounding area.

7.3. Subsidence

7.3.1. Liquefaction induced settlement

Soils that are usually considered to be liquefiable comprise saturated geologically young (i.e. Holocene and late Pleistocene) loose sands and silts. With this in mind, we consider that the interbedded silt / sandy silt / silty sand overbank deposits of the Springston Formation may be susceptible to liquefaction and that a triggering analysis will determine which soil layers will liquefy when subjected to the SLS and ULS earthquake demands.

SLS and ULS design earthquake scenarios are assessed using the parameters provided by the MBIE Guidance for an Importance Level 2 (IL2) structure and a Class D subsoil site. The earthquake parameters adopted for design and for the liquefaction analysis are presented in Table 3.

Table 3: Earthquake scenario and parameters for analysis

Earthquake scenario	Moment magnitude (M_w)	α_{max} (g)
SLS	7.5	0.13
	6.0	0.19
ULS	7.5	0.35

The liquefaction triggering analysis was carried out for the CPTs shown on the site plan (Appendix A) using the Boulanger and Idriss (2014) method[4] and proprietary liquefaction assessment software[5], in accordance with the updates to the MBIE Guidance[1] (Issue 7 October 2014).

For a more accurate representation of the stratified soils in the CPT profiles, the auto transition layer detection (ATL) function was selected in the Geologismiki software. This function addresses the disparity between friction and end tip recordings of a CPT where the tip recordings are influenced by a softer layer above or beneath a harder / denser layer.

The liquefaction triggering analyses show that under SLS and ULS conditions, some of the interbedded silt / sandy silt / silty sand overbank deposits encountered at each CPT location are vulnerable to liquefaction whereas the clay-like soils in the eastern portion are considered unlikely to liquefy.

7.3.2. Free-field settlements

The type of settlement that is most commonly estimated when liquefaction analysis is conducted (refer to Section 6.3) is referred to as the *free-field settlement*. Free-field settlement is the component of land settlement that does not take account of foundation influences (e.g. loads and stiffness), or the effects of ground loss, lateral spread, strength degradation, sand ejecta and ground cracks.

According to the MBIE Guidance, an “Index Value” for categorising future expected land performance can be assigned by analysing the upper 10m of the soil profile. The rationale for this is that liquefaction in the upper 10m of the profile is known to be most manifested at the ground surface. Where CPTs refused before 10m, we have assigned Technical Categories based on the results of the MASW confirming dense non-liquefiable deposits below termination depths of the CPTs.

The estimated free-field settlement values and the correlated residential foundation Technical Category, as defined by Table 3.1 of the MBIE Guidance, are given in Table 4.

[4] Boulanger, R.W., Idriss, I.M., CPT and SPT liquefaction triggering procedures, Report No. UCD/CGM-14/01, April 2014, Centre for Geotechnical Modelling, Department of Civil and Environmental Engineering at the University of California, Davis, California
[5] Geologismiki Geotechnical Software, CLiq v.3.0.3.2 – CPT Liquefaction Assessment Software

Table 4: Estimated "free-field" post-liquefaction ground surface settlements and Technical Category[6]

CPT Location	Termination Depth (mbgl)	Free-field settlements to refusal depth (mm)		MBIE Technical Category
		SLS	ULS	TC
CPT01	7.5	~15	~25	TC1
CPT02	5.21	~10	~25	TC1
CPT03	5.83	<5	<10	TC1
CPT04	6.24	<15	~20	TC1
CPT05	4.37	<10	~20	TC1
CPT06	12.02	~15	~25	TC1
CPT07	4.15	<5	~10	TC1
CPT08	5.24	<15	~20	TC1
CPT09	4.94	<10	~15	TC1
CPT10	6.34	<10	~25	TC1
CPT11	5.91	~15	~40	TC2
CPT12	6.65	~15	~35	TC2
CPT13	7.82	~25	~50	TC2
CPT14	4.36	<10	~15	TC1
CPT15	4.91	<5	<5	TC1
CPT16	2.28	<5	~25	TC1
CPT17	5.60	<10	~25	TC1
CPT18	2.22	<5	~15	TC1
CPT19	7.62	~15	~25	TC1
CPT20	1.53	N/A	N/A	Not assessed

The CPT analyses show that the site is predominantly TC1-like with small areas that contain TC2-like ground. Once a groundwater monitoring programme has been carried out, we consider that an updated liquefaction analysis will generally reduce the predicted free-field settlements for the currently TC2-like locations as the groundwater measured in the CPT holes is generally deeper than that conservatively assumed for these analyses.

7.3.3. Static settlement

The presence of potentially organic soils in the low-lying eastern portion of the site increases the risk of static settlement in this area. It is likely that this area may be used for stormwater detention basins and as a result of this usage, residential buildings are unlikely. This risk will be assessed further once the overall development plan is confirmed. However, we do not anticipate this limiting development in the area with appropriate geotechnical design and construction.

[6] It should be noted that these settlement estimates only account for the free-field component of the expected settlement. Actual total settlements under SLS or ULS earthquake loading may be greater.

7.4. Slippage

We have not observed any sources of land instability on the site and due to the flat site topography, we consider the risk of slope failure to be very low. The appropriate design of batter slopes near waterways will mitigate this risk further.

7.5. Inundation

In relation to stormwater inundation, we recommend that drainage design and management be addressed by specialist consultants as it is beyond the scope of this report. We expect that with appropriate stormwater and flood control systems, the risk of inundation will be low.

8. Conclusions

The overall site is well covered with CPT probes and MASW profile investigations. Based on the on-site testing carried out to date, the majority of the site is TC1-like with some minor pockets of TC2-like performance.

We consider that the site is suitable for development subject to further investigation and design at the subdivision consent stage.

It is likely that additional geotechnical investigation will be required to refine the technical categories for the proposed Lots once a subdivision plan has been further developed. We also recommend that a groundwater monitoring programme is implemented to allow for more accurate liquefaction and ground settlement analyses.

9. Limitations

This report has been prepared solely for the use of our client, Rolleston Industrial Developments Ltd, their professional advisers and Selwyn District Council (SDC) in relation to the specific project described herein. No liability is accepted in respect of its use for any other purpose or by any other person or entity.

It is recommended that all other parties seek professional geotechnical advice to satisfy themselves as to its on-going suitability for their intended use.

As subsurface information has been obtained from discrete investigation locations, which by their nature only provide information about a relatively small volume of subsoils, there may be special conditions pertaining to this site which have not been disclosed by the investigation and which have not been taken into account in the report. If variations in the subsoils occur from those described or assumed to exist, then the matter should be referred to us immediately.

Please also refer to the enclosed *Important Information about Your Coffey Report*.

10. Closure

If you have queries or require further clarification regarding aspects of this report, please contact the undersigned.

For and on behalf of Coffey

Prepared by

Chris Thompson
BSc (Tech)
Associate Engineering Geologist

Reviewed by

Richmond Beetham
BSc MSc Eng BE CMEngNZ CPEng PEngGeol
Principal Geotechnical Engineer

Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

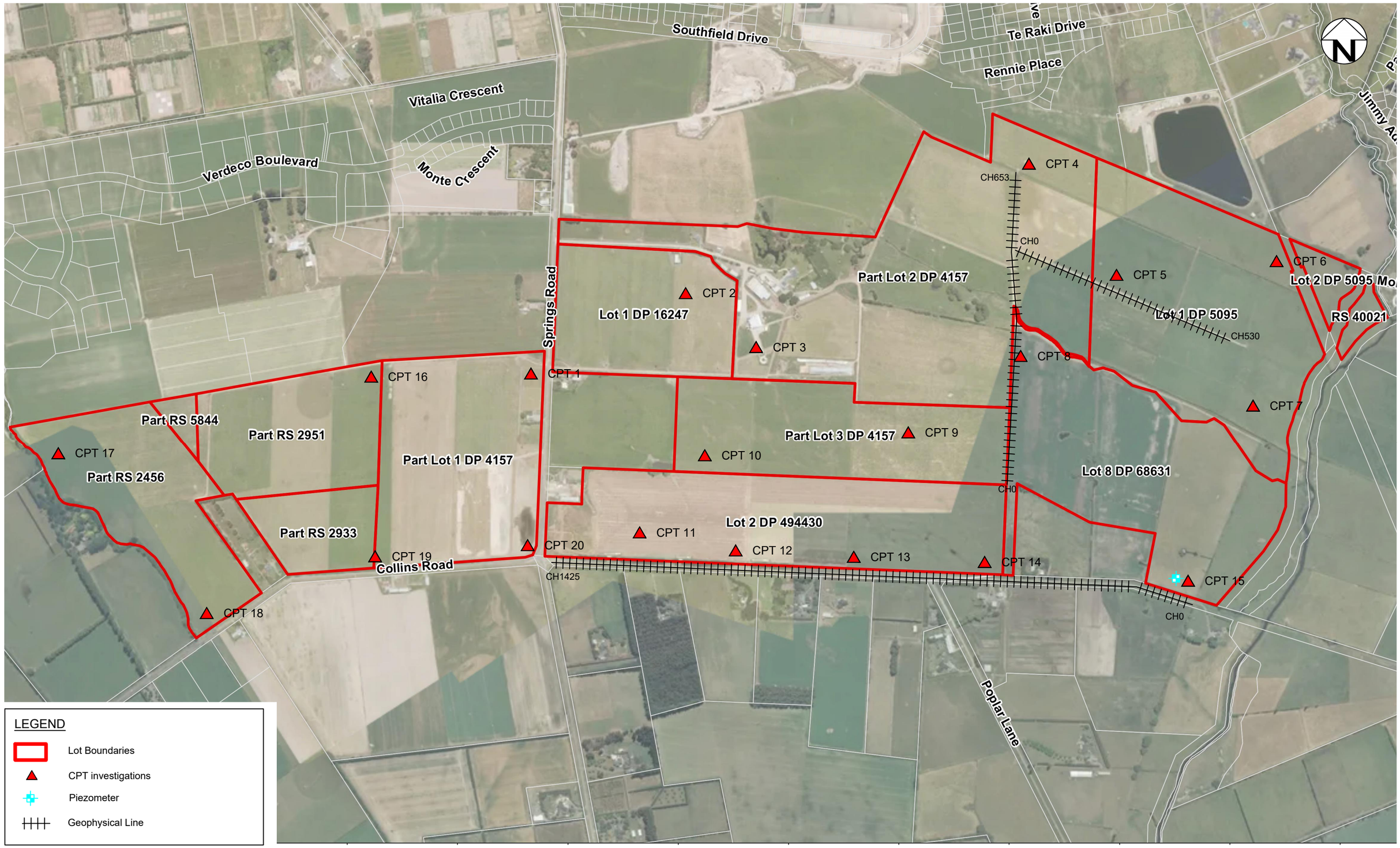
Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

Appendix A - Site Plan



LEGEND

- Lot Boundaries
- CPT investigations
- Piezometer
- Geophysical Line

revision	no.	description	drawn	approved	date
	A	ORIGINAL ISSUE	LM	CT	13/10/2020

100 0 100 200 300 400

Scale (metres) 1:8000

drawn	LM
approved	CT
date	13/10/2020
scale	1:8000
original size	A3

coffey
A TETRA TECH COMPANY

client:	Carter Group Ltd
project:	1491 Springs Road Lincoln, Christchurch
title:	Site Investigation Plan
project no:	773-CHCGE280252
figure no:	Figure1
rev:	A

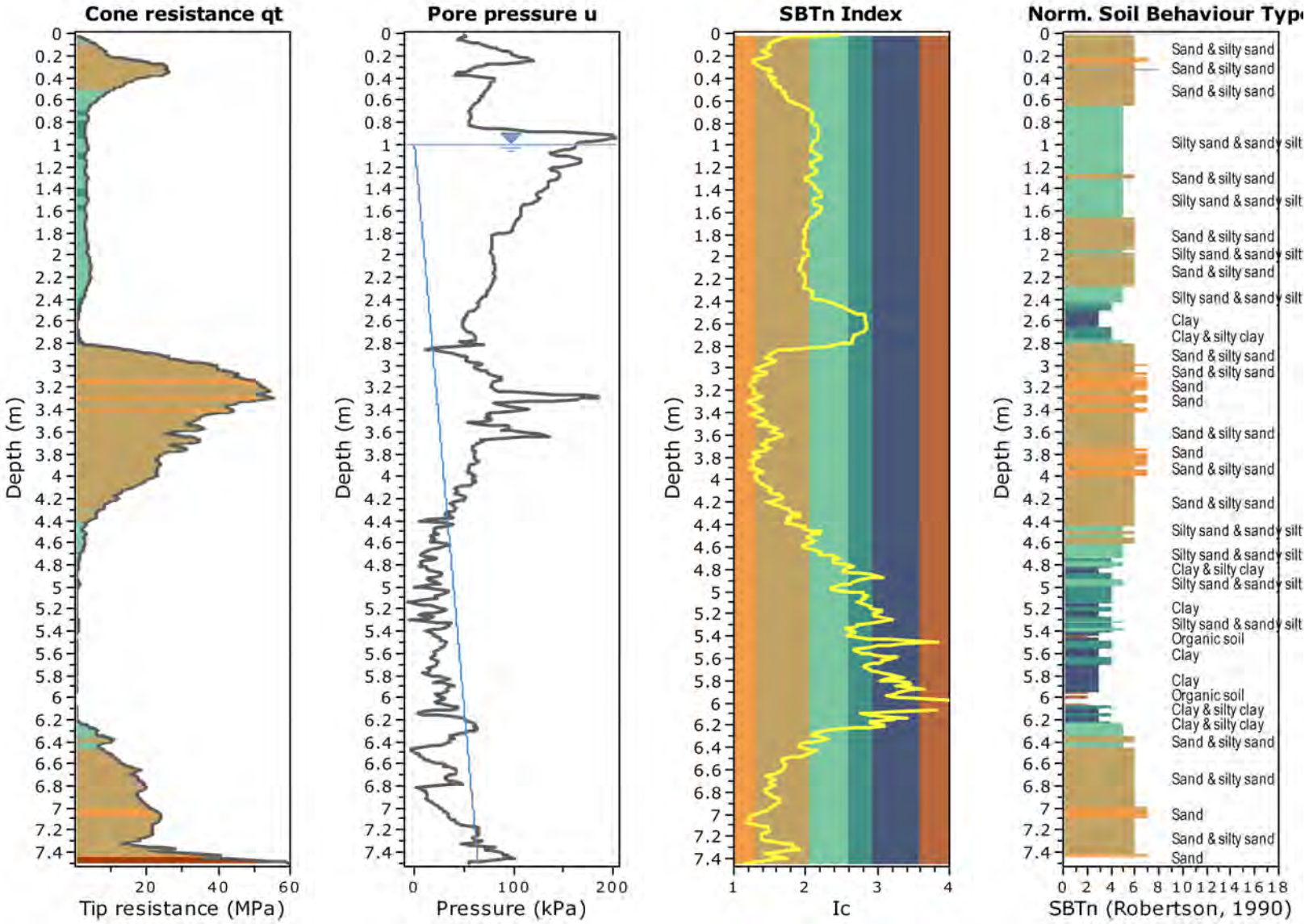
PLOT DATE: 13/10/2020 4:46:28 PM DWG FILE: F:\GENZ\PROJECTS\03 TETRALINX PROJECTS\280000 - 289999\280252 - 1491 SPRINGS ROAD, LINCOLN\06 DRAWINGS\CNZ DRAWINGS\SITE PLAN.DWG

Appendix B - CPT traces

Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 1
Total depth: 7.50 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

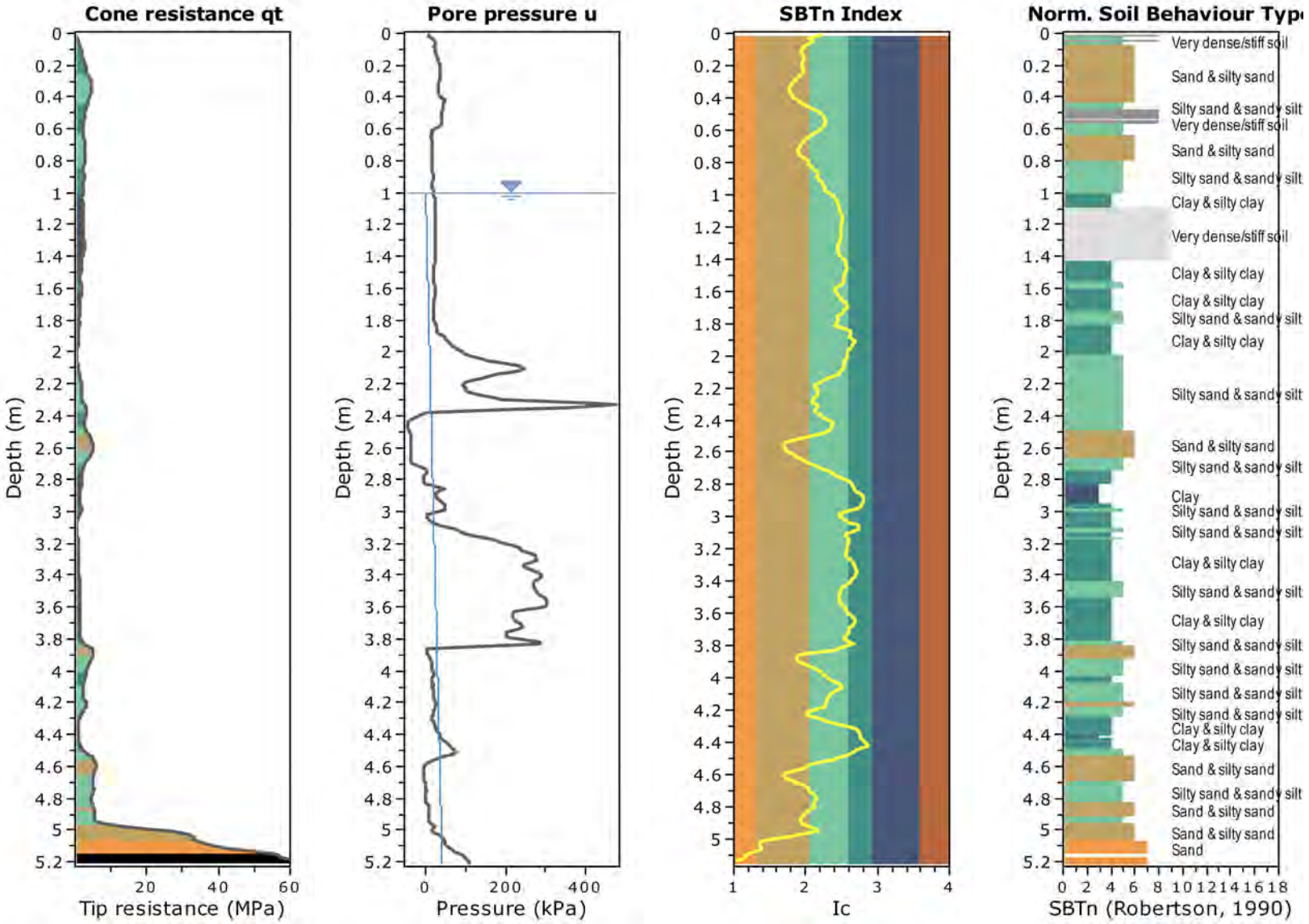
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 2
Total depth: 5.21 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

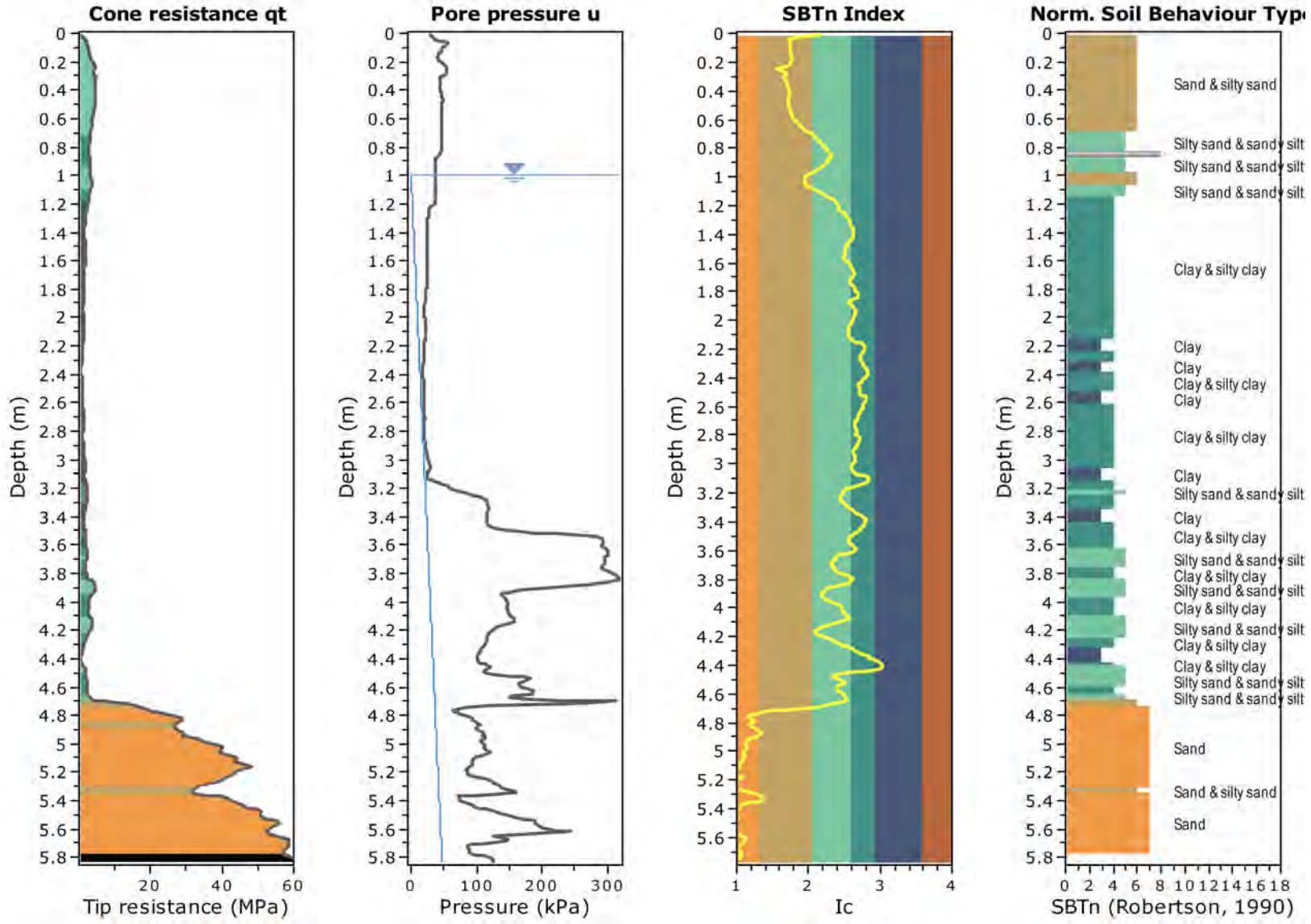
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 3
Total depth: 5.83 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



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1/254 Montreal Street
Christchurch 8013
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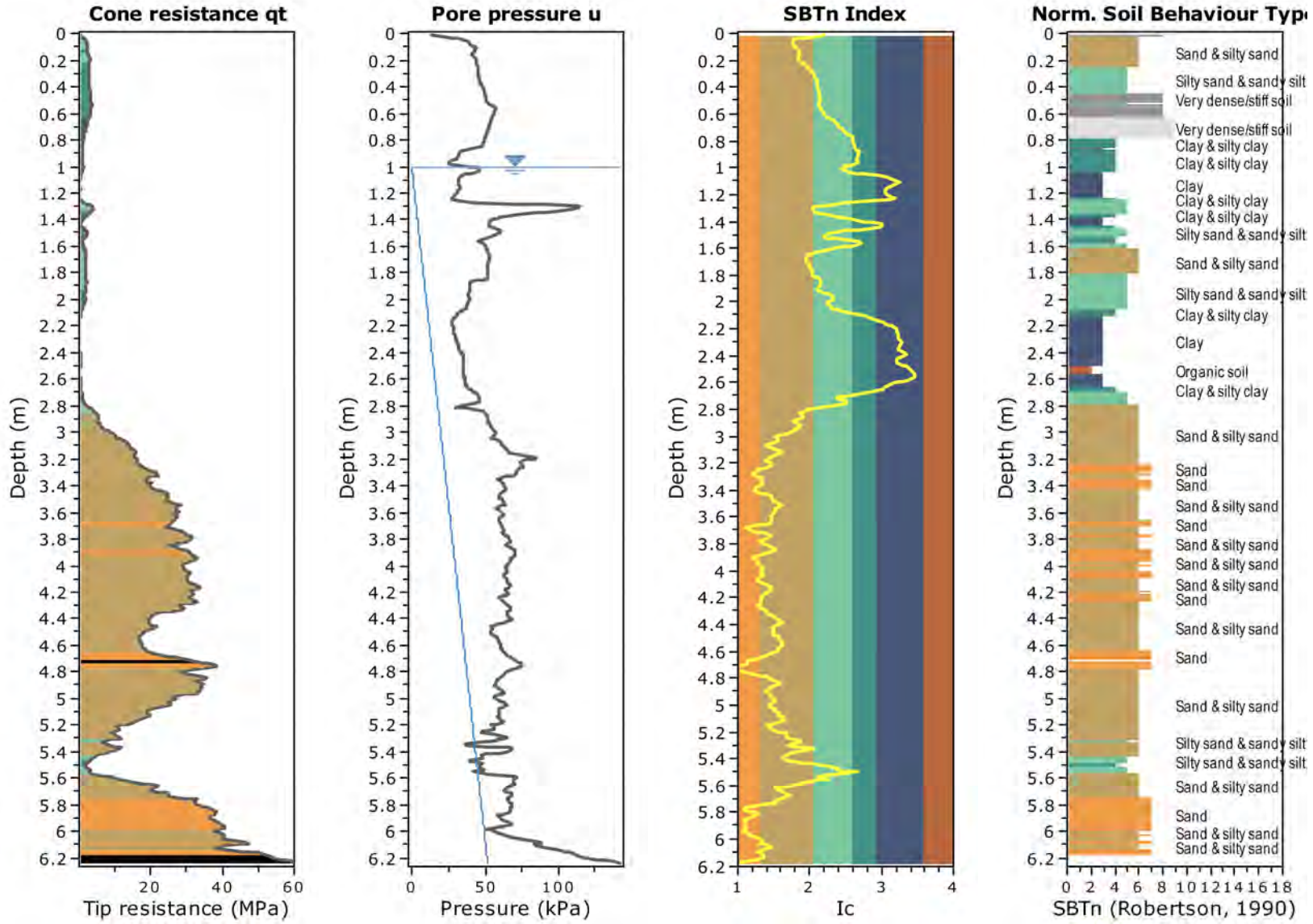
CPT: CPT 4
Total depth: 6.24 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

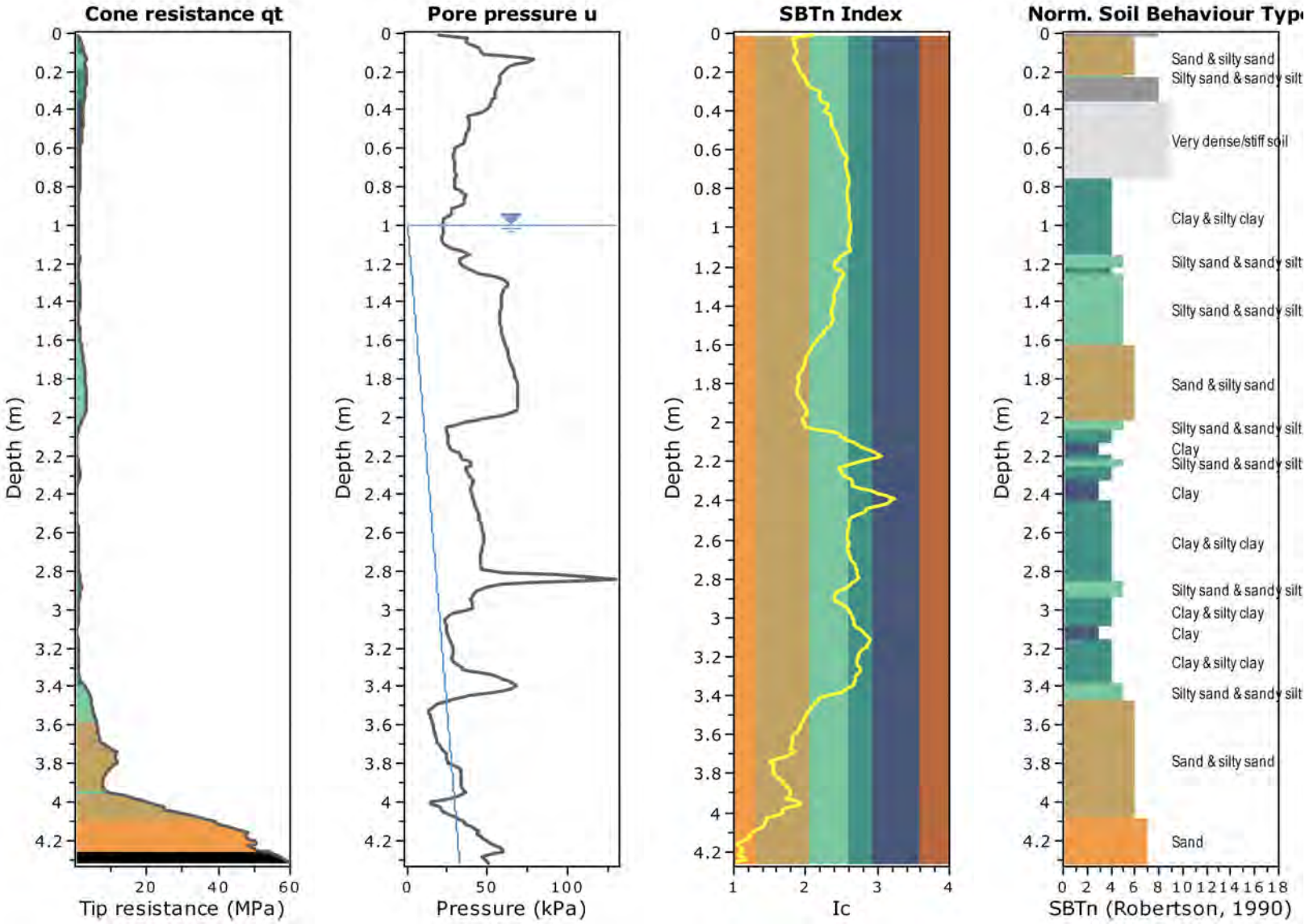
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 5
Total depth: 4.32 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

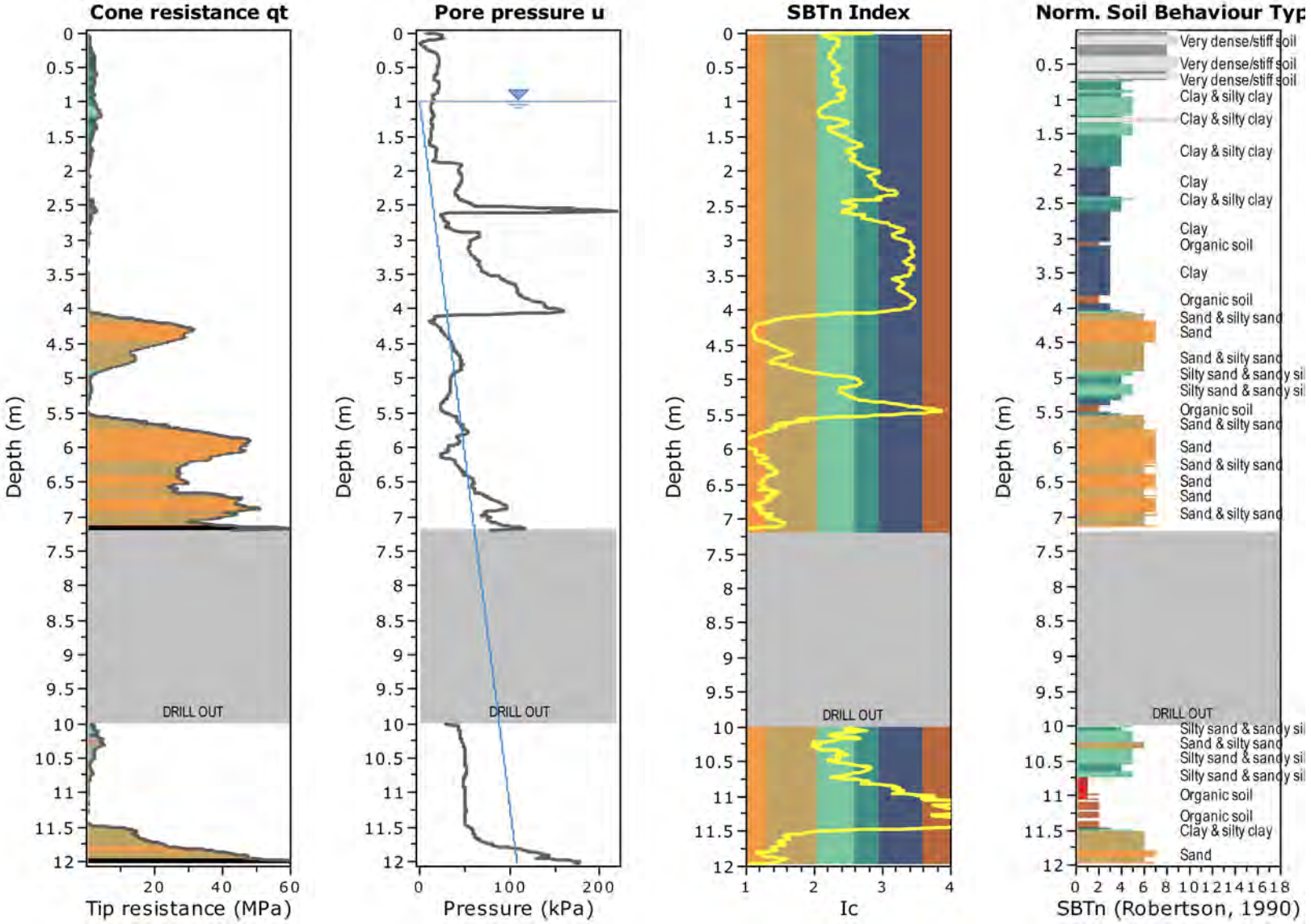
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 6
Total depth: 12.02 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

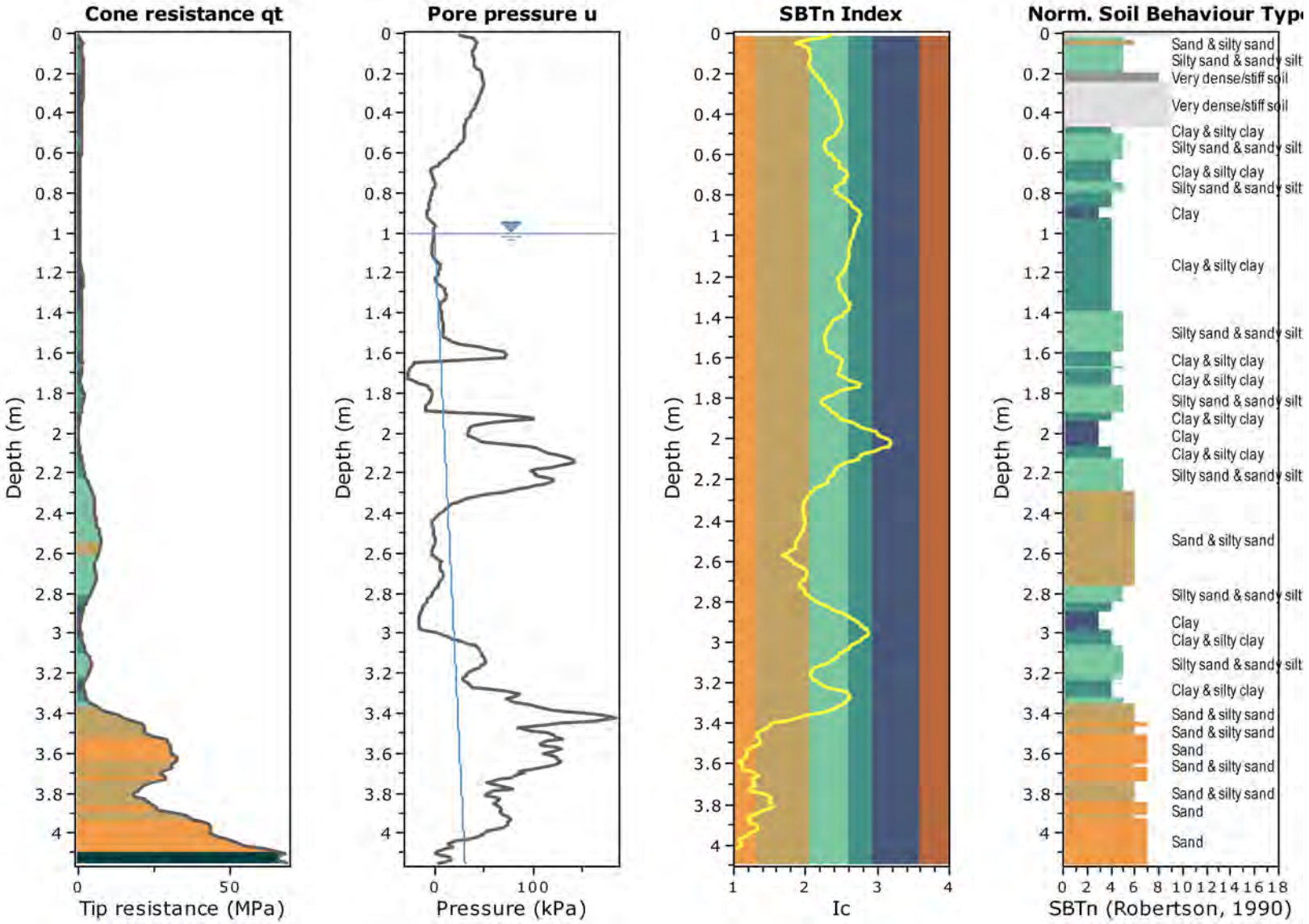
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 7
Total depth: 4.15 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

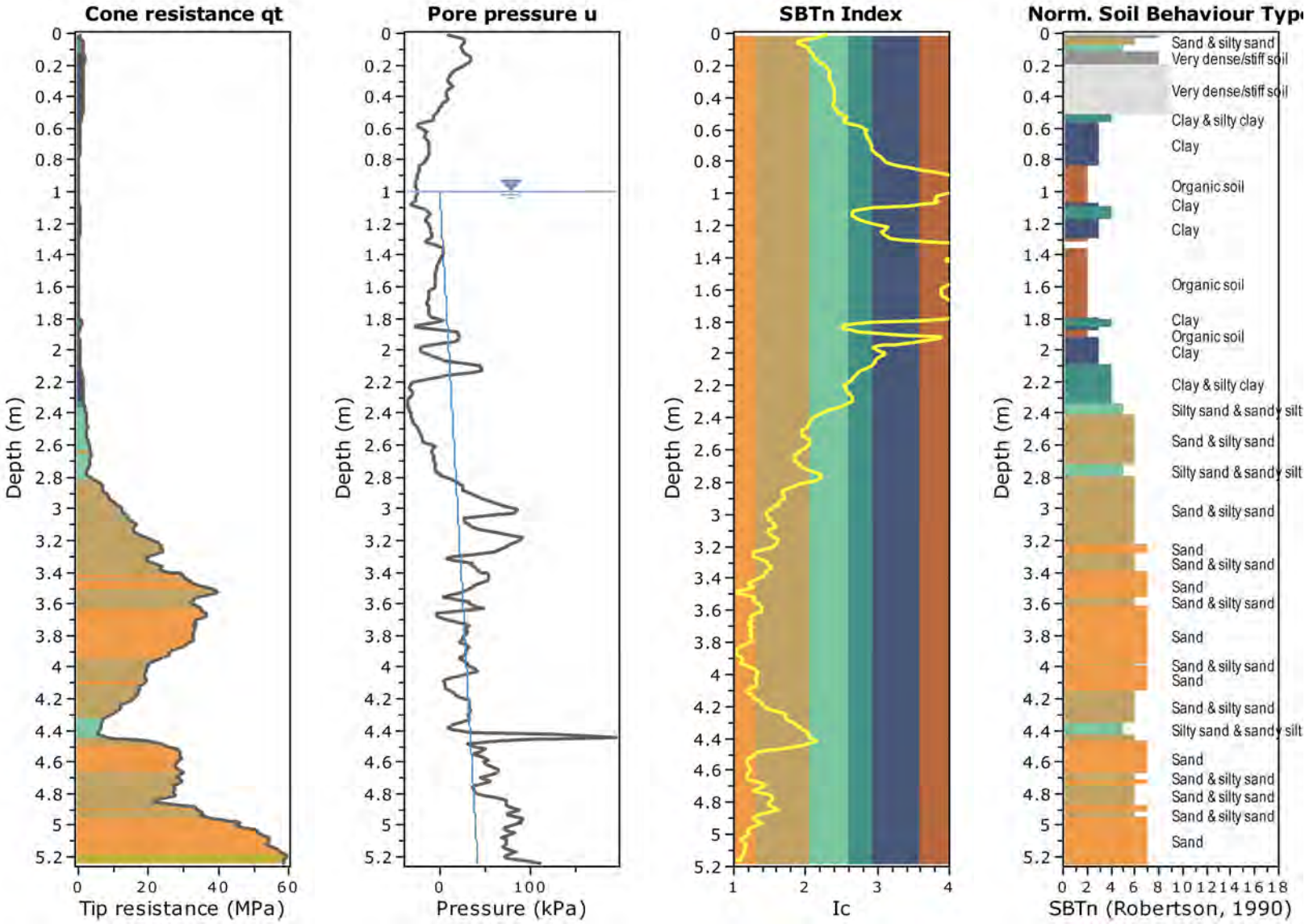
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 8
Total depth: 5.24 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

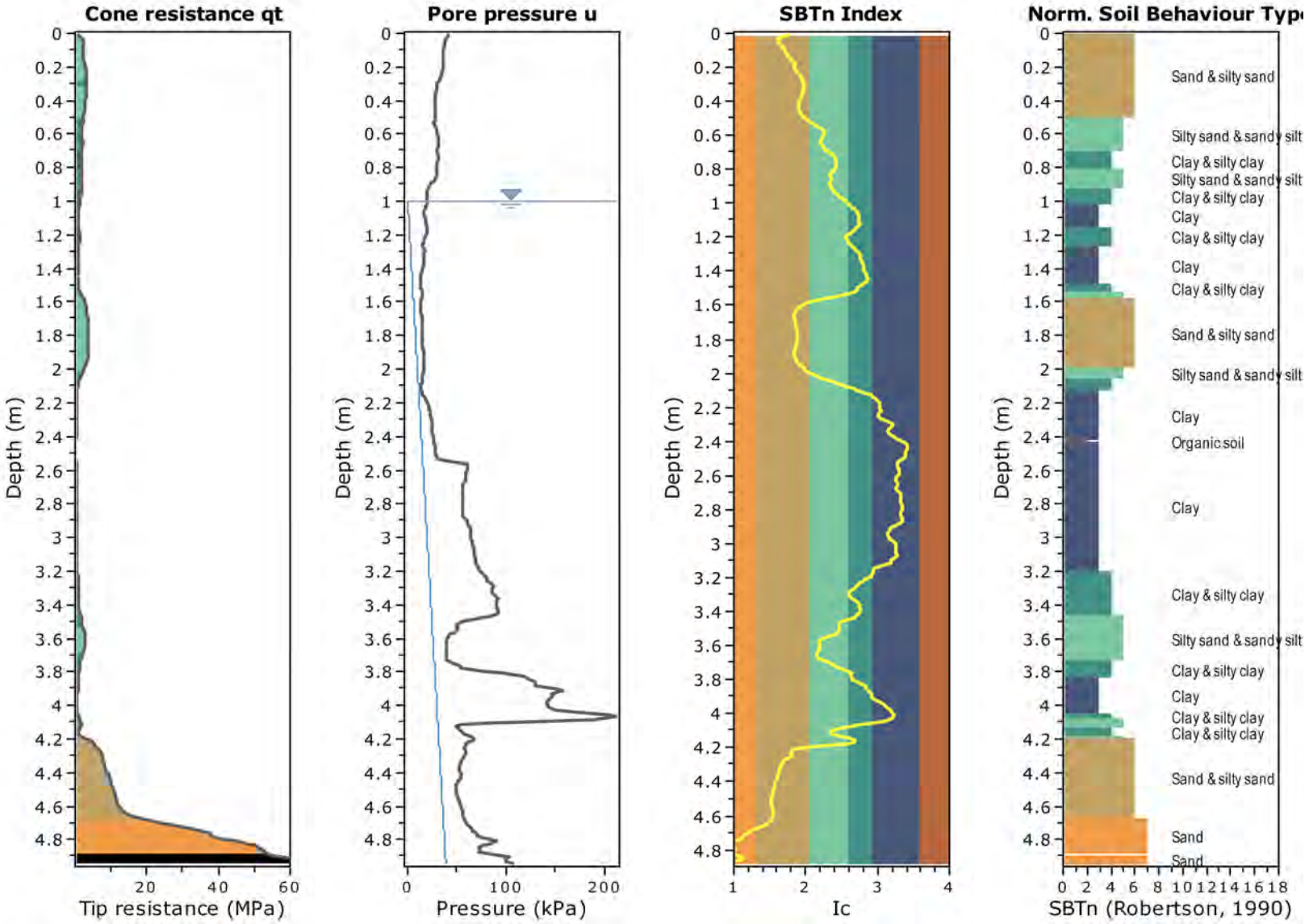
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 9
Total depth: 4.94 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

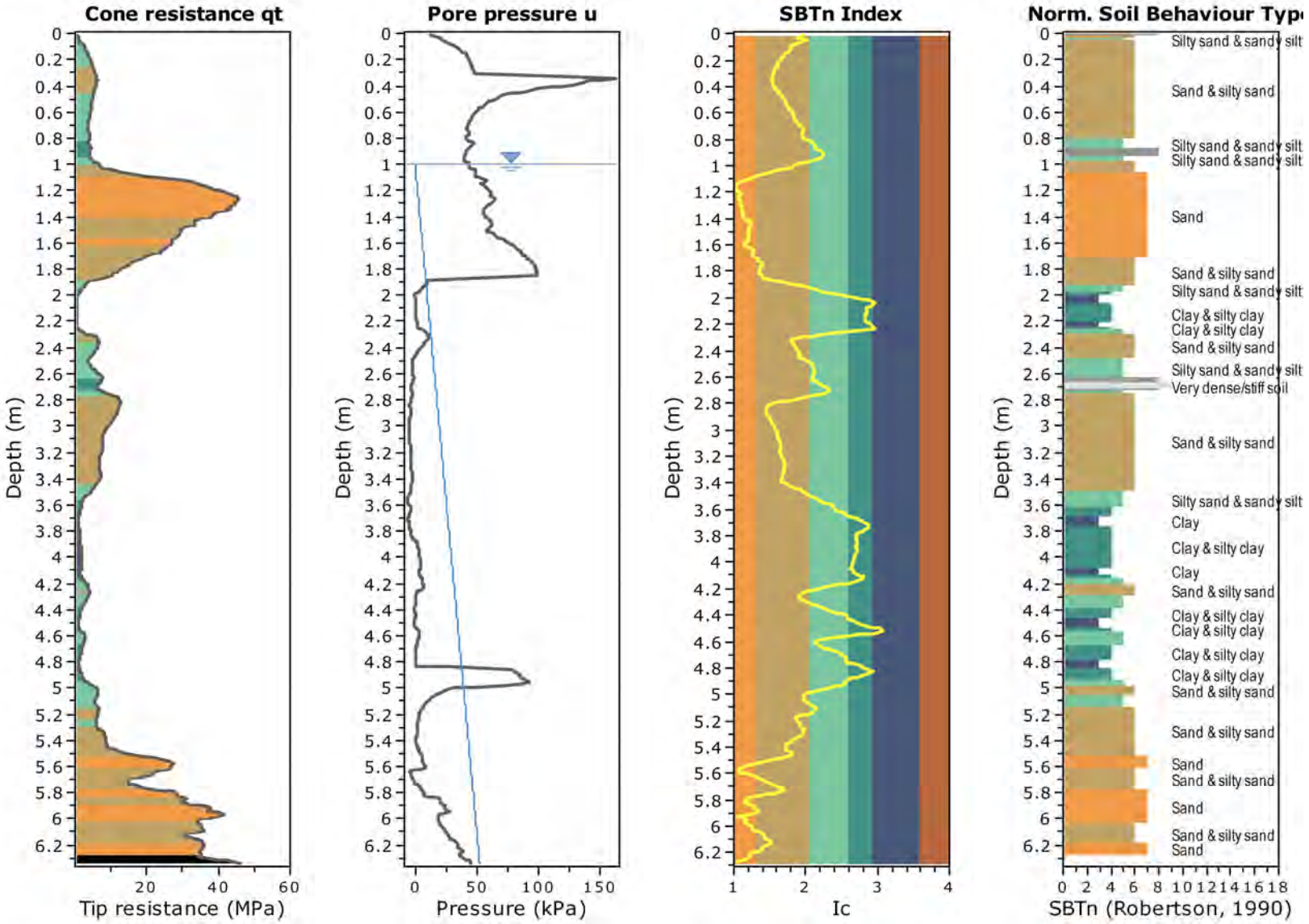
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 10
Total depth: 6.34 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

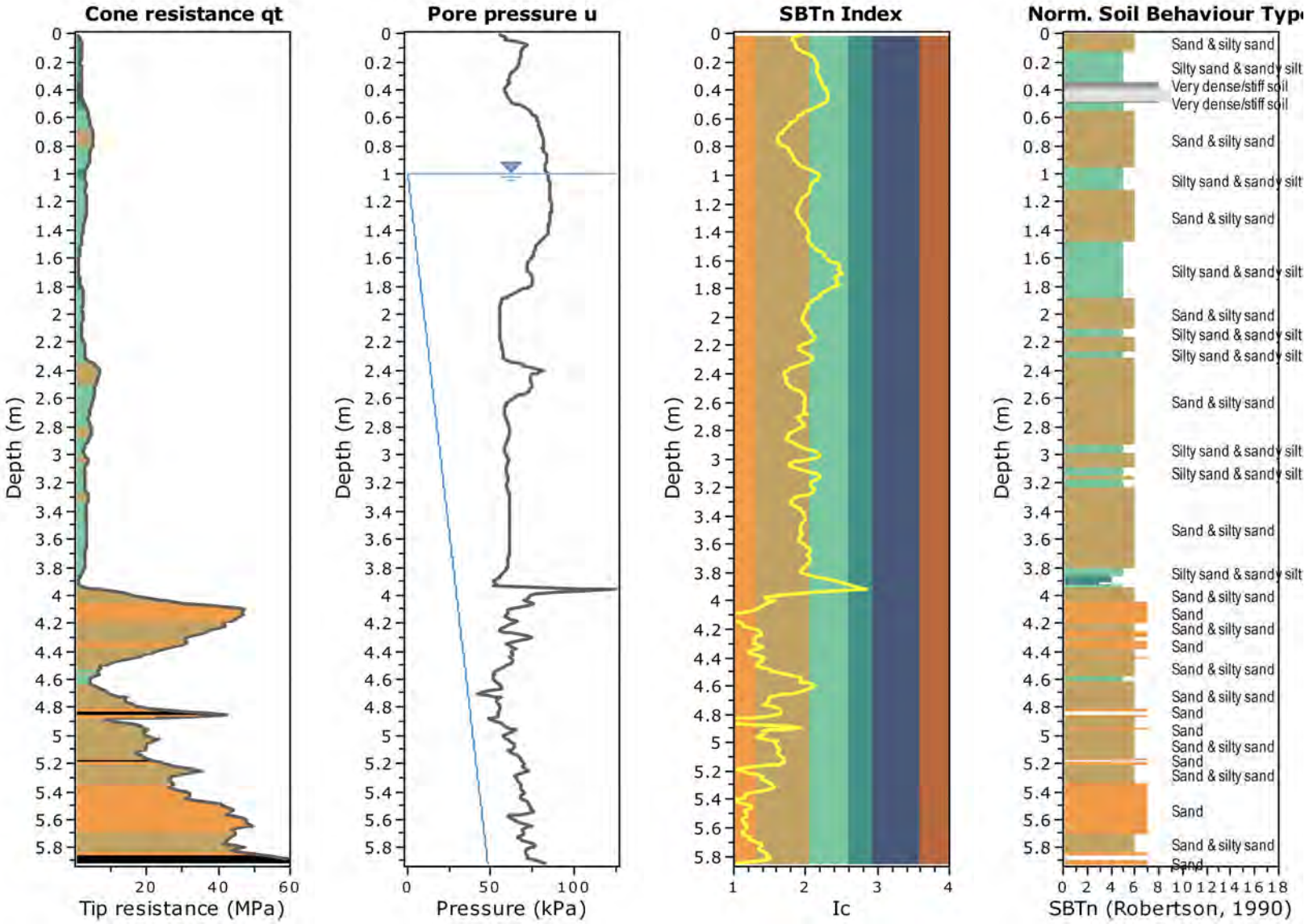
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**

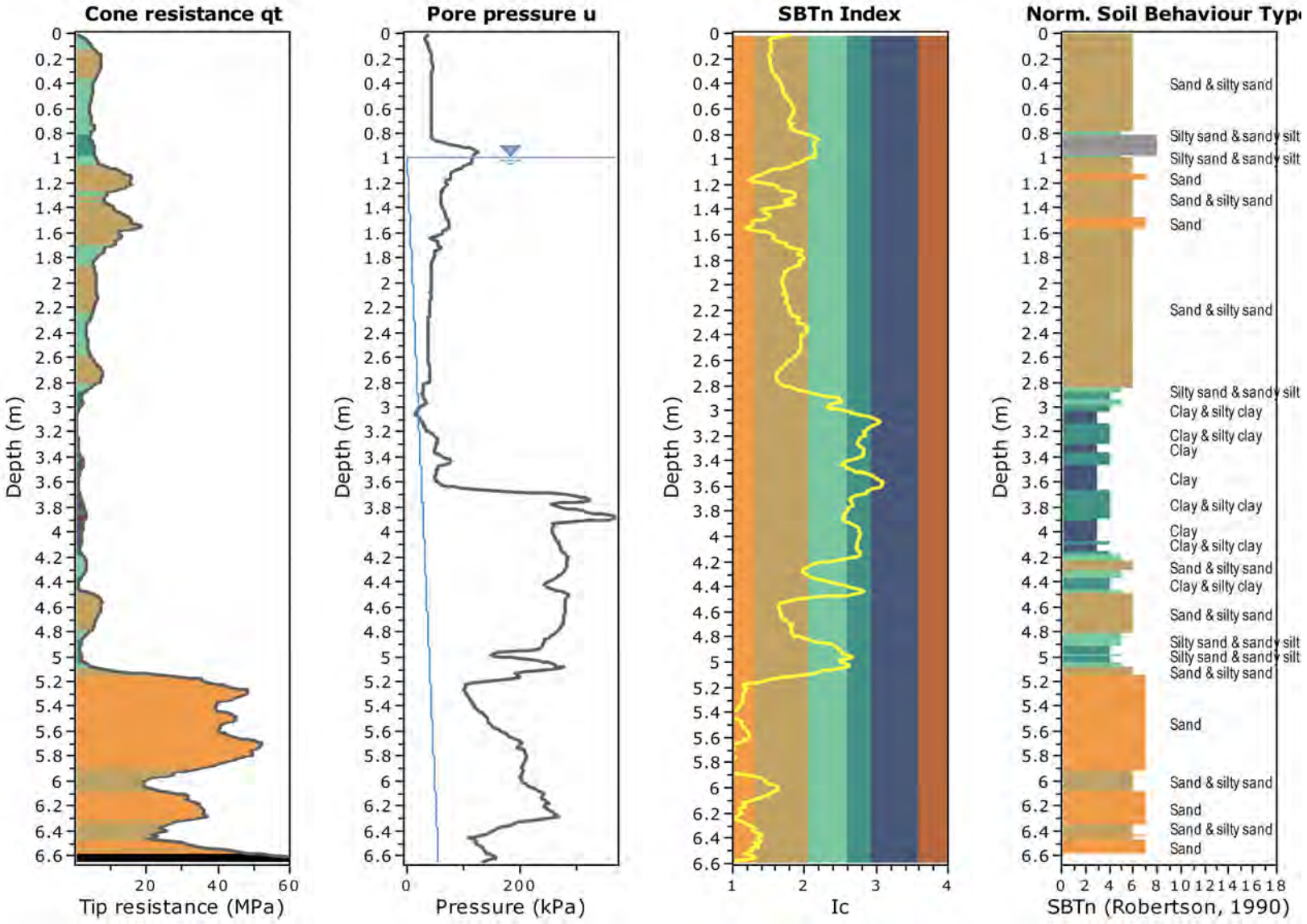
CPT: CPT 11
Total depth: 5.91 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 12
Total depth: 6.65 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

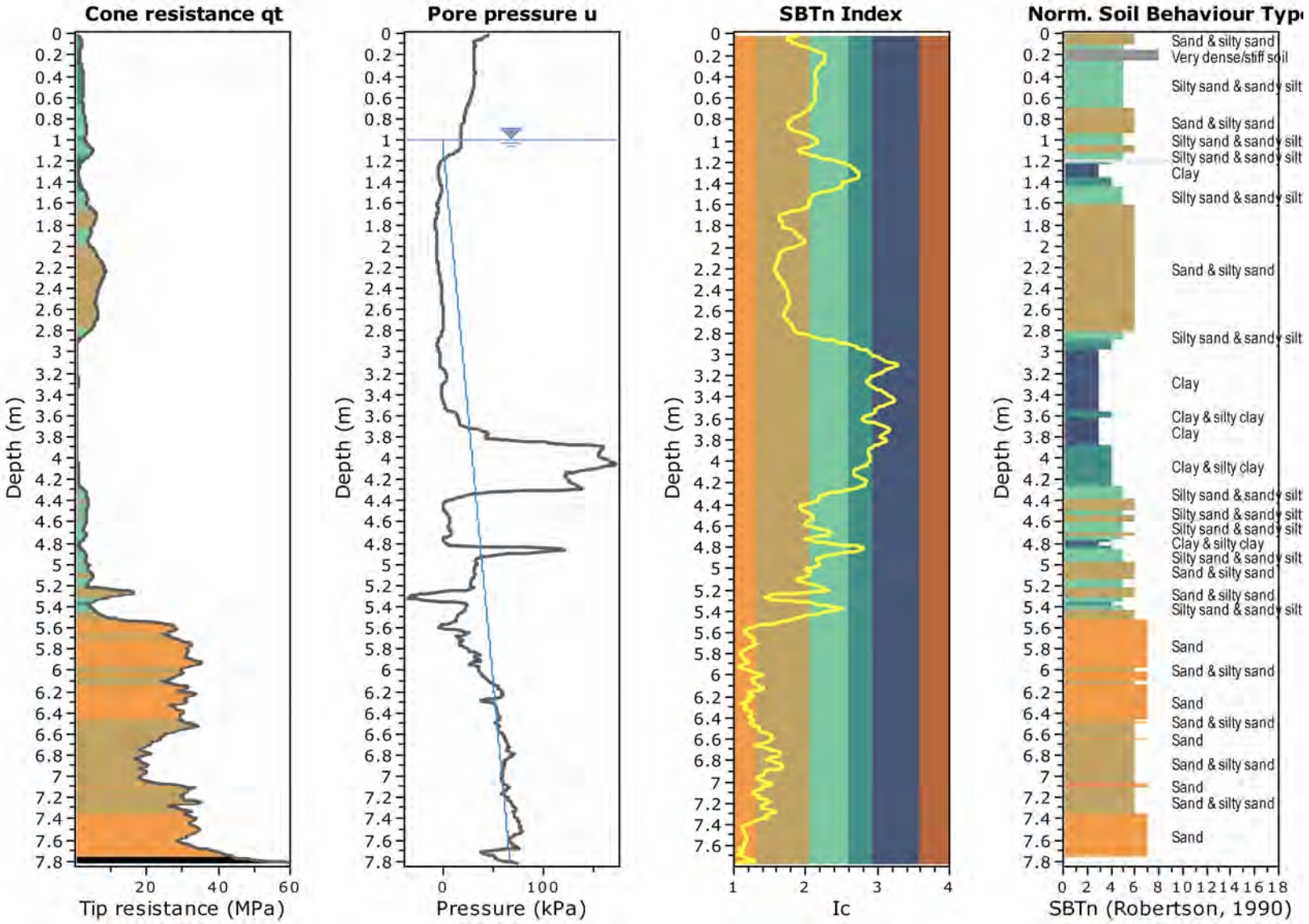
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 13
Total depth: 7.82 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

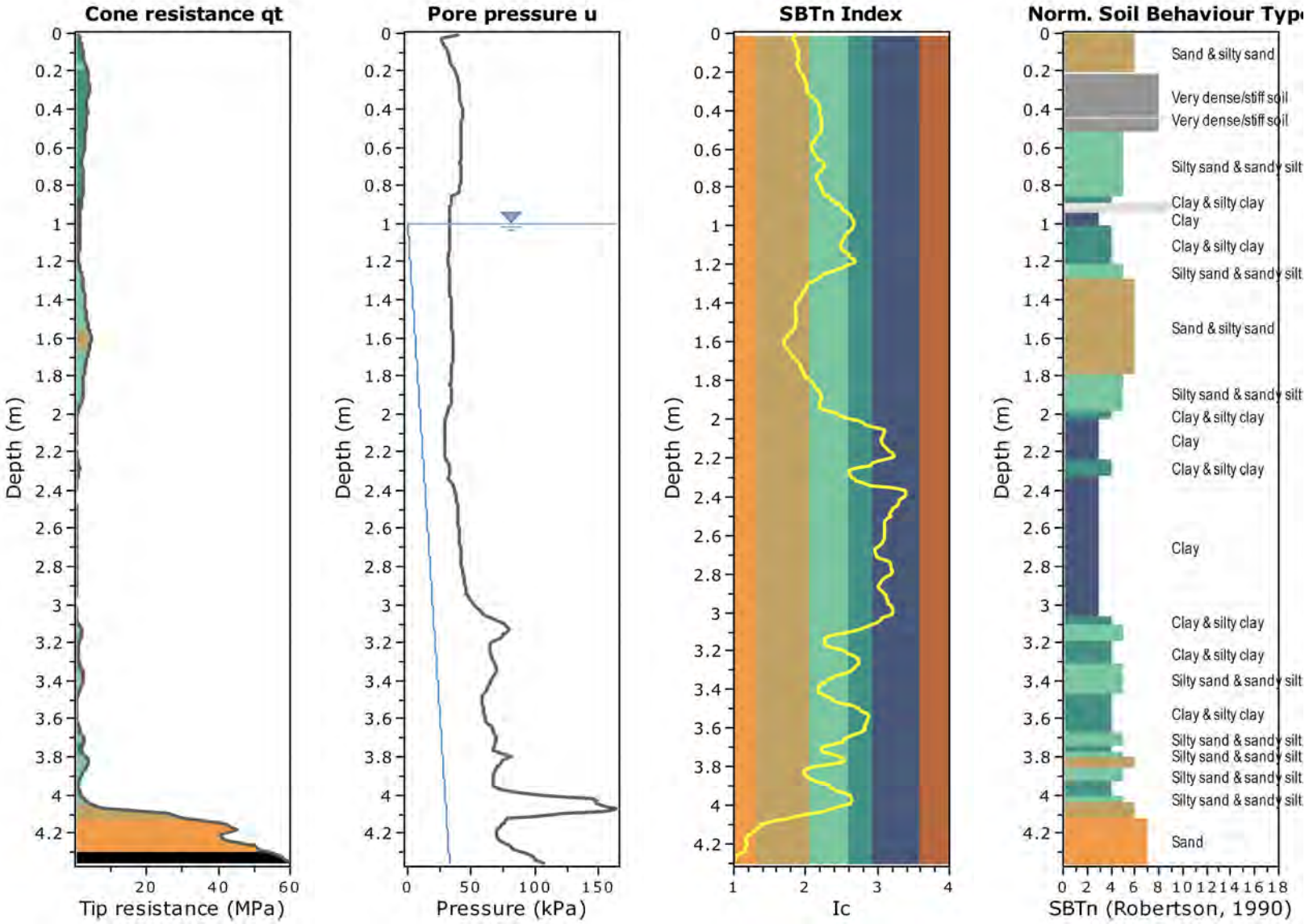
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 14
Total depth: 4.36 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

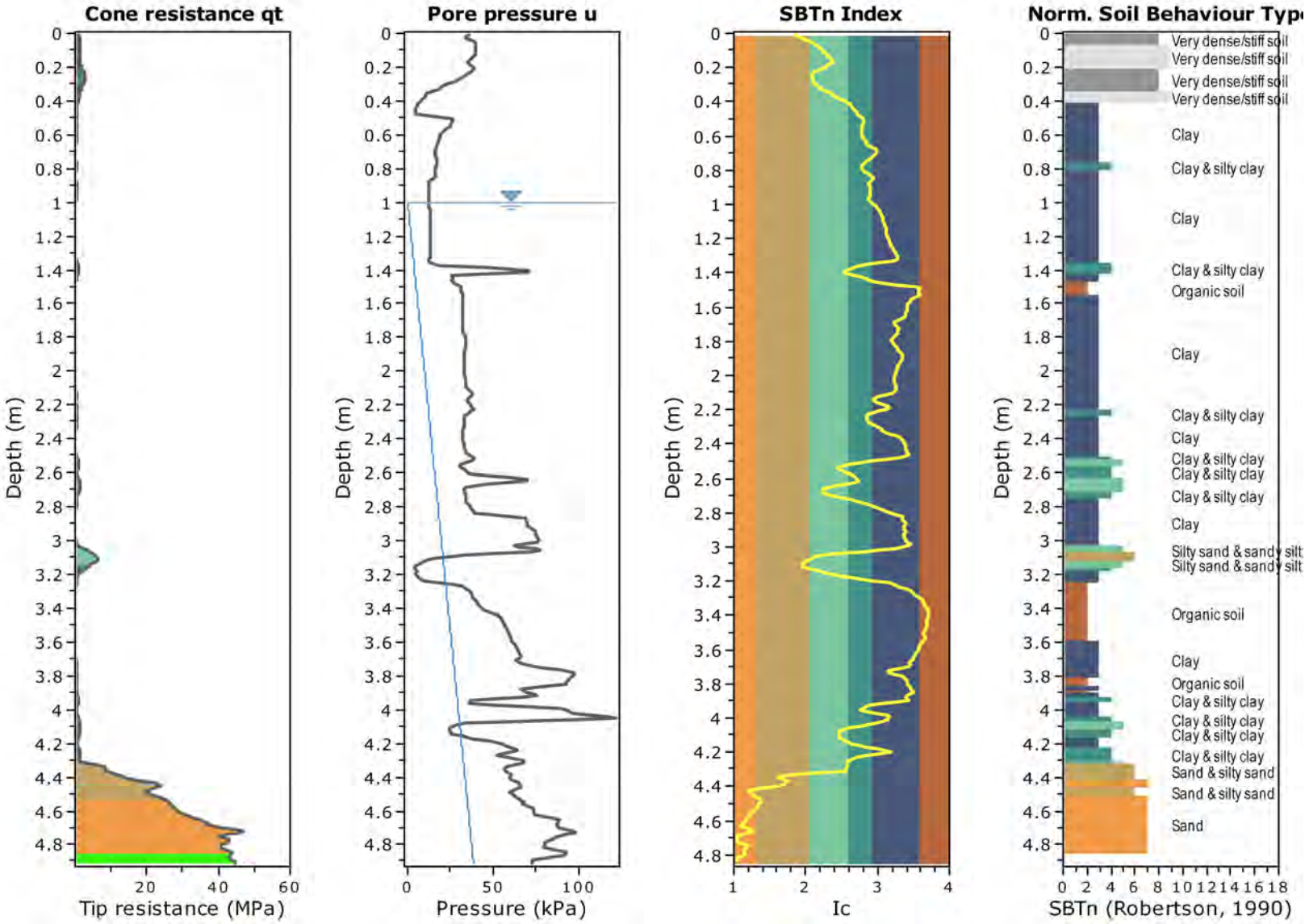
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 15
Total depth: 4.91 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

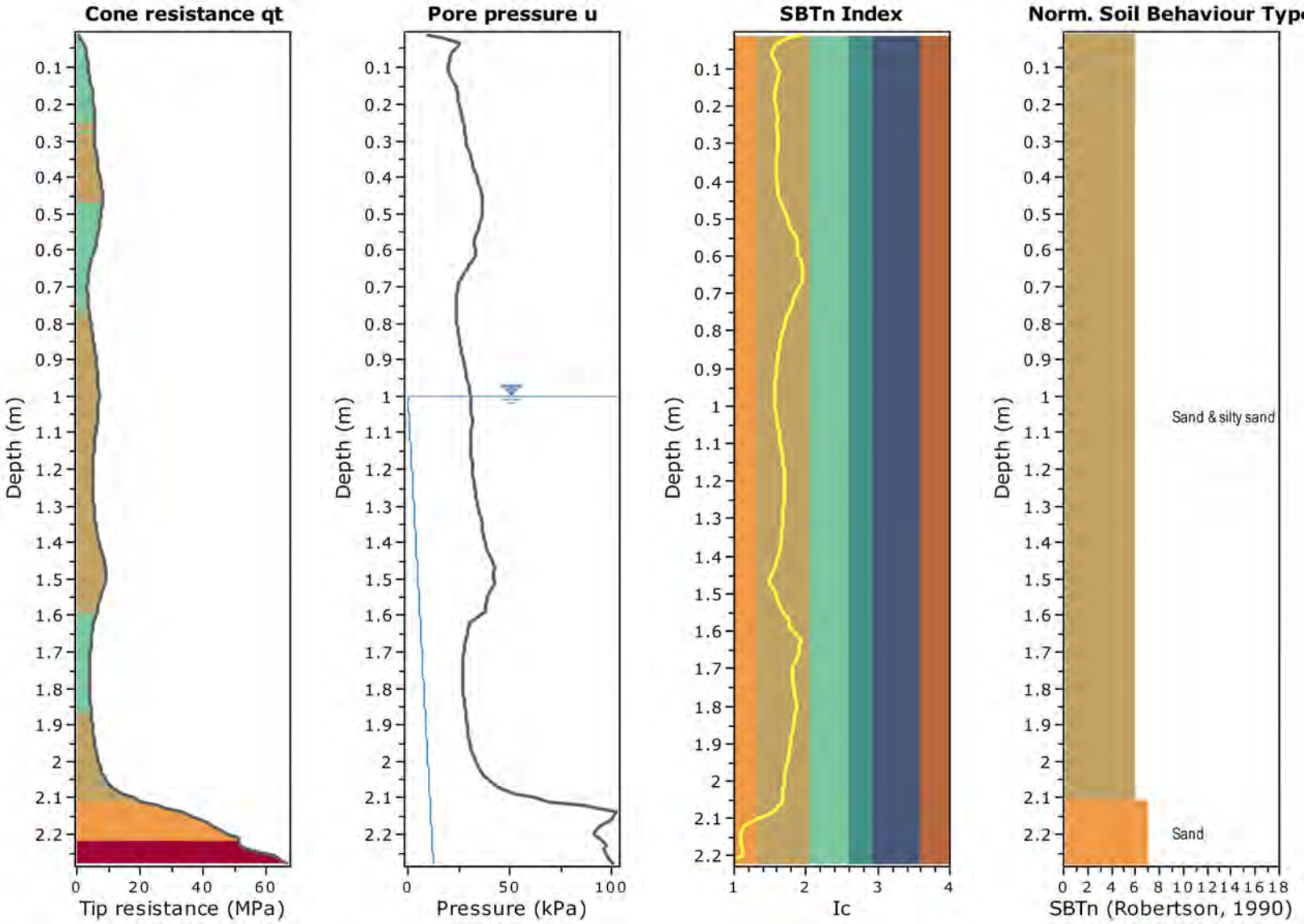
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 16
Total depth: 2.28 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

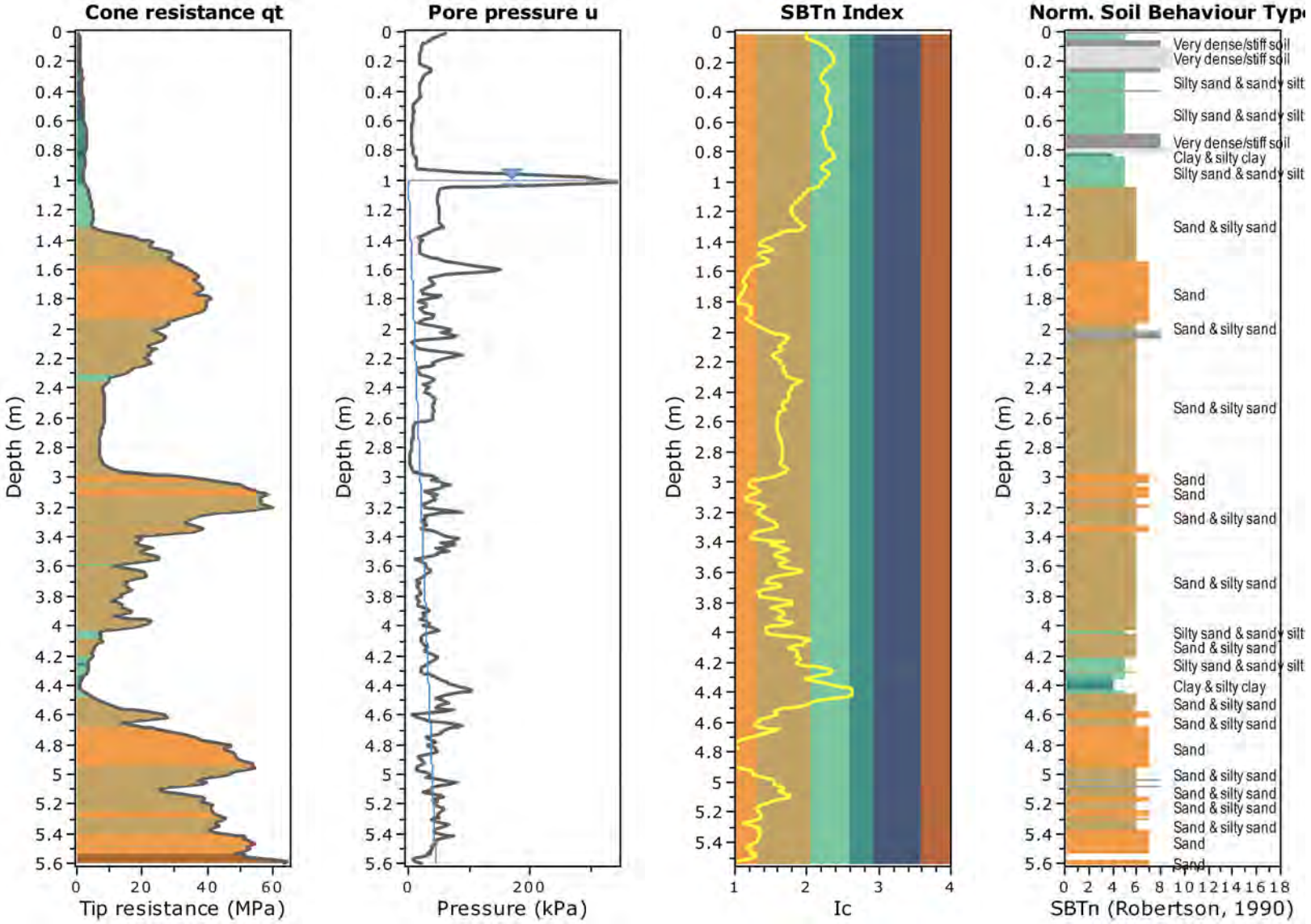
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 17
Total depth: 5.60 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

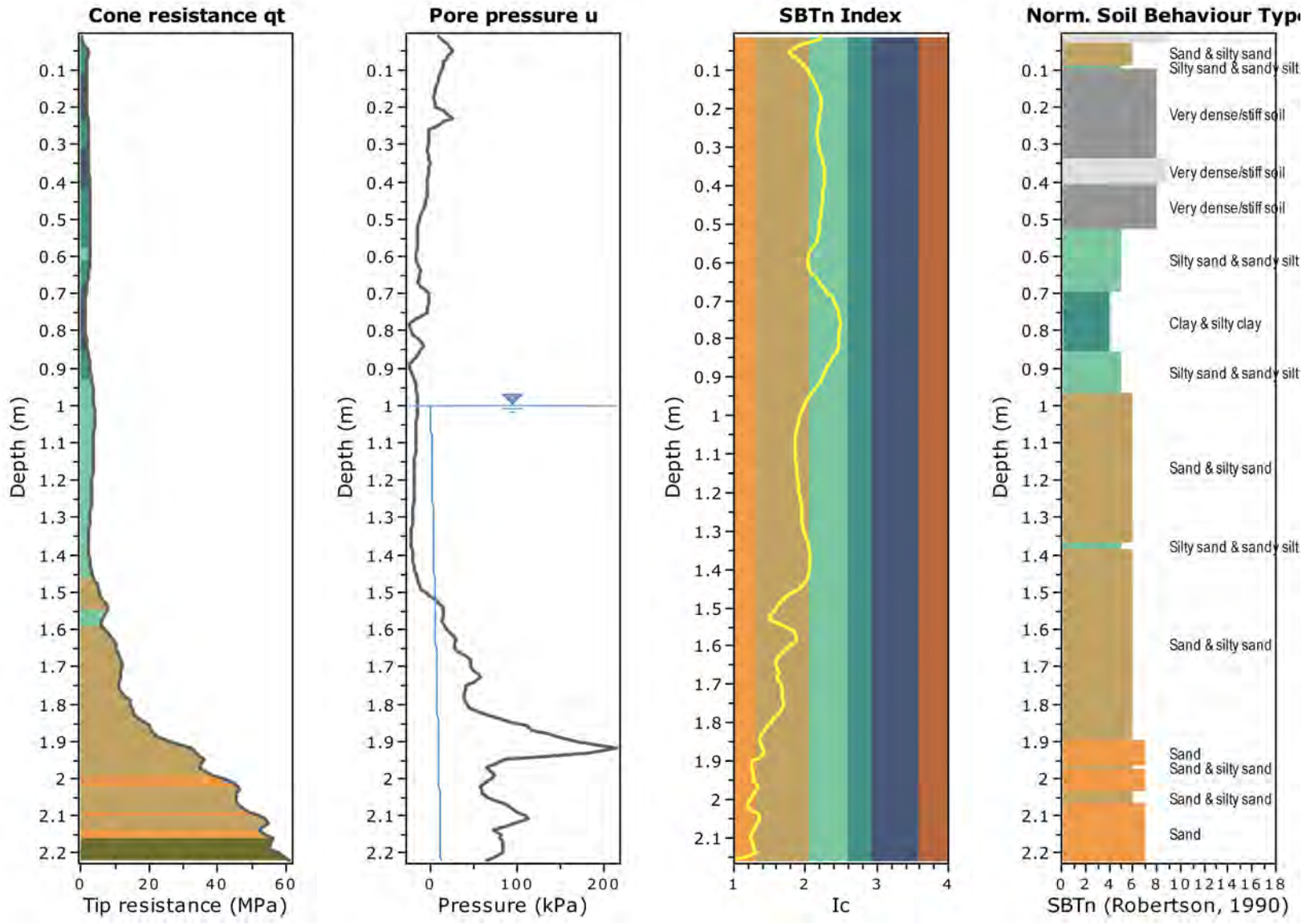
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

CPT: CPT 18
Total depth: 2.22 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

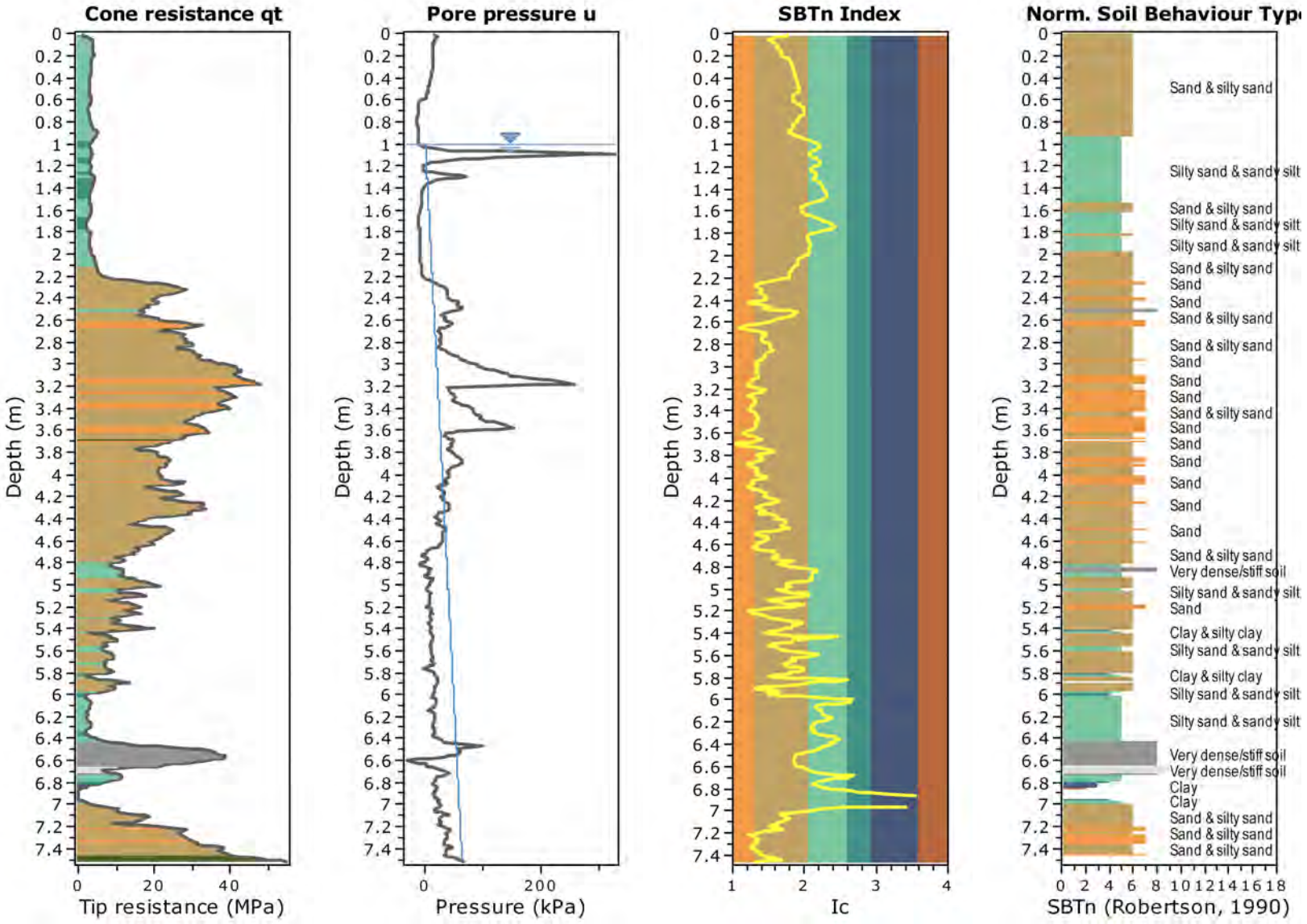
Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**

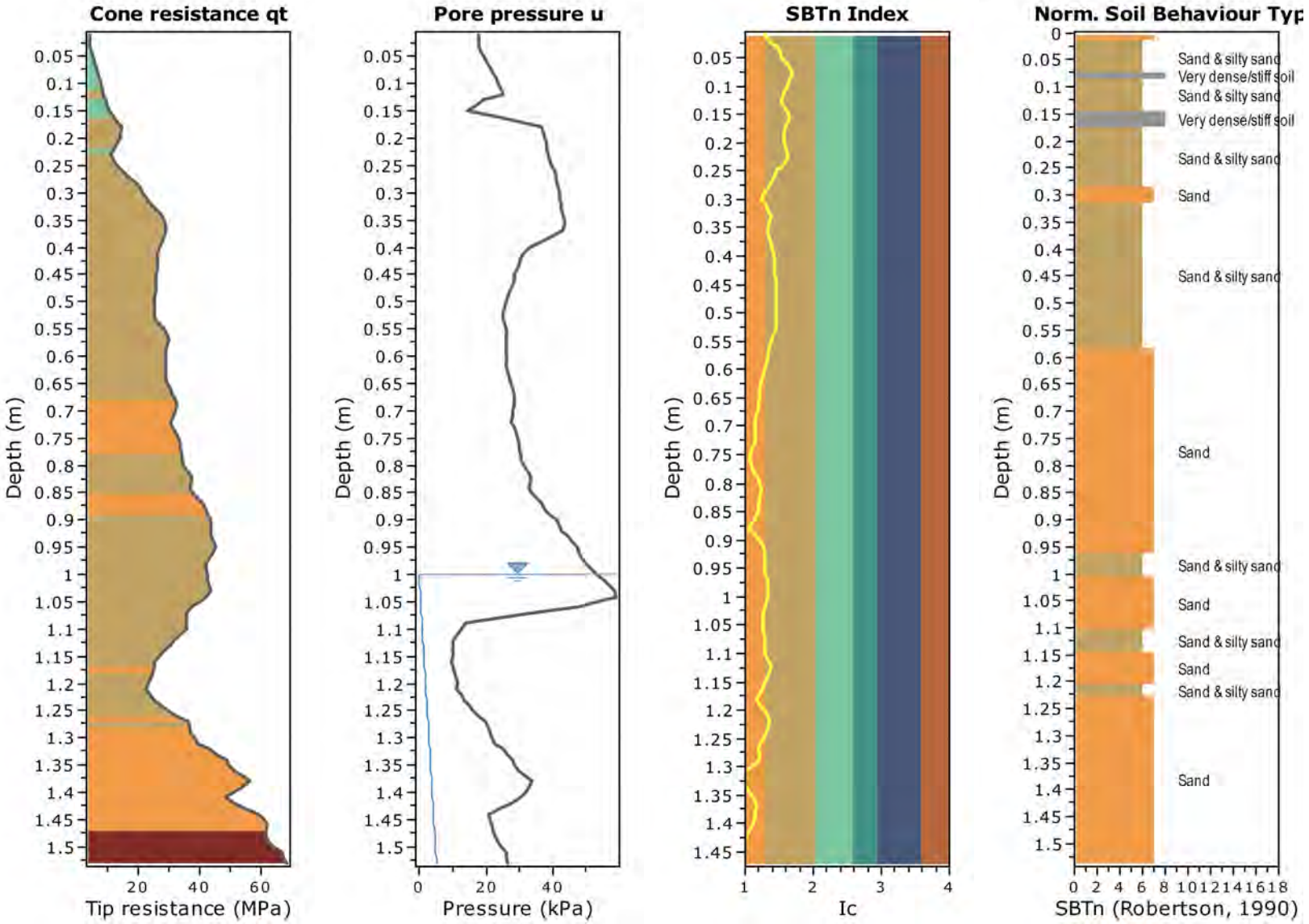
CPT: CPT 19
Total depth: 7.52 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:



Coffey
1/254 Montreal Street
Christchurch 8013
www.coffey.com

Project: **Lincoln South**
Location: **1491 Springs Road, Lincoln**

CPT: CPT 20
Total depth: 1.53 m, Date: 13-Oct-20
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:



Appendix C - Geophysical Report

GEOPHYSICAL REPORT

October 2020

1491 Springs Road, Lincoln:

MASW Survey

Report prepared for Coffey Services (NZ) Ltd

Southern Geophysical Ltd

3/28 Tanya St, Bromley, Christchurch 8062

Ph: 03 384 4302

Web: www.southerngeophysical.com

Data collected and report prepared for Southern Geophysical Ltd by:

Christian Rüegg, MSc, Senior Geophysicist

Nick McConachie, BSc, Geophysicist

Internal review by:

Mike Finnemore, PhD, Senior Geophysicist

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SGL Reference: 2054

Report Version 1

Summary:

Southern Geophysical Ltd was contracted to undertake a geophysical survey using Multi-channel Analysis of Surface Waves (MASW) at a site at 1491 Springs Road, Lincoln, Christchurch. The survey was conducted on October 9, 2020, and included three MASW lines (Figure 1). The aim of the survey was to assess the shear-wave velocities of the subsurface to a depth of over 20 m. The results show shear-wave velocities (V_s) varying across the site. The depth to velocities consistent with gravels (180 m/s to 220 m/s) ranges from very near the surface to approximately 15 m depth.

Methodology:

MASW is a geophysical technique that uses the dispersive nature of surface waves to model shear-wave velocity versus depth.

A MASW survey is undertaken as a series of lines or points across the surface of the site. The MASW lines in this survey were acquired using a 24-channel towed seismic array, with 4.5 Hz geophones. The geophone spacing was 1 m and the source offset was 10 m. The seismic source was an 8 lb sledgehammer impacting an aluminium plate. Recording parameters for the MASW survey were set with a 0.125 ms sample interval, 1.5 s record length, 24 dB gains, and a geophone trigger system. Shot records were acquired at 10 m spacing along the MASW lines.

The shot records were processed using the Kansas Geological Survey software package SurfSeis6++ ©. The geometry for each shot record was set according to the survey parameters and the dispersion curves were generated and edited. The inversions were run using a 10 layer variable depth model. The velocity data was interpolated into 2D profiles showing V_s variations with depth (Figures 2 to 6). The output shear-wave velocity data is included as data files (CSV format), supplementary to this report.

Survey positions were recorded using a Geo 7X Trimble GNSS system with a Tornado antenna. The GNSS positions were differentially corrected using a local GeoNet base station. The GNSS points were output in the Mt Pleasant 2000 datum, with heights in Mean Sea Level (MSL). The accuracy of the survey positions is +/- 0.1 m. The site had minor changes in topography (heights ranging from 3.07 to 9.96 MSL), but the changes were very gradual across a large area.

Results:

Three MASW lines were acquired at the site with a total line length of 2.6 kilometres (Figure 1). The ground conditions were farm tracks and roads for MASW 1 and 2, and a roadside grass verge for MASW 3.

The MASW profiles have been plotted at a 1:2000 scaling ratio in order to show all the data in one display (Figure 2), as well as at a 1:700 scaling ratio to show more detail along each MASW line (Figures 3 to 6).

In homogenous soils, with gradually increasing shear-wave velocities and no sharp lateral discontinuities, the accuracy of the shear-wave velocities derived from the MASW processing is considered to be +/- 10%.[1] The quality of the seismic data and the dispersion curves used in this report is excellent, with a good signal-to-noise ratio. If there is a velocity inversion present in the shear-wave profile (decreasing velocity with depth), the shear-wave velocity of the reduced velocity zone and the thickness of that zone can often be underestimated by the inversion process.

Conclusions:

While the limitations of the MASW method should be considered when evaluating these results, the quality of the data collected at the site and the confidence in the shear-wave velocities derived from the MASW data is high. It is suggested that the 200 m/s shear-wave velocity contour likely correlates with a gravel surface, however the results should be correlated with intrusive ground tests to confirm the site geology.

[1] Stephenson, W.J., Louie, J.N., Pullammanappallil, S., Williams, R.A., and Odum, J.K. 2005. Blind Shear-wave Velocity Comparison of ReMi and MASW Results with Boreholes to 200 m in Santa Clara Valley: Implications for Earthquake Ground-Motion Assessment. *Bulletin of the Seismological Society of America*, Vol. 95, pp. 2506-2516.

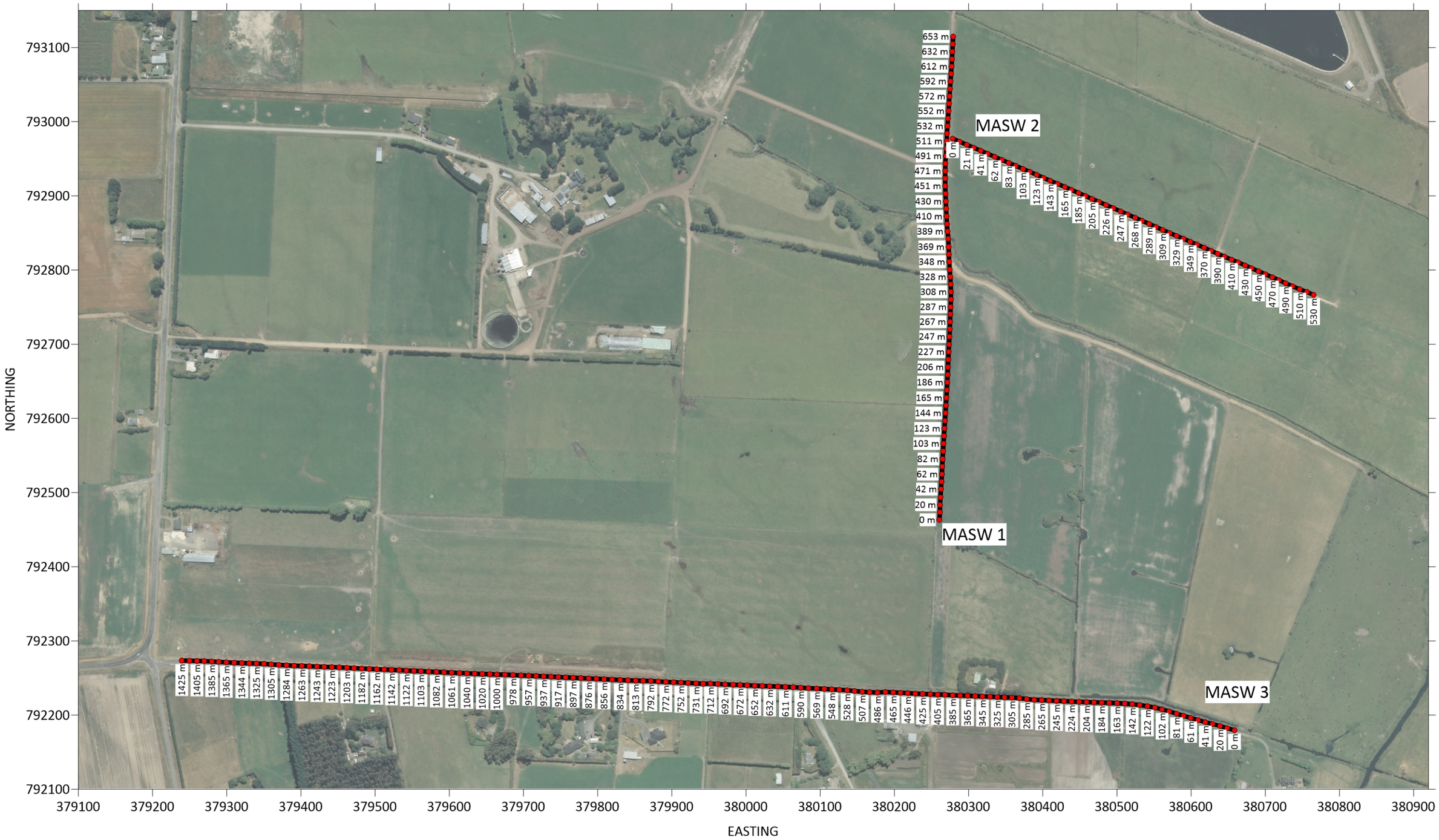
Disclaimer:

This document has been provided by Southern Geophysical Ltd subject to the following:

Non-invasive geophysical testing has limitations and is not a complete source of testing. Often there is a need to couple non-invasive methods with invasive testing methods, such as drilling, especially in cases where the non-invasive testing indicates anomalies.

This document has been prepared for the particular purpose outlined in the project proposal and no responsibility is accepted for the use of this document, in whole or in part, in other contexts or for any other purpose. Southern Geophysical Ltd did not perform a complete assessment of all possible conditions or circumstances that may exist at the site. Conditions may exist which were undetectable given the limited nature of the enquiry Southern Geophysical Ltd was retained to undertake with respect to the site. Variations in conditions often occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account. Accordingly, additional studies and actions may be required by the client.

We collected our data and based our report on information which was collected at a specific point in time. The passage of time affects the information and assessment provided by Southern Geophysical Ltd. It is understood that the services provided allowed Southern Geophysical Ltd to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes for whatever reason. Where data is supplied by the client or other sources, including where previous site investigation data have been used, it has been assumed that the information is correct. No responsibility is accepted by Southern Geophysical Ltd for incomplete or inaccurate data supplied by others. This document is provided for sole use by the client and is confidential to that client and its professional advisers. No responsibility whatsoever for the contents of this document will be accepted to any person other than the client. Any use which a third party makes of this document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Southern Geophysical Ltd accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.



DRAWING- **Figure 1: Geophysical Site Investigation**

LOCATION- **1491 Springs Road, Lincoln**

NOTES-

Coordinates Mount Pleasant 2000 TM Grid.
Aerial photograph sourced from LINZ, Crown Copyright ©
Every second MASW point is labelled with chainage along the line.

SCALE (m)

0 100 200 300 400

N

A3

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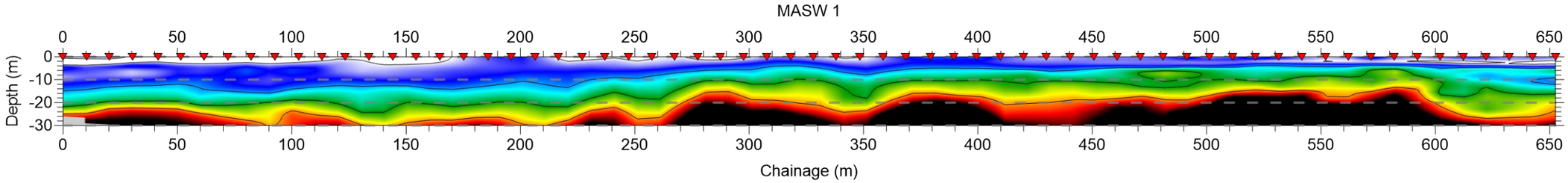
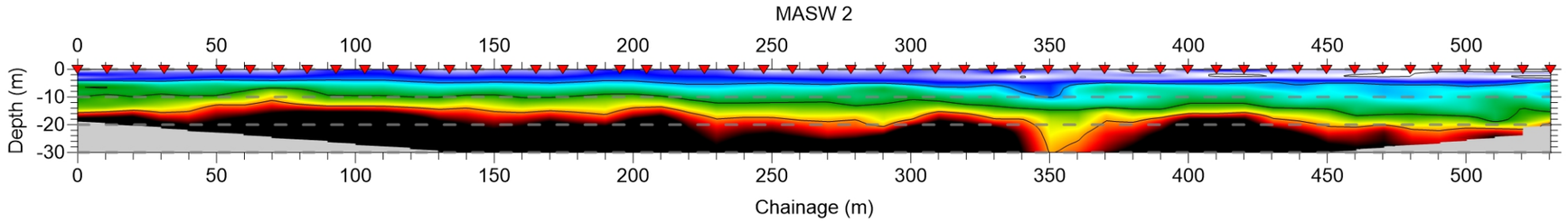
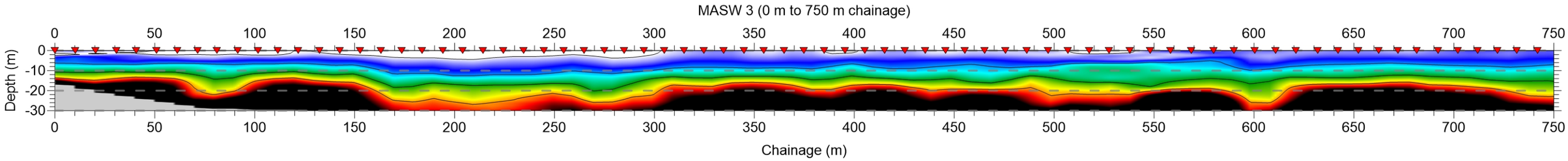
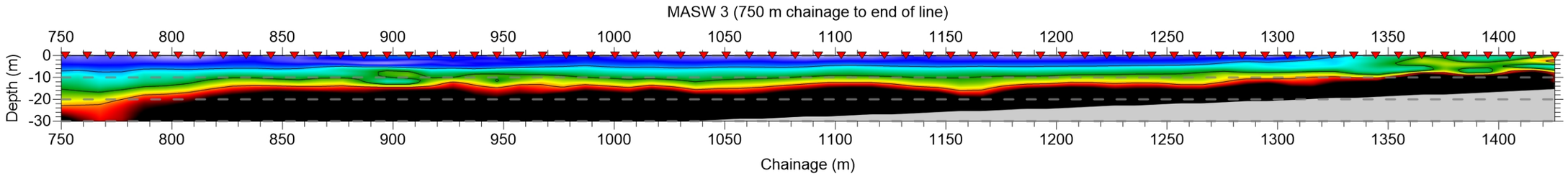
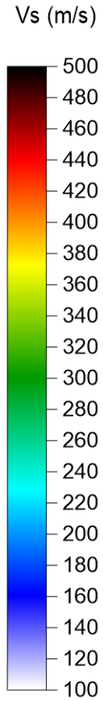
www.southerngeophysical.com











DRAWING- **Figure 2: All MASW Profiles (1:2000 scaling ratio)**

LOCATION- **1491 Springs Road, Lincoln**

NOTES MASW Vs profiles have contour intervals of 100 m/s (Vs).

See site map for location of points.

Surface position of MASW shot records (contours interpolated between data points)

No data (insufficient depth imaging with MASW)

A3

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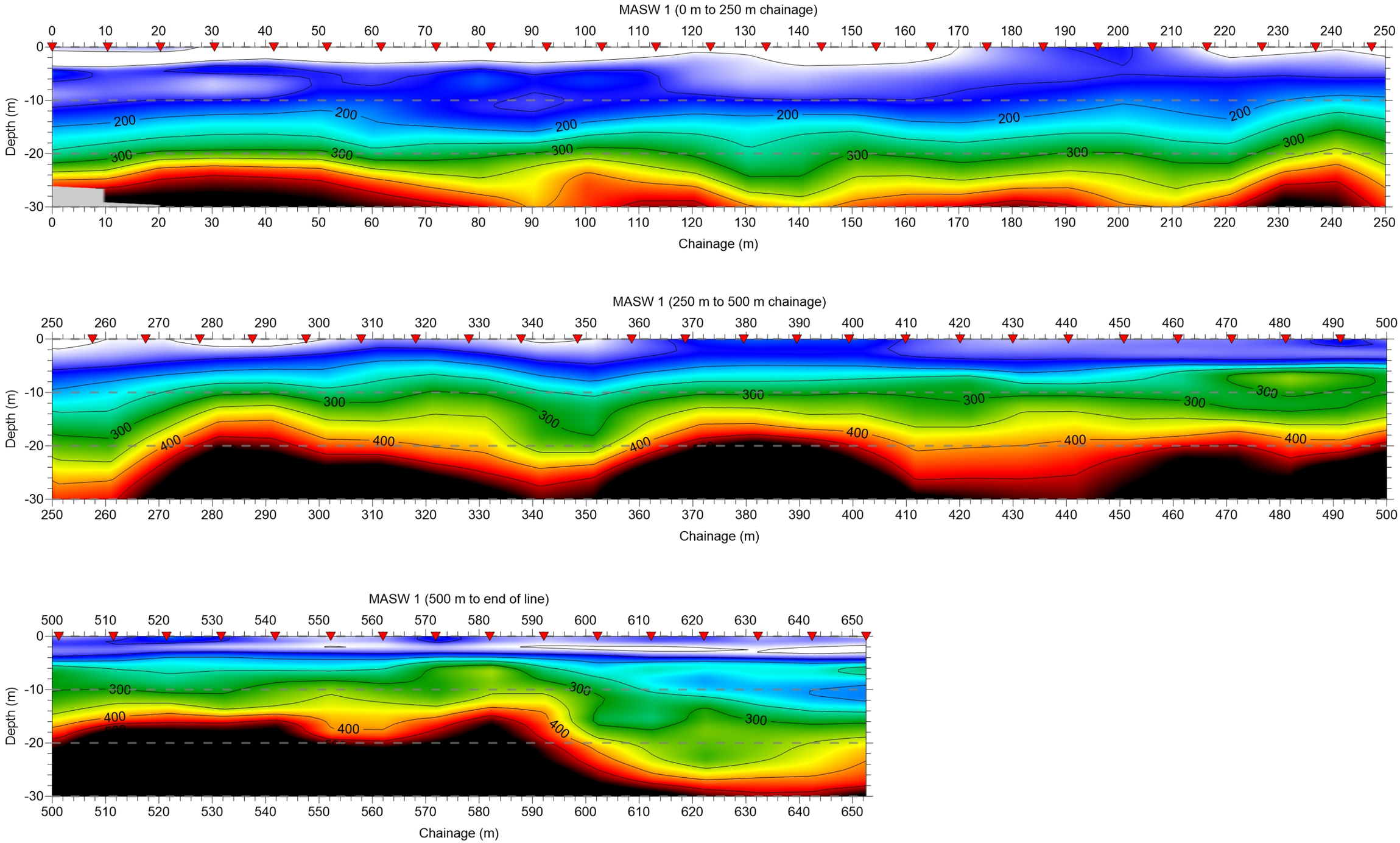
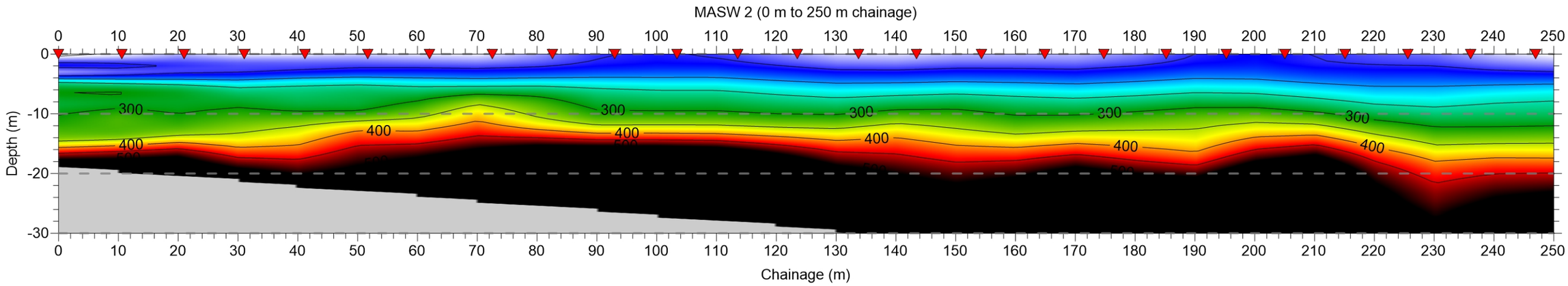
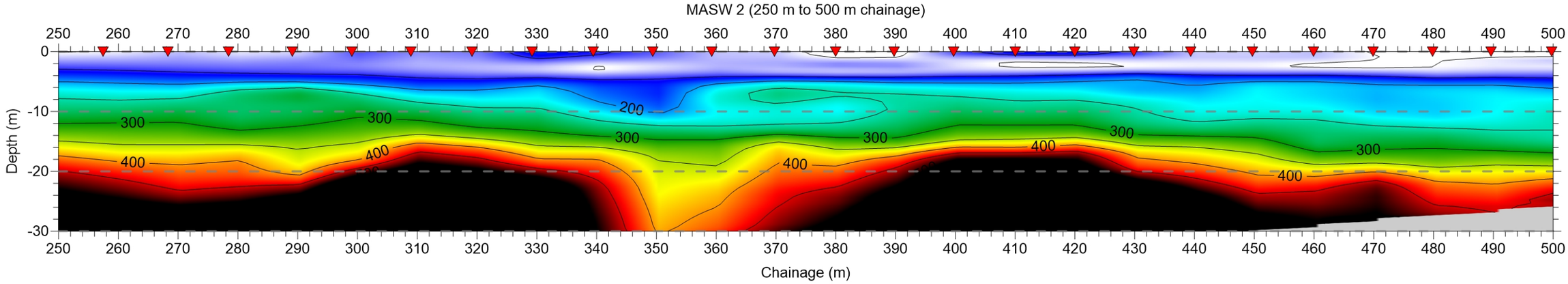
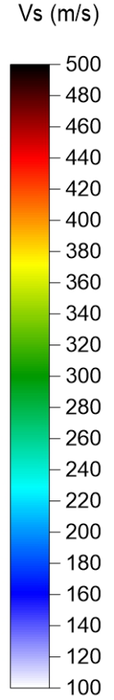
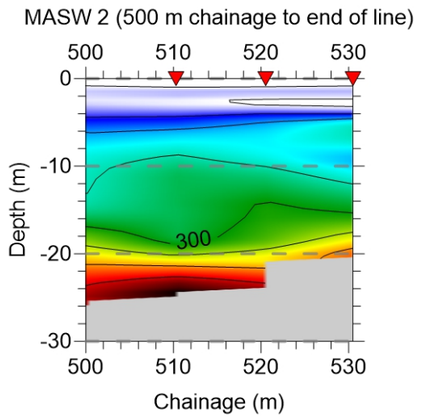


DRAWING- **Figure 3: MASW 1 (1:700 scaling ratio)**	NOTES MASW Vs profiles have contour intervals of 50 m/s (Vs).	▼ Surface position of MASW shot records (contours interpolated between data points)		Southern Geophysical Ltd
LOCATION- **1491 Springs Road, Lincoln**	See site map for location of points.	No data (insufficient depth imaging with MASW)	A3	www.southerngeophysical.com









DRAWING- **Figure 4: MASW 2 (1:700 scaling ratio)**

LOCATION- **1491 Springs Road, Lincoln**

NOTES MASW Vs profiles have contour intervals of 50 m/s (Vs).

See site map for location of points.

▼ Surface position of MASW shot records (contours interpolated between data points)

No data (insufficient depth imaging with MASW)

A3

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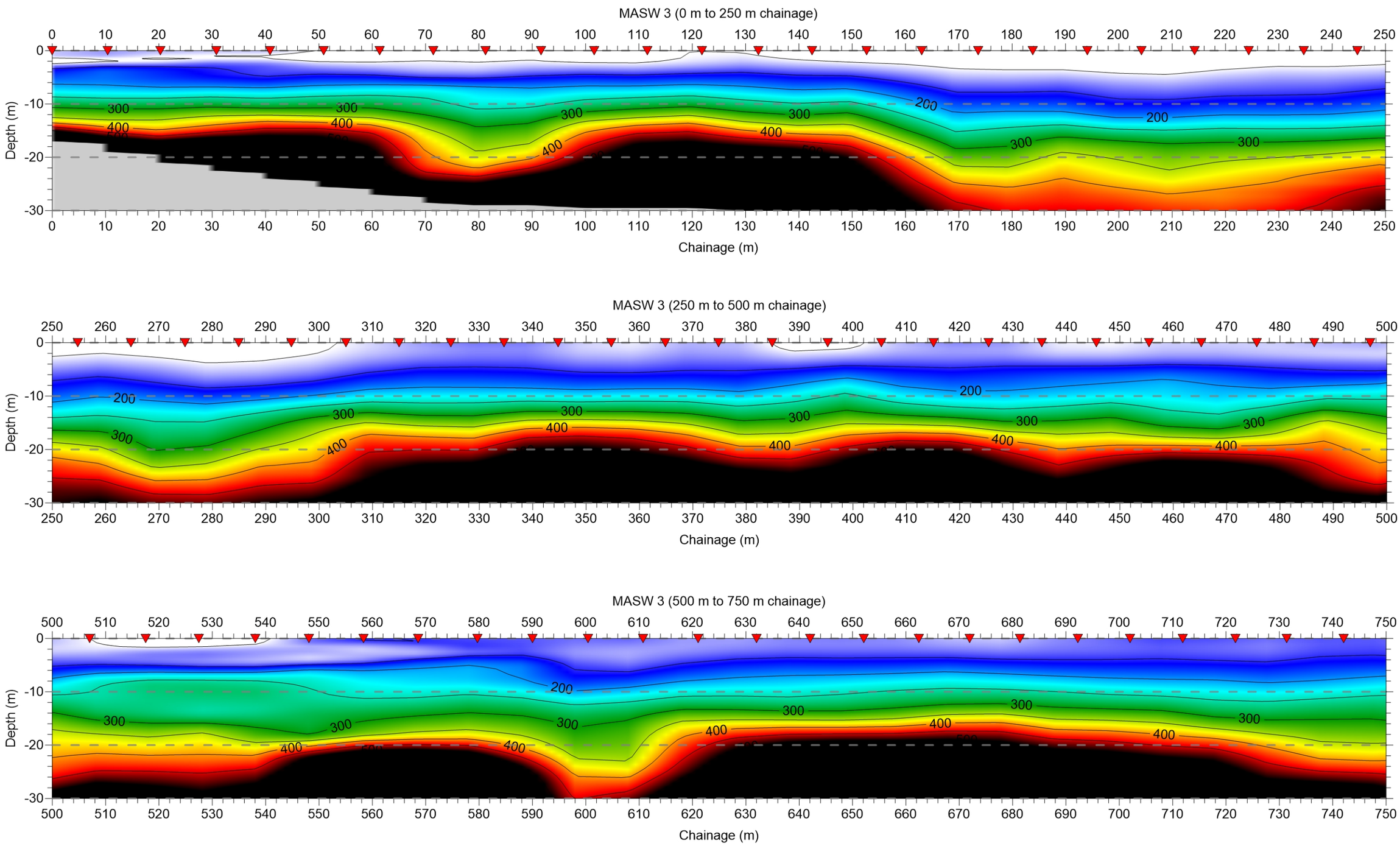


DRAWING- **Figure 5: MASW 3 (1:700 scaling ratio)**

LOCATION- **1491 Springs Road, Lincoln**

NOTES MASW Vs profiles have contour intervals of 50 m/s (Vs).

See site map for location of points.

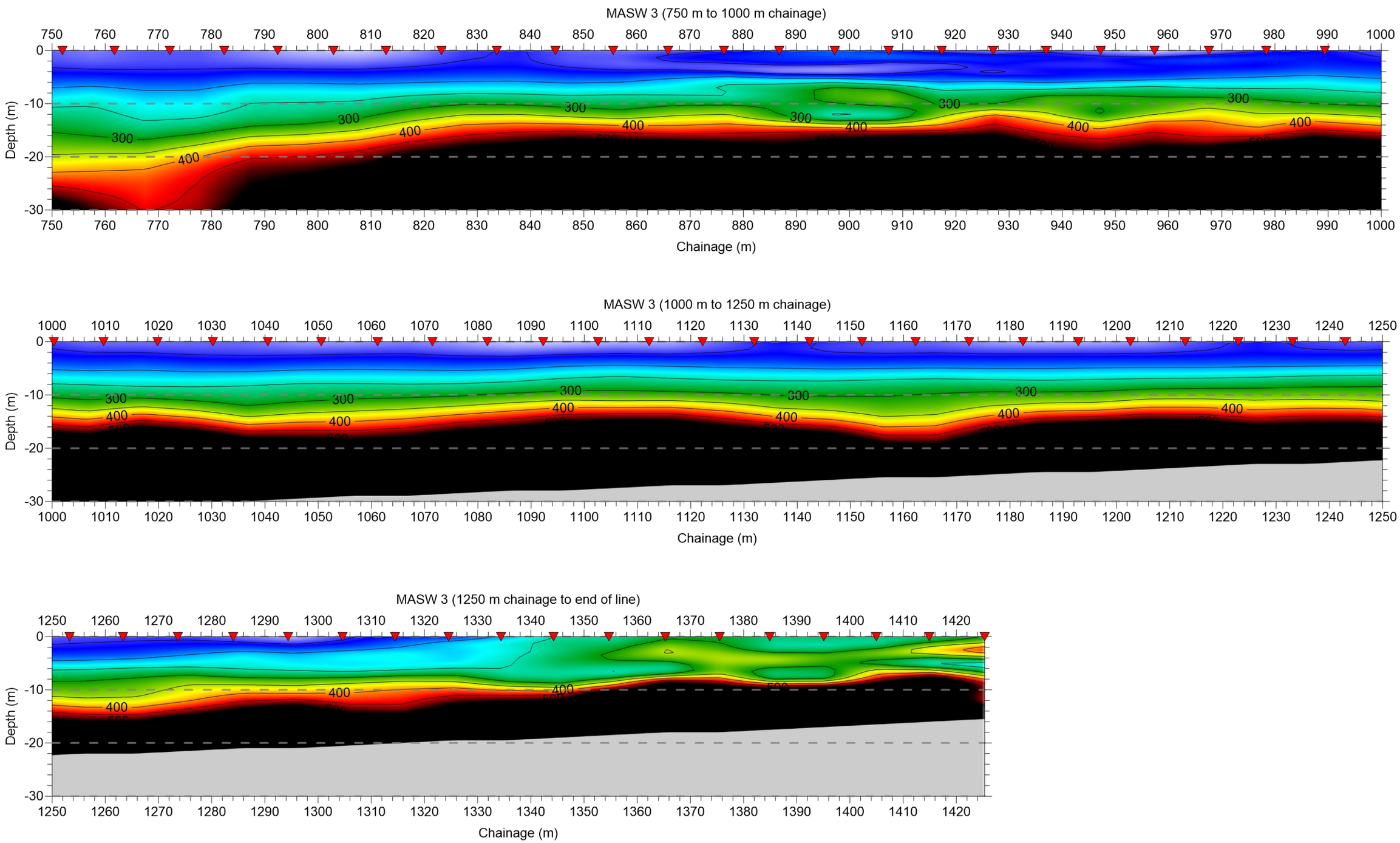
Surface position of MASW shot records (contours interpolated between data points)

No data (insufficient depth imaging with MASW)

A3

Southern Geophysical Ltd

www.southerngeophysical.com



DRAWING- **Figure 6: MASW 3 (1:700 scaling ratio)**

LOCATION- **1491 Springs Road, Lincoln**

NOTES MASW Vs profiles have contour intervals of 50 m/s (Vs).

See site map for location of points.

Surface position of MASW shot records (contours interpolated between data points)

No data (insufficient depth imaging with MASW)

A3

Southern Geophysical Ltd

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