BEFORE THE WAIMAKARIRI DISTRICT PLAN REVIEW HEARINGS PANEL

IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	the hearing of submissions and further submissions on the Proposed Waimakariri District Plan
AND	hearing of submissions and further submissions on Variations 1 and 2 to the Proposed Waimakariri District Plan
	Hearing Stream 12E: Rezoning Requests

FIRST STATEMENT OF EVIDENCE OF MASON VOUT REED
(GEOTECHNICAL ENGINEERING)
FOR RICHARD AND GEOFF SPARK
(PDP SUBMITTER 183 / VARIATION 1 SUBMITTER 61)

Dated 4 March 2024

Aston Consultants Limited
Resource Management and Planning
PO Box 1435
Christchurch

Attention: Fiona Aston
Phone: 0275 332213
Email: fiona@astonconsultants.co.nz

Counsel instructed:
David Caldwell, Barrister
Bridgeside Chambers
PO Box 3180
Christchurch

Phone: 021 221 4113
Email: dcc@bridgeside.co.nz

Introduction

1. My name is Mason Vout Reed. I have 27 years' experience as working as a geotechnical engineer. I have worked in New Zealand since 1996, with the exception of the period 1997 -1998 when I gained professional experience in Australia and the UK.

2. I am the geotechnical Director and Christchurch Branch Manager at Fraser Thomas Limited (**Fraser Thomas**) and have worked at this employment for the past 10 years (or equivalent).

3. I hold a Bachelor of Engineering (Civil) from Auckland University, 1996. I am a Chartered Professional Engineer (CMEngNZ), and an International Professional Engineer (IntPE NZ). I have recently been appointed a Fellow of Engineering New Zealand (FEngNZ), in recognition of my significant contribution to geotechnical engineering in New Zealand.

4. I have previously (for a period of approximately 7 years) been a Practice Area Assessor for EngNZ, which involved assessing the competence of geotechnical engineers applying for CMEngNZ status.

5. I have provided geotechnical advice for a variety of projects, including residential and commercial building developments, roading projects and municipal landfills.

6. Over the past 10 years I have been involved in the geotechnical investigation, analysis and reporting for several hundred sites in the Canterbury region with projects including, residential and commercial sites. I am routinely asked to carry out assessments of the liquefaction potential of numerous residential and commercial sites in the Canterbury region, including the risk of liquefaction induced lateral ground spread occurring.

7. I was the geotechnical engineer responsible for assessing and reporting for all geotechnical aspects associated with the Te Whāriki residential subdivision in Lincoln, Canterbury. Te Whāriki is a 1,000 lot residential subdivision with a variety of potential geotechnical hazards, including organic soils, complex hydrological conditions and potentially liquefiable soils.

8. As well as assisting developers, I also assist local authorities. I currently provide technical engineering advice to the resource and building consent teams of Marlborough District Council, regarding geotechnical matters. I have also prepared the Liquefaction Assessment Guidelines for MDC.

Code of Conduct

9. I have read the Code of Conduct for Expert Witnesses (contained in the Environment Court Practice Note 2023) and I agree to comply with it. Except where I state that I rely on the evidence of another person, I confirm that the issues addressed in this statement of evidence are within my area of expertise, and I have not omitted to consider material facts known to me that might alter or detract from my expressed opinions.

Scope of Evidence

10. My evidence addresses the geotechnical engineering matters associated with the subject site.

11. The "subject site" comprises:

    (a) Block A: North of Boys Road (approximately 25.7 ha),

    (b) Block B: South of Boys Road and west of a future Eastern Bypass Arterial Road (approximately 36.4 ha).

    The approximate location and extent of the subject site, and 'Block A' and 'Block B', are shown on Fraser Thomas Ltd drawing CH01508-G-02, appended to my November 2023 Geotechnical Report.

12. I understand the Spark submission on this site seeks to rezone:

    (a) the land north of Boys Road, and within the South East Rangiora Development Area (Block A), to Medium Density Residential (MRZ), and

    (b) the land south of Boys Road and west of the eastern bypass (Block B), to MRZ or, in the alternative, rezone this land to MRZ, BIZ (Business Industrial Zone), Format Retail/Mixed Use or a mix of these zones.

    Block B comprises two portions, a large northern portion and a smaller southern area (Block C). Our Block B findings include the Block C area.

13. This First Statement of Evidence introduces, relies upon and summarises the Fraser Thomas Geotechnical Report, dated 23 November 2023 (**Geotechnical Report**). The Geotechnical Report is **Attachment A** to this evidence. I was responsible for scoping the geotechnical investigation works for this project, undertaking the appraisal works relating to the potential peat settlement, reviewing all analyses, preparing the majority of the report and reviewing the final Geotechnical Report, in its entirety, as part of my role as Geotechnical Director for Fraser Thomas.

14. The principal geotechnical matters addressed in the Geotechnical Report include:

(a) Identification of the subsurface conditions on site - including the presence of topsoil, organic soils, non-engineered fill, silts, sandy gravels and groundwater;

(b) The liquefaction potential of the site;

(c) The appropriate foundation technical category for the site;

(d) An assessment of settlement potential, given the subsurface conditions on site, and recommendations to ensure suitable building platforms can be provided;

(e) suitable foundation design solutions for the site;

(f) earthworks considerations;

(g) compaction recommendations.

Geotechnical Assessment

15. The Geotechnical Report assesses:

(a) The subsoil conditions beneath the subject site as they may affect future residential and potentially light industrial development, with particular regard to foundation design considerations; and

(b) The suitability of the subject site for residential and potentially light industrial development.

Overall, I reach the conclusion the site is appropriate for development – either wholly residential or a mix of residential, business/commercial and light industrial.

<u>Subsurface Conditions</u>

16. The subsurface conditions underlying the subject site have been investigated by means of thirteen Cone Penetration Test probes, eighteen machine excavated test pits and associated Dynamic Cone Penetrometer (DCP) scala tests, and a review of existing water bore well logs. A visual appraisal of the site and a study of geological maps have also been undertaken.

17. Two existing machine boreholes, understood to have been put down under the direction of other consultants, are also located in the vicinity of the site. Subsoil information has been obtained from the previous machine borehole and has been used for appraisal purposes.

18. The results of my field investigations indicates that the subject site is, in general, underlain by soils inferred to be alluvial sediments of Holocene Age.

19. A layer of material, generally comprising peat, was encountered at depths ranging between approximately 0.3 m and 0.8 m below the existing ground surface (generally immediately below the topsoil layer), at the locations of Test Pits TP2 to TP11 inclusive, TP16 to TP18 inclusive, and CPT probes CPT1 to CPT7 inclusive, and CPT10 to CPT13 inclusive. These soils were encountered to depths of between approximately 0.4 m and 1.5 m below the existing ground surface, at the locations of these test positions, corresponding to a layer thickness of between approximately 0.1 m and 1.1 m. The layer of peat soils appears to be thicker within Block A, on the northern side of Boys Road. On the southern side of Boys Road, within Block B, the peat layer is generally no thicker than approximately 0.4 m.

20. The surficial peat soils were generally located across the majority of Block A. The approximate inferred location and extent of the area underlain by the surficial layer of peat soils, is shown on Fraser Thomas drawing CH01508-G-02, which is appended to the Geotechnical Report. I have been involved in numerous subdivision developments for sites across New Zealand, which are underlain by peat soils. Recently I was the geotechnical lead engineer for Te Whāriki subdivision- Lincoln, which has similar ground conditions to the subject site, i.e. peat soils and high groundwater. In 2023, I was also the geotechnical lead engineer for a subdivision site in Papamoa (Bay of Plenty) which was underlain by significant peat deposits. Based on my experience, the presence of peat soil layers is not unique to the subject site.

<u>The Development of Suitable Building Platforms</u>

21. It is understood that any future subdivisional development at the site will likely involve cut and fill earthworks, in order to form suitable building platforms and to provide for the construction of suitable gravity wastewater and stormwater reticulation systems.

22. It is further understood that the proposed earthworks will require some imported fill material. The fill is expected to be up to approximately 2.1 m depth, for Block A (north of Boys Road), but generally the fill is expected to be no greater than approximately 0.7 m depth, in this area. The fill is expected to be up to approximately 1.2 m depth, for Block B (south of Boys Road), but generally the fill is expected to be no greater than approximately 0.8 m depth, in this area.

23. I have undertaken settlement analyses, in order to determine the expected settlement magnitudes of the underlying soil layers under the proposed subdivisional fill loads and also the expected foundation loadings (associated with future residential construction).

24. There is a risk, in my opinion, that differential settlement could occur, particularly in areas where subdivisional filling extends over parts of the site which ‘transition’ between areas underlain by peat soils and areas underlain by less compressible soils. This has the potential to adversely affect shallow service lines and shallow foundations, if these are not appropriately designed for the site conditions. However, it is my opinion that the estimated ground settlements are not ‘excessive’ - particularly for Block B, because the peat is generally less thick.

25. To address this, I therefore recommend that any proposed subdivisional fill earthworks undertaken for the site should incorporate appropriately designed and monitored preloading, in order to provide suitable building platforms at the site.

26. An alternative to preloading would be to excavate (i.e. remove) the surficial peat soils from beneath the site. This is considered to be more practical, for Block B where the base of the peat soils is expected to be between approximately 0.6 m and 0.8 m below the existing ground surface. For Block A, the base of the peat extends to depths of up to approximately 1.5 m below the existing ground surface. The removal of the peat, in this area, would likely require some dewatering and would therefore likely be less practical/economical than for Block B.

27. It is my opinion, providing any subdivisional earthworks are undertaken in accordance with the relevant New Zealand Standard Codes of Practice and any recommendations provided in the Geotechnical Report, that building platforms should be available at the site, which would be suitable for future residential and potentially light industrial development.

<u>Foundation Design Solutions</u>

28. In my opinion, appropriately designed earthworks and associated preloading is expected to provide suitable building platforms for residential construction. However, in order to provide for an even more robust foundation system, I have also recommended that the foundation systems comprise a concrete waffle slab type foundation system and are designed assuming “TC1 site conditions” and designed in accordance with the recommendations presented in the Geotechnical Report.

Groundwater Conditions

29. The hydrological conditions across the subject are complex. Based on the results of our shallow and deep investigations (and shallow and deep piezometers), it is likely that there are some 'perched' water tables, in some of the surficial soils, and also a confined aquifer (within the underlying gravels).

30. For concept design purposes, the Geotechnical Report assumed that the surveyed water levels in the various farm drains and streams located at the site are representative of the phreatic surface underlying the site. In my opinion, this remains an appropriate assumption to make.

31. The elevation of the phreatic surface, as indicated by the water levels in the various drains, varies from approximately RL 16.53 m (measured at the western end of the Boys Road), to approximately RL 12.75 m (measured at the eastern end of Boys Road). At these locations, these surveyed groundwater elevations are equivalent to a depth to groundwater of approximately 600 mm below the surrounding ground surface (i.e. immediately abutting the drain).

32. I have been provided with the drill log for a new water well, recently installed at the subject site. The drill log indicates that a confined aquifer underlies the subject site, with the top of the confined aquifer inferred to be at a depth of approximately 29 m below the existing ground surface. It therefore appears all groundwater encountered at relatively shallow levels is perched groundwater or represents the phreatic surface, rather than water from the confined aquifer, which appears to sit at a much lower level below the site.

33. Although detailed design of subdivision infrastructure has not yet been undertaken, it should be appreciated that land development typically involves the installation of underground infrastructure, e.g. underground serviceline trenches. Given the nature of the upper hydrological conditions at the site, it is likely that some serviceline trenches, associated with 'normal' land development activities, could intercept[1] some of the perched groundwater lenses and possibly the phreatic surface. This is not unusual for land development activities undertaken around the country, including the Waimakariri District.

34. Provided civil infrastructure construction works are undertaken in accordance with the relevant New Zealand Standard Codes of Practice, the interception of any surficial perched water lenses or the phreatic surface by underground serviceline trenches, is

[1] For the purposes of my assessment, "intercept" means making contact with or touching groundwater.

expected to have a 'less than minor' effect on the receiving environment. Given its apparent depth (of around 29m), I would not expect any civil infrastructure works to intercept the confined aquifer underlying the site.

35. If it is deemed a requirement to avoid the interception of any surficial perched water lenses or the phreatic surface, one of the ways this could be achieved would be by providing a 'cushion layer' of engineered fill, above the existing ground surface, in which the underground serviceline trenches could be founded. This is likely to result in an increase in the depth and volume of fill required for subdivisional development.

Liquefaction Potential

36. I have undertaken analyses, using the computer programme CLiq, to assess the theoretical liquefaction triggering potential and expected ground settlements for the soils underlying the subject site.

37. Based on the results of the analyses, reported in my November 2023 Geotechnical Report, and given the nature of the upper soils underlying the site, i.e. generally surficial cohesive soils underlain by dense to very dense gravel soils, it is my opinion:

(a) That the subject site, for the purposes of the proposed rezoning submission should be assumed to be within Foundation Technical Category 1 (TC1), as defined by the MBIE Canterbury guidance document; and

(b) It is unlikely that liquefaction induced ground deformation would occur within the area in response to a large earthquake event; and

(c) The ground settlements within the site, in response to seismic loading, should be "within normally accepted tolerances" as defined by the MBIE Canterbury guidance document.

38. It should be noted that the liquefaction analyses reported in the Geotechnical Report, assumed a groundwater level of 1.5 m below the existing ground surface, for analyses purposes. This groundwater level was based on the observed groundwater level, encountered during the test pit investigation.

39. The results of subsequent standpipe piezometer monitoring and site observations, indicates, for liquefaction triggering potential assessment purposes, that it would be more appropriate to assume a groundwater level of 0.6 m below the existing ground surface. The theoretical liquefaction triggering analyses have been re-run, assuming a groundwater level of 0.6 m below the existing ground surface. I confirm that the results indicate that the subject site has the liquefaction potential characteristics of a 'TC1 site',

as defined by the MBIE Canterbury guidance document, which remains consistent with the findings of the Geotechnical Report.

Conclusion

40. I consider the site suitable for its intended use, subject to the various recommendations and qualifications I have discussed above and as reported in more detail in the Geotechnical Report. My opinion also assumes the design and inspection of foundations is carried out in accordance with the requirements of the relevant New Zealand Standard Codes of Practice.

41. In general, the site does not possess any unusual characteristics from a geotechnical perspective and nothing that would preclude development of the site. As noted in both the Geotechnical Report and above, some special considerations arise as a result of peat soils underlying some parts of the site. The Geotechnical Report provides recommendations which will mitigate the effect peat soils might have on development of the site. In my opinion, there are well-recognised solutions available and recommended for this site which can address all potential Geotechnical hazards identified for the site.

42. In my view, the Geotechnical Report includes recommendations which will appropriately avoid, remedy or mitigate potential Geotechnical hazards on the land subject to the application, in accordance with the provisions of Section 106 of the Resource Management Act.

Mason Reed
4 March 2024

Appendix A

Fraser Thomas Ltd "Geotechnical Investigation Report",
dated 23 November 2023

RICHARD AND
GEOFF SPARK

Fraser Thomas
ENGINEERS • RESOURCE MANAGERS • SURVEYORS

PROPOSED DISTRICT PLAN, REZONING REQUEST – SPARK DAIRY FARM, BOYS ROAD, RANGIORA

GEOTECHNICAL INVESTIGATION REPORT

RICHARD AND GEOFF SPARK

PROPOSED DISTRICT PLAN, REZONING REQUEST – SPARK DAIRY FARM, BOYS ROAD, RANGIORA

GEOTECHNICAL INVESTIGATION REPORT

Project No.	CH01508	Approved for Issue	
Version No.	1	Name	M V Reed
Status	Final	Signature	
Authors	K E Twohill		
Reviewer	M V Reed	Date	23 November 2023

Fraser Thomas Limited
Consulting Engineers, Licensed Surveyors
Planners & Resource Managers
Unit 3a Barry Hogan Place,
Riccarton 8041
PO Box 39 154, Harewood Post Centre,8545
Christchurch, New Zealand
Tel : +64 3 358-5936
Email: mreed@ftl.co.nz

SUMMARY

This report presents the results of a geotechnical investigation and appraisal undertaken for the proposed rezoning submission on Variation 1 to the Waimakariri District Plan for the subject site located at Boys Road, Rangiora.

The subject site comprises multiple titles and is best broken down into two separate areas for the purpose of this report. These areas being:

(i) Block A: North of Boys Road (approximately 25.7 ha),

(ii) Block B: South of Boys Road and west of a future Eastern Bypass Arterial Road (approximately 36.4 ha).

The submission is seeking that the above land be rezoned as follows:

(1) With respect to the land south of Boys Road and west of the eastern bypass, rezone the land to Medium Density Residential (MRZ) or, in the alternative, rezone this land to MRZ, BIZ (Business Industrial Zone), Format Retail/Mixed Use or a mix of these zones,

(2) All land north of Boys Road, and within the South East Rangiora Development Area, to MRZ.

The approximate location and extent of the subject site, and 'Block A' and 'Block B', are shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

The subsoil information, presented in Appendix A of this report, indicates that the subject site is, in general, underlain by soils inferred to be alluvial sediments of Holocene Age.

It is our opinion that the subject site, for the purposes of the proposed rezoning submission should be assumed to be within Foundation Technical Category 1 (TC1), as defined by the MBIE Canterbury guidance document, and that it is unlikely that liquefaction induced ground deformation could occur within the area in response to a large earthquake event, and that the ground settlements within the area in response to seismic loading should be considered to be "within normally accepted tolerances" as defined by the MBIE Canterbury guidance document.

Earthworks design recommendations are provided in Sections 13.5 and 17.0 of this report.

Likely suitable foundation solutions are discussed in Section 14.0 of this report.

In general terms and within the limits of the investigation as outlined and reported herein, except for the issues associated with the peat soils underlying the site, no unusual problems, from a geotechnical perspective, are anticipated with future residential and light industrial development at the subject site.

We confirm that this report includes recommendations which will appropriately avoid, remedy or mitigate potential geotechnical hazards on the land subject to the submission, in accordance with the provisions of Section 106 of the Resource Management Act.

The site is, in general, considered suitable for its intended use, with satisfactory conditions for future residential and light industrial building development, subject to the recommendations and qualifications reported herein, and provided the design and inspection of foundations are carried out as would be done under normal circumstances in accordance with the requirements of the relevant New Zealand Standard Codes of Practice.

PROPOSED DISTRICT PLAN, REZONING REQUEST, SPARK DAIRY FARM, BOYS ROAD, RANGIORA

RICHARD AND GEOFF SPARK

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RICHARD AND GEOFF SPARK

1.0 INTRODUCTION

This report presents the results of a geotechnical investigation and appraisal undertaken for the proposed rezoning submission on Variation 1 to the Waimakariri District Plan for the subject site located at Boys Road, Rangiora.

The subject site comprises multiple titles and is best broken down into two separate areas for the purpose of this report. These areas being:

(i) Block A: North of Boys Road (approximately 25.7 ha),

(ii) Block B: South of Boys Road and west of a future Eastern Bypass Arterial Road (approximately 36.4 ha).

The submission is seeking that the above land be rezoned as follows:

(1) With respect to the land south of Boys Road and west of the eastern bypass, rezone the land to Medium Density Residential (MRZ) or, in the alternative, rezone this land to MRZ, BIZ (Business Industrial Zone), Format Retail/Mixed Use or a mix of these zones,

(2) All land north of Boys Road, and within the South East Rangiora Development Area, to MRZ.

The approximate location and extent of the subject site, and ‘Block A’ and ‘Block B’, are shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

The subsurface conditions underlying the subject site have been investigated by means of thirteen Cone Penetration Test probes, eighteen machine excavated test pits and associated Dynamic Cone Penetrometer (DCP) scala tests, and a review of existing water bore well logs.

A visual appraisal of the site and a study of geological maps have also been undertaken.

The purpose of the geotechnical investigation reported herein was to determine the subsoil conditions beneath the subject site as they may affect future residential and potentially light industrial development, with particular regard to foundation design considerations, and to determine the suitability of the subject site for residential and potentially light industrial development, in support of a submission a plan change.

2.0 PREVIOUS REPORTS

A previous report titled "Review of liquefaction hazard information in eastern Canterbury, including Christchurch City and parts of Selwyn, Waimakariri and Hurunui Districts", dated December 2012, was prepared by the Institute of Geological and Nuclear Sciences Limited (GNS Science) for the Environment Canterbury Regional Council.

The December 2012 report was prepared in order to determine the parts of the Canterbury area which may be susceptible to the damaging effects of liquefaction induced ground deformations and areas where liquefaction induced damage is unlikely to occur.

Figure 2.1 presented in the December 2012 report, indicates that the majority (west and central portions) of the subject site is sited in the zone where the December 2012 report indicates that damaging liquefaction induced ground deformation is considered to be "unlikely". The December 2012 report goes on to state the following with regard to the zone which the subject site is located within:

> *"... in this area there is little or no likelihood of damaging liquefaction occurring during strong ground shaking. This assessment area consists of the western part of the project area, and most of Banks Peninsula. Within this area, investigations in most cases can be designed primarily for other geotechnical hazards. Liquefaction however must at least be considered by the geotechnical professional in all cases."*

Figure 2.1 presented in the December 2012 report, indicates that the eastern portion of the subject site is sited within the zone where the December 2012 report indicates that a liquefaction assessment is "needed". The December 2012 report goes on to state the following with regard to the zone which the subject site is located within:

> *"... in this area there is a small to considerable likelihood of damaging liquefaction occurring during strong ground shaking. The eastern part of the project area and some low-lying areas of Banks Peninsula, close to the sea or the Canterbury Plains lie within this area. Specific investigation of liquefaction susceptibility is required as well as assessment of other geotechnical hazards."*

3.0 AERIAL PHOTOGRAPHS

A range of historic aerial photography of the site, ranging from 1940's to 2018, has been examined, as part of the site appreciation.

<u>1940's Aerial Photography</u>

Aerial photography, captured between 1940 and 1944, shows that the subject site comprised pastoral farmland. The site was surrounded by paddocks of a similar nature, and residential dwellings. The Middle Brook Stream. It appears that this stream meandered through the paddocks at this time.

<u>1955 Aerial Photography</u>

Aerial photography, captured in 1955, and imagery from the subsequent decades, indicates that the Middle Brook Stream appears to have been infilled prior to this date, with the present day straight diversion in place, bordering several paddocks. The backfill material is of unknown origin and nature. This area is to the south-west of, and outside of, the proposed development.

4.0 GEOLOGY

In assessing the geology of the site, reference has been made to the Institute of Geological & Nuclear Sciences Geological Map 16, scale 1:250,000, “Christchurch”.

The geological map indicates that the site is underlain by alluvial deposits comprising “*Brownish-grey river alluvium*” of Late Pleistocene age.

The results of the CPT probe, machine borehole and machine excavated test pit investigation reported herein, in general, indicate that the surficial soils underlying the site are likely to comprise alluvial sediments, inferred to be of Holocene age.

5.0 PROPOSED DEVELOPMENT

As discussed in Section 1.0 of this report, the subject site comprises multiple titles and is best broken down into two separate areas for the purpose of this report. These areas being:

(iii) Block A: North of Boys Road (approximately 25.7 ha),

(iv) Block B: South of Boys Road and west of a future Eastern Bypass Arterial Road (approximately 36.4 ha).

The submission is seeking that the above land be rezoned as follows:

(3) With respect to the land south of Boys Road and west of the eastern bypass, rezone the land to Medium Density Residential (MRZ) or, in the alternative, rezone this land to MRZ, BIZ (Business Industrial Zone), Format Retail/Mixed Use or a mix of these zones,

(4) All land north of Boys Road, and within the South East Rangiora Development Area, to MRZ.

The approximate location and extent of the subject site, and ‘Block A’ and ‘Block B’, are shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

It is understood that any future subdivisional development at the site will likely involve cut and fill earthworks, in order form suitable building platforms and to provide for the construction of suitable gravity wastewater and stormwater reticulation systems. It is understood that the proposed earthworks will also require some imported fill material. The fill is expected to be up to approximately 2.1 m depth, for Block A (north of Boys Road), but generally the fill is expected to be no greater than approximately 0.7 m depth, in this area. The fill is expected to be up to approximately 1.2 m depth, for Block B (south of Boys Road), but generally the fill is expected to be no greater than approximately 0.8 m depth, in this area.

It is also understood that it is likely that stormwater management systems would be required to be constructed at the site, as part of any future subdivisional development (i.e. first flush basins).

It is also understood that the existing farm building structures (sheds and farm house), located at the site, will likely be removed as part of any future subdivision development.

6.0 FIELD INVESTIGATION

6.1 GENERAL

The field investigation comprised a visual appraisal, 13 Cone Penetration Test probes, and 18 machine excavated test pits with associated Dynamic Cone Penetrometer (DCP) scala tests.

Two existing machine boreholes, understood to have been put down under the direction of other consultants, are also located in close proximity to the site.

The approximate locations of the investigation test positions are shown on Fraser Thomas Ltd drawing CH01508-G-02.

6.2 RESULTS OF VISUAL APPRAISAL

A visual appraisal of the subject site was undertaken by a Fraser Thomas Ltd engineering geologist on 14 and 15 November 2022.

The subject site is generally located between North Brook Stream (to the north), and Marsh Road (to the south. Boys Road roughly bisects the site, centrally. Existing rural properties abut the eastern site boundary, and by existing semi-rural and residential properties to the west.

The approximate location and extent of the subject site is shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

The topography within the subject site is generally flat.

The majority of the site comprises paddocks vegetated with grass.

Two existing single storey dwellings are located across the site. The dwellings generally comprise light timber frame construction, with brick claddings. The existing dwellings generally have several ancillary sheds and garages, of various construction styles and claddings.

An existing lake, associated with the Northbrook wetlands, is located along the northern side of the site. The Middle Brook Stream abuts the south-western corner of the site.

The approximate inferred locations and extents of the existing structures and other site features are shown on drawing CH01508-G-02.

No obvious signs of any significant ground deformation, that could be attributed to liquefaction induced ground movement, were observed within the subject site, at the time of the investigation reported herein.

6.3 MACHINE EXCAVATED TEST PIT INVESTIGATION

Eighteen machine excavated test pits, numbered TP1 to TP18 inclusive, and associated DCP tests, were put down at the site, in order to investigate the shallow subsurface conditions beneath the subject site.

The test pits were excavated under the supervision of a qualified Fraser Thomas Ltd engineering geologist.

The test pits were terminated at depths ranging between approximately 1.0 m and 2.5 m below the ground surface existing at the time of the investigation reported herein (the existing ground surface).

All soils in the test pits were carefully logged.

Dynamic Cone Penetrometer (DCP) scala tests were performed from the ground surface adjacent to Test Pits TP11 and TP15.

The approximate locations of the test positions are shown on the appended drawing CH01508-G-02.

6.4 CPT INVESTIGATION

Thirteen Cone Penetration Test (CPT) probes, numbered CPT1 to CPT13 inclusive, were carried out at the site on 28 and 29 November 2022, under the direction of Fraser Thomas Ltd. The CPT probes were pushed in order to obtain continuous strength profiles for the subsoils, and for the purpose of determining the theoretical liquefaction potential of the soils.

The CPT probes were terminated at depths of between approximately 5.0 m and 9.5 m below the existing ground surface, due to the probes being unable to be progressed through dense gravelly soils.

The CPT data has been interpreted using the computer program CPeT-IT. The results of the interpretation of the CPT data are presented in Appendix A of this report.

The approximate locations of the CPT probes are shown on drawing CH01508-G-02.

6.5 MACHINE BOREHOLE INVESTIGATION

As discussed in Section 6.1 of this report, two existing machine boreholes, understood to have been put down under the direction of other consultants, are also located in the vicinity of the site. Subsoil information has been obtained from the previous machine borehole and has been used for appraisal purposes in this report.

For the purposes of this report, the existing machine boreholes are identified as Machine Boreholes M1 and M2.

Standard Penetration Tests (SPT) were carried out, in order to quantify the properties of the soils.

The logs of the machine boreholes are presented in Appendix A of this report.

Machine Borehole M1 was terminated at a depth of approximately 15.3 m below the existing ground surface.

Machine Borehole M2 was terminated at a depth of approximately 6.1 m below the existing ground surface.

The approximate locations of the machine boreholes are shown on drawing CH01508-G-02.

7.0 SUBSURFACE CONDITIONS

7.1 GENERAL

The subsoil information, presented in Appendix A of this report, indicates that the subject site is, in general, underlain by soils inferred to be alluvial sediments of Holocene Age.

It has been assumed that even though the various subsoil strata (depths, thicknesses, and locations of groundwater levels) have been determined only at the locations and within the depths of the various test positions recorded herein, these various subsurface features can be projected between the various test positions. Even though such inference is made, no guarantee can be given as to the validity of this inference or of the nature and continuity of these various subsurface features.

7.2 TOPSOIL

A surficial layer of topsoil, generally comprising silts, was encountered to depths of between approximately 0.3 m and 0.5 m below the existing ground surface, at the locations of the test pits. Generally, the surficial topsoil layer is no thicker than approximately 0.3 m.

7.3 NON-ENGINEERED FILL

It is understood that some previous works have been undertaken, in the eastern corner of the site, to re-align the North Brook Stream in this area. It is understood that some non-engineered fill material was placed, in this area, as part of these works.

The approximate inferred location and extent of the non-engineered fill material, associated with the previous re-alignment works, is shown on the drawing CH01508-G-02.

7.4 ALLUVIAL SEDIMENTS

7.4.1 Organic Soils

A layer of material, generally comprising peat, was encountered at depths ranging between approximately 0.3 m and 0.8 m below the existing ground surface (generally immediately below the topsoil layer), at the locations of Test Pits TP2 to TP11 inclusive, TP16 to TP18 inclusive, and CPT probes CPT1 to CPT7 inclusive, and CPT10 to CPT13 inclusive. These soils were encountered to depths of between approximately 0.4 m and 1.5 m below the existing ground surface, at the locations of these test positions, corresponding to a layer thickness of between approximately 0.1 m and 1.1 m. The layer of peat soils appears to be thicker within Block A, on the northern side of Boys Road. On the southern side of Boys Road, within Block B, the peat layer is generally no thicker than approximately 0.4 m.

The surficial peat soils were generally located in the northern and central parts of the site. These soils were generally absent in the southern part of the site (i.e. the southern part of Block B).
The approximate inferred location and extent of the area of the site inferred to be underlain by the surficial layer of peat soils, is shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

In situ undrained shear strength values of between approximately 42 kPa and 90 kPa were generally measured in these sediments, using hand held shear vane equipment, corresponding to a firm to stiff consistency.

The CPT probe generally obtained cone resistance (q_t) values of between approximately 0.1 MPa and 0.3 MPa in the organic soils, corresponding to in situ undrained shear strength values of between approximately 6 kPa and 20 kPa, corresponding to a very soft to soft consistency.

Due to its nature and consistency, the layer of peat soils is inferred to be highly compressible.

7.4.2 Silts and Sandy Silts

The results of the CPT probes and machine excavated test pit investigation reported herein indicate that the surficial layers of topsoil and organic soils at the site are generally underlain by an upper layer of soils, generally comprising non-organic clayey silts, sandy silts and silts, inferred to be alluvial sediments of Holocene age. These sediments were generally encountered to a depth of between approximately 0.6 m and 1.5 m below the existing ground surface, in the northern and central parts of the site, and at a depth of approximately 0.3 m below the existing ground surface, in the southern part of the site.

In situ undrained shear strength values of between approximately 50 kPa and greater than 200 kPa were generally measured in these cohesive sediments, using hand held shear vane equipment, corresponding to a stiff to hard consistency.

The CPT probe generally obtained cone resistance (q_t) values of between approximately 0.5 MPa and 6.3 MPa in the non-organic alluvial sediments, corresponding to in situ undrained shear strength values of between approximately 35 kPa and in excess of 200 Pa, corresponding to a firm to hard consistency.

7.4.3 Sandy Gravels

The results of the machine excavated test pit, CPT probes and machine borehole investigations reported herein indicate that the surficial soils at the site are generally underlain by a layer of material, generally comprising sandy gravels. These soils were generally encountered at depths ranging between approximately 0.6 m and 2.6 m below the existing ground surface, at the locations of the CPT probes and machine excavated test pits. The sandy gravels were encountered to the extents of the test positions. The CPT probes were unable to be progressed through the sandy gravels.

The results of the DCP tests undertaken in the sandy gravels generally obtained DCP blow counts of between approximately 2 and greater than 15 blows per 50 mm penetration, corresponding to a SPT 'N' value of greater than 50, corresponding to a very dense consistency.

The CPT probes obtained cone resistance (q_t) values of generally greater than 20 MPa in these sediments, corresponding to very dense consistency.

Generally the gravel soils were encountered at shallower depths in the southern part of the site (between approximately 0.6 m and 1.1 m below the existing ground surface), and were at deeper depths north of Boys Road (between approximately 1.3 m and 2.3 m below the existing ground surface).

Boreholes M1 and M2 indicate that sandy gravels were located from the existing ground surface. The borehole logs indicate that these sandy gravels generally extended to depths in excess of 15.3 m (i.e. the extents of the machine boreholes).

SPT tests carried out in these sandy gravels obtained 'N' values ranging between approximately 20 and greater than 50, corresponding to a medium dense to very dense consistency.

The logs of water bores, put down in the vicinity of the subject site, have been sourced from Environment Canterbury records. The existing water bore logs indicate that sandy gravels are generally located at shallow depths, which is consistent with the subsoil conditions encountered at the subject site. The bore logs indicate that these sandy gravels generally extend to depths in excess of approximately 20 m below the ground surface. Based on the foregoing, it is, in our opinion, likely that the gravels underlying the site extend to significant depths below the existing ground surface.

7.5 GROUNDWATER

During the machine excavated test pit investigations undertaken at the site, the groundwater level was inferred to be at depths generally ranging between approximately 1.5 m and 2.1 m below the existing ground surface.

It should be noted that standpipe piezometers were installed at the locations of CPT1, CPT7, CPT8 and CPT10, during the field investigation undertaken in November 2022. Monitoring of these standpipes indicates the following average measured groundwater levels:

(i) CPT1 - 0.6 m below ground level

(ii) CPT7 - 0.1 m below ground level

(iii) CPT8 - 1.0 m below ground level

(iv) CPT10 - 0.25 m below ground level.

These levels are higher than the groundwater levels encountered during the test pit investigation, in particular at the locations of CPT7 and CPT10. The standpipes are founded at depths of between approximately 5.0 m and 5.8 m below the existing ground surface, generally within sandy gravel material. It is possible that the standpipes are founded within a shallow confined aquifer, which is resulting in ‘elevated’ standpipe piezometer levels.

8.0 LIQUEFACTION POTENTIAL ASSESSMENT

8.1 GENERAL

Liquefaction is defined as the phenomenon that occurs when soils are subject to a sudden loss in shear stiffness and strength associated with a reduction in effective stress due to cyclic loading (i.e. ground shaking associated with an earthquake).

The two main effects of liquefaction on soils are:

(a) Consolidation of the liquefied soils,

(b) Reduction in shear strength within the liquefied soils.

Liquefaction is considered to occur when the soils reach a condition of “zero effective stress”. It is considered that only “sand like” soils can reach a condition of “zero effective stress” and therefore only “sand like” soils are considered to be liquefiable.

An indication that the underlying soils have been subject to liquefaction is the surface expression of ejected sand and water. This occurs as a result of the dissipation of excess pore water pressures generated within the liquefied soils as a result of the cyclic loading.

It should be noted that cohesive type materials or "clay like" soils are unlikely to be subject to liquefaction, as these soils (due to their nature) are unlikely to develop sufficient excess pore water pressures during cyclic loading to reach a condition of zero effective stress, i.e. the point of liquefaction.

However, "clay like" soils do develop some excess pore water pressures during cyclic loading which can result in consolidation settlement and a temporary reduction of the shear strength (i.e. softening) of the soils. Sensitive "clay like" soils are in particular susceptible to softening as a result of cyclic loading.

A liquefaction potential assessment has been undertaken for the soils underlying the subject site.

8.2 METHOD OF ANALYSIS

The New Zealand Geotechnical Society released Guidelines, in 2016, with the objective of summarising current best practice in earthquake geotechnical engineering with a focus on New Zealand conditions. The main purpose of the Guidelines is to promote consistency of approach to everyday engineering practice in New Zealand and, thus, improve geotechnical earthquake aspects of the performance of the built environment.

The Guidelines consists of six modules (identified as Modules 1 to 6 inclusive).

"*Module 3: Identification Assessment and Mitigation of Liquefaction Hazards*" of the Guidelines provides guidance on the identification of liquefaction hazards, and also provides details regarding different methodologies for determining theoretical liquefaction triggering.

The Module 3 guideline suggests a three step process for the liquefaction assessment of sites, generally being:

(i) Step 1: Assessment of liquefaction susceptibility,

(ii) Step 2: Triggering of liquefaction,

(iii) Step 3: Consequences of liquefaction.

The Module 3 guideline refers to the methods suggested by "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils", dated October 2001. The guideline, among others, also refers to papers by Youd et al; Seed; Idriss; Boulanger; Robertson and Bray.

A liquefaction potential assessment of the soils underlying the subject site has been undertaken using the methods suggested by the Module 3 guideline.

8.3 ASSESSMENT OF LIQUEFACTION SUSCEPTIBILITY

The following soils are generally considered to be susceptible to liquefaction:

(a) Young (typically Holocene age) alluvial sediments (typically fluvial deposits laid down in a low energy environment) or man-made fills,

(b) Poorly consolidated/compacted sands and silty sands,

(c) Areas with a high groundwater level.

As discussed in Section 4.0 of this report, the geological map for the Canterbury area indicates that the site is likely to be underlain by "*Brownish-grey river alluvium*" of Late Pleistocene age.

As discussed in Section 7.4 of this report, the results of the CPT probes, machine excavated test pits and machine borehole investigations indicate the site is generally underlain by surficial alluvial sediments, comprising surficial organic sediments, underlain by cohesive sediments, which in turn are underlain by sandy gravels, at depth.

Based on the results of the machine excavated test pit investigation, the groundwater level is inferred to be at a depth of approximately 1.5 m below the existing ground surface, for analysis purposes.

Based on the foregoing, it is our opinion that some soils underlying the site are likely to be susceptible to liquefaction.

8.4 TRIGGERING OF LIQUEFACTION

The NCEER report, dated October 2001, suggests the triggering of liquefaction within soils be assessed using the methods suggested by Seed and Idriss (1971), which states that:

FL = CRR/CSR

-where FL = Liquefaction Triggering Factor

CRR = Cyclic Resistance Ratio (ability of soils to resist liquefaction)

CSR = Cyclic Stress Ratio (seismic demand on soil caused by earthquake)

When FL £ 1.0 - Liquefaction is assumed to occur within the soil layer.

Generally, the calculation of the CRR value for a certain soil is determined taking into account the soil type, density and the depth (confinement) of the soil layer.

Generally, the calculation of the CSR value for a certain soil is determined taking into account the theoretical PGA resulting from an earthquake and the depth (confinement) of the soil layer. Computer programs are available which can compute the CRR and CSR values for soils using the data obtained from the CPT probes.

The CRR and CSR values, and the theoretical triggering of liquefaction within the soils underlying the site, have been assessed using the computer program CLiq using the data obtained from the CPT probe investigation discussed in Section 6.4 of this report.

CLiq is a computer program that uses the methods suggested by the NCEER report (October 2001) and which also applies amended calibration/methodology procedures suggested by Zhang, Idriss and Boulanger, Robertson et al.

The results of the analyses to determine the theoretical liquefaction triggering potential of the site soils are presented in Section 9.4 of this report.

8.5 CONSEQUENCES OF LIQUEFACTION

The possible consequences of liquefaction of the soils beneath a site may include:

(i) Ground settlement,

(ii) Ejection of sand at the surface,

(iii) Differential building foundation settlement as a result of differential ground settlement,

(iv) Foundation settlement as a result of bearing capacity failure of the soils (both "sand like" and "clay like"),

(v) Lateral displacement of the ground as a result of "lateral spread".

Theoretical analyses have been undertaken using the computer program CLiq to determine the theoretical ground settlements expected to occur as a result of liquefaction of soil layers. The analyses have been undertaken using the CPT probe data obtained from the site.
CLiq uses the methods suggested by Zhang et al (2002 and 2004) to predict ground settlements expected to occur as a result of liquefaction of "sand like" soil layers.

The results of the analyses to determine the theoretical ground settlements as a result of liquefaction of the subsoils are presented in Section 9.4 of this report.

9.0 THEORETICAL ANALYSES OF LIQUEFACTION TRIGGERING POTENTIAL AND EXPECTED GROUND SETTLEMENTS

9.1 GENERAL

Analyses have been undertaken using the computer programme CLiq to assess the theoretical liquefaction triggering potential and expected ground settlements for the soils underlying the subject site.

The analyses have been undertaken for the subsoil profile obtained at the locations of CPT1 to CPT13 inclusive.

9.2 PEAK GROUND ACCELERATION (PGA) VALUES ASSUMED FOR ANALYSES

The following design earthquake events have been assessed for the site for the purposes of the analyses reported herein:

(a) Serviceability Limit State (SLS) – 25 year return period,

(b) Intermediate Limit State (ILS) – 100 year return period,

(c) Ultimate Limit State (ULS) – 500 year return period.

It is noted that *"Module 1: Overview of the Guidelines"*, indicates that generally, in New Zealand, the unweighted seismic hazard factors and corresponding effective earthquake magnitude presented in the NZTA Bridge Manual (2014) should be used in liquefaction triggering analyses. However, the guideline indicates that the seismic hazard factors provided in the Ministry of Business, Innovation & Employment (MBIE) document entitled "Repairing and rebuilding houses affected by the Canterbury earthquakes"; Version 3, dated December 2012, should be used in the Canterbury area.

The MBIE guidance provides recommendations as to the PGAs that should be used for liquefaction potential assessments within the Christchurch area, for the SLS and ULS design earthquakes.

The theoretical PGA values and corresponding earthquake Moment Magnitudes (Mw) for liquefaction potential assessments for the SLS and ULS design conditions, recommended by the MBIE, are presented in Table 1 of this report.

As a result of further research undertaken by Boulanger & Idriss (2014) - B&I (2014), which takes into account case history data from the Christchurch area, a new formulation for the determination of the Magnitude Scaling Factor (MSF) has been developed, which takes into account the nature and density of the soils. The new formulation has negligible effect on the determination of the MSF for ULS design strength earthquake events but can have a significant effect on the MSF determined for sites under loading from an SLS design earthquake event. For this reason, the MBIE guidelines (Update No. 50, dated October 2014) recommends, when undertaking analyses using the B&I (2014) method of analyses, that an "intermediate" design strength earthquake (ILS) also be analysed when predicting the expected liquefaction triggering and associated ground settlements for the SLS design earthquake event.

It is recommended by the MBIE guidelines that the larger theoretical index settlement value calculated using the earthquake loading parameters for the SLS and ILS design earthquake events be used as the theoretical SLS index settlement value, when assessing the theoretical liquefaction potential for sites in Christchurch.

TABLE 1: DESIGN PEAK GROUND ACCELERATION (PGA) VALUES FOR ASSUMED DESIGN CONDITIONS

Design Condition	Design Peak Ground Acceleration (pga) (proportion of gravity acceleration (m/s^2))	Earthquake Moment Magnitude (M_w)
SLS	0.13g	7.5
ULS	0.35g	7.5
ILS	0.19g	6.0

9.3 METHOD OF ANALYSES

9.3.1 General

The MBIE guidance document (2012) recommends that the theoretical settlement “index number” is calculated using the following methodology:

(i) assessing liquefaction induced settlement only for the upper 10 m of subsoils under SLS seismic load conditions,

(ii) using the liquefaction potential assessment methods suggested by Idriss & Boulanger (2008).

The MBIE guidelines (Update No. 50, dated October 2014), also allows the liquefaction triggering analyses of sites in Christchurch to be undertaken using the deterministic methodology suggested by Boulanger & Idriss (2014).

The research paper prepared by B&I (2014) provides an update to the CPT database case histories and updates the CPT-based liquefaction triggering correlations, based on new information obtained from sites in the Christchurch area.

Because the deterministic methodology, suggested by B&I (2014), takes into account additional case history data obtained from sites in Christchurch, it is our opinion that the 2014 methodology will likely provide more reliable predictions of liquefaction triggering and associated ground settlements for sites in Christchurch than the 2008 methodology. For this reason, we have adopted the methodology suggested by Boulanger & Idriss (2014) for the analyses reported herein.
It should also be noted that the Module 3 guidelines also recommends using the Boulanger & Idriss (2014) methodology, for determining theoretical liquefaction triggering.

9.3.2 Fines Content Correlations

B&I (2014) states the following:

> *“The revised CPT-based liquefaction triggering procedure* [i.e. the B&I- 2014 methodology] *included a recommend relationship and approach for estimating FC and soil classification from the I_c index when site specific sampling and lab testing data are not available. For analyses in the absence of site-specific soil sampling and lab testing data, it would be prudent to perform parametric analyses to determine if reasonable variations in the FC and soil classification parameters have a significant effect on the final engineering recommendation.”*

B&I (2014) goes on to recommend that a sensitivity analyses be undertaken, varying the C_{FC} (fitting parameter), for the FC-I_c correlations.

Lees, et al (2015) used the results of an extensive geotechnical investigation dataset collected following the 2010/2011 Canterbury earthquake sequence to examine the correlations of the liquefaction susceptibility and FC with I_c for the Christchurch soils.

Borehole and CPT data were used to assess the appropriateness of the FC-I_c correlations, presented in B&I (2014), as well as the I_c cut-off threshold. The results of the study indicate, for Christchurch soils, that the default C_{FC} value of 0.0 will generally over-predict liquefaction triggering, and that a C_{FC} parameter of 0.2 is appropriate for Christchurch soils.

9.3.3 Thin Sand Layer "Transition Zones"

Robertson, Idriss and Boulanger et al recognise that the reliability of CPT based theoretical liquefaction triggering analyses, can be affected by an effect known as the "thin sand layer" transition zone. This occurs because the CPT probe provides readings from a soil influence zone, which is located some distance in front of the cone tip (the influence zone varies with soil types), which can underestimate the cone resistance of sand layers (particularly when sandwiched between soft cohesive soil layers), which can consequently incorrectly estimate liquefaction triggering for some layered sandy soils.

PK Robertson (2009) provides a method for adjusting for this effect in the CLiq program. The adjustment is based on the rate of change of the Soil Behaviour Type Index (I_c).

It should be noted, however, that recent research has shown that there is currently no reliable method for dealing with the problem of thin sand layer 'transition zones', and that Geoprofessionals should therefore be prudent when attempting to allow for the "thin sand layer" transition zone, in their analyses.

In order to provide some allowance for the 'thin sand layer' issue, we have undertaken liquefaction triggering analyses using the thin sand layer adjustment methodology or "transition zone" adjustment methodology, suggested by PK Robertson, and have also undertaken the analyses allowing for no thin sand layer adjustment. The results of the two analyses have been averaged, in order to more reliably determine the theoretical liquefaction triggering potential of the soils, by allowing for some 'thin sand layer' influence.

9.3.4 Summary

The input parameters used for the theoretical liquefaction triggering analyses reported herein are summarised in Table 2.

TABLE 2: INPUT PARAMETERS FOR LIQUEFACTION ANALYSES

Input parameter	Value adopted	Comments
Design Seismic Loading	See Table 1	See Section 9.2
I_c cut-off	2.6	Appropriate value for Christchurch (Lees, et al)
Probability of Liquefaction (PL)	16%	Deterministic value - in accordance with B&I (2014)
FC Fitting Parameter C_{FC}	Range (0.0 to 0.2)	Sensitivity analyses undertaken

9.4 RESULTS OF ANALYSES

As discussed in Section 9.3.2 of this report, the results of the study undertaken by Lees, et al, indicates, for Christchurch soils, that the default C_{FC} value of 0.0 will generally over-predict liquefaction triggering, and that a C_{FC} parameter of 0.2 is appropriate for Christchurch soils.

For the purposes of the theoretical liquefaction analyses reported herein, a sensitivity analyses have been undertaken to more reliably determine the FC-I_c correlation. The sensitivity analyses have been undertaken assuming the following C_{FC} values: 0.0, 0.1 and 0.2.

The results of the liquefaction analyses undertaken for the site for the SLS, ILS and ULS design earthquake events are summarised in Tables 3, 4 and 5 respectively.

TABLE 3: THEORETICAL EXPECTED GROUND SETTLEMENTS FOR SERVICEABILITY LIMIT STATE (SLS) DESIGN EARTHQUAKE EVENT

CPT probe	Range of theoretical expected ground settlement (mm) (C_{FC}= 0.0, 0.1, 0.2)	Mean theoretical expected ground settlement (mm) (C_{FC}= 0.0 to 0.2)
1	0, 0, 0	0
2	0, 0, 0	0
3	0, 0, 0	0
4	0, 0, 0	0
5	0, 0, 0	0
6	0, 0, 0	0
7	0, 0, 0	0
8	0, 0, 0	0
9	0, 0, 0	0

10	0, 0, 0	0
11	0, 0, 0	0
12	0, 0, 0	0
13	0, 0, 0	0

TABLE 4: THEORETICAL EXPECTED GROUND SETTLEMENTS FOR INTERMEDIATE LIMIT STATE (ILS) DESIGN EARTHQUAKE EVENT

CPT probe	Range of theoretical expected ground settlement (mm) (C_{FC}= 0.0, 0.1, 0.2)	Mean theoretical expected ground settlement (mm) (C_{FC}= 0.0 to 0.2)
1	0, 0, 0	0
2	0, 0, 0	0
3	0, 0, 0	0
4	0, 0, 0	0
5	0, 0, 0	0
6	0, 0, 0	0
7	0, 0, 0	0
8	0, 0, 0	0
9	0, 0, 0	0

10	0, 0, 0	0
11	0, 0, 0	0
12	0, 0, 0	0
13	0, 0, 0	0

TABLE 5: THEORETICAL EXPECTED GROUND SETTLEMENTS FOR ULTIMATE LIMIT STATE (ULS) DESIGN EARTHQUAKE EVENT

CPT probe	Range of theoretical expected ground settlement (mm) (C_{FC}= 0.0, 0.1, 0.2)	Mean theoretical expected ground settlement (mm) (C_{FC}= 0.0 to 0.2)
1	0, 0, 0	0
2	0, 0, 0	0
3	1, 1, 1	1
4	0, 0, 0	0
5	1, 1, 1	1
6	0, 0, 0	0
7	1, 1, 1	1
8	0, 0, 0	0
9	0, 0, 0	0

10	1, 1, 1	1
11	0, 0, 0	0
12	0, 0, 0	0
13	1, 1, 1	1

The results of the analyses are presented in Appendix B of this report.

It should be noted that the theoretical liquefaction induced ground settlements presented in Tables 3, 4 and 5, for the soils encountered at the locations of the CPT probes, have only been obtained for the analyses of the upper 5.1 m to 9.5 m depth of the subsoils, due to the CPT probes being unable to be progressed through the sandy gravels.

It is conventionally acceptable to analyse the upper 10 m of the subsoils when assessing the potential liquefaction induced ground settlements that could be expected to affect a site, in accordance with the MBIE guidelines. It is possible that liquefiable soils are located beneath the upper 5.1 m to 9.5 m depth of the subsoils, which could increase the theoretical liquefaction induced ground settlements for the site. For this reason, the theoretical settlement values presented in Tables 3, 4 and 5, could be considered to be conservatively low.

That been said, it is unlikely, in our opinion, that any significant liquefaction induced ground settlement would occur as a result of liquefaction of the dense to very dense sandy gravels (i.e. the layer located below the upper 5.1 m to 9.5 m of soils), as these soils, due to their nature, are generally not expected to be liquefiable.

10.0 LIQUEFACTION SEVERITY NUMBER (LSN)

Following the Canterbury Earthquake Sequence (CES), S. van Ballegooy, et al (2013) developed an unweighted assessment methodology, to assess the vulnerability of land to liquefaction-induced damage. The methodology suggests the use of a dimensionless number termed the Liquefaction Severity Number (LSN).

The LSN, is defined as:

$$LSN = 1000 \int \frac{\varepsilon_v}{z} dz$$

- where ε_v is the calculated post-liquefaction volumetric reconsolidation strain, and z is the depth below the ground surface in metres. The LSN is calculated over the upper 10 m depth profile of the subsoil.

The theoretical value of LSN varies from 0 (representing no liquefaction vulnerability) to more than 100 (representing very high liquefaction vulnerability).

S. van Ballegooy, et al (2013) suggest a range of LSN values, which relate to three categories of expected degree of liquefaction-induced ground damage, namely:

(i) None to minor,

(ii) Minor to moderate,

(iii) Moderate to severe.

The original LSN 'boundary' values, suggested by Ballegooy (2013), have been amended by more up-to-date studies. The suggested range of LSN values for each ground damage category, are presented in Table 6.

TABLE 6: LSN RANGES - CORRESPONDING TO EXPECTED LIQUEFACTION-INDUCED GROUND DAMAGE

LSN	Expected liquefaction-induced ground damage category
< 13	None to minor
13 – 18	Minor to moderate
18+	Moderate to severe

The typical consequences at the ground surface, for the various categories presented in Table 8 are described in Table 2.2 of the MBIE guidance document, titled "Planning and Engineering Guidance for Potentially Liquefaction Prone Land", dated September 2017.

For the purposes of the theoretical liquefaction analyses reported herein, and in order to determine the LSN values for the various design earthquake events, a sensitivity analyses has been undertaken assuming the following C_{FC} values: 0.0, 0.1 and 0.2.

The mean LSN value has been calculated from the sensitivity analyses, for the SLS, ILS and ULS design earthquake events, and has been adopted for the site. The results of the analyses to determine the LSN values are presented in Tables 7, 8 and 9.

TABLE 7: MEAN LSN VALUE - FOR SERVICEABILITY LIMIT STATE (SLS) DESIGN EARTHQUAKE EVENT

CPT probe	Mean LSN value	Expected liquefaction-induced ground damage category
1	0	None to minor
2	0	None to minor
3	0	None to minor
4	0	None to minor
5	0	None to minor
6	0	None to minor
7	0	None to minor
8	0	None to minor
9	0	None to minor
10	0	None to minor
11	0	None to minor
12	0	None to minor
13	0	None to minor

TABLE 8: MEAN LSN VALUE - FOR INTERMEDIATE LIMIT STATE (ILS) DESIGN EARTHQUAKE EVENT

CPT probe	Mean LSN value	Expected liquefaction-induced ground damage category
1	0	None to minor
2	0	None to minor
3	0	None to minor
4	0	None to minor
5	0	None to minor
6	0	None to minor
7	0	None to minor
8	0	None to minor
9	0	None to minor
10	0	None to minor
11	0	None to minor
12	0	None to minor
13	0	None to minor

TABLE 9: MEAN LSN VALUE - FOR ULTIMATE LIMIT STATE (ULS) DESIGN EARTHQUAKE EVENT

CPT probe	Mean LSN value	Expected liquefaction-induced ground damage category
1	0	None to minor
2	0	None to minor
3	0	None to minor
4	0	None to minor
5	0	None to minor
6	0	None to minor
7	0	None to minor
8	0	None to minor
9	0	None to minor
10	0	None to minor
11	0	None to minor
12	0	None to minor
13	0	None to minor

Based on the results of the investigation and appraisal reported herein (and as indicated in Tables 7 and 8 of this report), it is our opinion that the liquefaction-induced ground damage expected to occur at the site, in response to a SLS design earthquake event, is considered to be none to minor.

Based on the results of the investigation and appraisal reported herein (and as indicated in Table 9 of this report), it is our opinion that the liquefaction-induced ground damage expected to occur at the site, in response to a ULS design earthquake event, is also considered to be none to minor.

11.0 FOUNDATION TECHNICAL CATEGORY FOR THE SITE

The Ministry of Business, Innovation & Employment (MBIE) released a document entitled "Repairing and rebuilding houses affected by the Canterbury earthquakes"; Version 3, dated December 2012.

It should be noted that the MBIE guidance document supersedes the following previous Department of Building and Housing (DBH) and MBIE documents:

(a) "Revised guidelines on repairing and rebuilding houses affected by the Canterbury earthquake sequence", dated November 2011,

(b) "Interim guidance for repairing and rebuilding foundations in Technical Category 3", dated 27 April 2012,

(c) "Guidelines for the geotechnical investigation and assessment of subdivisions in the Canterbury region".

The principal objective of the MBIE guidance document is to provide building repair and reconstruction solutions and options that:

(i) are appropriate to the level of land and building damage experienced;

(ii) take account of the likely future performance of the ground;

(iii) meet Building Act and Building Code requirements; and

(iv) are acceptable to insurers and property owners.

The document also divides the previous CERA "Green Zone" on flat land, into three technical categories that reflect both the liquefaction experienced to date, and future performance expectations. The Foundation Technical Categories are identified as TC1, TC2 and TC3.

Table 3.1 of the MBIE guidance document provides expected future land performance for the various Foundation Technical Categories. These are summarised in Table 10 of this report.

TABLE 10: EXPECTED FUTURE LAND PERFORMANCE FOR VARIOUS FOUNDATION TECHNICAL CATEGORIES

Foundation Technical Category	Future Land Performance Expectation in Response to Liquefaction	Expected Ground Settlement in Response to an SLS Strength Earthquake	Expected Ground Settlement in Response to a ULS Strength Earthquake
TC1 (where confirmed)	Liquefaction damage is unlikely in a future large earthquake	0 – 15 mm	0 – 25 mm
TC2 (where confirmed)	Liquefaction damage is possible in a future large earthquake	0 – 50 mm	0 – 100 mm
TC3 (where confirmed)	Liquefaction damage is possible in a future large earthquake	>50 mm	>100 mm

The MBIE guidance document states that:

> *"In order to characterise the potential behaviour of the site and to effectively subdivide the TC3 land into 'less' and 'more vulnerable' categories an 'index number' for TC3 properties has been developed. This index reflects the consequential effects of settlement taking into account the behaviour of the shallower soils being more influential than that of deeper soils."*

Table 12.5 of the guidance document provides categories of vertical land settlement, for the calculated "index number" theoretical ground settlement. The guidance document suggests that for sites with SLS "index number" theoretical ground settlements of less than 100 mm the land settlement should be assumed to be "minor to moderate". For sites with SLS "index number" theoretical ground settlements of greater than 100 mm the land settlement should be assumed to be "potentially significant".

Using the methodology recommended by the MBIE guidance document and described in Section 9.4 of this report, an "index number" theoretical ground settlement value of 0 mm has been calculated for the site soils under the assumed SLS seismic loading (which was the larger value determined for the SLS and ILS design earthquake events, as discussed in Section 9.2 of this report).

"Index number" theoretical ground settlement values of between 0 mm to 1 mm have been calculated for the site soils under ULS seismic loading.

The results of the CLiq analyses, using the analyses methods suggested by the MBIE guidance document, are presented in Appendix B of this report.

The foregoing "index number" theoretical ground settlement values indicate that the site has the liquefaction potential characteristics of a Foundation Technical Category 1 (TC1) site. However, as discussed in Section 9.4 of this report, the CPT probes put down at the site were unable to penetrate to a sufficient depth in order to reliably determine the theoretical liquefaction induced ground settlements expected to occur at the site in response to the SLS and ULS design earthquake events.

However, as discussed in Section 7.4.3 of this report, there is existing ground investigation data available for the site which indicates that the gravel soils extend to significant depths beneath the subject site. It is unlikely, in our opinion, that any significant liquefaction induced ground settlement would occur as a result of liquefaction of the dense to very dense sandy gravels (i.e. the layer located below the upper 5.1 m to 9.5 m of soils), as these soils, due to their nature, are generally not expected to be liquefiable.

Based on the foregoing, and given the nature of the upper soils underlying the site, i.e. generally surficial cohesive soils underlain by dense to very dense gravel soils, it is our opinion that the subject site, for the purposes of the proposed rezoning submission should be assumed to be within Foundation Technical Category 1 (TC1), as defined by the MBIE Canterbury guidance document, and that it is unlikely that liquefaction induced ground deformation could occur within the area in response to a large earthquake event, and that the ground settlements within the area in response to seismic loading should be considered to be "within normally accepted tolerances" as defined by the MBIE Canterbury guidance document.

12.0 SUITABLE SHALLOW FOUNDATIONS FOR TC1 SITES, AS SUGGESTED BY THE MBIE GUIDANCE DOCUMENT, DATED DECEMBER 2012

The MBIE Canterbury guidance document provides guidance for foundation repairs and reconstruction for houses within Foundation Technical Category 1 (TC1).

The document states the following with regard to new foundation construction within the TC1 zone:

> *"In TC1, foundation Types A* [suspended timber floor supported on piles] *and B* [suspended timber floor supported on piles with a perimeter foundation wall] *can be built as per NZS 3604. Type C foundations* [concrete slab on ground flooring system] *will require reinforced concrete slabs as provided in NZS 3604 Timber Framed Buildings, as modified by B1/AS1, which requires ductile reinforcing in slabs."*

13.0 SETTLEMENT CONSIDERATIONS

13.1 GENERAL

As discussed in Section 7.4.1 of this report, a layer of material, generally comprising peat, was encountered at depths ranging between approximately 0.3 m and 0.8 m below the existing ground surface (generally immediately below the topsoil layer), at the locations of Test Pits TP2 to TP11 inclusive, TP16 to TP18 inclusive, and CPT probes CPT1 to CPT7 inclusive, and CPT10 to CPT13 inclusive. These soils were encountered to depths of between approximately 0.4 m and 1.5 m below the existing ground surface, at the locations of these test positions, corresponding to a layer thickness of between approximately 0.1 m and 1.1 m. The layer of peat soils appears to be thicker within Block A, on the northern side of Boys Road. On the southern side of Boys Road, within Block B, the peat layer is generally no thicker than approximately 0.4 m.

In situ undrained shear strength values of between approximately 42 kPa and 90 kPa were generally measured in these sediments, using hand held shear vane equipment, corresponding to a firm to stiff consistency.

The CPT probe generally obtained cone resistance (q_t) values of between approximately 0.1 MPa and 0.3 MPa in the organic soils, corresponding to in situ undrained shear strength values of between approximately 6 kPa and 20 kPa, corresponding to a very soft to soft consistency.

Due to its nature and consistency, the layer of peat soils is inferred to be highly compressible.

Settlement analyses have been undertaken in order to determine the expected settlement magnitudes of the underlying soil layers under the proposed subdivisional fill loads and also the expected foundation loadings (associated with future residential construction).

As discussed in Section 5.0 of this report, it is understood that any future subdivisional development at the site will likely involve cut and fill earthworks, in order form suitable building platforms and to provide for the construction of suitable gravity wastewater and stormwater reticulation systems. It is understood that the proposed earthworks will also require some imported fill material. The fill is expected to be up to approximately 2.1 m depth, for Block A (north of Boys Road), but generally the fill is expected to be no greater than approximately 0.7 m depth, in this area. The fill is expected to be up to approximately 1.2 m depth, for Block B (south of Boys Road), but generally the fill is expected to be no greater than approximately 0.8 m depth, in this area.

For the purposes of the settlement analyses, for the proposed fill loadings, the unit weight of the engineered fill material has been assumed to be 19.0 kN/m^3.

For the purposes of the settlement analyses, for the proposed foundations loadings, the following has been assumed:

(i) the possible future houses will have concrete slab-on-ground flooring systems supported on conventional shallow concrete strip footings (0.3 m wide),

(ii) a net unfactored vertical contact foundation pressure (G+0.3Q) of 40 kPa, is imposed at the base of the perimeter footings on the underlying soils.

(iii) that no fill will be placed above the existing ground surface in order to form a building platform (at the house building stage).

13.2 PRIMARY CONSOLIDATION OF THE UNDERLYING SOILS

Theoretical analyses were undertaken to estimate the likely magnitude of settlement due to primary consolidation of the underlying soils beneath the proposed subdivisional fill loadings.

As discussed in Section 7.4.1 of this report, surficial peat soils were generally located in the northern and central parts of the site. These soils were generally absent in the southern part of the site (i.e. the southern part of Block B).

The approximate inferred location and extent of the parts of the site inferred to be underlain by the surficial layer of peat soils, is shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

The ‘peat’ soils generally comprised highly fibrous peat material. The results of laboratory testing, undertaken on similar soils in the Canterbury region, indicate that the peat soils could be expected to have the following characteristics:

(fibrous peat)- water content (300% to 400%)
Organic content (45% to 60%)

Based on the results of the field investigations reported herein, for the purposes of the analyses reported herein, an M_v value of 2.0 m^2/MN has been assumed for the peat soils underlying some parts of the site.

The results of our analyses indicate that theoretical vertical displacements, due to primary consolidation of the underlying soils, beneath Block A, due to the imposed subdivisional fill loadings, of between approximately 40 mm and 75 mm are expected. The results of our analyses indicate that theoretical vertical displacements, due to primary consolidation of the underlying soils, beneath Block B, due to the imposed subdivisional fill loadings, of between approximately 20 mm and 32 mm are expected.

The results of our analyses indicate that theoretical vertical displacements, due to primary consolidation of the underlying soils (following the likely subdivisional earthworks), due to the assumed foundation loadings associated with residential development, of between approximately 7 mm and 14 mm are expected.

13.3 SECONDARY COMPRESSION OF THE ORGANIC SOILS

Theoretical analyses have also been undertaken to estimate the likely magnitude of settlement due to secondary compression of the organic soils beneath the subdivisional fill areas.

Secondary compression is expected to continue to occur in the more highly organic soils beneath the fill areas for some time after the end of construction. For the purposes of the analyses reported herein, the expected settlement due to secondary compression after a period of ten years after construction has been considered. The analysis was undertaken in accordance with the method recommended in the NAVFAC Design Manual 7.1.

Hobbs (1986), suggests that an organic material with a natural water content ranging between approximately 300% and 400%, which is the assumed range of water content for the peat soils underlying the site, can be assumed to have a coefficient of secondary compression (C_{sec}) of approximately 0.035. For the purposes of the analyses reported herein, a C_{sec} value of 0.035 has been assumed.

The results of the analyses indicate that a vertical displacement of generally less than 2 mm is expected for the subdivisional fill, due to secondary compression of the organic deposits, over a period of ten years following placement of the fill material.

13.4 SUMMARY OF SETTLEMENT ANALYSES RESULTS

The theoretical settlement analyses results for likely subdivisional fill loadings, discussed in Sections 13.2 and 13.3 of this report, are summarised in Table 11.

TABLE 11: EXPECTED SETTLEMENTS DUE TO SUBDIVISIONAL FILL LOADINGS

Site Location	Expected settlements due to subdivisional fill loading- (primary consolidation)	Expected settlements due to subdivisional fill loading- (secondary compression)	Total expected settlements due to subdivisional fill loading
Block A (north of Boys Road)	40 mm to 75 mm	< 2.0 mm	42 mm to 77 mm
Block B (south of Boys Road)	20 mm to 32 mm	< 2.0 mm	22 mm to 34 mm

The results of our analyses indicate that theoretical vertical displacements, due to primary consolidation of the underlying soils (following the likely subdivisional earthworks), due to the assumed foundation loadings associated with residential development, of between approximately 7 mm and 14 mm are expected.

13.5 DISCUSSION

The results of the settlement analyses reported herein indicate that total vertical displacements of between approximately 22 mm and 34 mm, due to primary consolidation and secondary compression of the underlying soils, are expected beneath the proposed subdivisional fill areas for Block B. Due to the thicker deposits of peat soils, these expected settlements are greater for Block A- north of Boys Road, where total vertical displacements of between approximately 42 mm and 77 mm are expected beneath the proposed subdivisional fill areas.

The estimated ground settlements are not considered to be 'excessive', particularly for Block B, however, there is a risk, in our opinion, that differential settlement could occur, particularly in areas where subdivisional filling extends over parts of the site which 'transition' between areas underlain by peat soils and areas underlain by less compressible soils. This has the potential to adversely affect shallow service lines and shallow foundations, if these are not appropriately designed for the site conditions.

As a result, it is recommended that any proposed subdivisional fill earthworks undertaken for the site should incorporate appropriately designed and monitored preloading, in order to provide suitable building platforms at the site.

The preloading would provide the following benefits:

(i) Over-consolidation of the subsoils (in particular the peat soils), which will prevent any on-going settlement of the ground surface, due to subdivisional fill loadings

(ii) Reduction in the compressibility of the peat soils, following removal of the preload, which will mitigate the risk of shallow foundations being adversely affected by differential settlement.

The requirement for preloading is considered to be more critical for Block A, which has thicker deposits of peat soils.

Any detailed preloading design would be expected to be undertaken at the subdivision consent application stage, and would likely incorporate the following:

(1) Further geotechnical investigation and appraisal work, likely involving additional machine excavated test pits, machine boreholes and CPT probes,

(2) collection of soils samples for laboratory testing purposes, in particular to more reliably determine the water content and organic content of the peat soils and the compressibility parameters for the peat soils,

(3) preparation of a settlement monitoring design/plan, which will likely include the installation of settlement plates, settlement cells, piezometers and settlement monitoring survey pins.

An alternative to preloading would be to excavate (i.e remove) the surficial peat soils from beneath the site. This is considered to be more practical, for Block B, where the base of the peat soils is expected to be between approximately 0.6 m and 0.8 m below the existing ground surface. For Block A, the base of the peat extends to depths of up to approximately 1.5 m below the existing ground surface. The removal of the peat, in this area, would likely require some dewatering and would therefore likely be less practical/economical than for Block B.

14.0 LIKELY SUITABLE FOUNDATION DESIGN SOLUTIONS

14.1 RESIDENTIAL

14.1.1 General

Providing any subdivisional earthworks are undertaken in accordance with the relevant New Zealand Standard Codes of Practice, and in accordance with any recommendations provided by Fraser Thomas Ltd, it is our opinion that suitable building platforms should be available at the site, which would be suitable for future residential development.

Although appropriately designed earthworks and associated preloading is expected to provide suitable building platforms for residential construction, in order to provide for a more robust foundation system, it is recommended that the foundation systems comprise a concrete waffle slab type foundation system, designed assuming “TC1 site conditions”, and in accordance with the recommendations presented herein.

Conventional concrete waffle slab type foundation systems comprise a series of reinforced concrete foundation beams, constructed in a grid pattern, which provides for a raft type foundation, which is more able than a conventional shallow foundation system (comprising perimeter strip footings), to accommodate any minor differential foundation movement.

It is also recommended that:

(a) unless further specific appraisal is undertaken, no more than 100 mm thickness of fill be placed above the existing ground surface, to form a building platform for any proposed new shallow foundation system,

(b) unless further specific appraisal is undertaken, any proposed concrete waffle slab type foundation system associated with any proposed new building at the site should be designed to impose a net unfactored vertical contact foundation pressure (G+0.3Q) at the base of the foundation system (i.e. over the entire base area of the proposed foundation system) of no greater than 12 kPa on the underlying soils.

14.1.2 Areas Inferred to be Underlain by Non-Engineered Fill

As discussed in Section 7.3 of this report, it is understood that some previous works have been undertaken, in the eastern corner of the site, to re-align the North Brook Stream in this area. It is understood that some non-engineered fill material was placed, in this area, as part of these works.

The approximate inferred location and extent of the non-engineered fill material, associated with the previous re-alignment works, is shown on the drawing CH01508-G-02.

There is, in our opinion, a risk that foundations founded on or within non-engineered fill material may be subject to differential settlement which may adversely affect future proposed building development. It is therefore recommended that foundations located in this area be founded beneath any non-engineered fill material into competent natural ground and that any floor slabs underlain by non-engineered fill be designed to span between foundations. Alternatively it is recommended that the non-engineered fill material be undercut from beneath the proposed building envelope and that the undercut be backfilled with engineered fill up to the required subgrade level.

It is recommended that Fraser Thomas Ltd be engaged to inspect any undercutting of non-engineered fill from beneath any proposed building envelope in order to confirm that the foundations and building subgrade are founded in competent natural ground.

14.2 LIGHT INDUSTRIAL

It is understood that there is the potential that the southern corner of Block B could be rezoned as 'Business Industrial Zone' or 'Format Retail/Mixed Use', which would likely accommodate light industrial type structures.

The surficial peat soils were generally located in the northern and central parts of the site. These soils were generally absent in the southern part of the site (i.e. the southern part of Block B). The approximate inferred location and extent of the area of the site inferred to be underlain by the surficial layer of peat soils, is shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

Structures sited in the southern part of Block B are expected to be generally underlain competent non-organic alluvial sediments, which are, in general, expected to be suitable for shallow foundations designed in accordance with the relevant New Zealand Standard Codes of Practice.

15.0 ALLOWABLE FOUNDATION BEARING PRESSURES

15.1 GENERAL

In this section of the report, ultimate bearing capacity values and strength reduction factors are provided in order to allow calculation of design (dependable) foundation bearing capacities, in accordance with the limit state design methods outlined in AS/NZS 1170: 2002, Structural Design Actions, by applying the appropriate strength reduction factors, as provided in this report, and the factored load combinations required by AS/NZS 1170. Allowable foundation bearing pressures are also provided, based on conventional factors of safety, for cases where unfactored load combinations are being considered.

15.2 SHALLOW PAD OR BEAM FOUNDATIONS

A minimum ultimate static bearing capacity value for vertical loading of 300 kPa is recommended for shallow concrete pads or beam foundations, founded in the underlying alluvial sediments or engineered fill. It is recommended that a strength reduction factor (Φ_{bc}) of 0.5 be adopted for limit state design in accordance with the requirements of AS/NZS 1170, resulting in a design (dependable) bearing capacity value of 150 kPa.

If unfactored load combinations are to be considered, the allowable foundation bearing pressures presented in Table 12 are recommended for shallow concrete pads or beam foundations, founded in the underlying alluvial sediments or engineered fill.

TABLE 12: ALLOWABLE FOUNDATION BEARING PRESSURES FOR SHALLOW CONCRETE PADS OR BEAM FOUNDATIONS FOUNDED IN THE UNDERLYING ALLUVIAL SEDIMENTS OR ENGINEERED FILL

Load Case	Factor of Safety	Allowable Bearing Pressure (kPa)
Dead Load and Permanent Live Load	3.0	100
Dead plus Live plus Transient Load	2.0	150

It should be noted, however, that the recommended maximum foundation bearing pressures provided in Section 14.1 of this report, will dictate foundation design, and not the allowable foundation bearing pressures shown in Table 12.

16.0 EXISTING SERVICE LINES

It is recommended that the location and depth of any buried services should be verified at the site prior to the commencement of foundation construction.

It is expected that any service line trenches would have been backfilled by conventionally acceptable means, which did not involve specific compaction. It would therefore be expected that some consolidation settlement of the service trench backfill could occur, which could result in lateral and vertical deformation of the undisturbed ground on each side of the trench backfill. The deformation is caused by the soil wedge behind the side wall of the trench moving downwards and inwards with time, towards the trench backfill as the backfill consolidates. The geometry of the soil wedge defines the theoretical zone of influence of the service trench backfill.

Due to the risk of consolidation settlement of the trench backfill occurring, it is recommended that, if any foundations of any proposed new building are located within the zone of influence of any existing service line, either the trench backfill be excavated and replaced with compacted hardfill or the foundations and floor of the proposed new building be designed to span across the trench backfill and the adjacent zone of influence.

The zone of influence is defined by a theoretical line projecting upwards in both directions from the centreline of the pipeline at the invert level of the pipeline at an angle of 45° to the vertical. The zone of influence is defined by the zone between the intersection point of the theoretical line and the ground surface on each side of the pipeline.

17.0 EARTHWORKS CONSIDERATIONS

17.1 GENERAL

It is understood that any future subdivisional development at the site will likely involve cut and fill earthworks, in order form suitable building platforms and to provide for the construction of suitable gravity wastewater and stormwater reticulation systems. It is understood that the proposed earthworks will also require some imported fill material. The fill is expected to be up to approximately 2.1 m depth, for Block A (north of Boys Road), but generally the fill is expected to be no greater than approximately 0.7 m depth, in this area. The fill is expected to be up to approximately 1.2 m depth, for Block B (south of Boys Road), but generally the fill is expected to be no greater than approximately 0.8 m depth, in this area.

It is also understood that the future earthworks will likely involve excavation works to construct suitable stormwater management systems at the site (i.e. first flush basins). It is understood that the base of the proposed stormwater management basins will likely range between approximately 1.0 m and 1.2 m below the ‘finished’ (post bulk earthworks) ground surface.

17.2 PROPOSED FILL AREAS

The maximum depth of filling anticipated at the site is approximately 2.1 m, but generally the fill is expected to be no greater than approximately 0.8 m depth.

Based on the investigation data and our visual examination of the onsite materials, the natural non-organic alluvial soils are generally considered to be suitable for placement and compaction as engineered fill after the removal of the topsoil or non-engineered fill layers. It is recommended that Fraser Thomas Ltd be engaged to inspect the undercutting of the topsoil/fill layers to ensure no substandard material underlies the proposed lots.

It is understood that it is proposed to undertake cut and fill earthworks at the site, in order form suitable building platforms, and to provide for the construction of suitable gravity wastewater and stormwater reticulation systems. It is understood that the proposed earthworks will also require some imported fill material.

It is recommended, prior to placement of any bulk fill material, that appropriate laboratory testing be undertaken, for any proposed borrow fill material (either 'site won' or imported), in order to determine the compaction parameter/characteristics of the proposed fill material (i.e compaction curves).

It is possible that some of the materials may require to be wetted to increase the water content of the fill material, in order to obtain the minimum compaction standards as presented in Section 17.5 of this report.

Any proposed 'engineered fill' will need to be subject to appropriate observation and testing, by a suitably qualified CPEng engineer, so as to confirm that the fill is suitable for its intended purpose.

It should be anticipated that the soils encountered in the proposed fill and cut areas will be sensitive to disturbance by earthworks plant and inclement weather. These two factors together could result in plant trafficability problems, and which may result in the artificial creation, by virtue of ill-conceived construction efforts, of excessive quantities of unsuitable (ie. unworkable) materials, unless earthworks construction activities and the nature of the earthmoving plant used in the site development are selected and controlled in cognisance of the particular characteristics of the site materials.

17.3 PROPOSED CUT AREAS

It is understood that the majority of the 'site won' cut material will be sourced from excavation works to construct the proposed stormwater management systems at the site (i.e. first flush basins). It is understood that the base of the proposed stormwater management basins will range between approximately 1.0 m and 1.2 m below the 'finished' (post bulk earthworks) ground surface.

It is anticipated that the proposed cut materials, undertaken in the eastern and southern corners of the site, will consist of alluvial sediments generally comprising silts, sandy silts and sandy gravels.

The undrained shear strength values in the proposed cut materials, as determined from the borehole logs of Appendix A, are expected to generally be between 70 kPa and in excess of 100 kPa, corresponding to a stiff to very stiff consistency.

17.4 SITE PREPARATION

Preparation prior to placing and compacting fill should involve the stripping of topsoil and non-engineered fill, as directed by the Engineer, to stockpile and all "unsuitable" soils to stockpile or waste.

17.5 COMPACTION CRITERIA

It is recommended that any fill material placed at the site be placed in accordance with the general requirements described in NZS 4431:2022; Engineered fill construction for lightweight structures, and in accordance with the recommended fill specification, and should be constructed so as to obtain the following:

(1) an average in situ undrained shear strength value of not less than 120 kPa, and any one test site value of not less than 100 kPa.

(2) an average air voids value of not more than 10% and any one test site value of not more than 12%.

It is recommended that Fraser Thomas Ltd be engaged to observe the placement and compaction of the proposed fill material to confirm that the fill has been placed in accordance with the recommended fill specification.

18.0 DEVELOPMENTAL EARTHWORKS

It is recommended that, unless the stability of any developmental earthworks (i.e. constructed for an access driveway, building platform or landscaping) is considered in detail by a chartered professional engineer experienced in geotechnical engineering, and particularly slope stability considerations, permanent fill end and cut slopes should be constructed to a maximum batter slope of 26° (1V:2H) with maximum batter heights of approximately 1.2 m. Any proposed higher permanent batter slopes should be subject to specific stability appreciation so as to determine stable limiting batter slopes.

It is recommended that any temporary excavated slopes be constructed to a maximum batter slope of 45° (1V:1H), with a maximum batter height of approximately one meter. It is recommended that any temporary excavation slopes not be left unsupported for a period exceeding one month. It is also recommended that stormwater run-off be diverted away from the crest of any proposed temporary excavation slopes.

19.0 STORMWATER AND EFFLUENT DISPOSAL

It is understood that issues relating to stormwater discharge and effluent disposal will be addressed by others.

20.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations should be read together and not be taken in isolation.

20.1 CONCLUSIONS

Our conclusions based on the field data obtained from the site and as presented in this report, our visual appraisal of the site, our study of the geological maps relating to the area and our professional judgement and opinions, are as follows:

(a) In general terms and within the limits of the investigation as outlined and reported herein, except for the issues associated with the peat soils underlying the site, no unusual problems, from a geotechnical perspective, are anticipated with future residential and light industrial development at the subject site.

We confirm that this report includes recommendations which will appropriately avoid, remedy or mitigate potential geotechnical hazards on the land subject to the submission, in accordance with the provisions of Section 106 of the Resource Management Act.

The site is, in general, considered suitable for its intended use, with satisfactory conditions for future residential and light industrial building development, subject to the recommendations and qualifications reported herein, and provided the design and inspection of foundations are carried out as would be done under normal circumstances in accordance with the requirements of the relevant New Zealand Standard Codes of Practice.

In arriving at this conclusion and expressing this opinion, reliance has been based on the various topographical data as discussed herein and on subsoil information which has only been obtained at the locations and within the depths of the test positions reported herein. It has been assumed that this subsoil information can be projected between the various test positions. Even though such inference is made and forms the basis of the conclusions and opinions expressed herein, no guarantee can be given as to the validity of this inference or of the nature and continuity of the subsoils underlying the proposed subdivision.

(b) The purpose of the geotechnical investigation reported herein was to determine the subsoil conditions beneath the subject site as they may affect future residential and potentially light industrial development, with particular regard to foundation design considerations, and to determine the suitability of the subject site for residential and potentially light industrial development, in support of a submission a plan change.

(c) A layer of material, generally comprising peat, was encountered at depths ranging between approximately 0.3 m and 0.8 m below the existing ground surface (generally immediately below the topsoil layer), at the locations of Test Pits TP2 to TP11 inclusive, TP16 to TP18 inclusive, and CPT probes CPT1 to CPT7 inclusive, and CPT10 to CPT13 inclusive. These soils were encountered to depths of between approximately 0.4 m and 1.5 m below the existing ground surface, at the locations of these test positions, corresponding to a layer thickness of between approximately 0.1 m and 1.1 m. The layer of peat soils appears to be thicker within Block A, on the northern side of Boys Road. On the southern side of Boys Road, within Block B, the peat layer is generally no thicker than approximately 0.4 m.

(d) The surficial peat soils were generally located in the northern and central parts of the site. These soils were generally absent in the southern part of the site (i.e. the southern part of Block B). The approximate inferred location and extent of the area of the site inferred to be underlain by the surficial layer of peat soils, is shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

(e) Based on the results of the machine excavated test pit investigations undertaken at the site, the groundwater level is inferred to be at a depth of approximately 1.5 m below the existing ground surface, for analysis purposes.

(f) Analyses have been undertaken using the computer programme CLiq to assess the theoretical liquefaction triggering potential and expected ground settlements for the soils underlying the subject site. The analyses have been undertaken for the subsoil profile obtained at the locations of CPT1 to CPT13 inclusive.

(g) Given the nature of the upper soils underlying the site, i.e. generally surficial cohesive soils underlain by dense to very dense gravel soils, it is our opinion that the subject site, for the purposes of the proposed rezoning submission should be assumed to be within Foundation Technical Category 1 (TC1), as defined by the MBIE Canterbury guidance document, and that it is unlikely that liquefaction induced ground deformation could occur within the area in response to a large earthquake event, and that the ground settlements within the area in response to seismic loading should be considered to be "within normally accepted tolerances" as defined by the MBIE Canterbury guidance document.

(h) Settlement analyses have been undertaken in order to determine the expected settlement magnitudes of the underlying soil layers under the proposed subdivisional fill loads and also the expected foundation loadings (associated with future residential construction).

(i) The results of the settlement analyses reported herein indicate that total vertical displacements of between approximately 22 mm and 34 mm, due to primary consolidation and secondary compression of the underlying soils, are expected beneath the proposed subdivisional fill areas for Block B. Due to the thicker deposits of peat soils, these expected settlements are greater for Block A- north of Boys Road, where total vertical displacements of between approximately 42 mm and 77 mm are expected beneath the proposed subdivisional fill areas.

(j) The requirement for preloading is considered to be more critical for Block A, which has thicker deposits of peat soils.

(k) Any detailed preloading design would be expected to be undertaken at the subdivision consent application stage, and would likely incorporate the following:

(1) Further geotechnical investigation and appraisal work, likely involving additional machine excavated test pits, machine boreholes and CPT probes,

(2) collection of soils samples for laboratory testing purposes, in particular to more reliably determine the water content and organic content of the peat soils and the compressibility parameters for the peat soils,

(3) preparation of a settlement monitoring design/plan, which will likely include the installation of settlement plates, settlement cells, piezometers and settlement monitoring survey pins.

(l) An alternative to preloading would be to excavate (i.e remove) the surficial peat soils from beneath the site. This is considered to be more practical, for Block B, where the base of the peat soils is expected to be between approximately 0.6 m and 0.8 m below the existing ground surface. For Block A, the base of the peat extends to depths of up to approximately 1.5 m below the existing ground surface. The removal of the peat, in this area, would likely require some dewatering and would therefore likely be less practical/economical than for Block B.

(m) Providing any subdivisional earthworks are undertaken in accordance with the relevant New Zealand Standard Codes of Practice, and in accordance with any recommendations provided by Fraser Thomas Ltd, it is our opinion that suitable building platforms should be available at the site, which would be suitable for future residential development.

(n) It is understood that there is the potential that the southern corner of Block B could be rezoned as 'Business Industrial Zone' or 'Format Retail/Mixed Use', which would likely accommodate light industrial type structures.

The surficial peat soils were generally located in the northern and central parts of the site. These soils were generally absent in the southern part of the site (i.e. the southern part of Block B).

The approximate inferred location and extent of the area of the site inferred to be underlain by the surficial layer of peat soils, is shown on the appended Fraser Thomas Ltd drawing CH01508-G-02.

Structures sited in the southern part of Block B are expected to be generally underlain competent non-organic alluvial sediments, which are, in general, expected to be suitable for shallow foundations designed in accordance with the relevant New Zealand Standard Codes of Practice.

20.2 RECOMMENDATIONS

Our recommendations based on the field data obtained from the site and as presented in this report, our visual appraisal of the site, our study of the geological maps relating to the area and our professional judgement and opinions, are as follows:

(a) The estimated ground settlements are not considered to be 'excessive', particularly for Block B, however, there is a risk, in our opinion, that differential settlement could occur, particularly in areas where subdivisional filling extends over parts of the site which 'transition' between areas underlain by peat soils and areas underlain by less compressible soils. This has the potential to adversely affect shallow service lines and shallow foundations, if these are not appropriately designed for the site conditions.

As a result, it is recommended that any proposed subdivisional fill earthworks undertaken for the site should incorporate appropriately designed and monitored preloading, in order to provide suitable building platforms at the site.

(b) Although appropriately designed earthworks and associated preloading is expected to provide suitable building platforms for residential construction, in order to provide for a more robust foundation system, it is recommended that the foundation systems comprise a concrete waffle slab type foundation system, designed assuming "TC1 site conditions", and in accordance with the recommendations presented herein.

Conventional concrete waffle slab type foundation systems comprise a series of reinforced concrete foundation beams, constructed in a grid pattern, which provides for a raft type foundation, which is more able than a conventional shallow foundation system (comprising perimeter strip footings), to accommodate any minor differential foundation movement.

It is also recommended that:

(1) unless further specific appraisal is undertaken, no more than 100 mm thickness of fill be placed above the existing ground surface, to form a building platform for any proposed new shallow foundation system,

(2) unless further specific appraisal is undertaken, any proposed concrete waffle slab type foundation system associated with any proposed new building at the site should be designed to impose a net unfactored vertical contact foundation pressure (G+0.3Q) at the base of the foundation system (i.e. over the entire base area of the proposed foundation system) of no greater than 12 kPa on the underlying soils.

(c) There is, in our opinion, a risk that foundations founded on or within non-engineered fill material may be subject to differential settlement which may adversely affect future proposed building development. It is therefore recommended that foundations located in this area be founded beneath any non-engineered fill material into competent natural ground and that any floor slabs underlain by non-engineered fill be designed to span between foundations. Alternatively it is recommended that the non-engineered fill material be undercut from beneath the proposed building envelope and that the undercut be backfilled with engineered fill up to the required subgrade level.

(d) It is recommended that Fraser Thomas Ltd be engaged to inspect any undercutting of non-engineered fill from beneath any proposed building envelope in order to confirm that the foundations and building subgrade are founded in competent natural ground.

(e) Earthworks design recommendations are provided in Sections 13.5 and 17.0 of this report.

21.0 LIMITATIONS

The professional opinion expressed herein has been prepared solely for, and is furnished to our clients, Richard and Geoff Spark, and their professional advisers, and Waimakariri District Council for their purposes only with respect to the particular brief given to us, on the express condition that it will not be relied upon by any other person or for any other purposes without our prior written agreement, and relates to the conditions that exist up to and at the time of this report.

No liability is accepted by this firm or by any principal, or director, or any servant or agent of this firm, in respect of the use of this report by any other person, and any other person who relies upon any matter contained in this report does so entirely at its own risk. This disclaimer shall apply notwithstanding that this report may be made available to any person by any person in connection with any application for permission or approval, or pursuant to any requirement of law.

This report does not comment on stormwater management, flooding, root effects and land uses outside the specific site, which may be required to be assessed to complete a foundation design for building consent application purposes.

Notwithstanding the foregoing, if the circumstances at the subject site change with respect to topography or the proposed development concept, or the buildings are subject to further damaging earthquakes, or if a period of more than three years has elapsed since the date of this report, this report should not be used without our prior review and written agreement.

The conclusions and recommendations expressed herein should be read in conjunction with the remainder of this report and should not be referred to out of context with the remainder of this report.

Report prepared by:
FRASER THOMAS LTD.

K E TWOHILL
Engineering Geologist

Report reviewed and approved by:

M V REED
Director
Chartered Professional Engineer

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Appendix A

Field Investigation Results

Machine Excavated Test Pits

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BOREHOLE AND TEST PIT LOGS SYMBOLS AND TERMS

SYMBOLS AND ABBREVIATIONS

RL	Reduced Level
EOH	End of Hole
•	Shear vane test result
UTP	Unable to Penetrate
TDTA	Too Difficult to Auger
SPT	Standard Penetration Test
N	SPT blows per 300mm penetration
35/90	35 blows per 90mm penetration after seating for SPT
(s)	Inclusive of seating blow count for SPT
GWL	Ground Water Level

Wf	Field water content
Wp	Plastic limit (%)
WL	Liquid Limit (%)
RQD	Rock Quality Designation
SG	Specific Gravity
%F	Percentage fines (<75 microns)
PSD	Particle size distribution
CONS	Consolidation test
COMP	Compaction test
UCS	Unconfined Compressive Strength
k	Permeability coefficient (m/s)
LS	Linear Shrinkage (%)
OC	Organic Content (%)

SOIL

- TOPSOIL
- CLAY
- SILT
- SAND
- GRAVEL
- COBBLES
- BOULDERS
- PEAT
- FILL

CONSISTENCY TERMS

Cohesive Description	Undrained Shear Strength (kPa)
Very Soft	<12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very Stiff	100 - 200
Hard	>200

RELATIVE DENSITY

Non-cohesive Description	SPT "N" Value
Very Loose	<4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	> 50

ROCK

- LIMESTONE
- MUDSTONE
- SANDSTONE
- CONGLOMERATE
- BRECCIA
- RYHOLITE
- ANDESITE
- BASALT

STRENGTH

Description	Unconfined Compressive Strength MPa
Extremely Weak	< 1
Very Weak	1 - 5
Weak	5 - 20
Moderately Strong	20 - 50
Strong	50 - 100
Very Strong	100 - 250
Extremely Strong	> 250

WEATHERING

- UW - Unweathered (fresh rock)
- SW - Slightly Weathered
- MW - Moderately Weathered
- HW - Highly Weathered
- CW - Completely Weathered
- RS - Residual Soil

SPACING OF DISCONTINUITIES

Term	Aperture (mm)
Very widely spaced	>2000
Widely spaced	600 - 2000
Moderately widely spaced	200 - 600
Closely spaced	60 - 200
Very closely spaced	20 - 60
Extremely closely spaced	<20

Notes

1. Based on New Zealand Geotechnical Society " Field Description of Soil and Rock,Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes" December 2005
2. Composite soil types are signified by combined symbols

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INVESTIGATION LOG

Hole No: TP1

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377; ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Depth (m)	Description of Strata	Geological Unit	Graphic Log	Shear Vane Values (kPa)	Groundwater
0.0 – 0.5	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S	TS		
0.5 – 1.0	SILT, greyish brown, stiff, moist, non plastic [ALLUVIAL SEDIMENTS]	Alluvial Sediments		86 (0.6 m), 96 (0.8 m), 116 (1.0 m)	
1.0 – 1.5	Clayey SILT, orangey brown, stiff to very stiff, moist to wet, low to moderate plasticity 1.2 m: Becomes bluish grey, contains large semi decomposed log (130 mm dia)	Alluvial Sediments		86 (1.3 m)	
1.5 – 2.2	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, trace cobbles, bluish grey, dense to very dense, wet to saturated 1.8 m: Becomes orangey brown, saturated	Alluvial Sediments			14/11/2022 (2.0 m)
2.20	EOTP: 2.20 m TDTE - HOLE COLLAPSE				

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 2.0 m, on 14/11/2022.

Datum:

Coordinates:

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INVESTIGATION LOG

Hole No: TP2

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377 — ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values	Groundwater
0.0 – 0.4	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.4 – 0.8	SILT, light grey, stiff, moist to wet, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	70, 50	
0.8 – 1.2	Organic SILT, trace gravel (fine), dark brown, stiff, moist, low to moderate plasticity, containing some semi decomposed wood and rootlets.	Alluvial Sediments	76, 27	
1.2 – 1.7	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, trace cobbles, bluish grey, dense to very dense, wet to saturated	Alluvial Sediments		14/11/2022
1.7	EOTP: 1.70 m TDTE - HOLE COLLAPSE			

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 1.5 m, on 14/11/2022.

Datum:

Coordinates:

INVESTIGATION LOG

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Hole No: TP3

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377 — ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0 – 0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3 – 0.7	SILT, grey mottled orangey brown, stiff, moist to wet, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	83 (0.6)	
0.7 – 1.1	Organic SILT, black to dark brown, stiff, moist, low to moderate plasticity, containing some decomposed wood and rootlets.	Alluvial Sediments	70 (0.7); 47 (0.9)	
1.1 – 1.6	Silty SAND (fine) and sandy SILT, trace gravel (fine), blush grey, stiff, wet, trace decomposed organics.	Alluvial Sediments	83 (1.3)	
1.6 – 2.0	SAND (fine to coarse), trace gravel (fine to coarse, subrounded greywacke), orangey brown and brownish grey, medium dense, wet to saturated	Alluvial Sediments		▼ 14/11/2022 (1.8)
2.0 – 2.5	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, trace cobbles, bluish grey, dense to very dense, wet to saturated	Alluvial Sediments		

EOTP: 2.50 m TDTE - HOLE COLLAPSE

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 2.0 m, and 1.8 m after an hour standing, on 14/11/2022.

Datum:

Coordinates:

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INVESTIGATION LOG

Hole No: TP4

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Description of Strata	Geological Unit	Graphic Log
SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S	TS
SILT, grey, stiff to very stiff, moist, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	
PEAT, black to dark brown, 'firm', wet to saturated, amorphous and semi decomposed organic material, containing sticks and flax fibres 0.9 m: Water ooze	Alluvial Sediments	
SILT, clayey, bluish grey, stiff, saturated, low plasticity	Alluvial Sediments	
Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, brownish grey, dense to very dense, wet to saturated	Alluvial Sediments	

EOTP: 2.40 m TDTE - HOLE COLLAPSE

Undrained Shear Strength (kPa)
Vane readings corrected as per BS 1377
Shear Vane / Residual Shear Vane
Axis: 50, 100, 150, 200

Values: 116, 56, 33, 33, 20, 50, 60

Depth (m): 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, 4.0, 4.2, 4.4, 4.6, 4.8

Dynamic Cone Penetrometer
Test Method: NZS 4402:1988, Test 6.5.2
(Blows / 0mm)
2 4 6 8 10 12 14 16

Groundwater
14/11/2022

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 2.3 m, and 2.0 m after half an hour standing, on 14/11/2022.

Datum:

Coordinates:

INVESTIGATION LOG

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Hole No: TP5

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Depth (m)	Description of Strata	Geological Unit	Undrained Shear Strength (kPa) – Shear Vane Values	Groundwater
0.0 – 0.4	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.4 – 1.2	PEAT, black to dark brown, 'firm', wet, amorphous and semi decomposed organic material, containing sticks and flax fibres, odiferous [ALLUVIAL SEDIMENTS] 0.9 m: Water ooze	Alluvial Sediments	0.4: 70; 0.6: 20; 0.8: 27; 1.2: 66	
1.2 – 1.4	SILT, some clay, bluish grey, stiff, wet, low plasticity	Alluvial Sediments		
1.4 – 2.2	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, greyish brown mottled orangey brown, dense to very dense, saturated	Alluvial Sediments		2.0 m: 14/11/2022

EOTP: 2.20 m TDTE - HOLE COLLAPSE

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377. ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 2.0 m, on 14/11/2022.

Datum:

Coordinates:

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INVESTIGATION LOG

Hole No: TP6

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Depth (m)	Description of Strata	Geological Unit	Undrained Shear Strength (kPa) Values	Groundwater
0.0 – 0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3 – 0.6	SILT, grey, stiff, moist, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	93	
0.6 – 1.5	PEAT, black to dark brown, 'firm', wet, amorphous and semi decomposed organic material, containing sticks and flax fibres, odiferous 0.9 m: Groundwater ooze	Alluvial Sediments	37 27 40	
1.5 – 2.0	SILT, sandy, and SAND, silty, bluish grey, stiff, wet, non plastic	Alluvial Sediments	70	14/11/2022 (2.0 m)
2.0 – 2.3	SILT, sandy, and SAND, silty, some fine to medium gravel, bluish grey, stiff, wet, non plastic	Alluvial Sediments		
2.3 – 2.8	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, brownish grey, dense to very dense, wet to saturated	Alluvial Sediments		

EOTP: 2.80 m TDTE - HOLE COLLAPSE

Vane readings corrected as per BS 1377. ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 2.0 m, on 14/11/2022.

Datum:

Coordinates:

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INVESTIGATION LOG

Hole No: TP7

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377 (● Shear Vane, ○ Residual Shear Vane)

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)
0.0 – 0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S	
0.3 – 0.6	SILT, grey, very stiff, moist, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	116 (0.4 m)
0.6 – 1.3	PEAT, black to dark brown, 'firm', wet to saturated, amorphous and semi decomposed organic material, containing sticks and flax fibres 1.1 m: Groundwater spring	Alluvial Sediments	56 (0.6 m), 33 (0.8 m), 33 (1.0 m), 20 (1.2 m)
1.3 – 1.6	SILT, sandy, bluish grey, stiff, wet, low plasticity	Alluvial Sediments	50 (1.4 m)
1.6 – 2.0	SAND (fine to coarse), gravelly (fine to coarse, subrounded greywacke), bluish grey, dense to very dense, saturated	Alluvial Sediments	
2.0 – 2.2	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, bluish grey, dense to very dense, saturated 1.9 m: Groundwater spring	Alluvial Sediments	

EOTP: 2.20 m TDTE - HOLE COLLAPSE

Groundwater: ▼ 14/11/2022 (approx. 2.1 m)

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 2.1 m, on 14/11/2022.

Datum:

Coordinates:

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INVESTIGATION LOG

Hole No: TP8

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark, Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377 (● Shear Vane, ○ Residual Shear Vane)

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0 – 0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3 – 0.6	SILT, grey, stiff, moist, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	83	
0.6 – 1.1	PEAT, black to dark brown, 'stiff', wet to saturated, amorphous and semi decomposed organic material, containing sticks and flax fibres 0.8 m: Groundwater trickle	Alluvial Sediments	66, 103	
1.1 – 1.5	SILT, clayey, bluish grey, very stiff, wet, low plasticity	Alluvial Sediments	100	
1.5 – 1.9	SILT, sandy, bluish grey, stiff, wet, low plasticity	Alluvial Sediments	70, 66	▼ 14/11/2022 (1.8 m)
1.9 – 2.5	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, yellowish brown mottled orangey brown, dense to very dense, saturated 2.2 m: Rapid groundwater inflow	Alluvial Sediments		

EOTP: 2.50 m TDTE - HOLE COLLAPSE

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 2.2 m, and 1.8 m after 10 min, on 14/11/2022.

Datum:

Coordinates:

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INVESTIGATION LOG

Hole No: **TP9**

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	14/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377; ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0–0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3–0.6	SILT, greyish brown, stiff, moist, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	96 (0.4 m)	
0.6–1.2	PEAT, black to dark brown, 'firm', wet to saturated, amorphous and semi decomposed organic material, containing sticks and flax fibres 1.0 m: Rapid groundwater inflow	Alluvial Sediments	47 (0.8 m); 33 (1.1 m)	
1.2–1.5	SILT, clayey, bluish grey, very stiff, wet, low plasticity	Alluvial Sediments	100 (1.2 m)	14/11/2022 (1.5 m)
1.5–2.0	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, yellowish brown mottled orangey brown, dense to very dense, saturated	Alluvial Sediments		

EOTP: 1.80 m TDTE - HOLE COLLAPSE

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 1.8 m, and 1.5 m after 10 min, on 14/11/2022.

Datum:

Coordinates:

Generated with CORE-GS by Geroc - Shallow Investigation with Photo EOTP test - 16/06/2023 5:07:06 pm

FRASER THOMAS — 50 Years — ENGINEERS • RESOURCE MANAGERS • SURVEYORS

INVESTIGATION LOG

Hole No: TP10

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark, Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377 (● Shear Vane, ○ Residual Shear Vane)

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 0mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0–0.4	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.4–1.0	PEAT, black to dark brown, 'firm', wet to saturated, amorphous and semi decomposed organic material, containing sticks and flax fibres [ALLUVIAL SEDIMENTS] 0.5 m: Steady water trickle	Alluvial Sediments	53 (0.4 m), 37 (0.6 m), 50 (0.8 m), 66 (1.0 m)	
1.0–1.5	SILT, clayey, bluish grey, stiff, moist, low to moderate plasticity	Alluvial Sediments	86 (1.4 m)	▼ 15/11/2022 (approx. 1.5 m)
1.5–2.1	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, yellowish brown mottled orangey brown, dense to very dense, saturated	Alluvial Sediments		

EOTP: 2.10 m TDTE - HOLE COLLAPSE

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 1.7 m, and 1.5 m after 10 min, on 15/11/2022.

Datum:

Coordinates:

Fraser Thomas — ENGINEERS • RESOURCE MANAGERS • SURVEYORS	INVESTIGATION LOG	Hole No: TP11

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377 — ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0–0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3–0.7	PEAT, black to dark brown, 'stiff', wet to saturated, mostly amorphous organic material [ALLUVIAL SEDIMENTS]	Alluvial Sediments	66 (0.4 m); 70 (0.6 m)	
0.7–0.9	SILT, grey, stiff, moist, low to moderate plasticity	Alluvial Sediments		
0.9–1.3	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, yellowish brown mottled orangey brown, dense to very dense, saturated. 1.1 m: Water trickle	Alluvial Sediments		15/11/2022
1.3–1.7	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), yellowish brown, dense to very dense, saturated. 1.4 m: Water trickle	Alluvial Sediments		

EOTP: 1.70 m TDTE - HOLE COLLAPSE

DCP (Blows / 50mm): 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 7, 10, 12, 12, 10, 10, 10, 15

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 1.4 m, and 1.3 m after 10 min, on 15/11/2022.

Datum:

Coordinates:

INVESTIGATION LOG

Fraser Thomas — ENGINEERS • RESOURCE MANAGERS • SURVEYORS

Hole No: TP12

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Depth (m)	Description of Strata	Geological Unit	Undrained Shear Strength (kPa) Values	Groundwater
0.0–0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3–0.7	SILT, greyish brown mottled orangey brown, very stiff, moist, low to moderate plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	146 (0.3 m), 113 (0.5 m), 116 (0.7 m)	
0.7–1.1	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, yellowish brown mottled orangey brown, dense to very dense, moist	Alluvial Sediments		
1.1–1.7	SAND (fine to coarse), bluish grey streaked orangey brown, dense to very dense, wet 1.4 m: Water trickle. Large tree stump	Alluvial Sediments		1.6 m (15/11/2022)
1.7–1.9	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), yellowish brown, dense to very dense, saturated 1.9 m: Groundwater spring	Alluvial Sediments		

EOTP: 1.90 m TDTE - HOLE COLLAPSE

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377. ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm)

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 1.9 m, and 1.6 m after 20 min, on 15/11/2022.

Datum:

Coordinates:

ENGINEERS • RESOURCE MANAGERS • SURVEYORS

INVESTIGATION LOG

Hole No: **TP13**

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

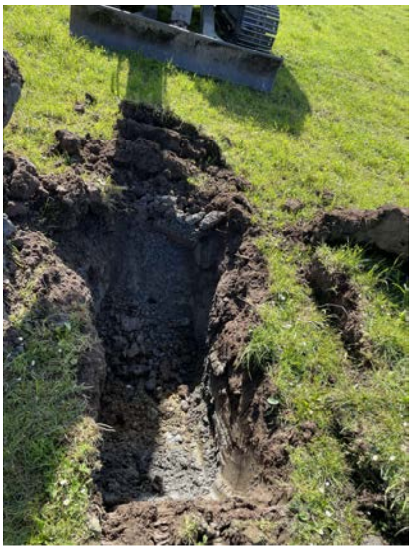
Depth (m)	Description of Strata	Geological Unit	Graphic Log	Undrained Shear Strength (kPa)	Dynamic Cone Penetrometer	Groundwater
0.0 – 0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S	TS			
0.3 – 0.7	SILT, greyish brown, stiff, moist, low to moderate plasticity [ALLUVIAL SEDIMENTS] 0.5 m - 0.6 m: Organic SILT lense, dark brown	Alluvial Sediments				
0.7 – 0.9	Clayey SILT, bluish grey, stiff, wet, trace semi decomposed wood fibres	Alluvial Sediments				▼ 15/11/2022 (0.9 m)
0.9 – 1.0	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), yellowish brown, dense to very dense, saturated	Alluvial Sediments				
1.00	EOTP: 1.00 m TARGET DEPTH					

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377. ● Shear Vane ○ Residual Shear Vane. Scale: 50, 100, 150, 200; Values

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm). Scale: 2, 4, 6, 8, 10, 12, 14, 16

Depth scale (m): 0.2 – 4.8

Profile:



Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 0.9 m, on 15/11/2022.

Datum:

Coordinates:

INVESTIGATION LOG

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Hole No: TP14

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377 — ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0 – 0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3 – 0.8	SILT, some clay, greyish brown mottled orangey brown, very sitff to hard, moist, low to moderate plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	209 (0.3); 183 (0.5); 183 (0.7)	
0.8 – 1.2	SAND (fine to coarse), trace gravel and silt, bluish grey mottled orangey brown, dense to very dense, wet	Alluvial Sediments		
1.2 – 1.7	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), bedded greyish brown and orangey brown, dense to very dense, saturated	Alluvial Sediments		15/11/2022 (1.6 m)

EOTP: 1.70 m TDTE - HOLE COLLAPSE

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 1.7 m, and 1.6 m after 10 min, on 15/11/2022.

Datum:

Coordinates:

Fraser Thomas
ENGINEERS • RESOURCE MANAGERS • SURVEYORS

INVESTIGATION LOG

Hole No: **TP15**

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377; ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values	Groundwater
0.0–0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3–0.7	SILT, some clay, greyish brown mottled orangey brown, hard, moist, low to moderate plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	UTP; UTP	
0.7–2.0	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), some silt, trace cobbles, orangey brown, dense to very dense, moist 0.9 m: Colour change to grey. 1.4 m: Water ooze. 1.5 m: Colour change to grey with orangey brown bedding. 1.8 m: Groundwater inflow. 2.0 m: Groundwater spring. Orangey brown water.	Alluvial Sediments		▼ 15/11/2022 (2.0 m)
2.0	EOTP: 2.00 m TDTE - HOLE COLLAPSE			

DCP (Blows / 50mm): 1, 1, 1, 1, 1, 1, 1, 1, 2, 1, 1, 1, 5, 7, 11, 10, 15

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 2.0 m, on 15/11/2022.

Datum:

Coordinates:

Generated with CORE-GS by Geroc - Shallow Investigation with Photo EOTP test - 16/06/2023 5:07:06 pm

Fraser Thomas
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INVESTIGATION LOG

Hole No: **TP16**

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark, Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377. ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)
0.0 – 0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S	
0.3 – 0.6	SILT, greyish brown, very stiff, moist, low plasticity [ALLUVIAL SEDIMENTS]	Alluvial Sediments	103 (0.4 m); 53 (0.5 m)
0.6 – 0.8	PEAT, black to dark brown, 'stiff', wet to saturated, mostly amorphous organic material	Alluvial Sediments	66 (0.7 m)
0.8 – 1.0	SILT, greyish brown, stiff, moist, low plasticity	Alluvial Sediments	
1.0 – 1.7	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, brownish grey, dense to very dense, wet to saturated 1.2 m: Water ooze 1.4 m: Colour change to yellowish brown.	Alluvial Sediments	

EOTP: 1.70 m TDTE - HOLE COLLAPSE

Groundwater: 1.4 m (14/11/2022)

Profile:

Excavation Method:

Remarks:
Groundwater encountered at depths of approximately 1.7 m, and 1.5 m after 10 min, on 15/11/2022.

Datum:

Coordinates:

INVESTIGATION LOG

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Hole No: TP17

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark, Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Undrained Shear Strength (kPa) — Vane readings corrected as per BS 1377 — ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer — Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0–0.3	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.3–0.6	SILT, greyish brown, very stiff, moist, non plastic [ALLUVIAL SEDIMENTS]	Alluvial Sediments	100 (0.4 m)	
0.6–1.1	PEAT, black to dark brown, 'firm', wet to saturated, amorphous and semi decomposed organic material, containing sticks and flax fibres. 0.7 m: Water ooze	Alluvial Sediments	33 (0.6 m); 33 (0.8 m); 66 (1.0 m)	
1.1–1.4	SILT, clayey, bluish grey, stiff, wet, low plasticity. 0.9 m: Water ooze	Alluvial Sediments		
1.4–1.9	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, yellowish brown, dense to very dense, wet to saturated	Alluvial Sediments		15/11/2022 (1.6 m)

EOTP: 1.90 m TDTE - HOLE COLLAPSE

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 1.6 m, on 15/11/2022.

Datum:

Coordinates:

INVESTIGATION LOG

Hole No: TP18

Fraser Thomas — ENGINEERS • RESOURCE MANAGERS • SURVEYORS

Project No:	Project:	Shear Vane:	Date Excavated:	Logged By:	Checked By:
CH01508	Richard and Geoff Spark, Spark Dairy Farm, Boys Road, Rangiora	1310	15/11/2022	KT	

Undrained Shear Strength (kPa): Vane readings corrected as per BS 1377. ● Shear Vane ○ Residual Shear Vane

Dynamic Cone Penetrometer: Test Method: NZS 4402:1988, Test 6.5.2 (Blows / 50mm)

Depth (m)	Description of Strata	Geological Unit	Shear Vane Values (kPa)	Groundwater
0.0 – 0.4	SILT, dark brown, moist, non plastic, rootlets [TOPSOIL]	T/S		
0.4 – 0.6	PEAT, black to dark brown, 'firm', wet to saturated, generally amorphous	Alluvial Sediments	43 (at 0.4 m)	
0.6 – 0.9	SILT, bluish grey, stiff, wet, low plasticity	Alluvial Sediments	70 (at 0.7 m)	
0.9 – 1.2	Gravelly (fine to coarse) SAND (fine to coarse), bluish grey, medium dense, saturated	Alluvial Sediments		
1.2 – 2.1	Sandy (fine to coarse) GRAVEL (fine to coarse, subrounded greywacke), trace cobbles, yellowish brown and orangey brown, dense to very dense, wet to saturated 1.3 m: Water seep 1.5 m: Groundwater inflow			▼ 15/11/2022 (approx. 1.9 m)

EOTP: 2.10 m TDTE - HOLE COLLAPSE

Profile:

Excavation Method:

Remarks:
Groundwater encountered at a depth of approximately 2.0 m, on 15/11/2022.

Datum:

Coordinates:

Machine Borehole

M1

Golder Associates

Soil Borehole Log

Location: 39 Oakgrove Drive, Rangiora

Reference: GA_20406

Grid: NZTM | **Datum:** MSL

North (m): 5203912
East (m): 1567821
Elevation (m): 19
Hole Depth (m): 15.27
Orientation (°): -
Inclination (°): 90

Depth (m)	Description	USC	Moisture Condition	Consistency / Density	Water Observations	Samples & In-situ Testing
0.00–2.00	Sandy fine to coarse GRAVEL with trace silt; brown. Very dense; wet; well graded; angular to rounded; sand, fine to coarse.	GW	W	VD	Groundwater at approx. 1.8 m	SPT N = 50+ Depth: 1.00m Type: Raymond Split Spoon 4, 8 / 6, 6, 12, 30 450mm penetration
2.00–3.00	Medium dense below 2.0 m.	GW	W	MD		SPT N = 20 Depth: 2.00m Type: Raymond Split Spoon 1, 6 / 5, 5, 5, 5 450mm penetration
3.00–4.00	SILT; light to dark grey. Stiff; wet; low plasticity.	ML	W	St		SPT N = 7 Depth: 3.00m Type: Raymond Split Spoon 1, 1 / 1, 1, 2, 3 450mm penetration
4.00–6.00	Sandy fine to coarse GRAVEL with minor silt; brown. Dense; saturated; rounded; sand, fine to coarse.	GW	S	D		SPT N = 46 Depth: 4.00m Type: Raymond Split Spoon 3, 7 / 10, 10, 12, 14 450mm penetration SPT N = 41 Depth: 5.00m Type: Raymond Split Spoon 6, 10 / 10, 10, 9, 12 450mm penetration
6.00–9.00	Rounded to subrounded below 6.0 m.	GW	S	D		SPT N = 33 Depth: 6.00m Type: Raymond Split Spoon 5, 7 / 9, 7, 8, 9 450mm penetration SPT N = 48 Depth: 7.00m Type: Raymond Split Spoon 8, 13 / 10, 12, 13, 13 450mm penetration SPT N = 43 Depth: 8.00m Type: Raymond Split Spoon 4, 12 / 10, 10, 11, 12 450mm penetration
9.00–10.00	Very dense below 9.0 m.	GW	S	VD		SPT N = 50+ Depth: 9.00m Type: Raymond Split Spoon 4, 11 / 12, 18, 13, 7 410mm penetration SPT N = 50+ Depth: 10.00m

Driller	Logger	Remarks
Speight Drilling	MS	Coordinates and elevation are estimates only. Hammer Energy ratio Ce = 0.95. Groundwater elevation measured on completion of drilling.
Drill Method / Rig HQ3/CS1000		
Start Date 21/05/2014	**Checked By** NAC	
End Date 21/05/2014		

Borehole logged in accordance with NZGS guideline "Field description of soil and rock" 2005
Vane tests completed in accordance with NZGS guideline

Hole Depth 15.27m

Location: 39 Oakgrove Drive, Rangiora

Reference: GA_20406

Soil Borehole Log

North (m): 5203912
East (m): 1567821
Elevation (m): 19
Hole Depth (m): 15.27
Orientation (°): -
Inclination (°): 90

Grid: NZTM **Datum:** MSL

Formation	Graphic Log	Description	USC	Moisture Condition	Consistency / Density	Water Observations	Depth	TCR (%)	SPT N-value (Uncorrected)	Samples & In-situ Testing	Backfill & Installation
		Sandy fine to coarse GRAVEL with minor silt; brown. Very dense; saturated; rounded to subrounded; sand, fine to coarse.	GW	S	VD		10.50, 11.00, 11.50			Type: Raymond Split Spoon 3, 17 / 18, 15, 17 375mm penetration SPT N = 50+ Depth: 11.00m Type: Raymond Split Spoon 8, 17 / 15, 15, 20 355mm penetration SPT N = 45 Depth: 12.00m	
		Dense below 12.0 m.	GW	S	D		12.00, 12.50			Type: Raymond Split Spoon 5, 14 / 11, 11, 11, 12 450mm penetration SPT N = 50+ Depth: 13.00m	
		Very dense below 13.0 m.	GW	S	VD		13.00, 13.50, 14.00, 14.50, 15.00			Type: Raymond Split Spoon 10, 28 / 20, 20, 10 350mm penetration SPT N = 50+ Depth: 14.00m Type: Raymond Split Spoon 6, 14 / 15, 20, 15 365mm penetration SPT N = 50+ Depth: 15.00m Type: Raymond Split Spoon 6, 17 / 35, 15 270mm penetration	

EOH: 15.27 m

Driller Speight Drilling	**Logger** MS	**Remarks** Coordinates and elevation are estimates only. Hammer Energy ratio Ce = 0.95. Groundwater elevation measured on completion of drilling.
Drill Method / Rig HQ3/CS1000		
Start Date 21/05/2014	**Checked By** NAC	**Hole Depth** 15.27m
End Date 21/05/2014		Borehole logged in accordance with NZGS guideline "Field description of soil and rock" 2005 Vane tests completed in accordance with NZGS guideline

M2

BOREHOLE No: **BH3**

MACHINE BOREHOLE LOG

SHEET 1 of 1

CH2M Beca

PROJECT: Rangiora Central Sewer Upgrade Piezometer Installation
JOB NUMBER: 6513078
SITE LOCATION: Rangiora
CLIENT: Waimakariri District Council

CIRCUIT: NZTM
COORDINATES: N 5,203,209 m
E 1,567,852 m
BOREHOLE LOCATION: Dunlops Road
R L: 17 m
DATUM: NZTM
COORDINATE ORIGIN: MAP
ACCURACY: ±1m

DEPTH (m)	CORE RECOVERY	METHOD	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT
0.0 – 0.2	13 %	VE	Fine to coarse GRAVEL; minor fine to coarse sand; moist; grey; non plastic. Gravel: SW, subrounded to subangular, sandstone. [FILL].	
0.2 – 1.5			0.2 - 1.5 m: no core recovery.	ALLUVIUM
1.5 – 2.6	100 %	Sonic	Silty fine to medium GRAVEL, minor fine to coarse sand; orangish brown; saturated; non plastic. Gravel: SW, subangular to subrounded, sandstone.	ALLUVIUM
2.6 – 3.0	100 %	Sonic	Fine to coarse sandy fine to medium GRAVEL, some silt; brown; saturated; non plastic. Gavel: SW, subangular to rounded, sandstone.	ALLUVIUM
3.0 – 4.0	100 %	Sonic	Fine to coarse GRAVEL, some fine to coarse sand, some silt, trace fine cobbles, trace clay; saturated; low plasticity (matrix). Cobbles/Gravel: SW, subangular to rounded, sandstone.	ALLUVIUM
4.0 – 4.6	100 %	Sonic	Fine to coarse sandy fine to medium GRAVEL, some silt greyish brown; saturated; non plastic. Gravel: SW, subangular to rounded, sandstone.	ALLUVIUM
4.6 – 5.6	100 %	Sonic	Silty fine to coarse GRAVEL, some fine to coarse sand, trace clay; brown; saturated; low plasticity (matrix). Gravel: SW, subangular to rounded, sandstone.	ALLUVIUM
5.6 – 6.1	100 %	Sonic	Fine to coarse sandy fine to coarse GRAVEL, trace silt; brown; wet; non plastic. Gravel: SW, subangular to rounded, sandstone.	ALLUVIUM
6.1			END OF LOG @ 6.1 m	

Daily water level: 13/10/2016 11:20:00 a.m.

Column headings: DRILLING (FLUID LOSS, DAILY WATER LEVEL, CORE RECOVERY, METHOD, CASING, RQD); IN-SITU TESTS (SV, τ (kPa), SPT 'N'); SAMPLES; DEPTH (m); GRAPHIC LOG; SOIL / ROCK DESCRIPTION; GEOLOGICAL UNIT; R L (m)

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9
R L (m) scale: 16, 15, 14, 13, 12, 11, 10, 9, 8

DATE STARTED: 12/10/16
DATE FINISHED: 12/10/16
LOGGED BY: LB
SHEAR VANE No: N/A
DRILLED BY: Prodrill Ltd
EQUIPMENT: Fraste XL2
DRILL METHOD: Sonic/VE
DRILL FLUID: Water
DIAMETER/INCLINATION: 122 mm/ 90°

COMMENTS:
Co-ordinates and elevation found using ECan GIS viewer. Groundwater measured inside piezometer 13/10/2016 11:20: 0.925 mbgl.

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET

A4 Scale 1:50

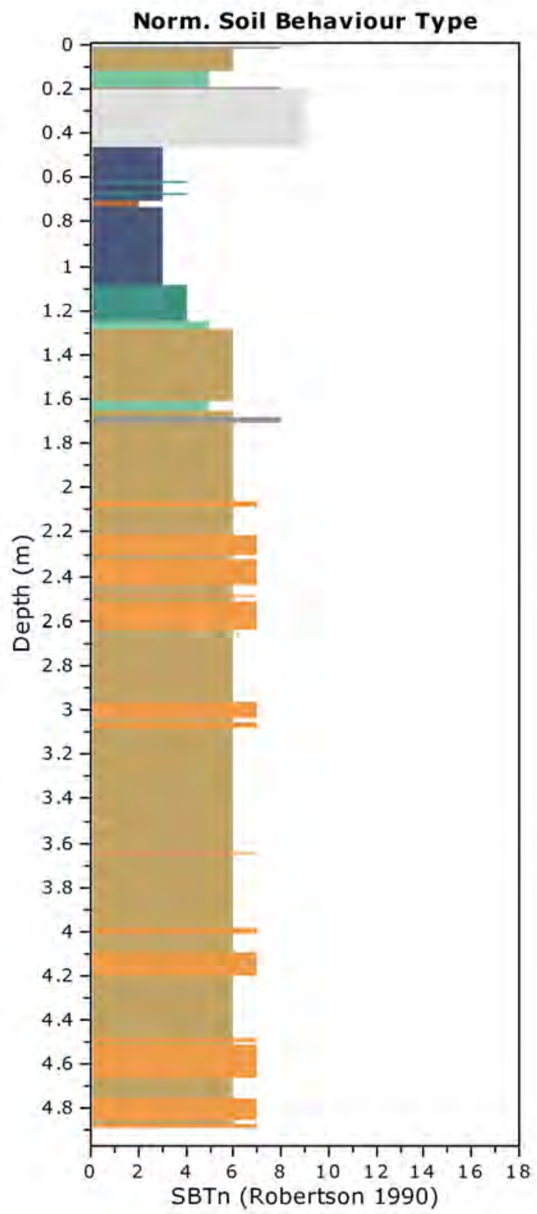
BECA LIB 1.07.4 GLB Log BECA MACHINE BOREHOLE RANGIORA-BOREHOLE-LOGS.GPJ DWG39854.GDW 09/11/2016 13:43 8.30.004 Datgel Lab and In Situ Tool - DGD | Lib: Beca 1.07.4 2016-01-15 Prj: Beca 1.07 2014-12-16

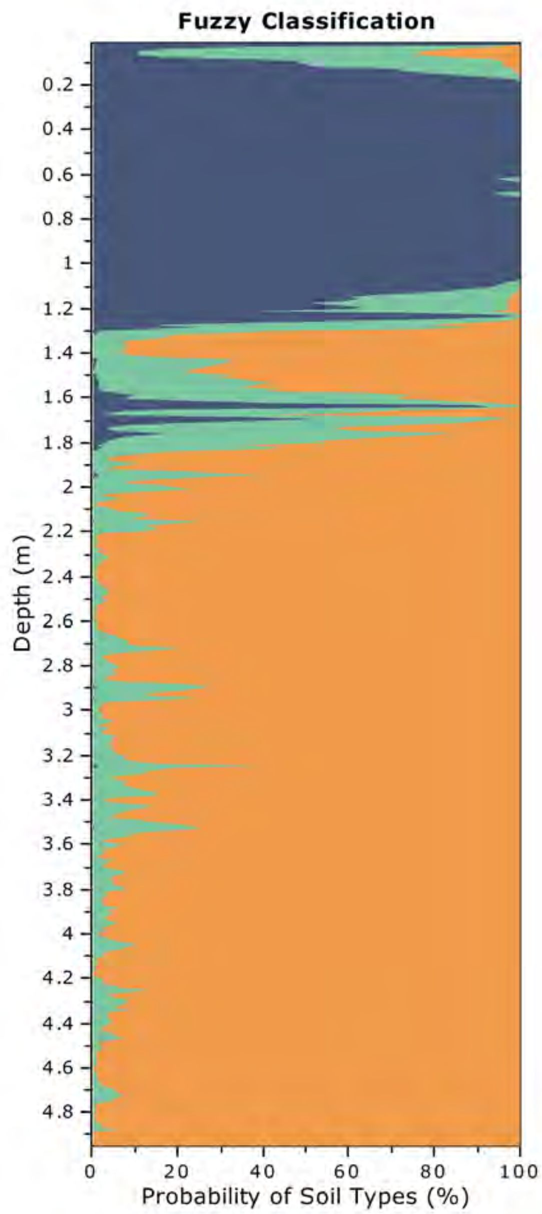
Cone Penetration Test (CPT) Results

Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT1
Total depth: 4.95 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora





Fuzzy classifiaction legend
- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

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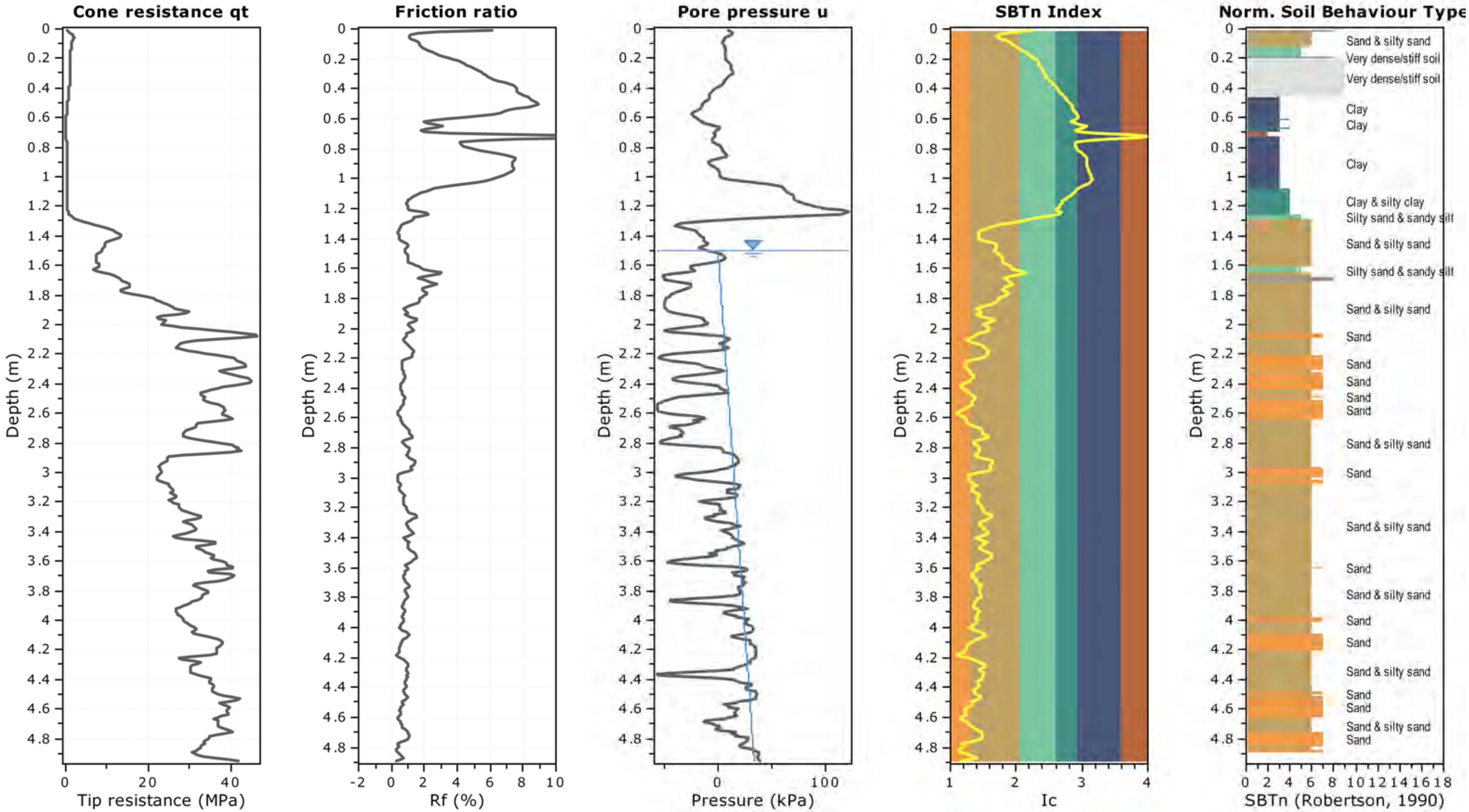
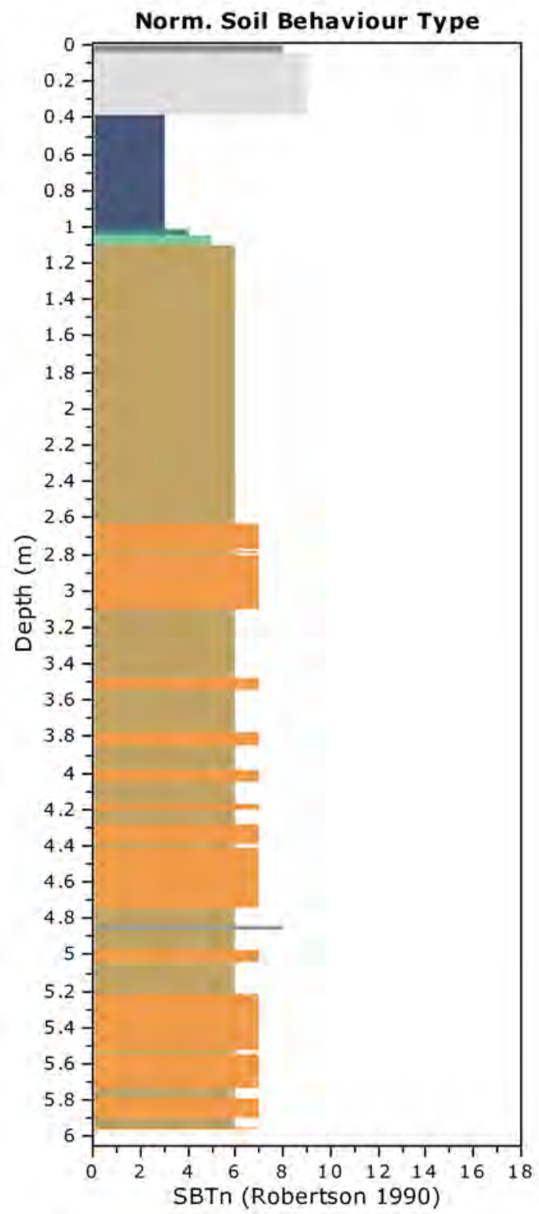
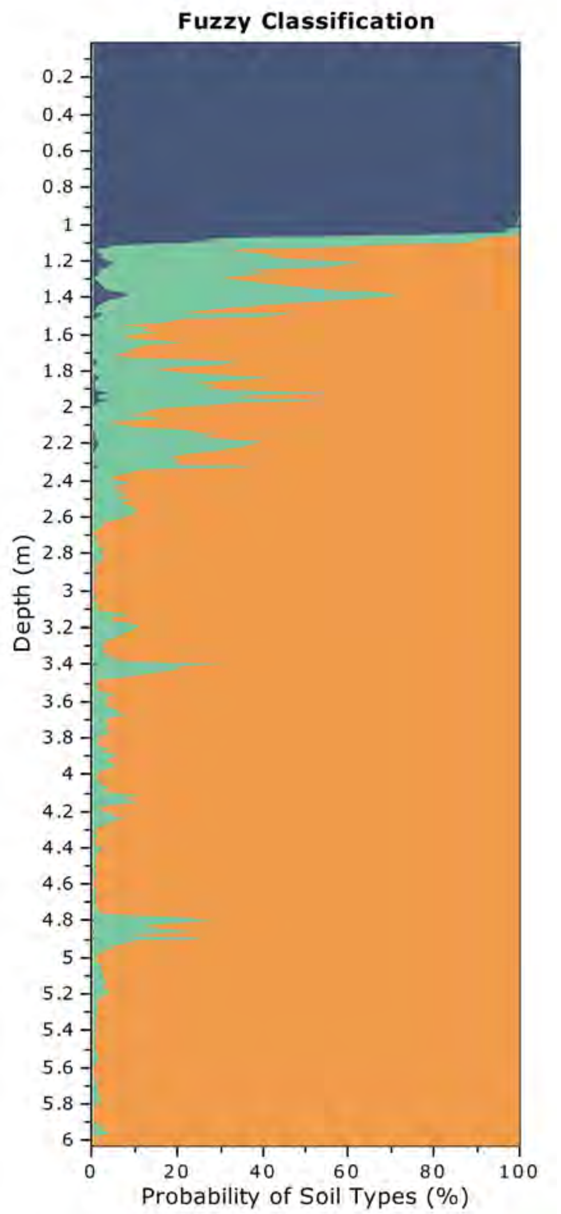
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT1
Total depth: 4.95 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

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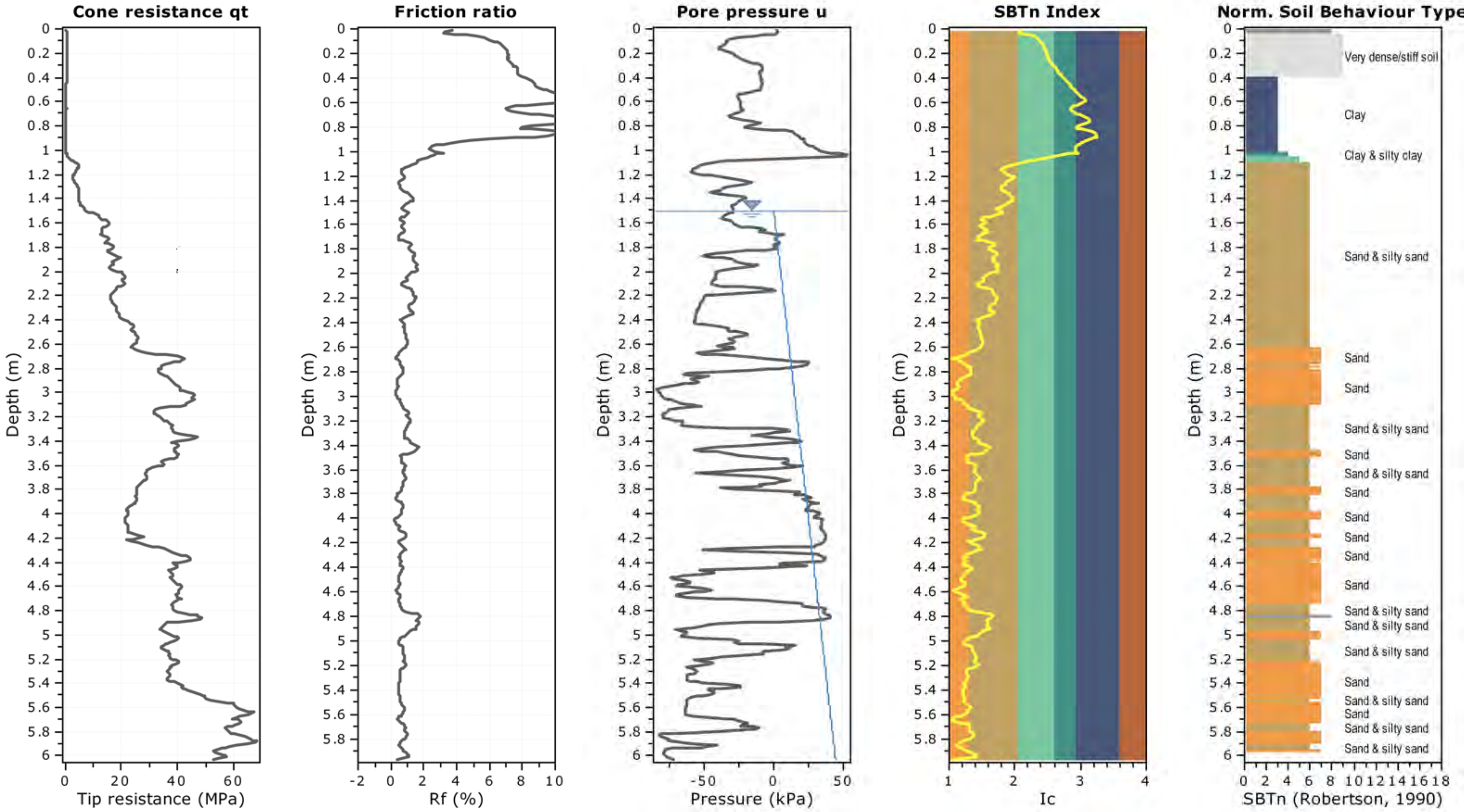
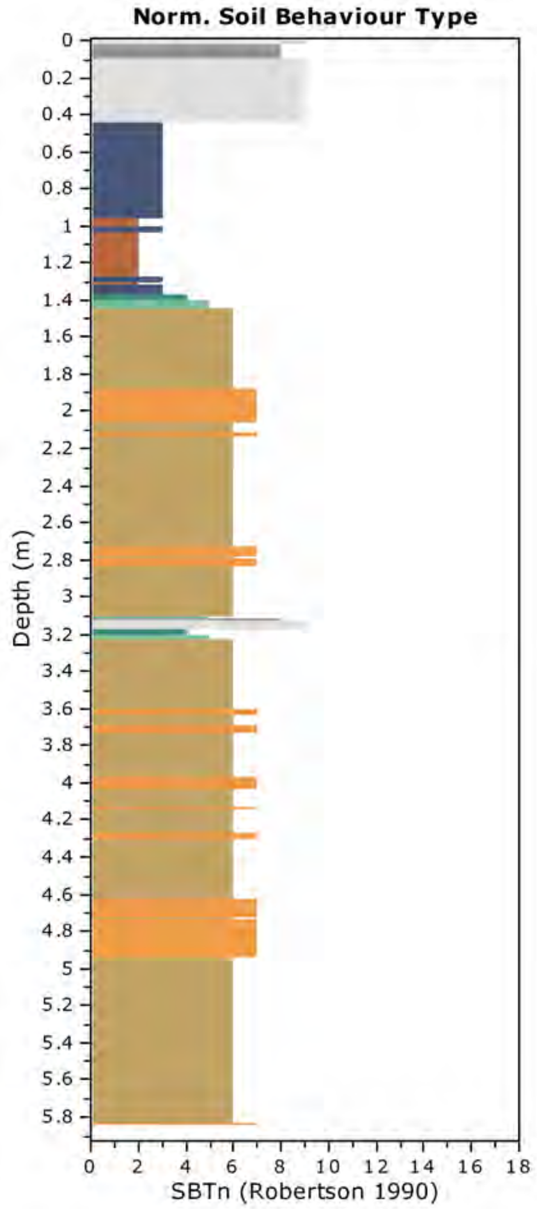
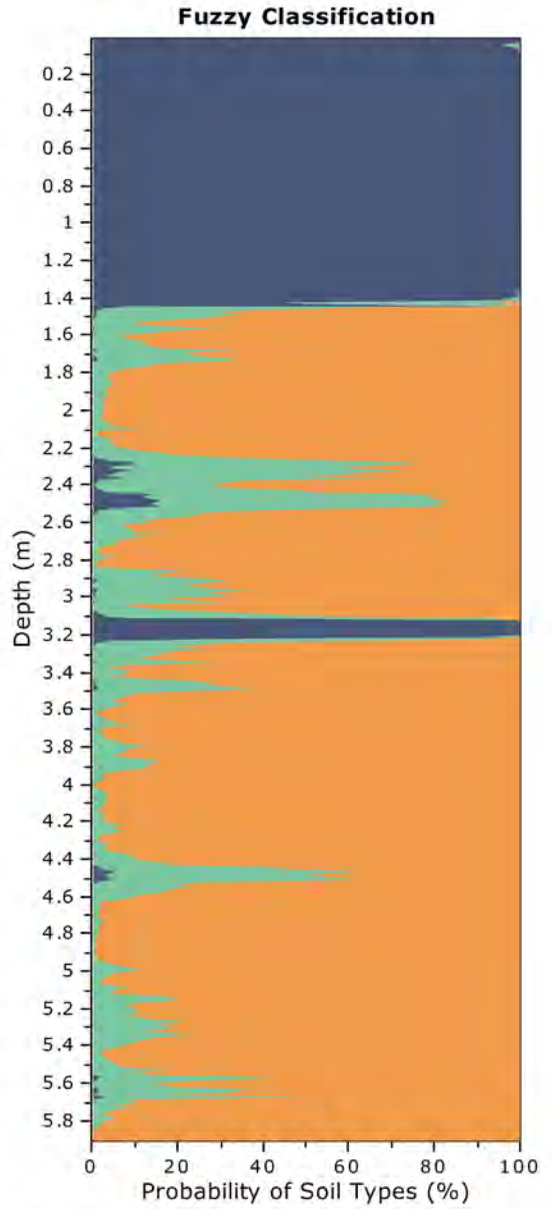
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT2
Total depth: 6.03 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

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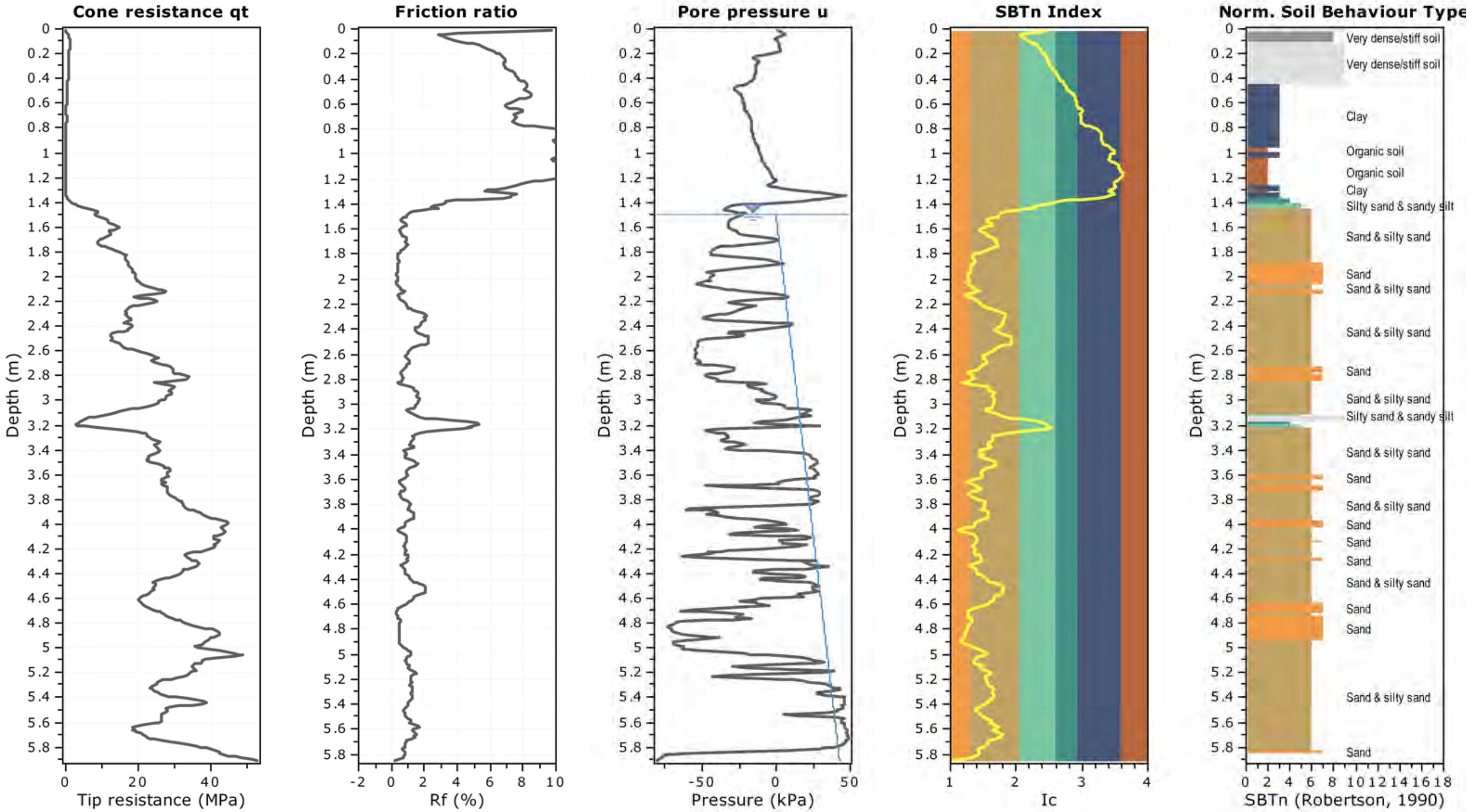
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT3
Total depth: 5.91 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora



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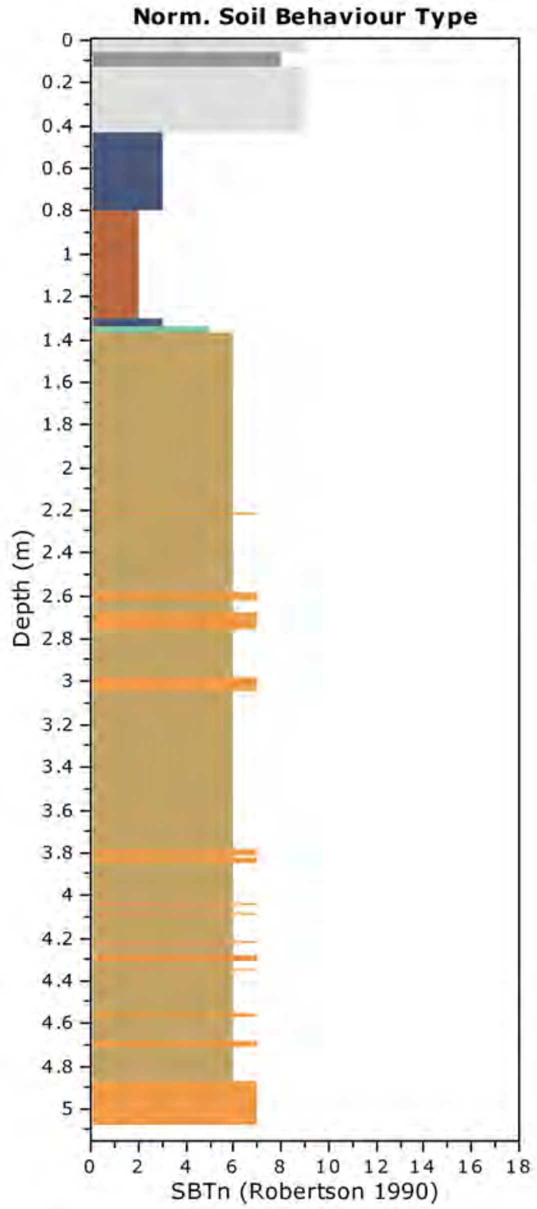
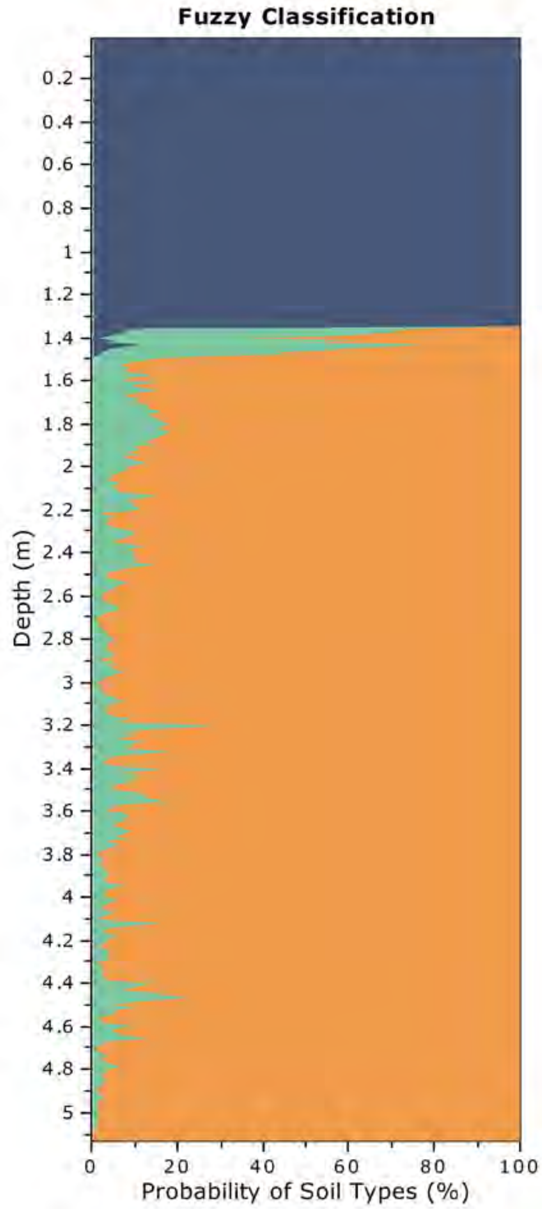
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT4
Total depth: 5.13 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**





Fuzzy classifiaction legend

- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

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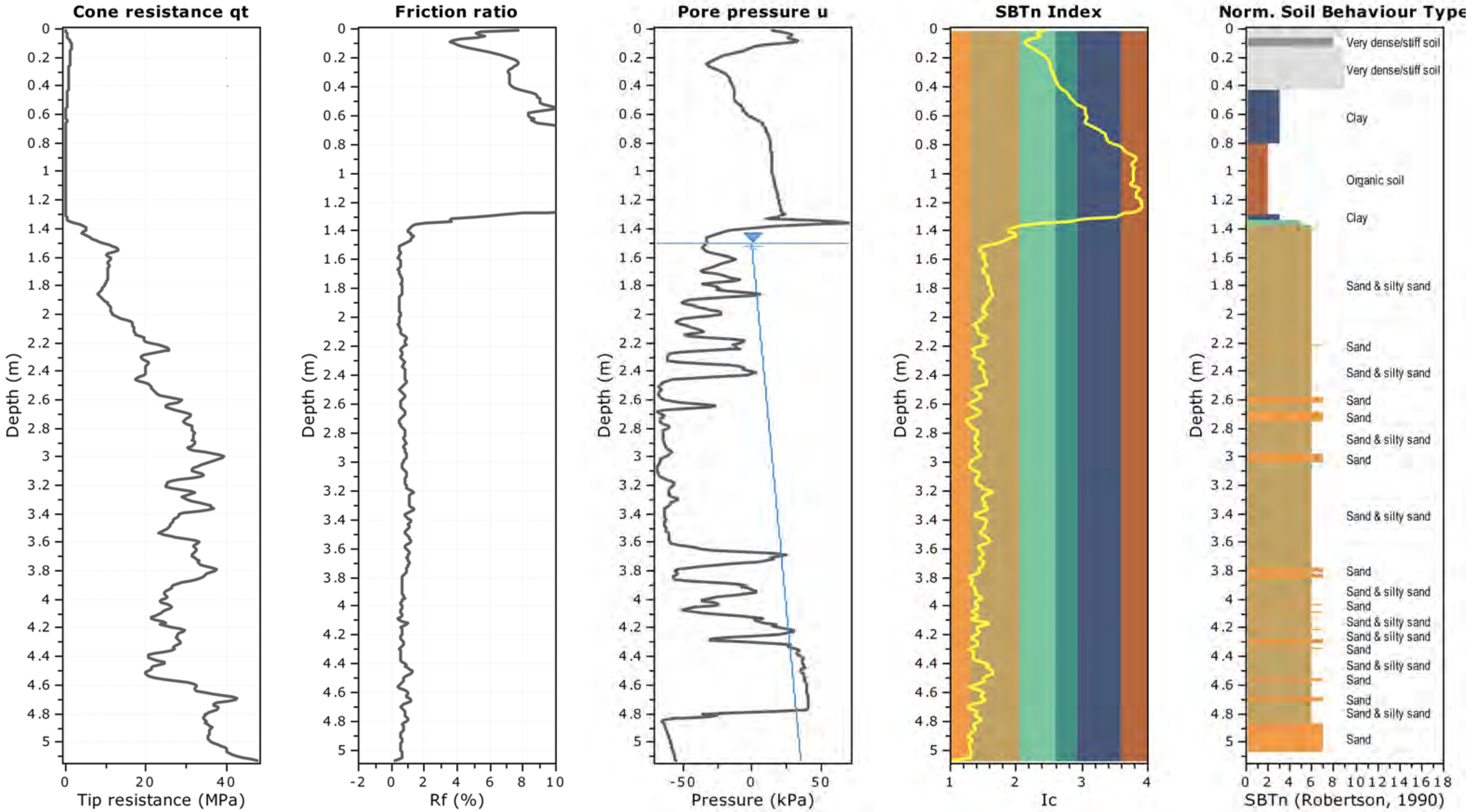
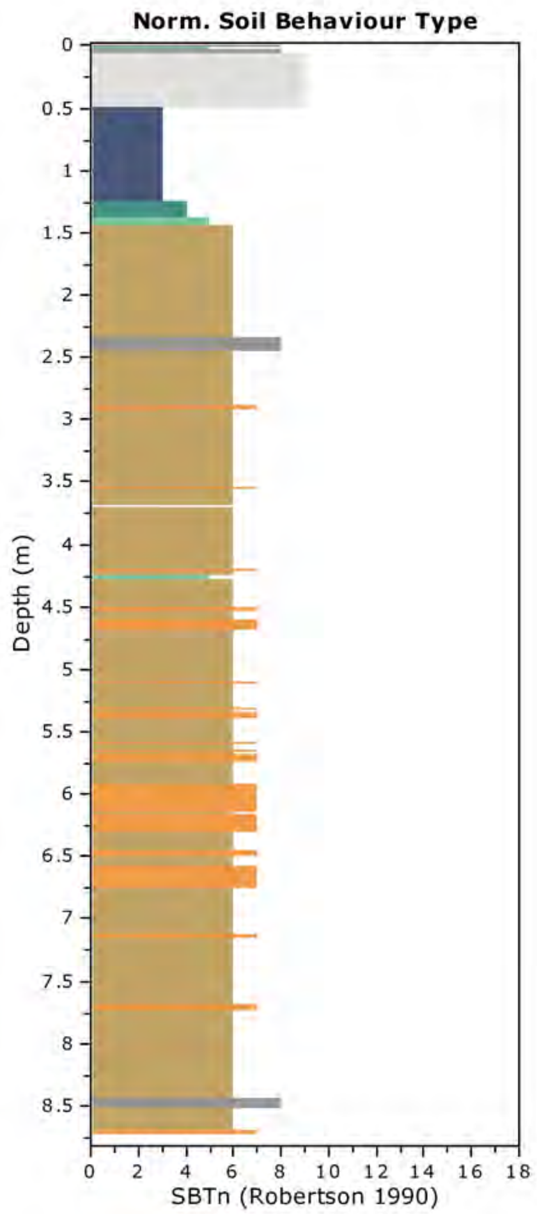
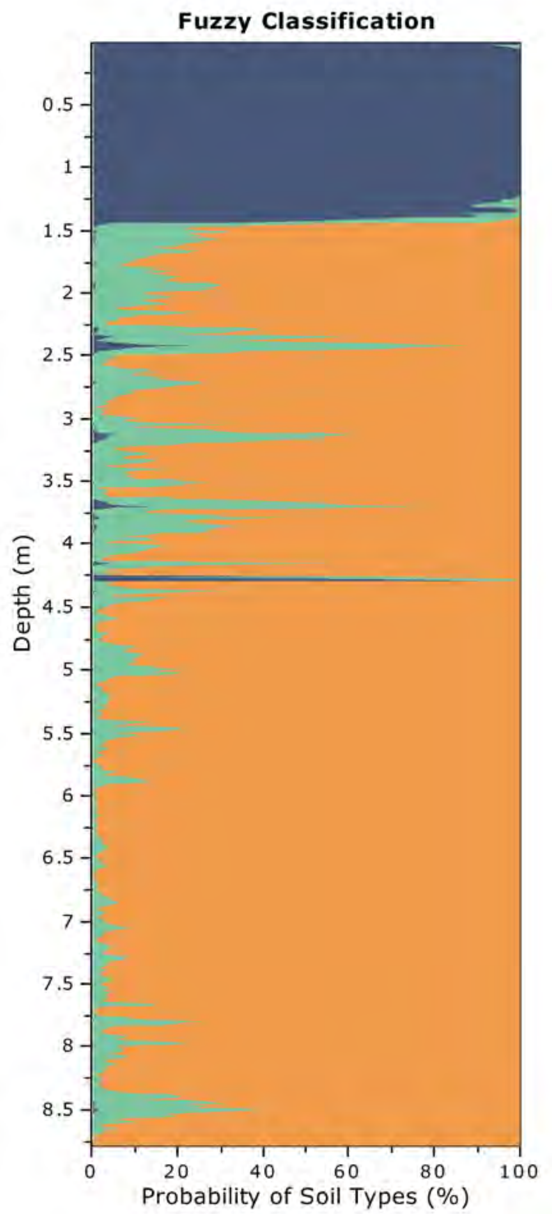
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT4
Total depth: 5.13 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

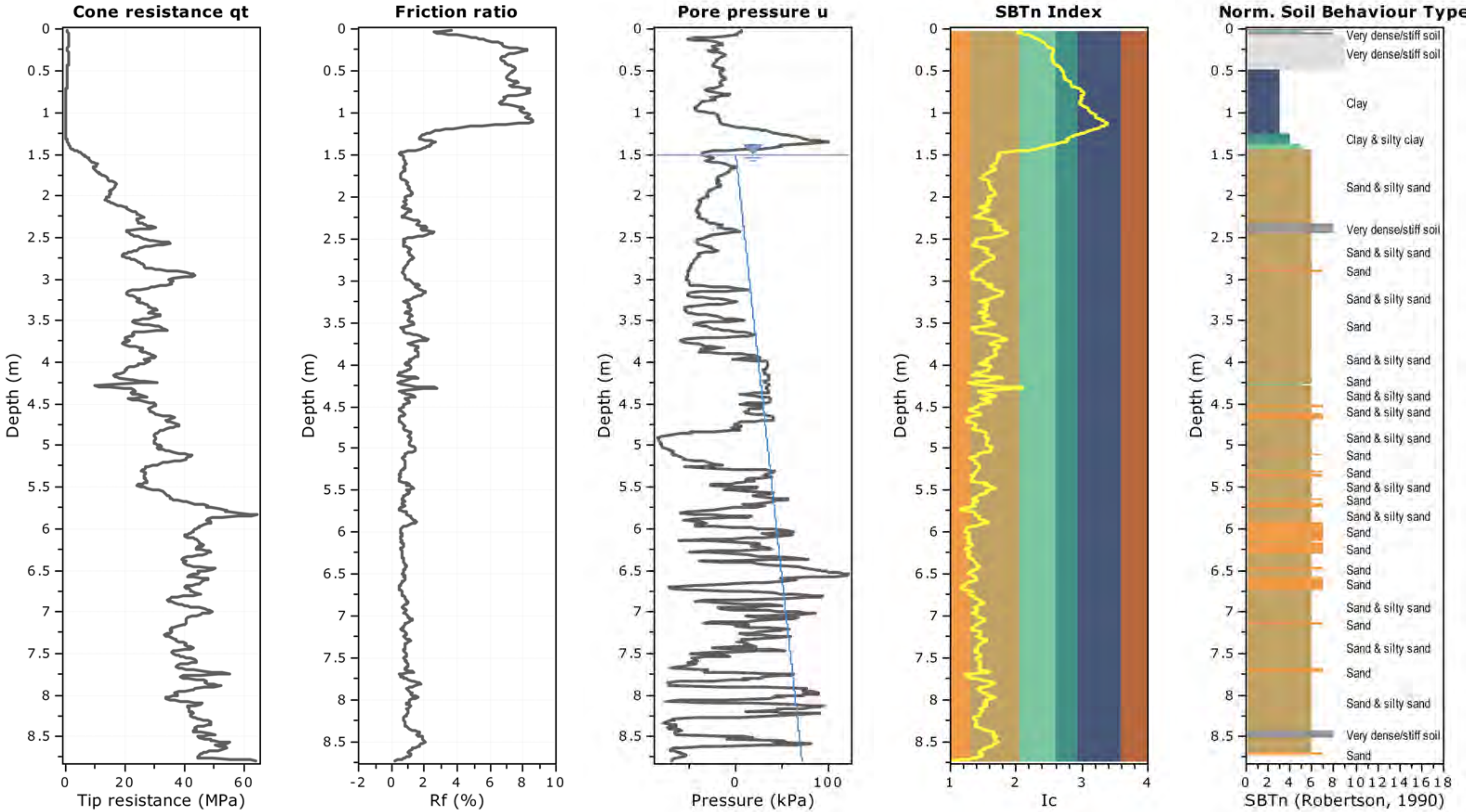
- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT5

Total depth: 8.79 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

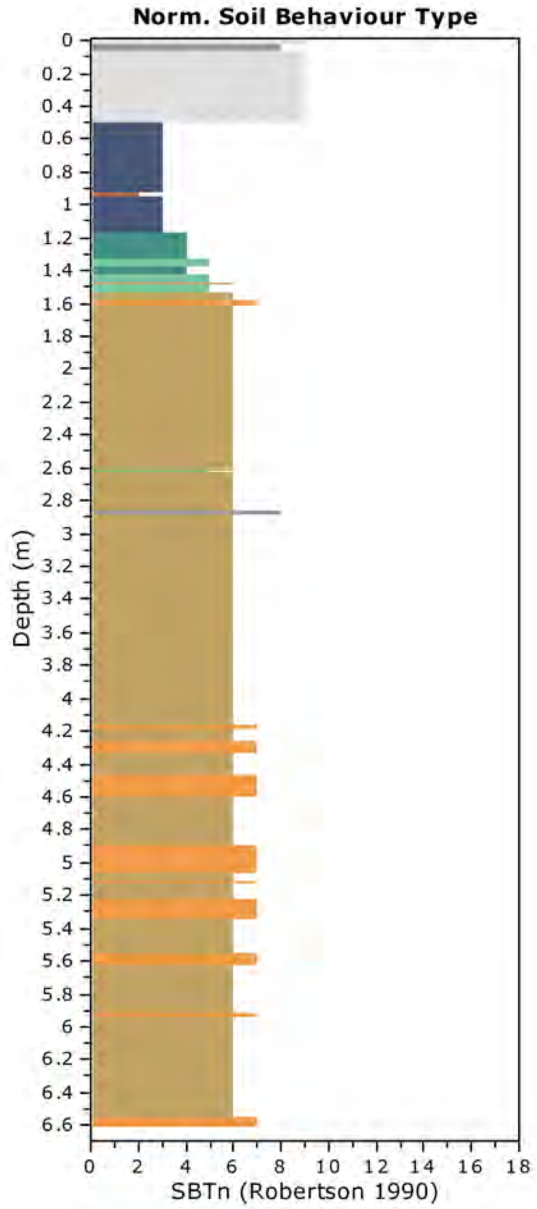
Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

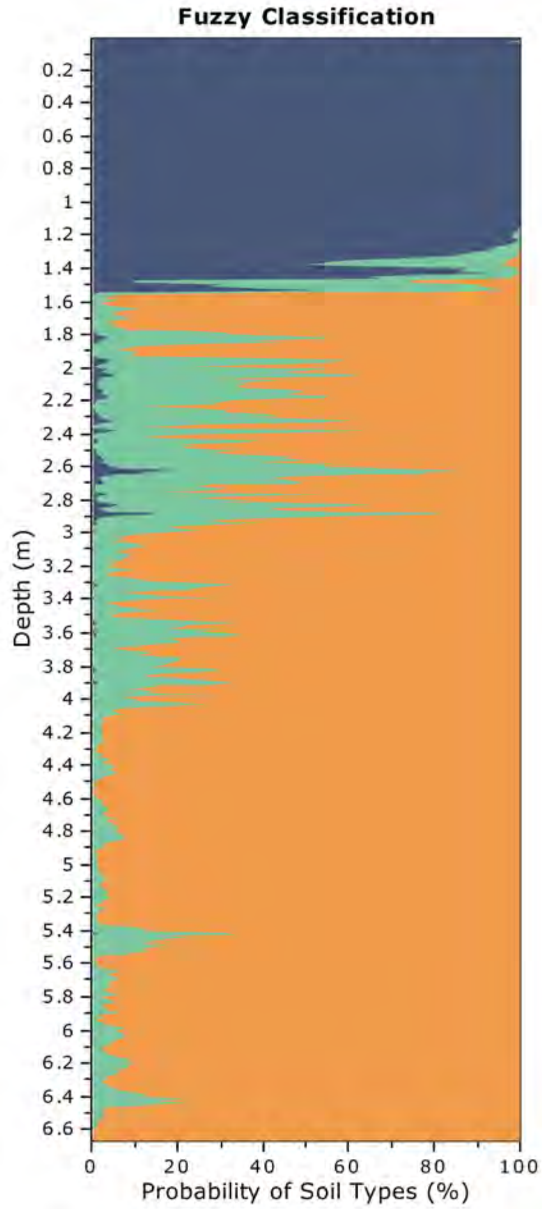


Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT6
Total depth: 6.67 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora





Fuzzy classifiaction legend
- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

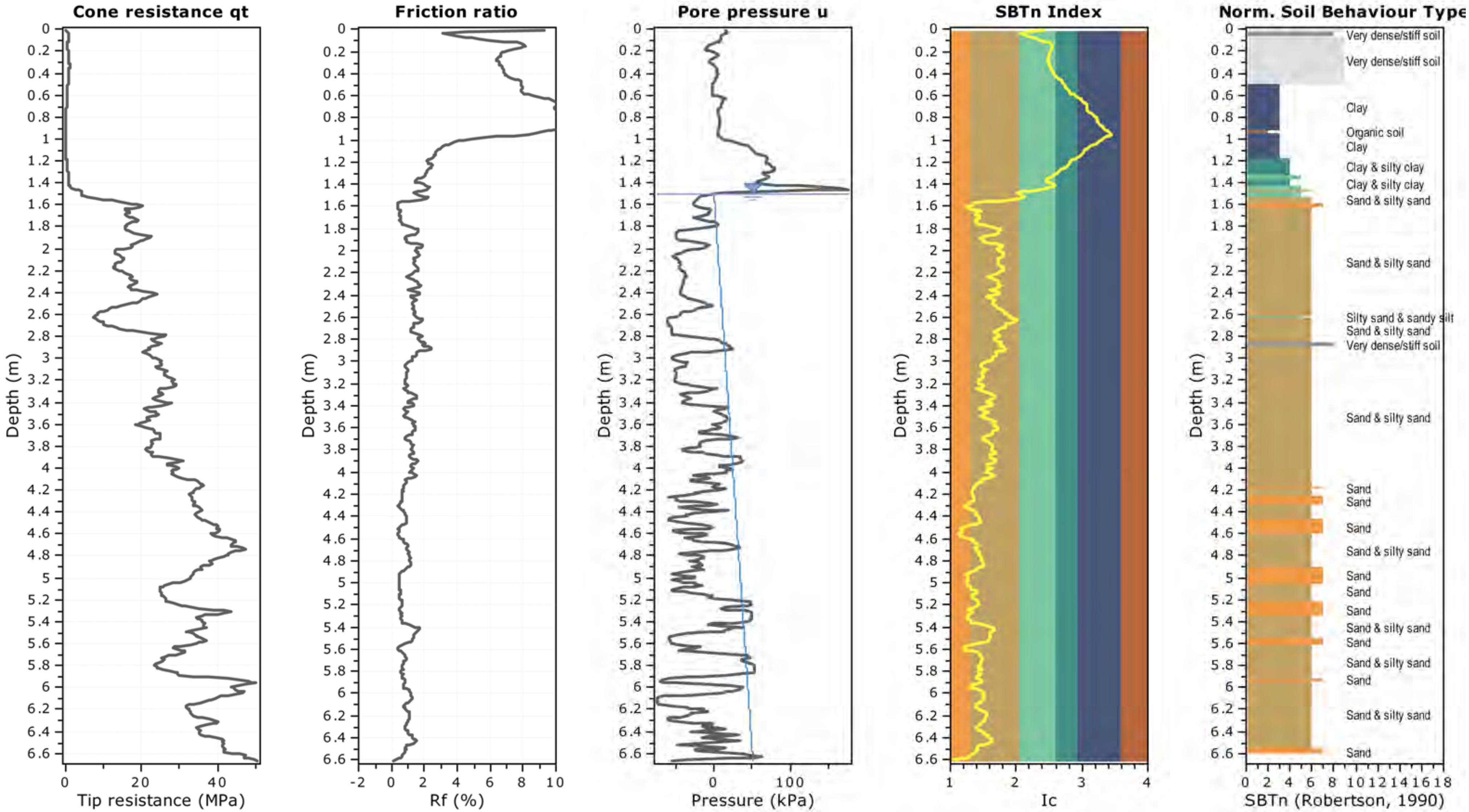
Unit 3a Barry Hogan Place
Riccarton 8041

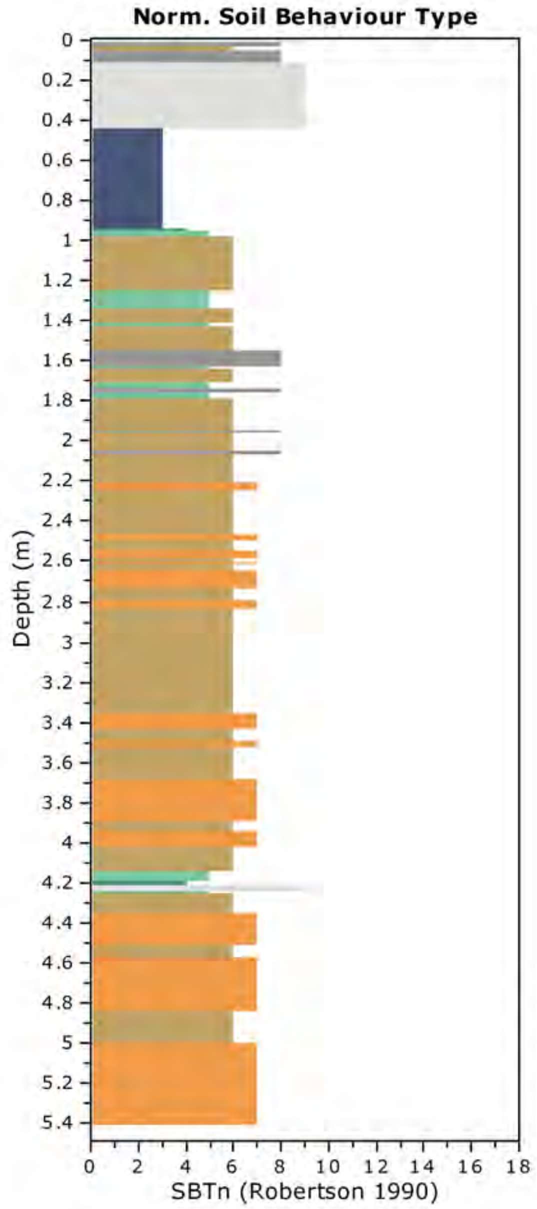
CPT: CPT6

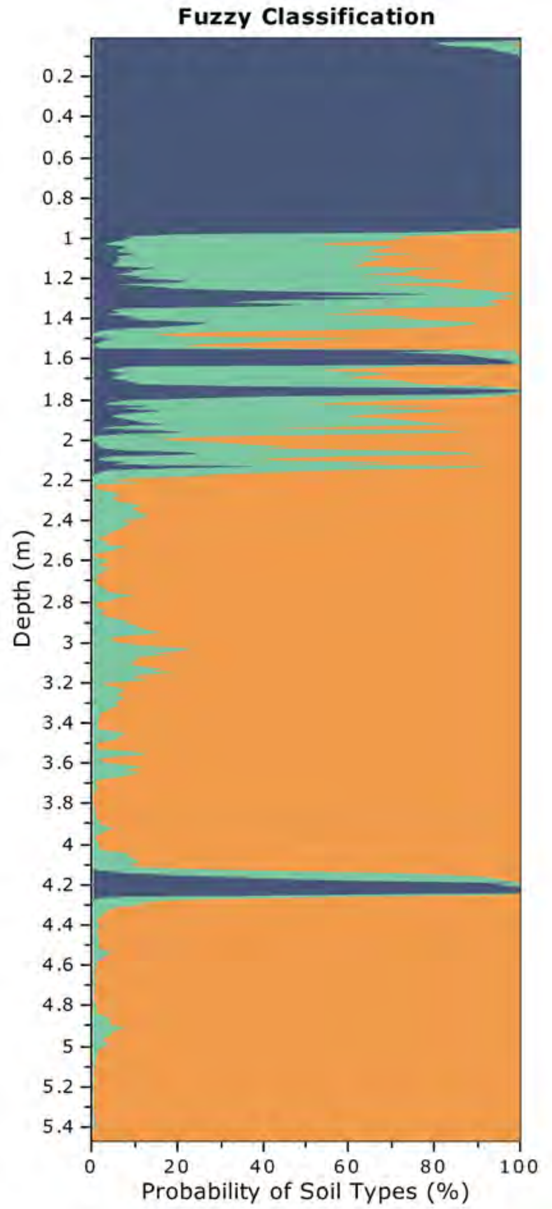
Total depth: 6.67 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark

Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

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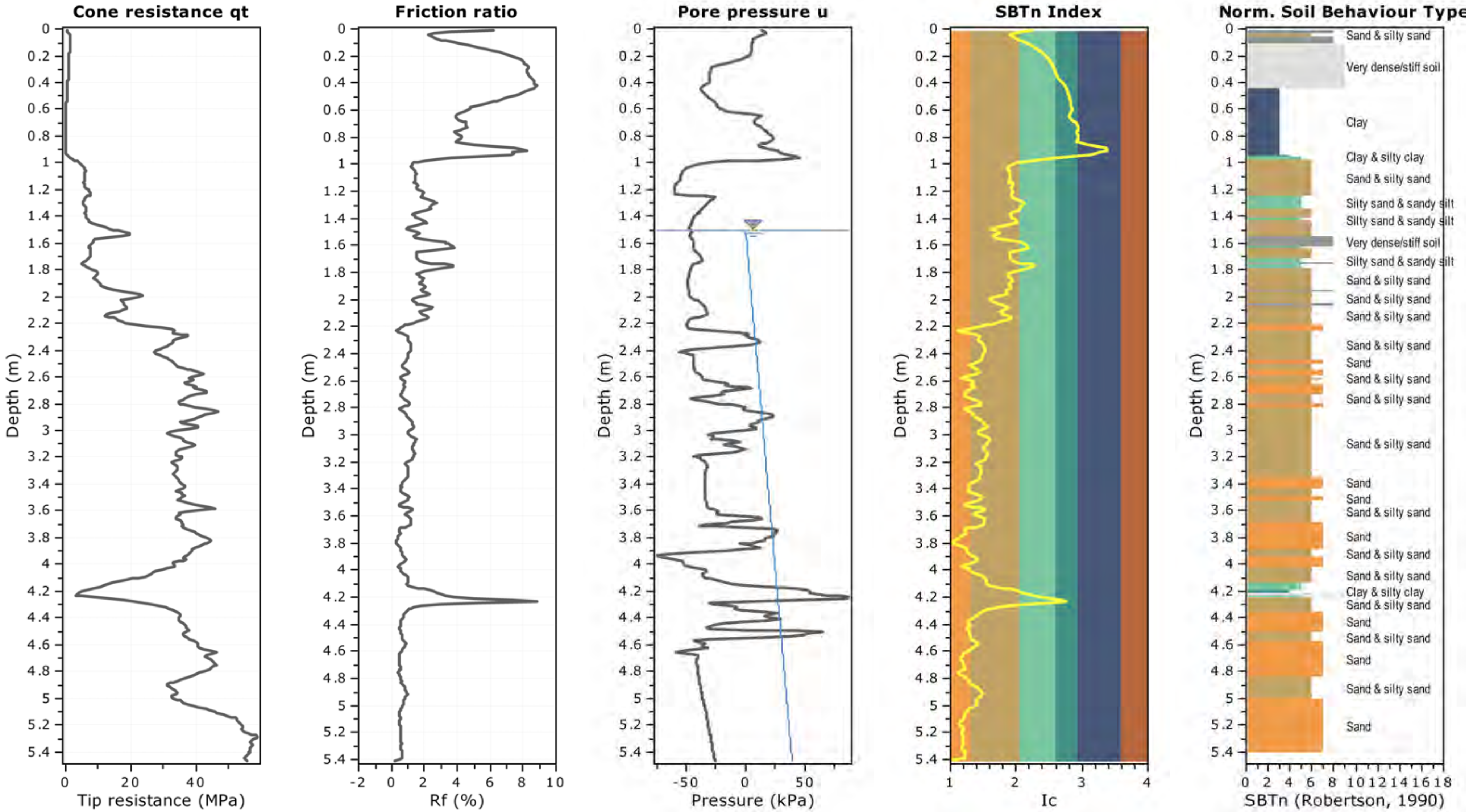
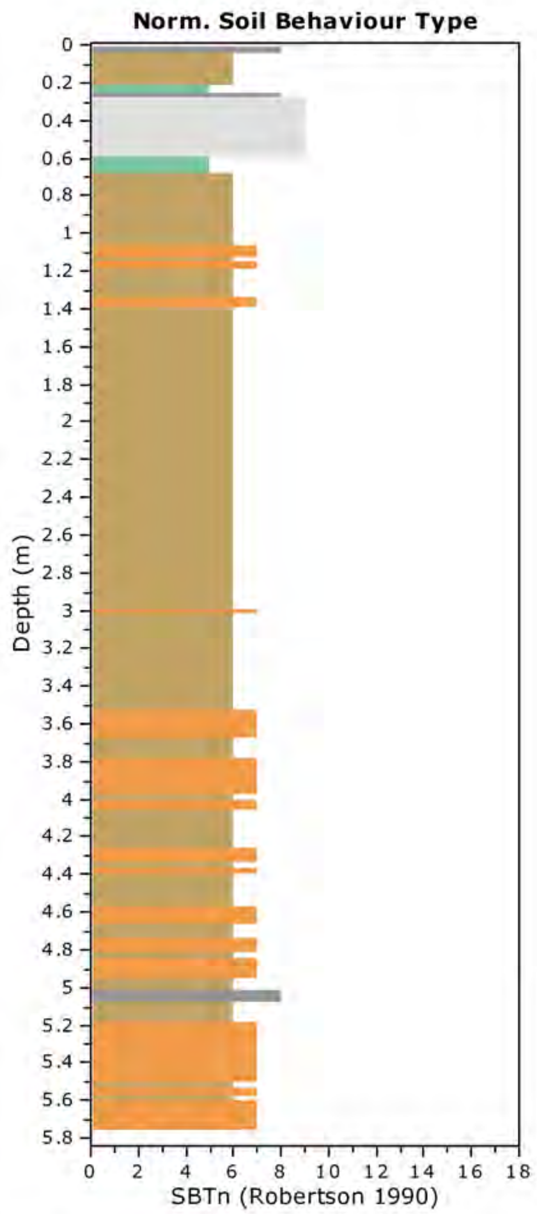
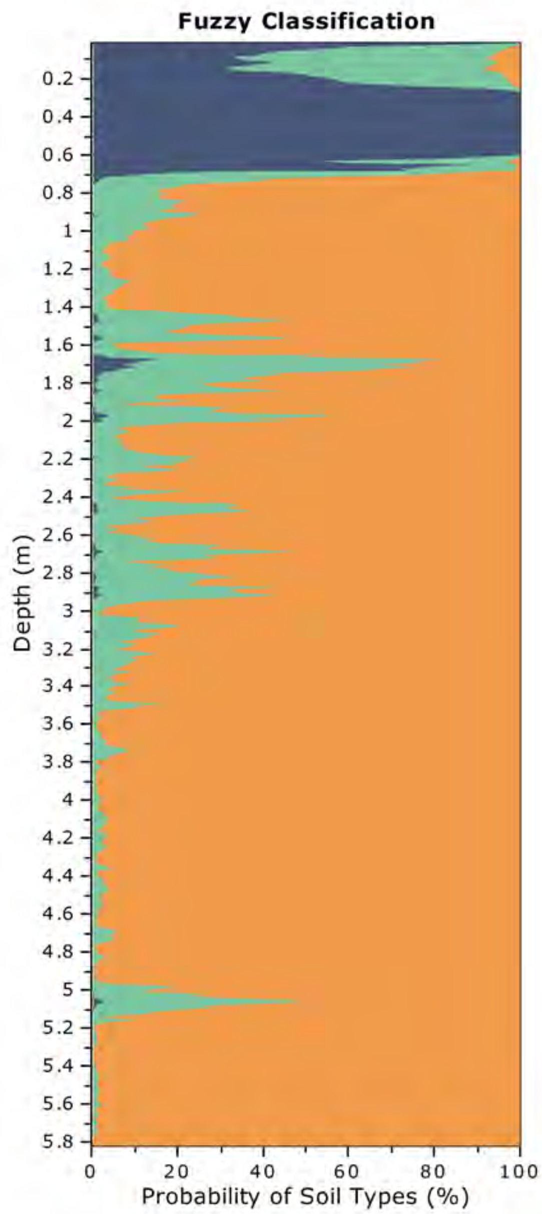
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT7
Total depth: 5.47 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

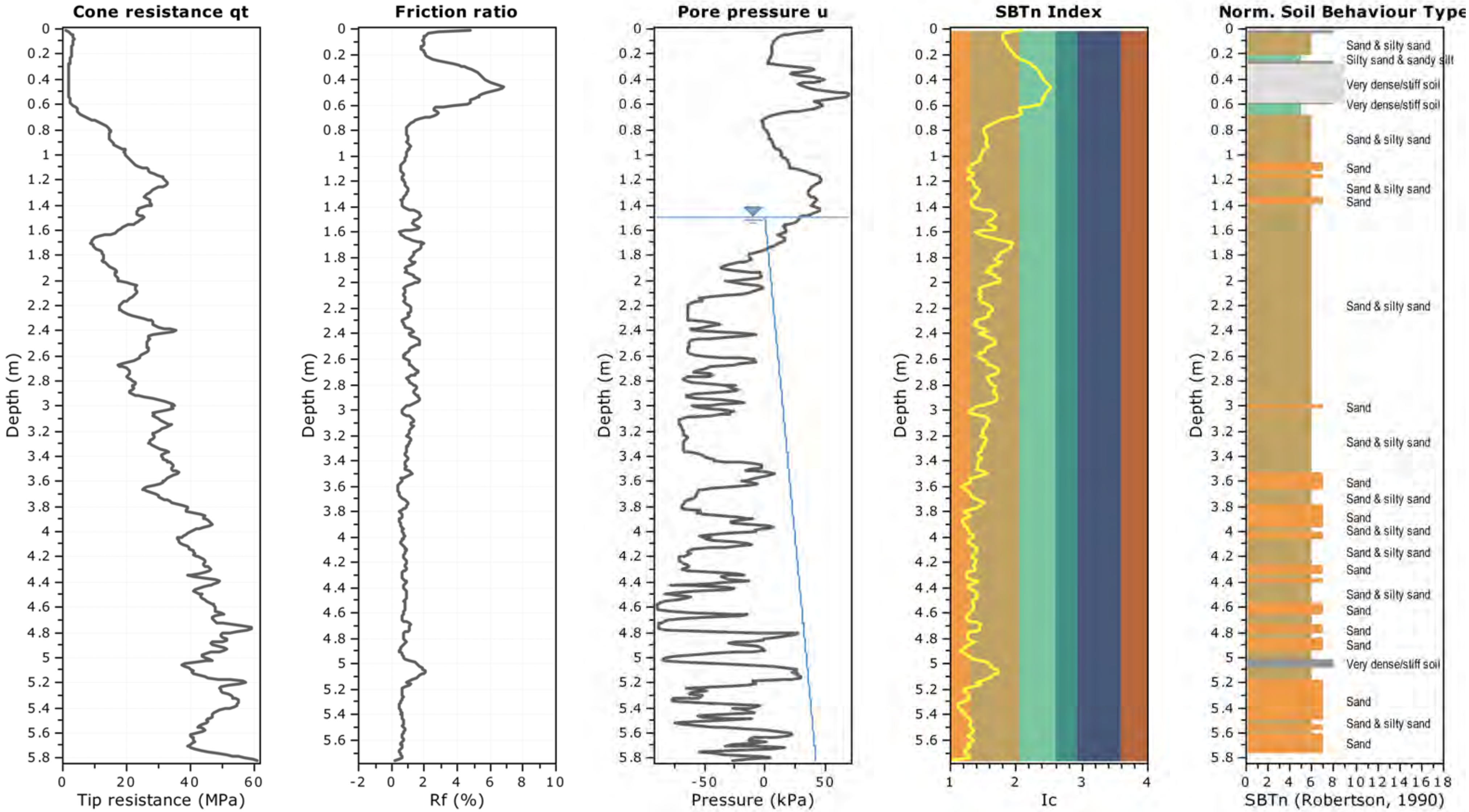
Unit 3a Barry Hogan Place
Riccarton 8041

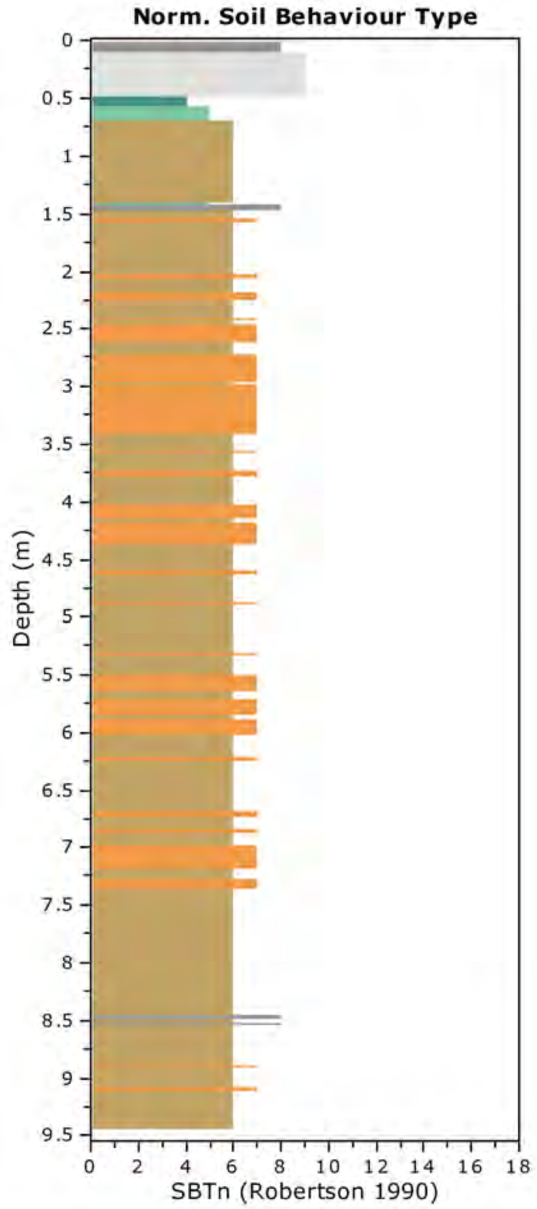
CPT: CPT8

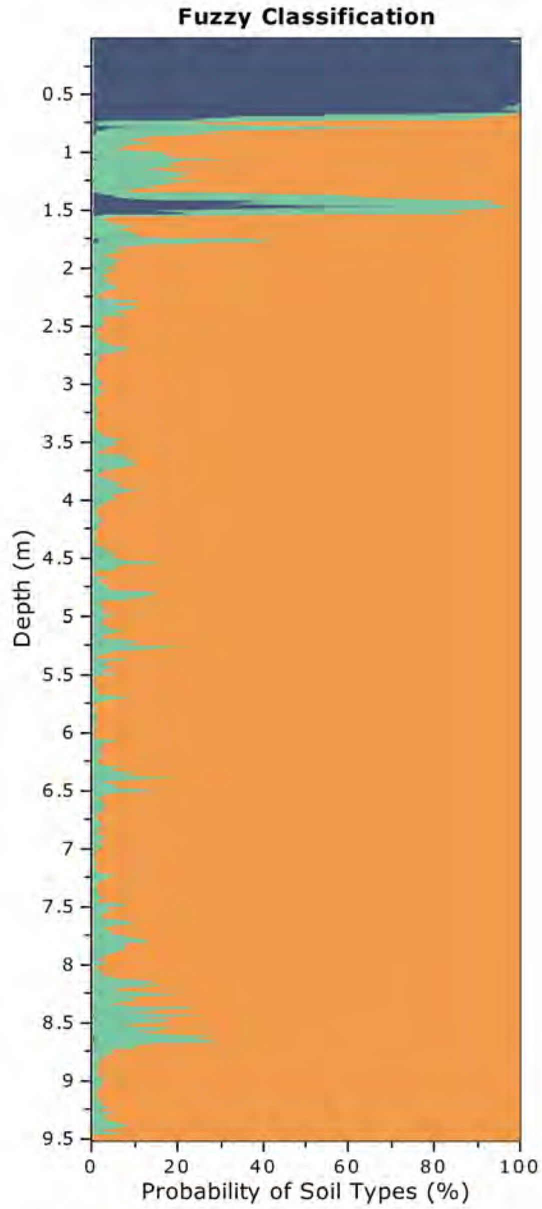
Total depth: 5.82 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark

Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

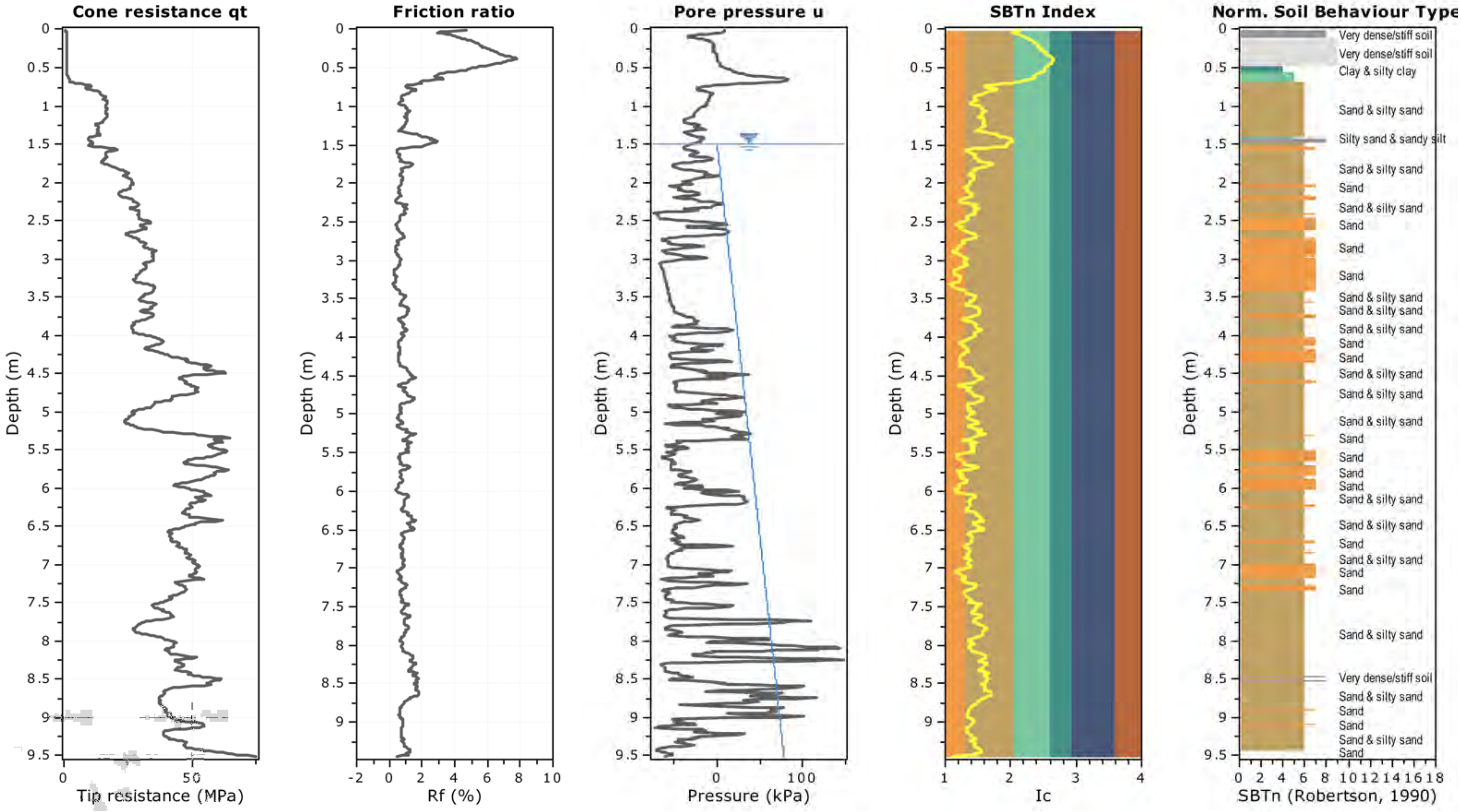
- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT9

Total depth: 9.51 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora



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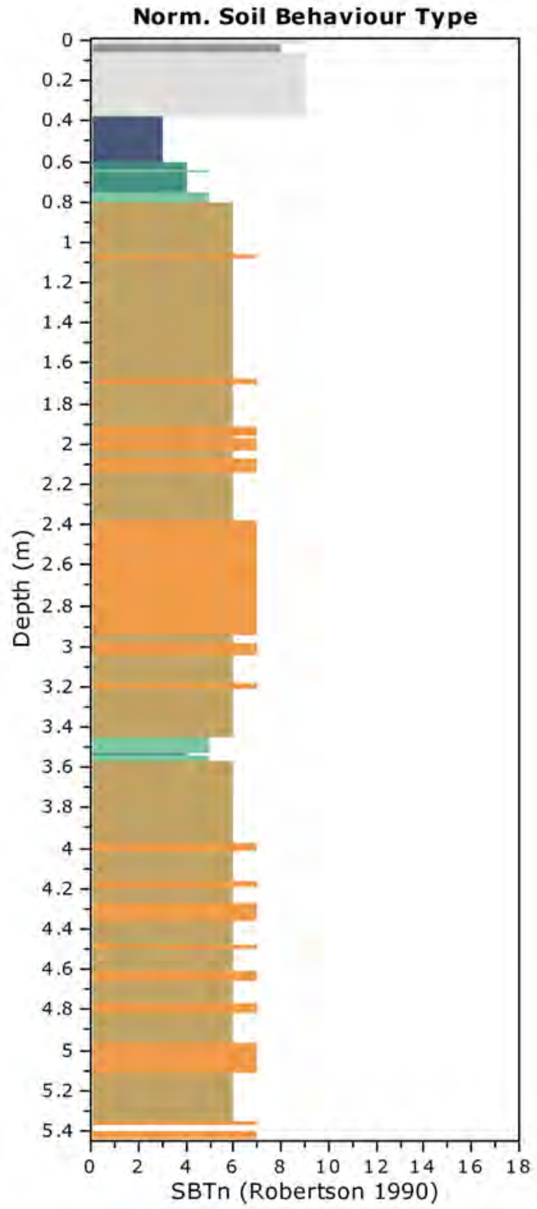
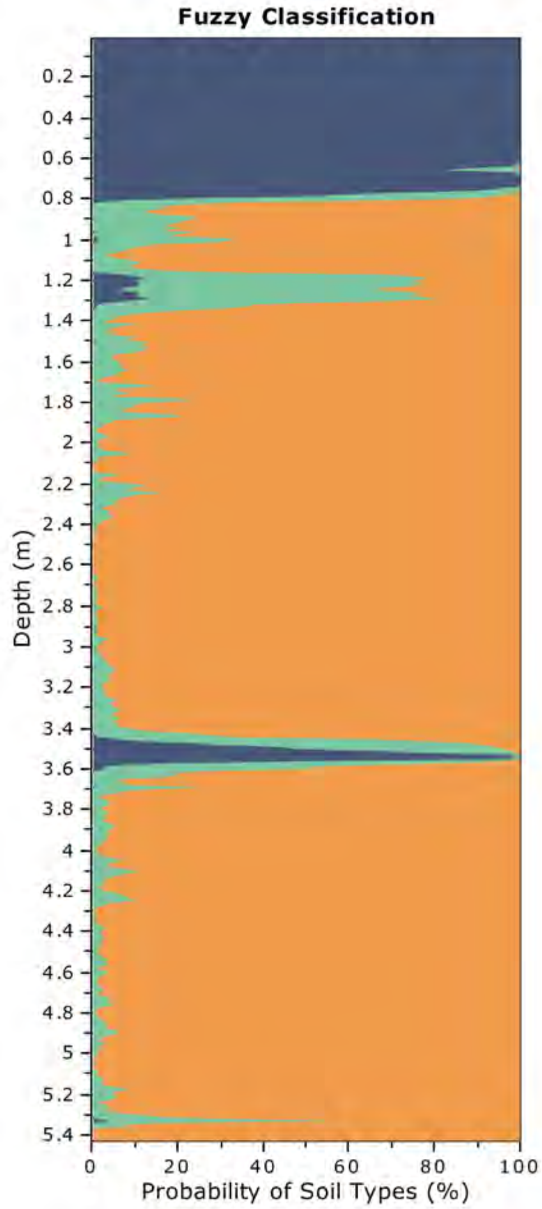
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT10
Total depth: 5.43 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**





Fuzzy classifiaction legend
- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

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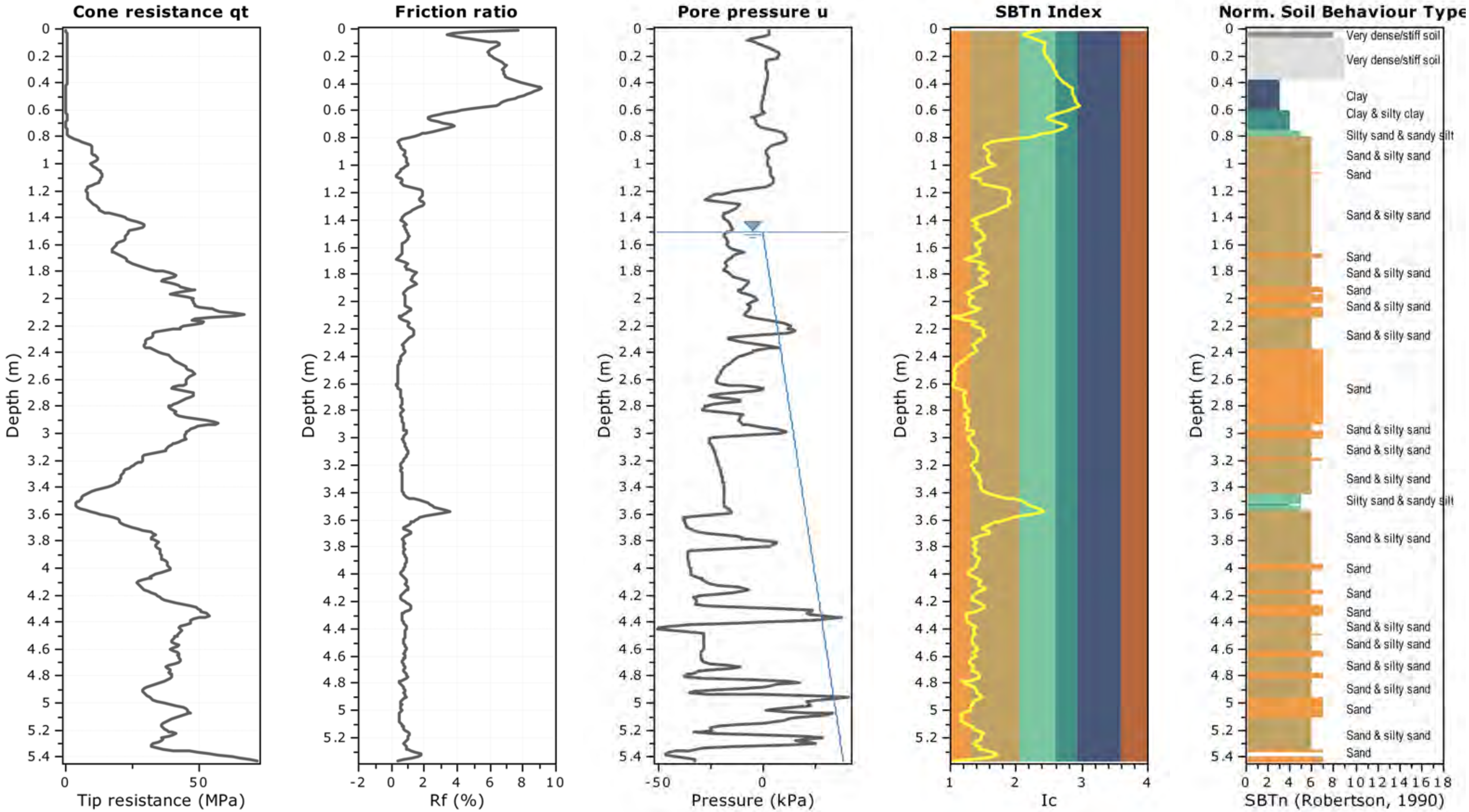
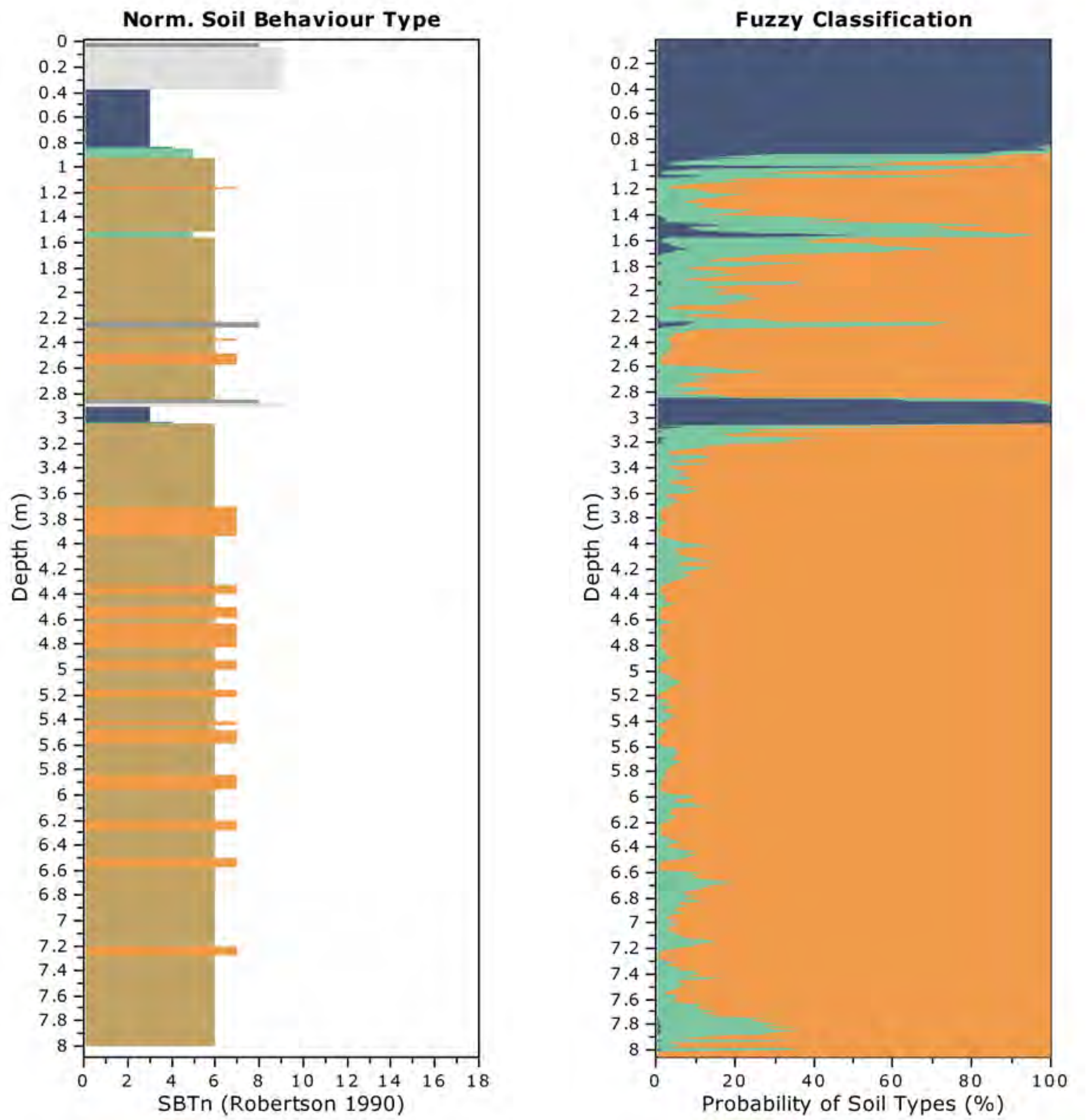
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT10
Total depth: 5.43 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora





Fuzzy classifiaction legend
Highly probable clayey soil
Highly probable mixture soil
Highly probable sandy soil

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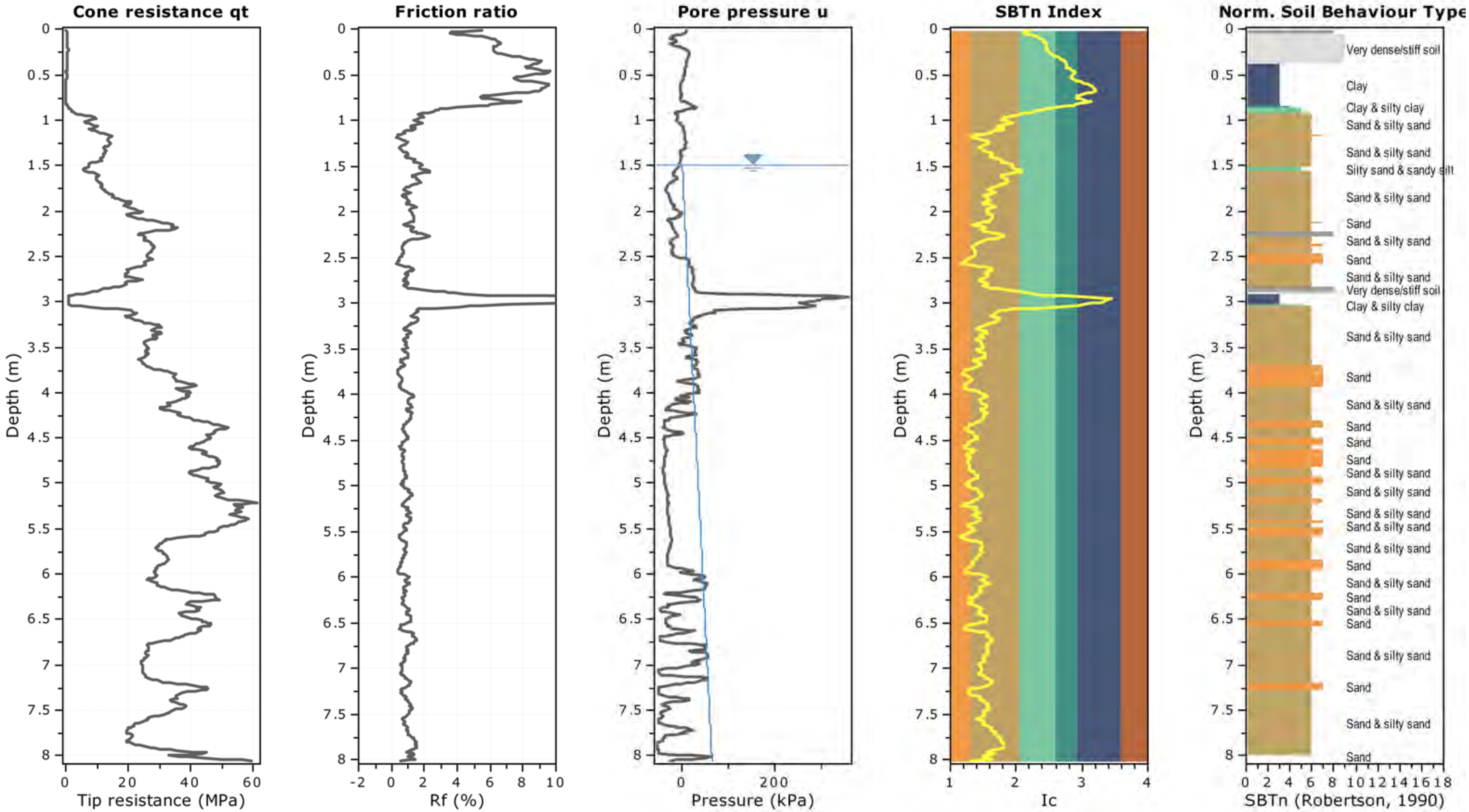
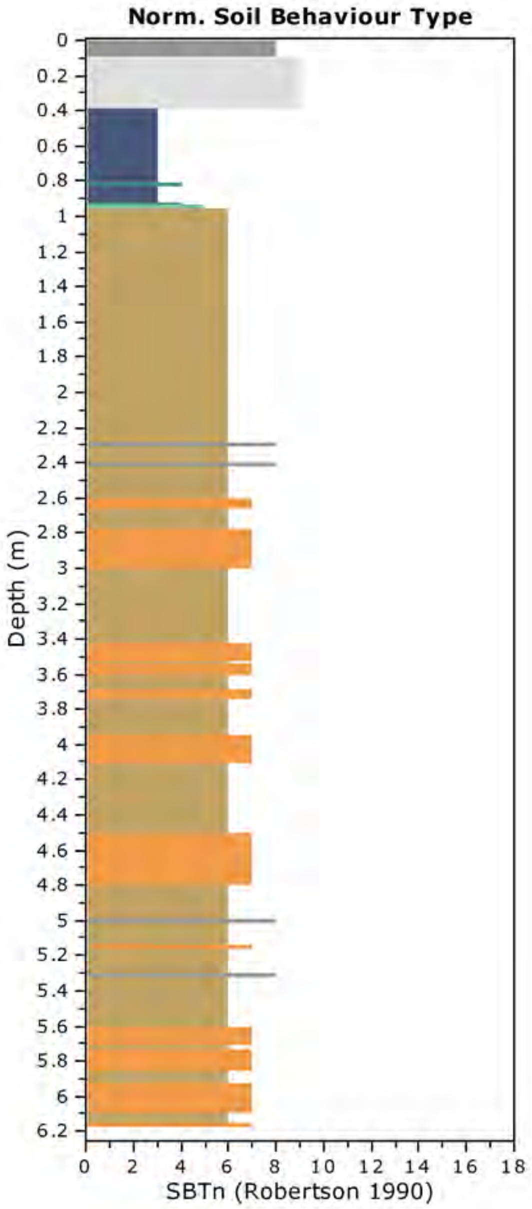
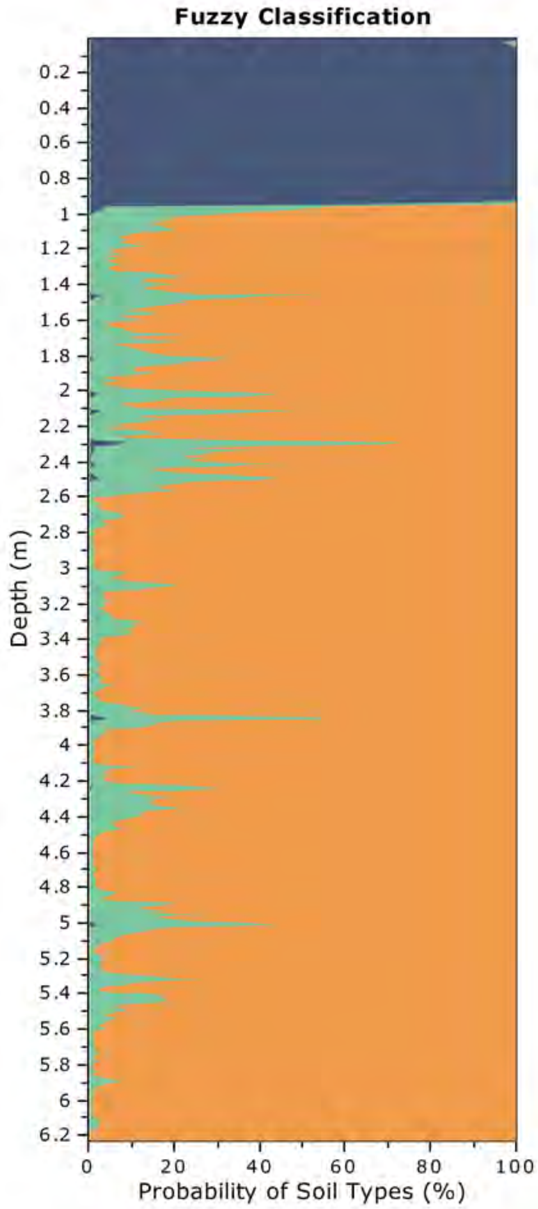
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT11
Total depth: 8.06 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

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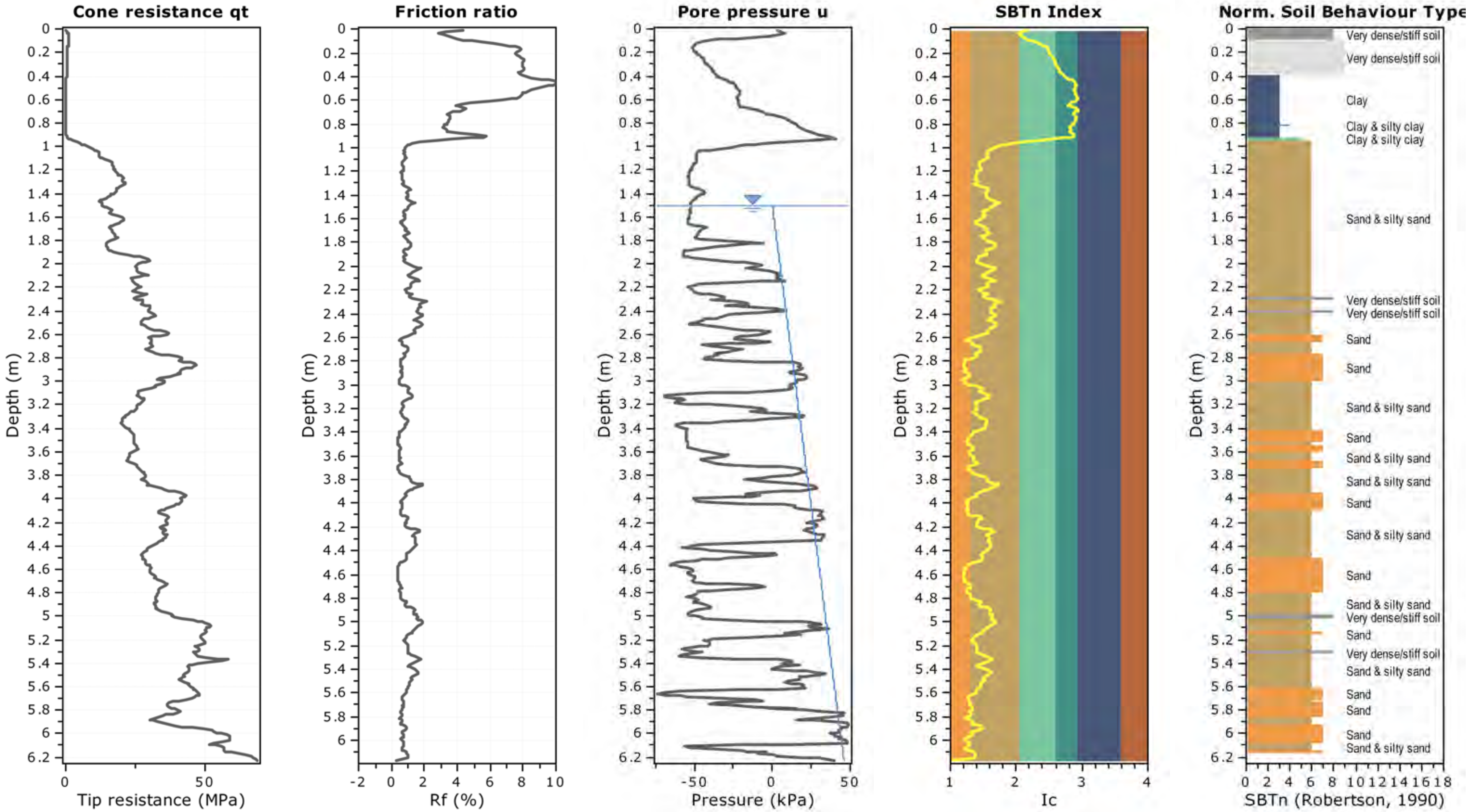
Unit 3a Barry Hogan Place
Riccarton 8041

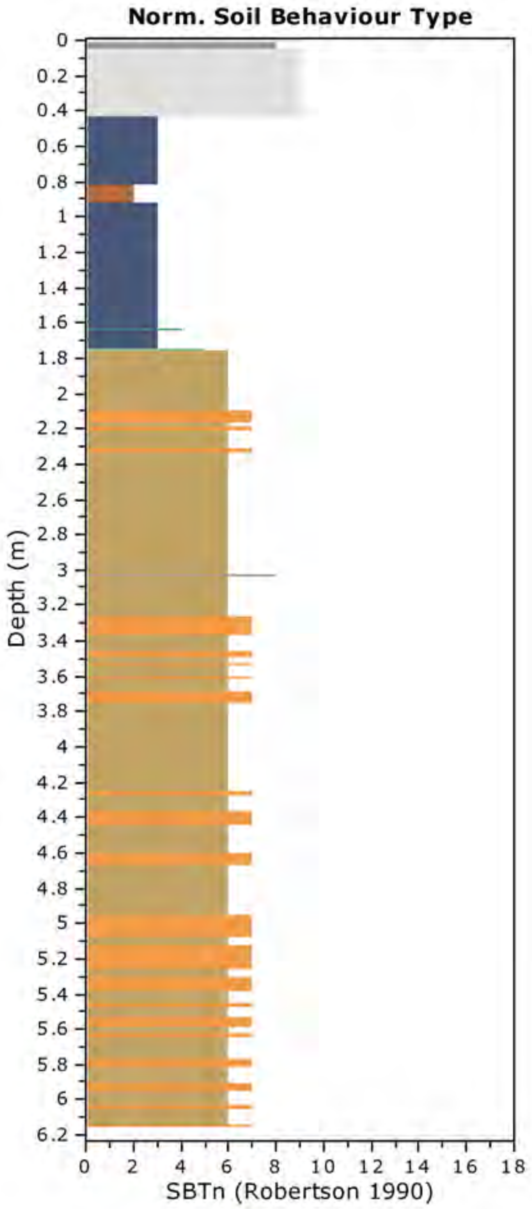
CPT: CPT12

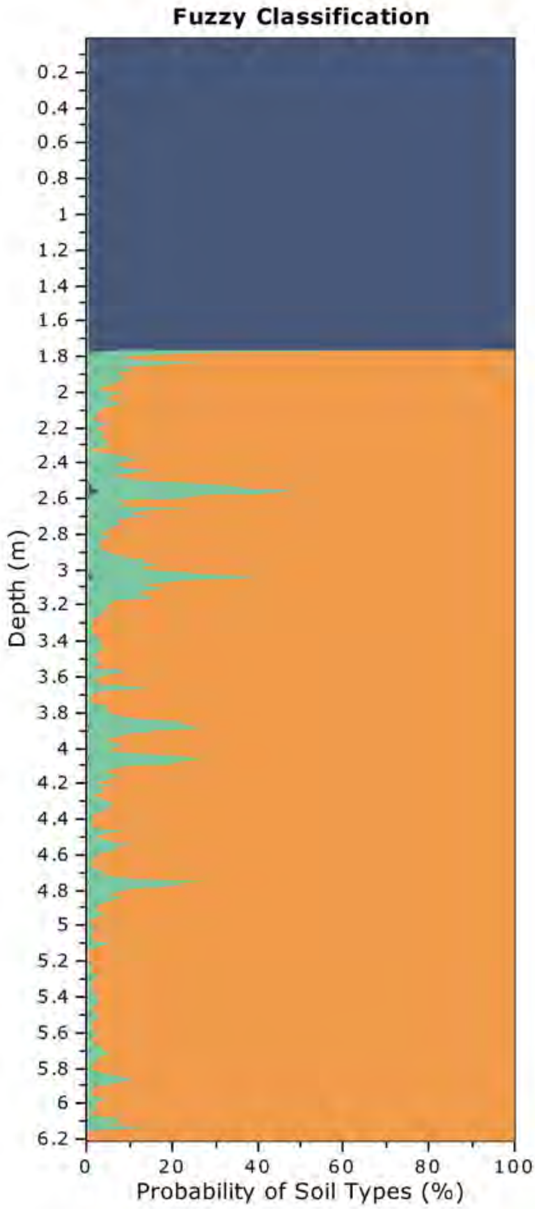
Total depth: 6.23 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark

Location: Spark Dairy Farm, Boys Road, Rangiora







Fuzzy classifiaction legend

- Highly probable clayey soil
- Highly probable mixture soil
- Highly probable sandy soil

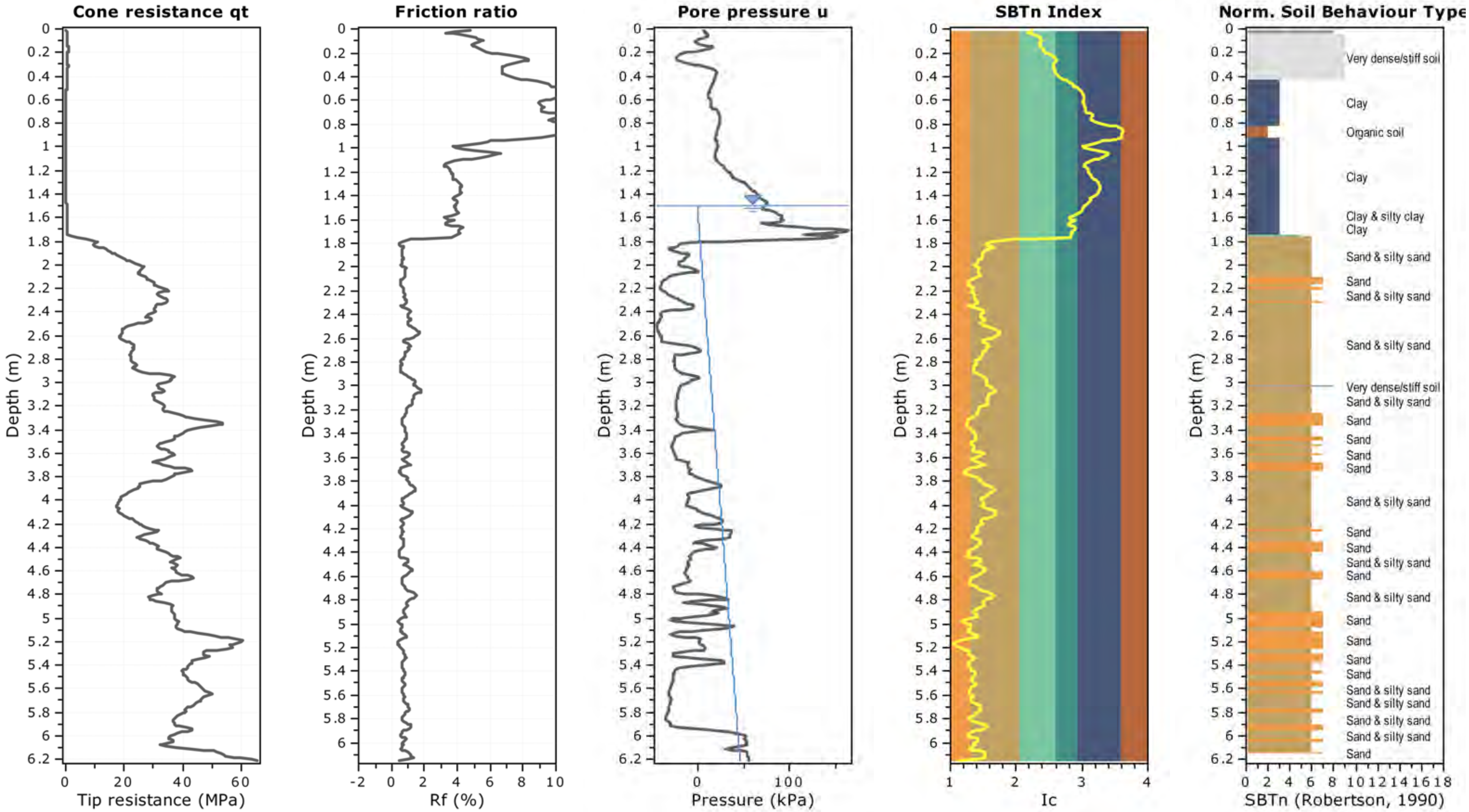
Unit 3a Barry Hogan Place
Riccarton 8041

CPT: CPT13

Total depth: 6.21 m, Date: 30/11/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project: Richard and Geoff Spark

Location: Spark Dairy Farm, Boys Road, Rangiora



Appendix B

CLiq Analyses Results

Serviceability Limit State (SLS) Design Earthquake Event

(i.e. the larger value determined for the SLS and ILS design earthquake events)

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Consulting Engineers and Surveyors
https://fraserthomas.co.nz/

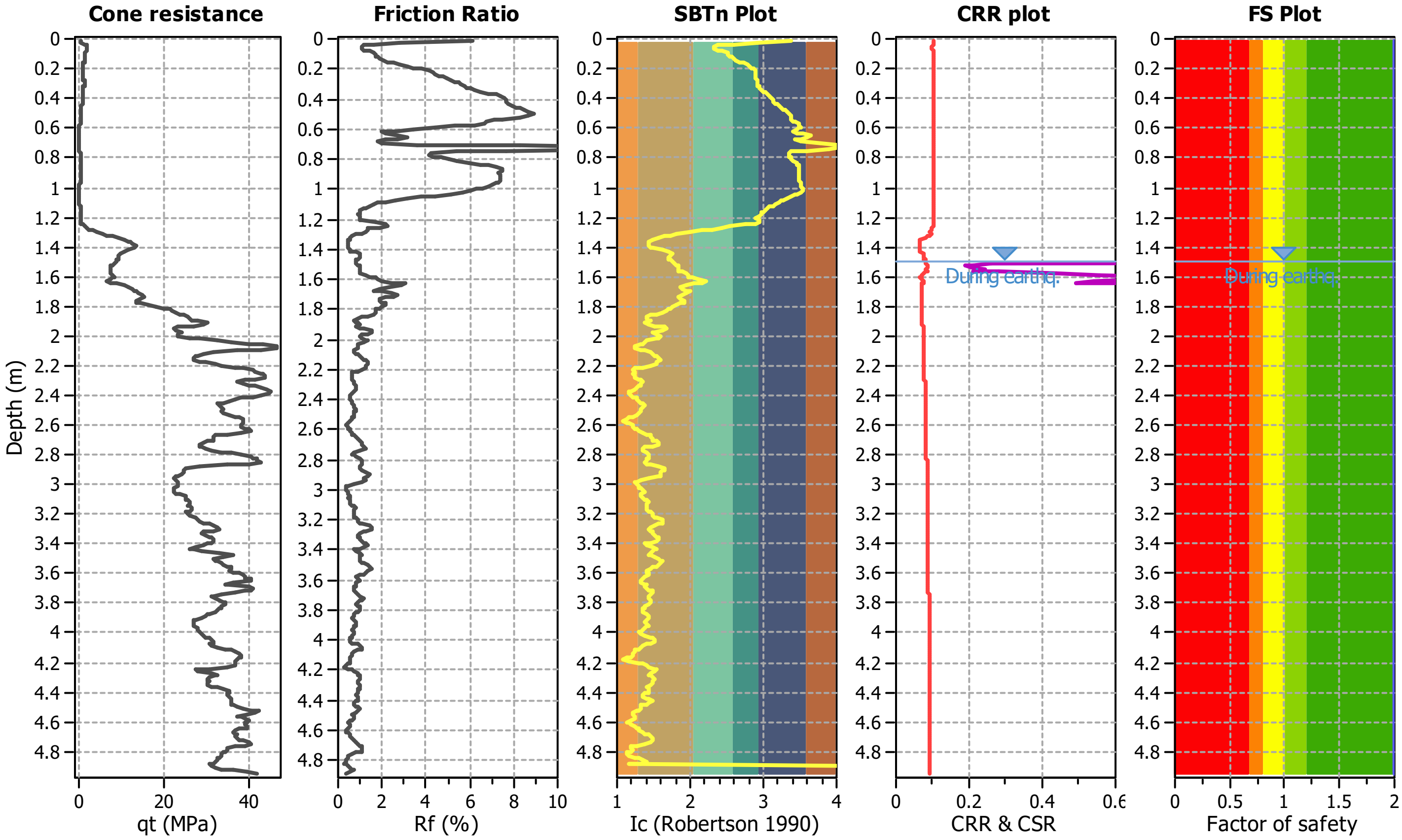
LIQUEFACTION ANALYSIS REPORT

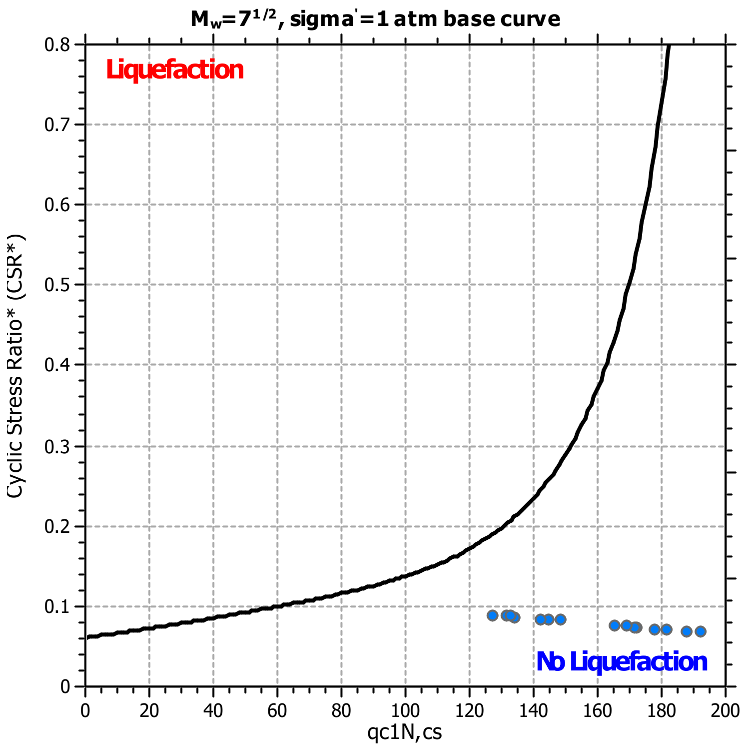
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

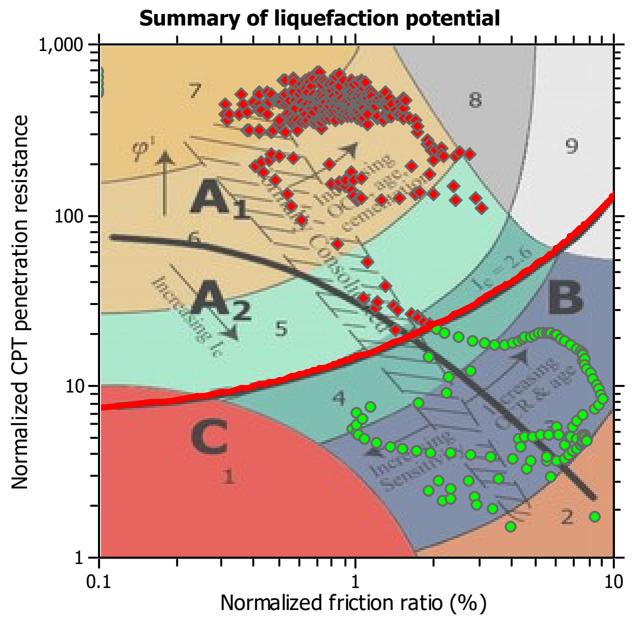
CPT file : CPT1

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

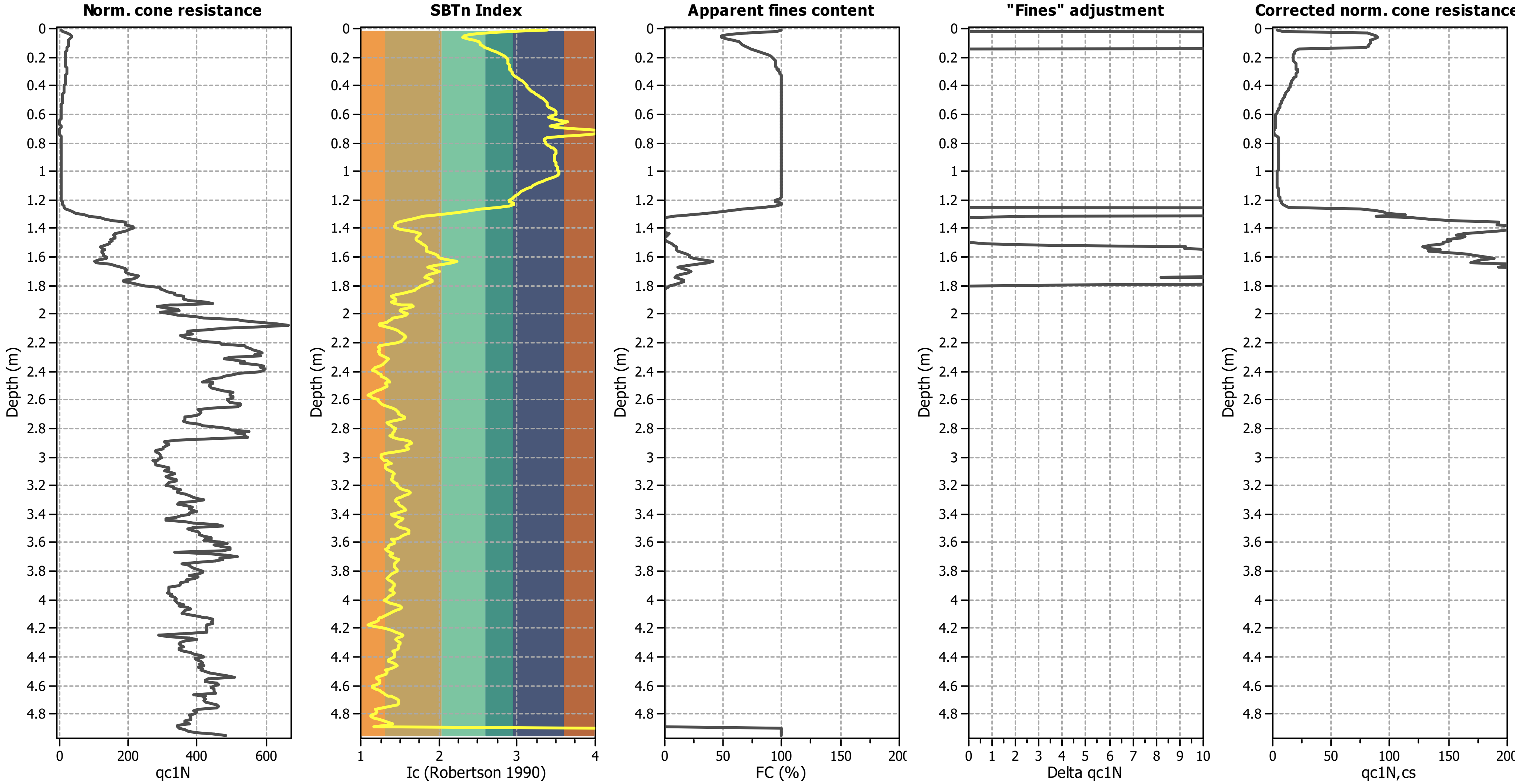






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

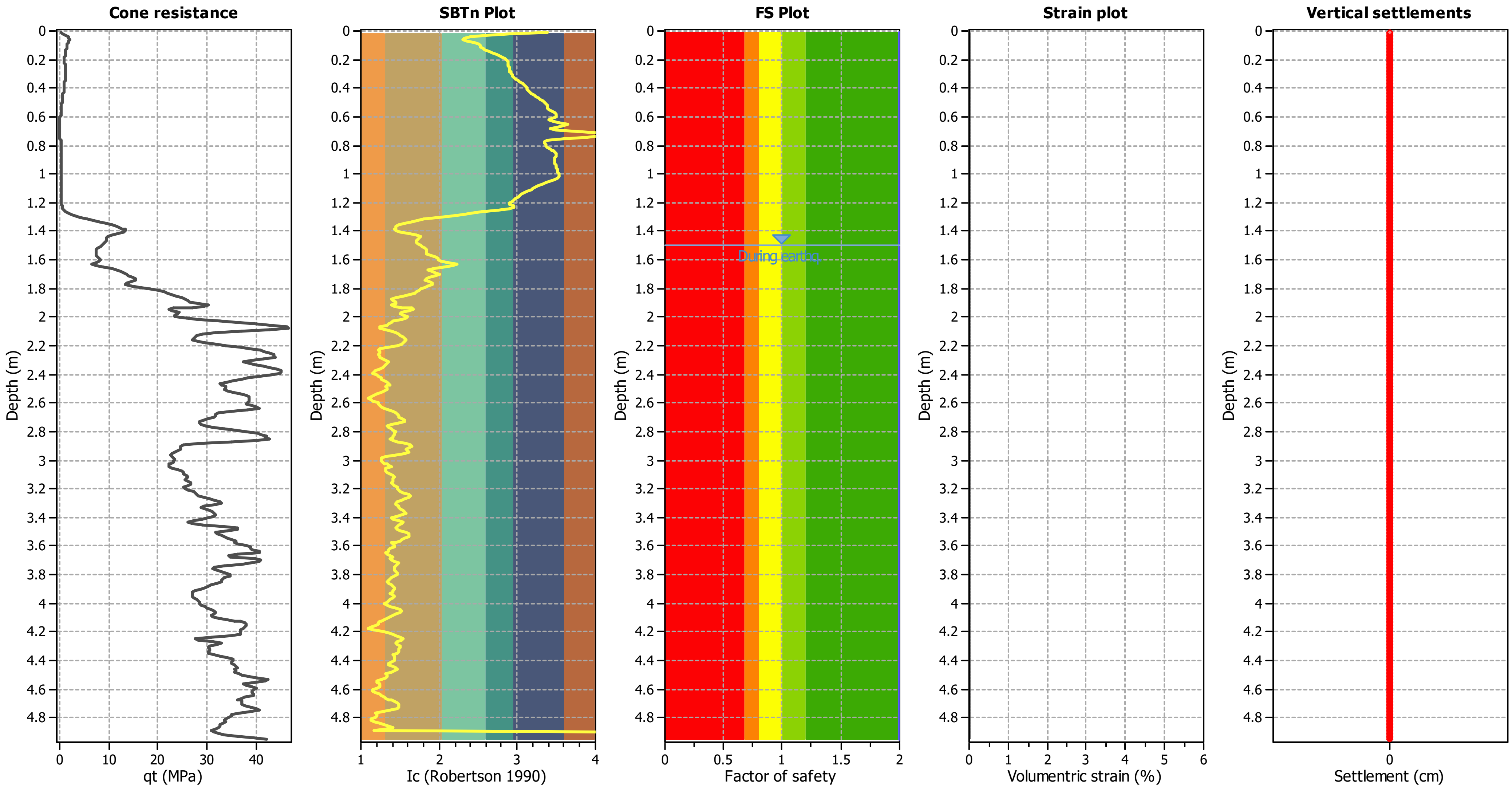
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

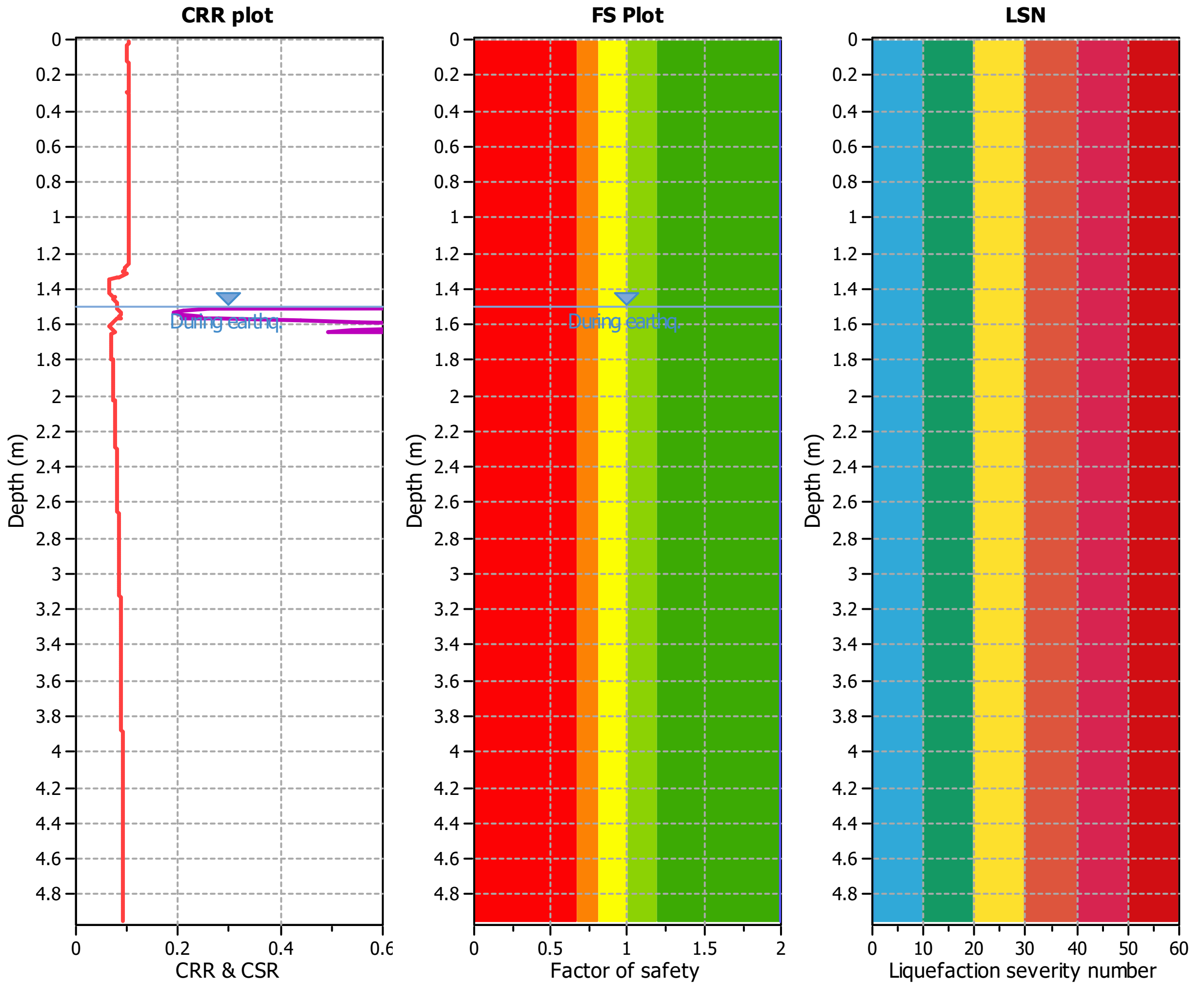


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT1
Total depth: 4.95 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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Fraser Thomas
Consulting Engineers and Surveyors
https://fraserthomas.co.nz/

LIQUEFACTION ANALYSIS REPORT

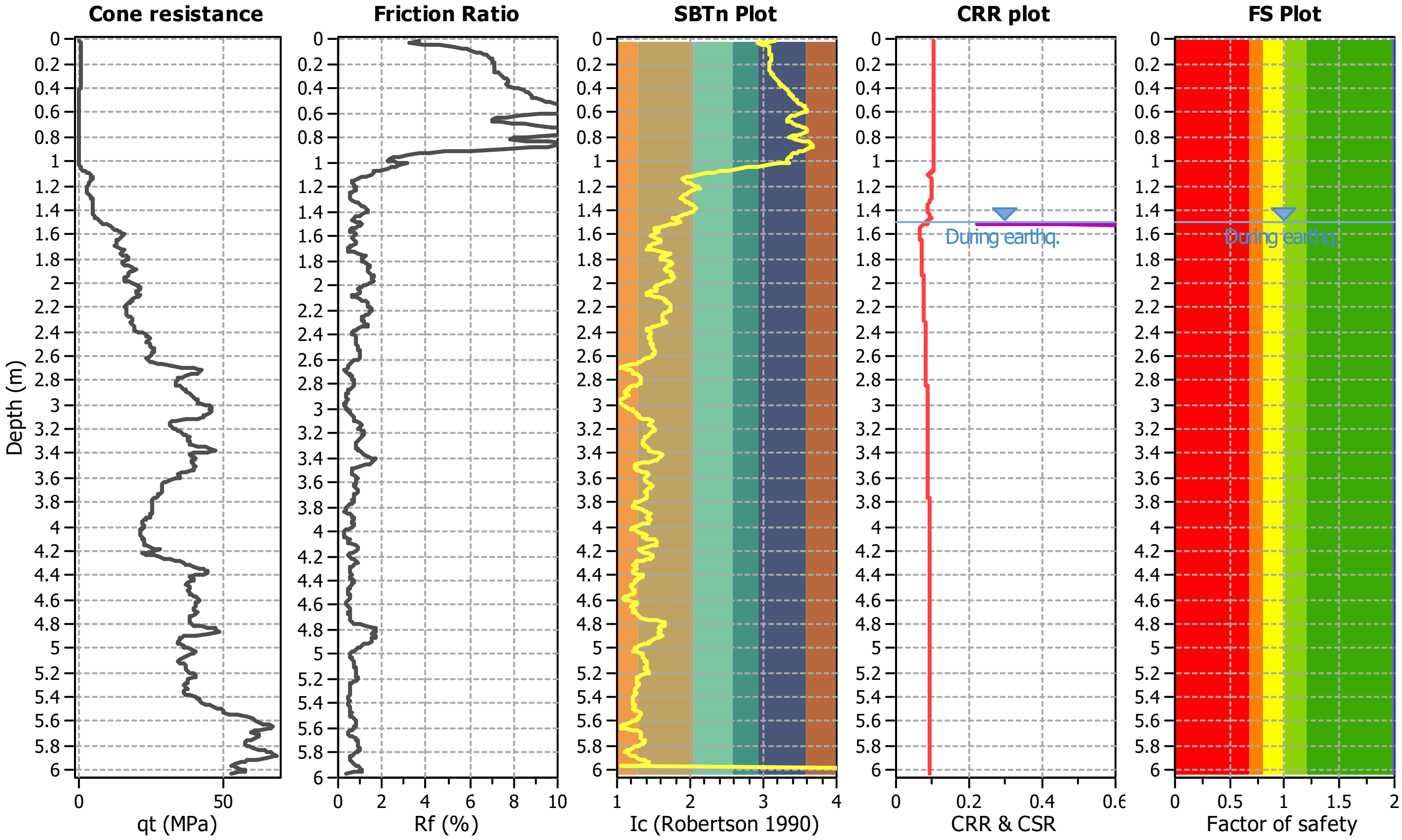
Project title : Richard and Geoff Spark

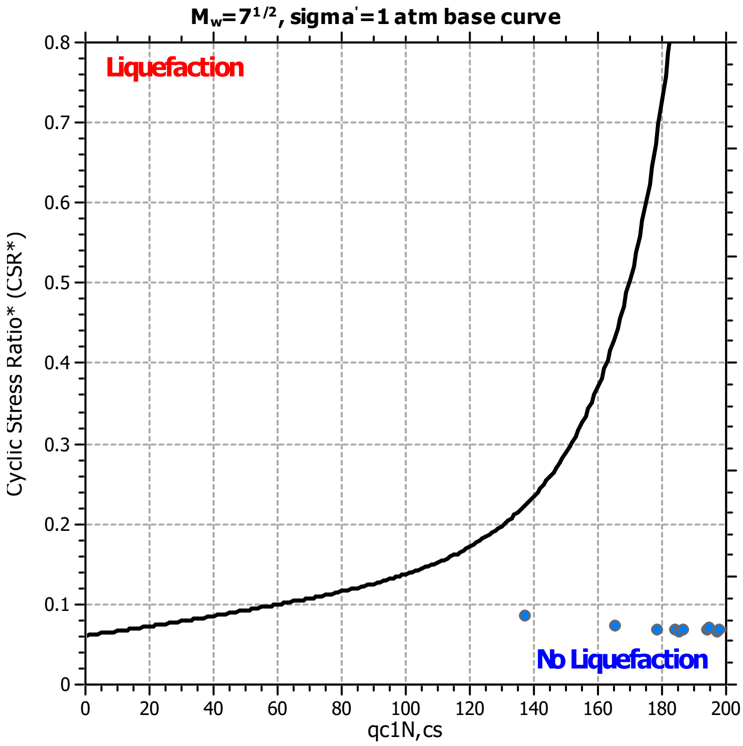
Location : Spark Dairy Farm, Boys Road, Rangiora

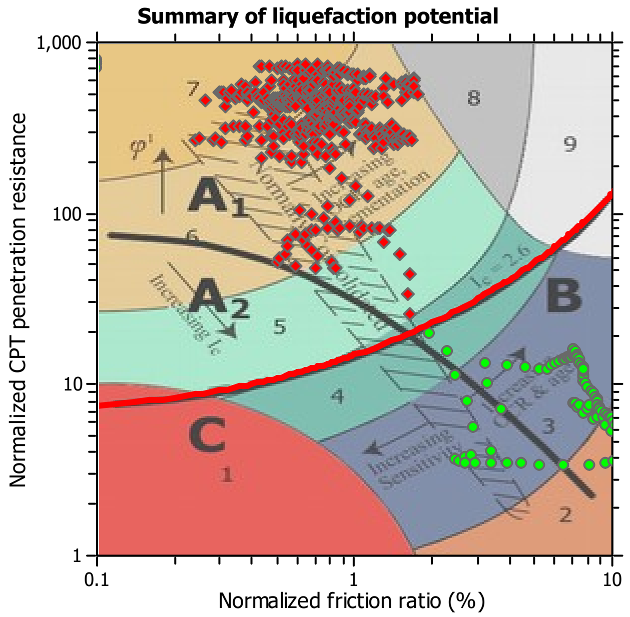
CPT file : CPT2

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

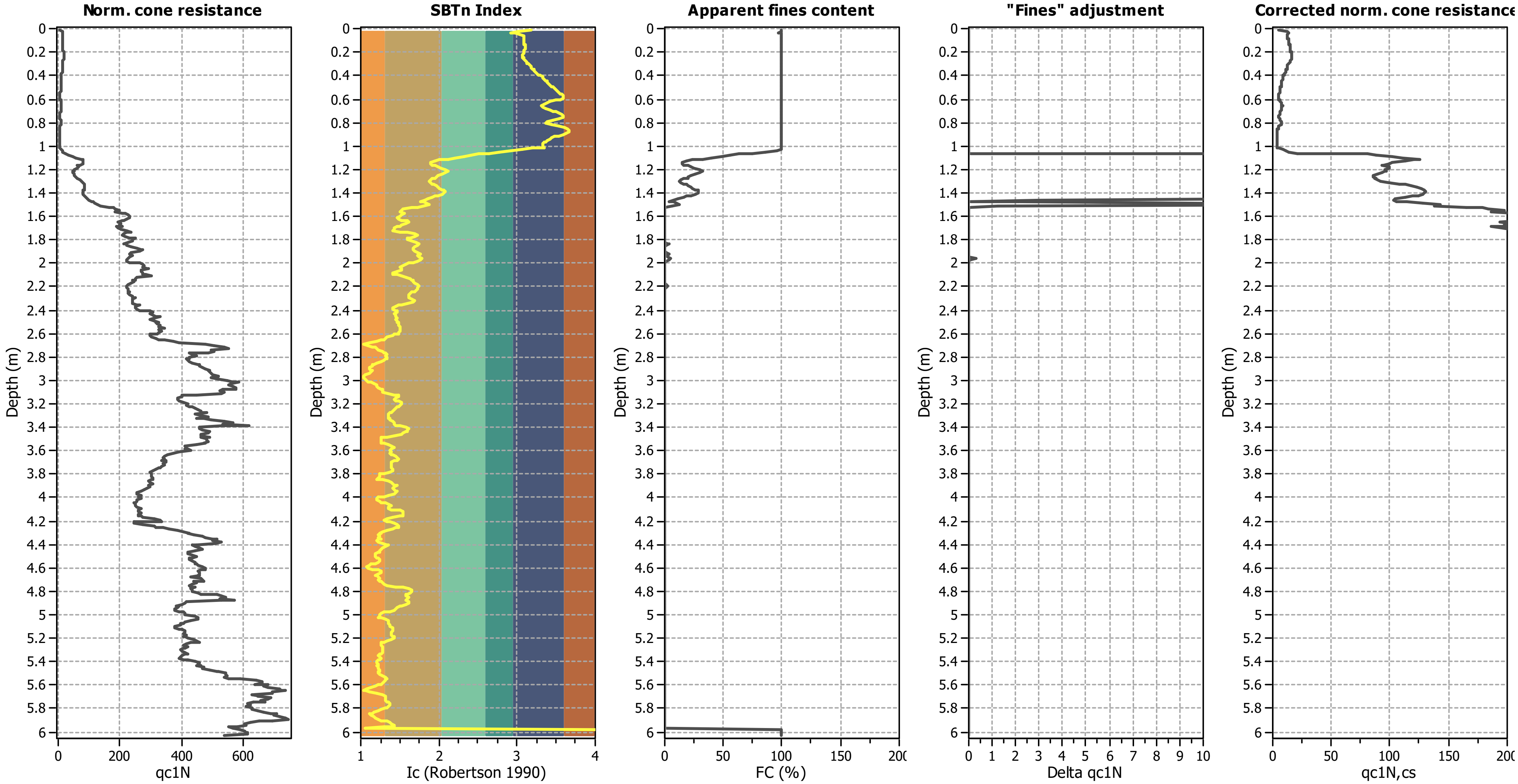






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

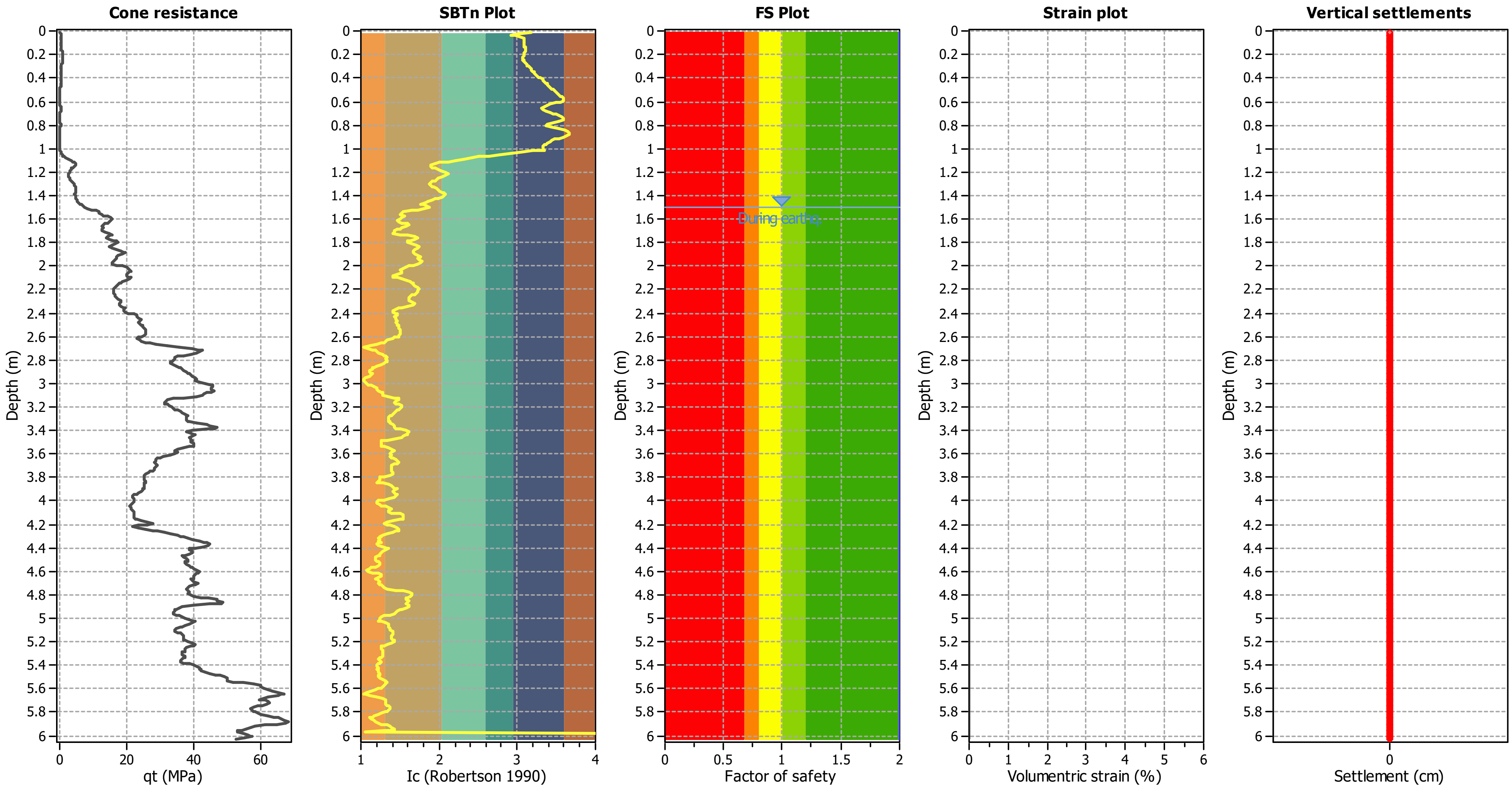
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

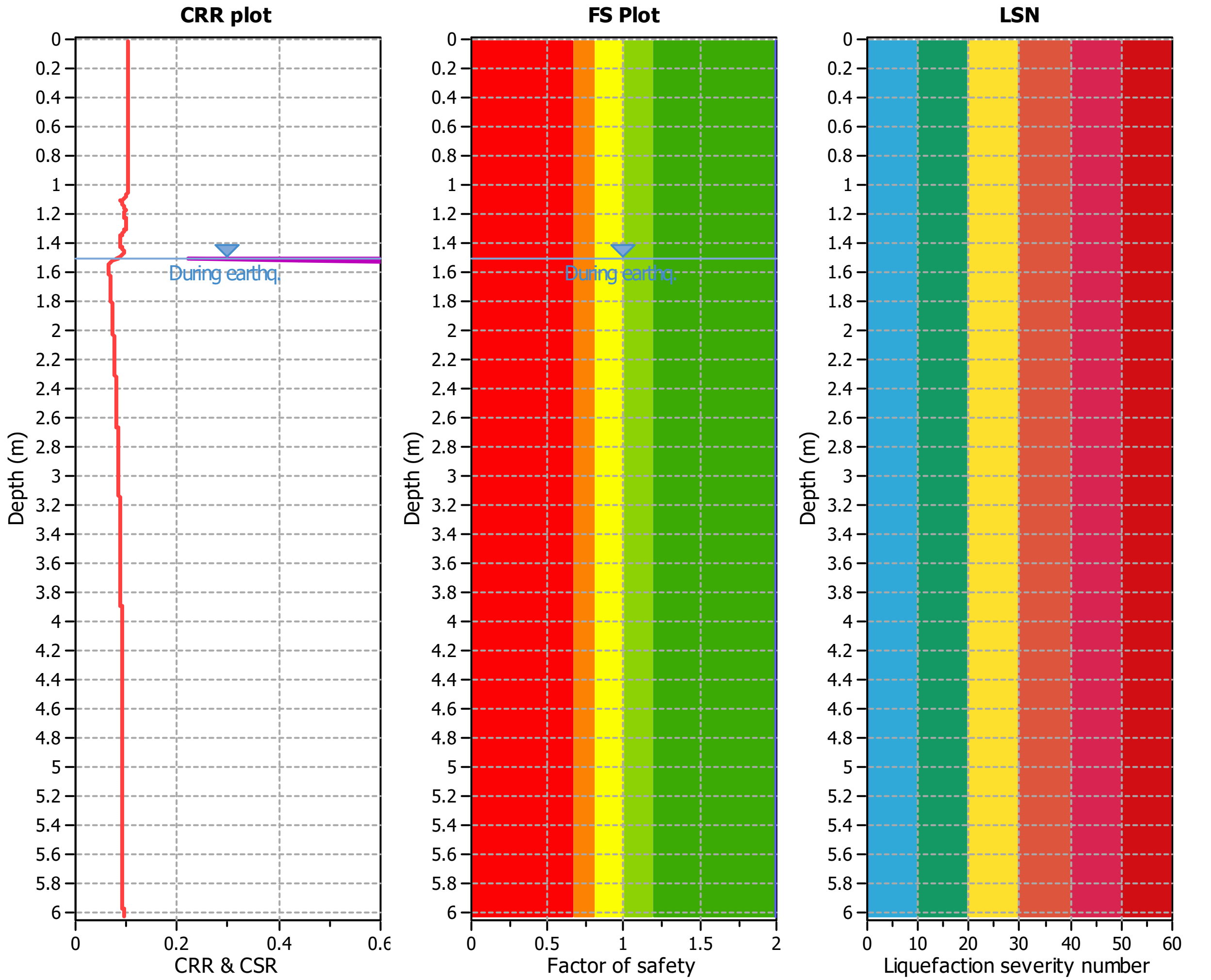


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT2
Total depth: 6.03 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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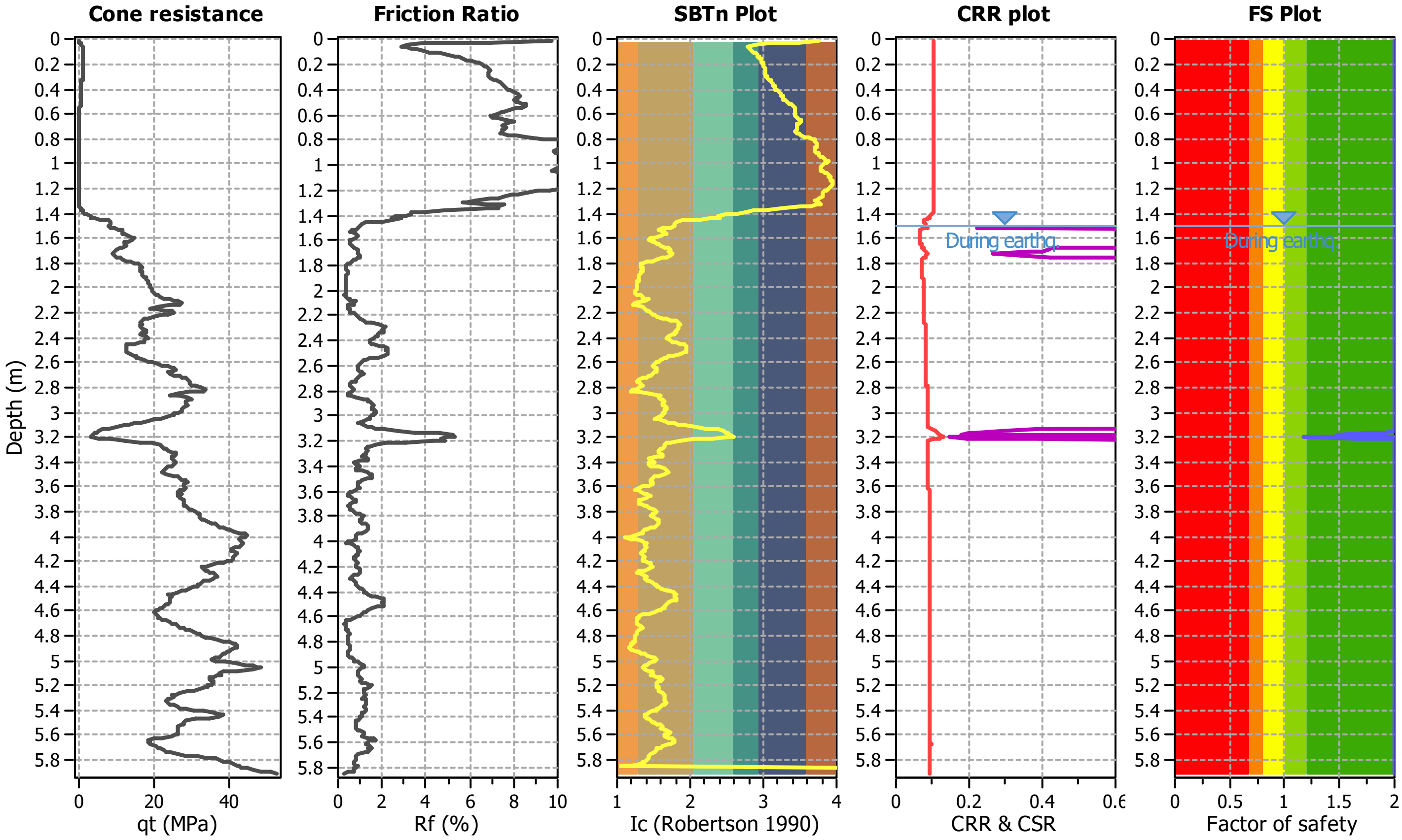
LIQUEFACTION ANALYSIS REPORT

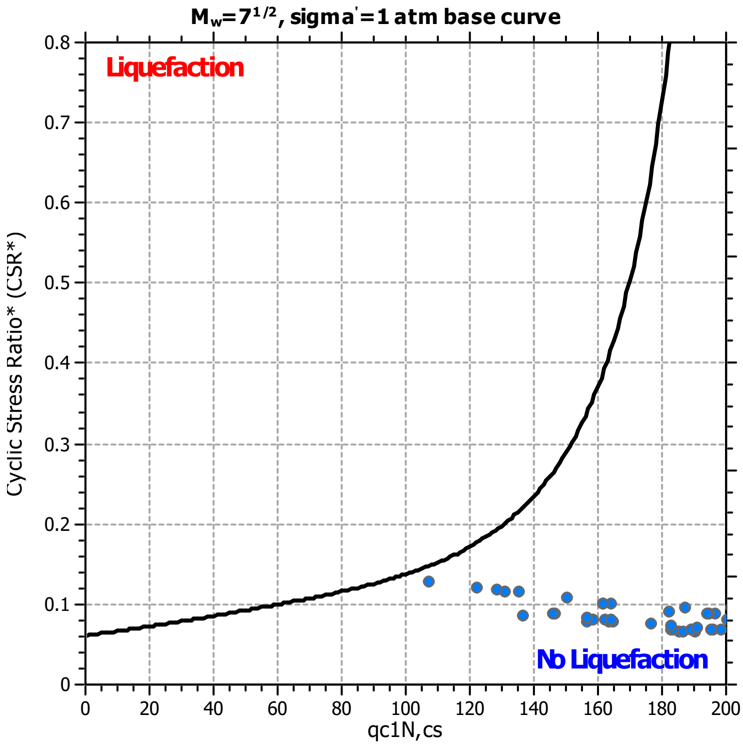
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

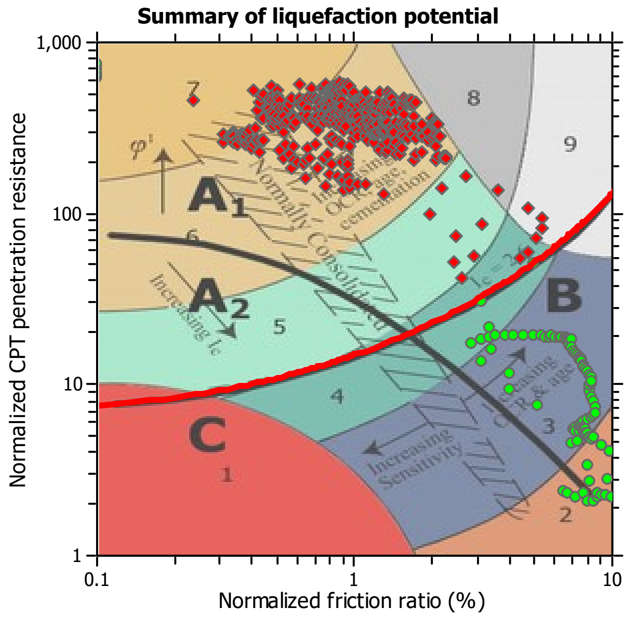
CPT file : CPT3

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

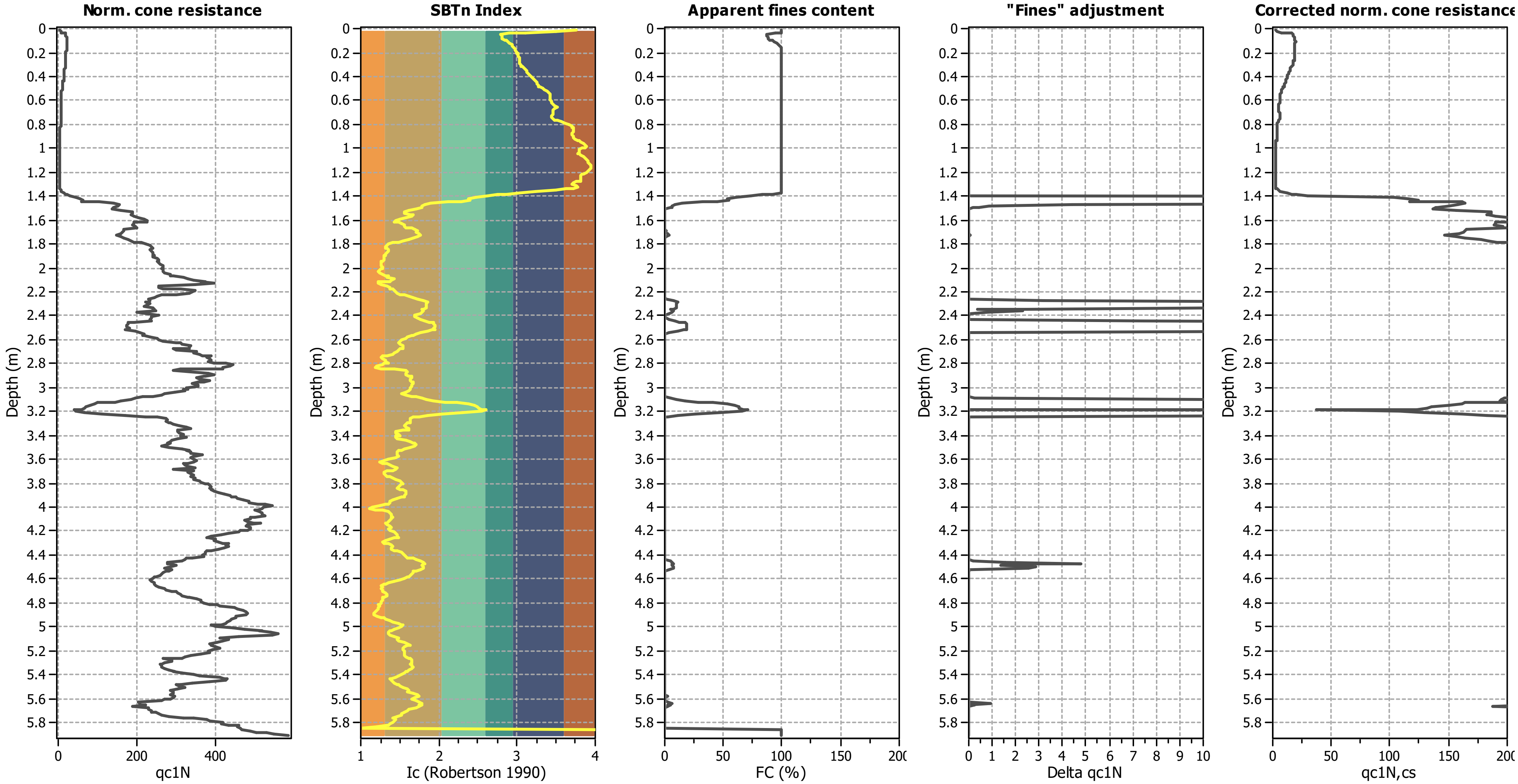






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

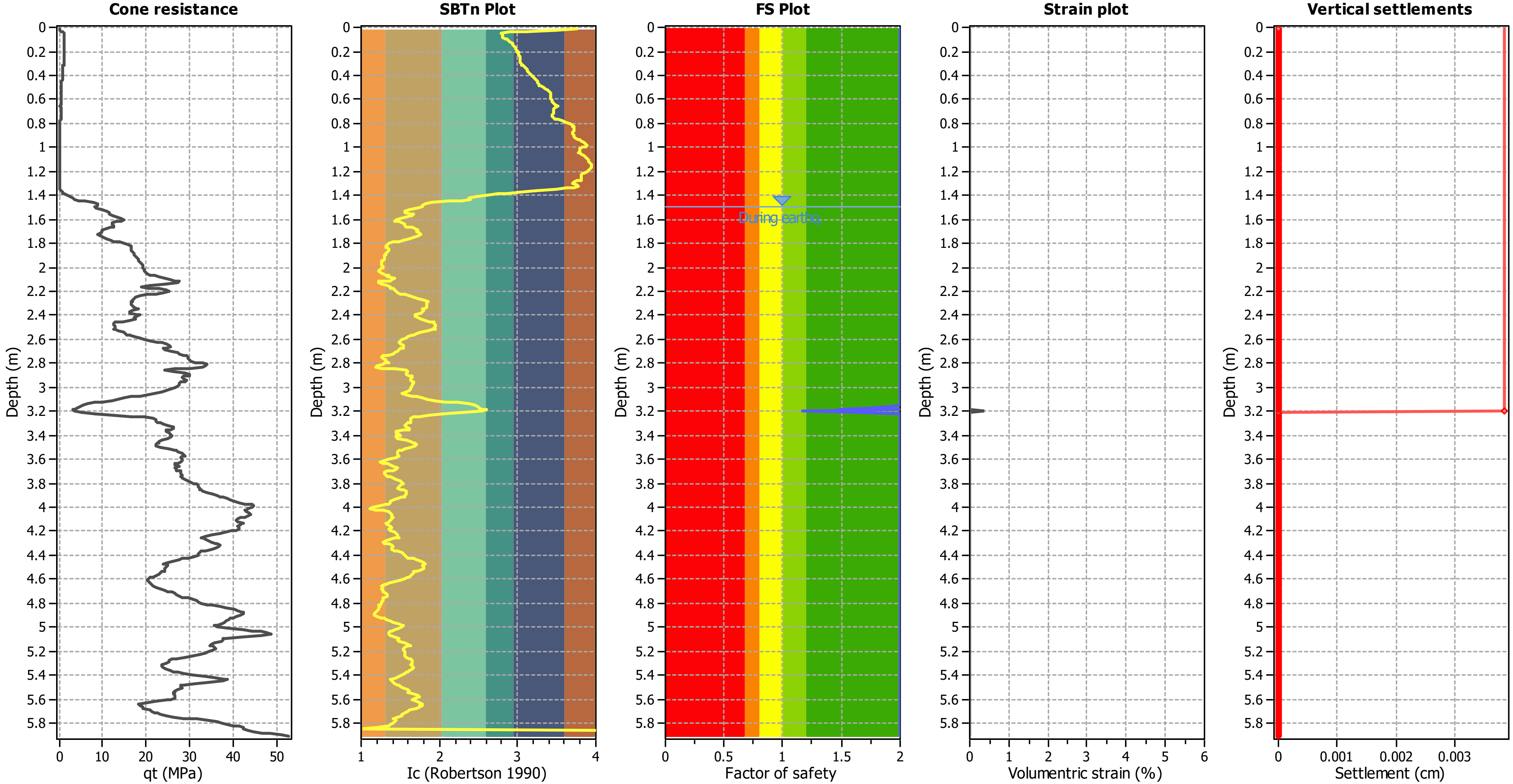
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

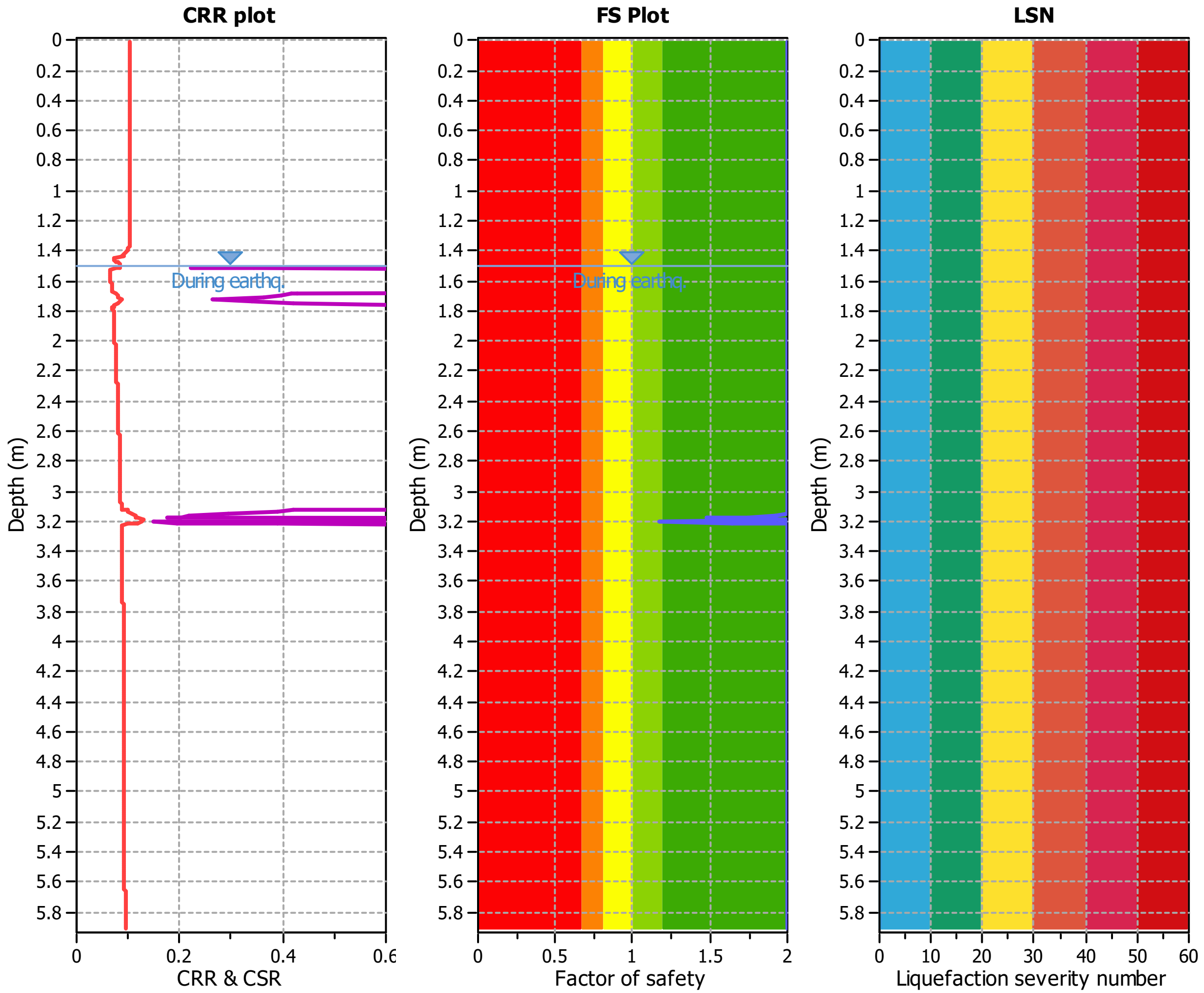


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT3
Total depth: 5.91 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

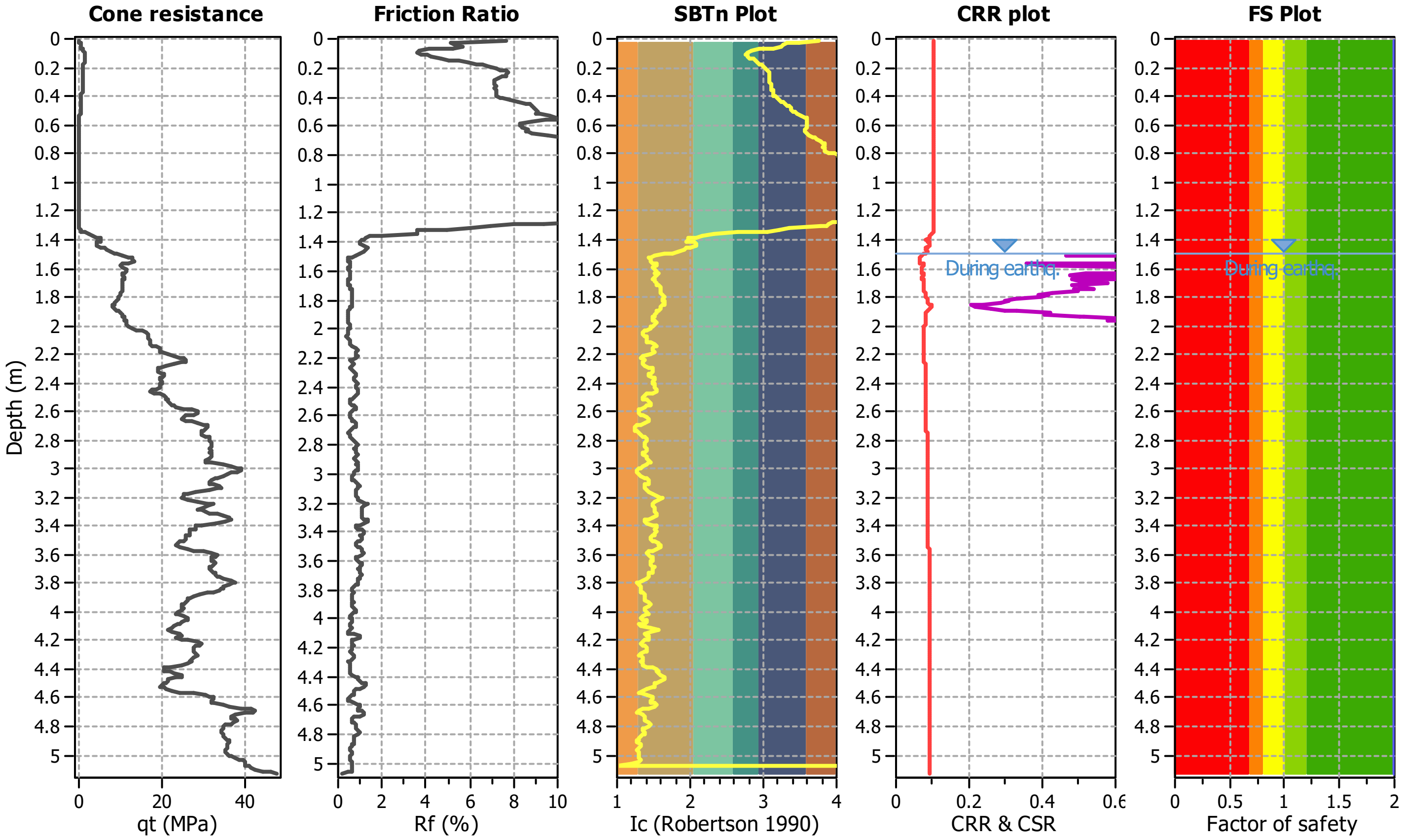
LIQUEFACTION ANALYSIS REPORT

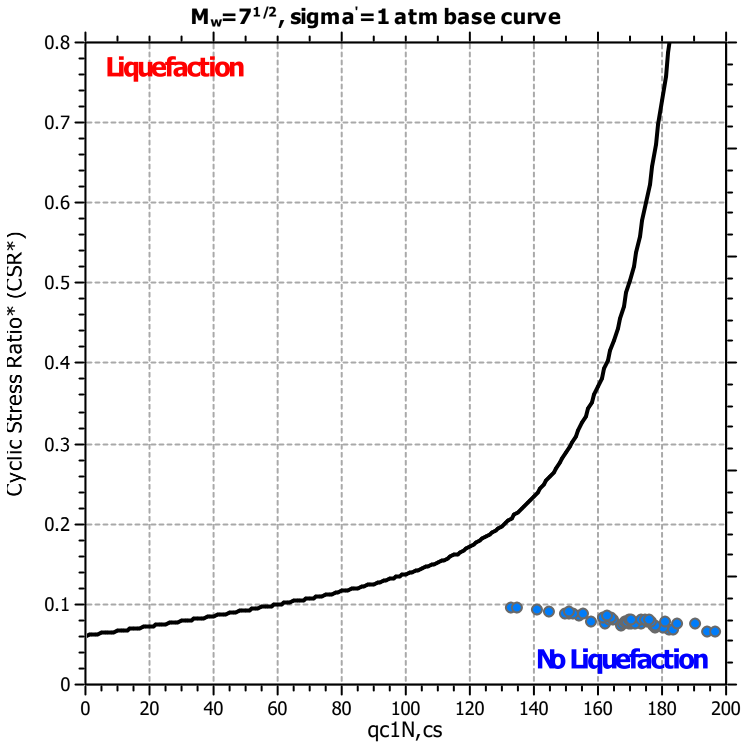
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

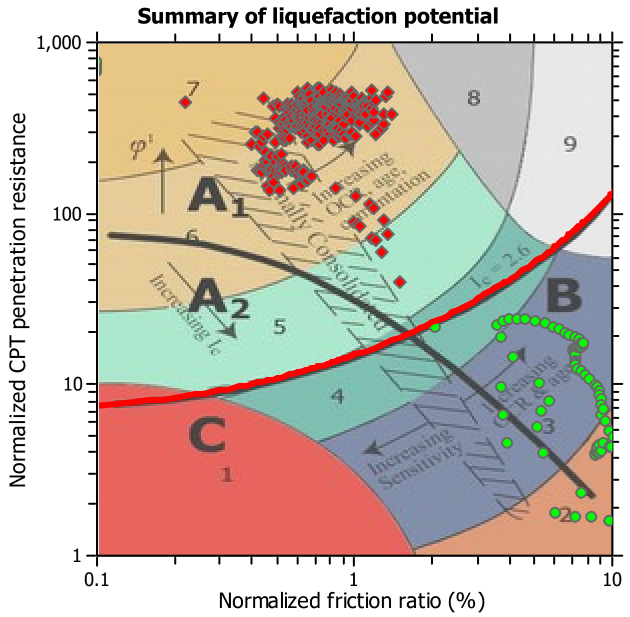
CPT file : CPT4

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

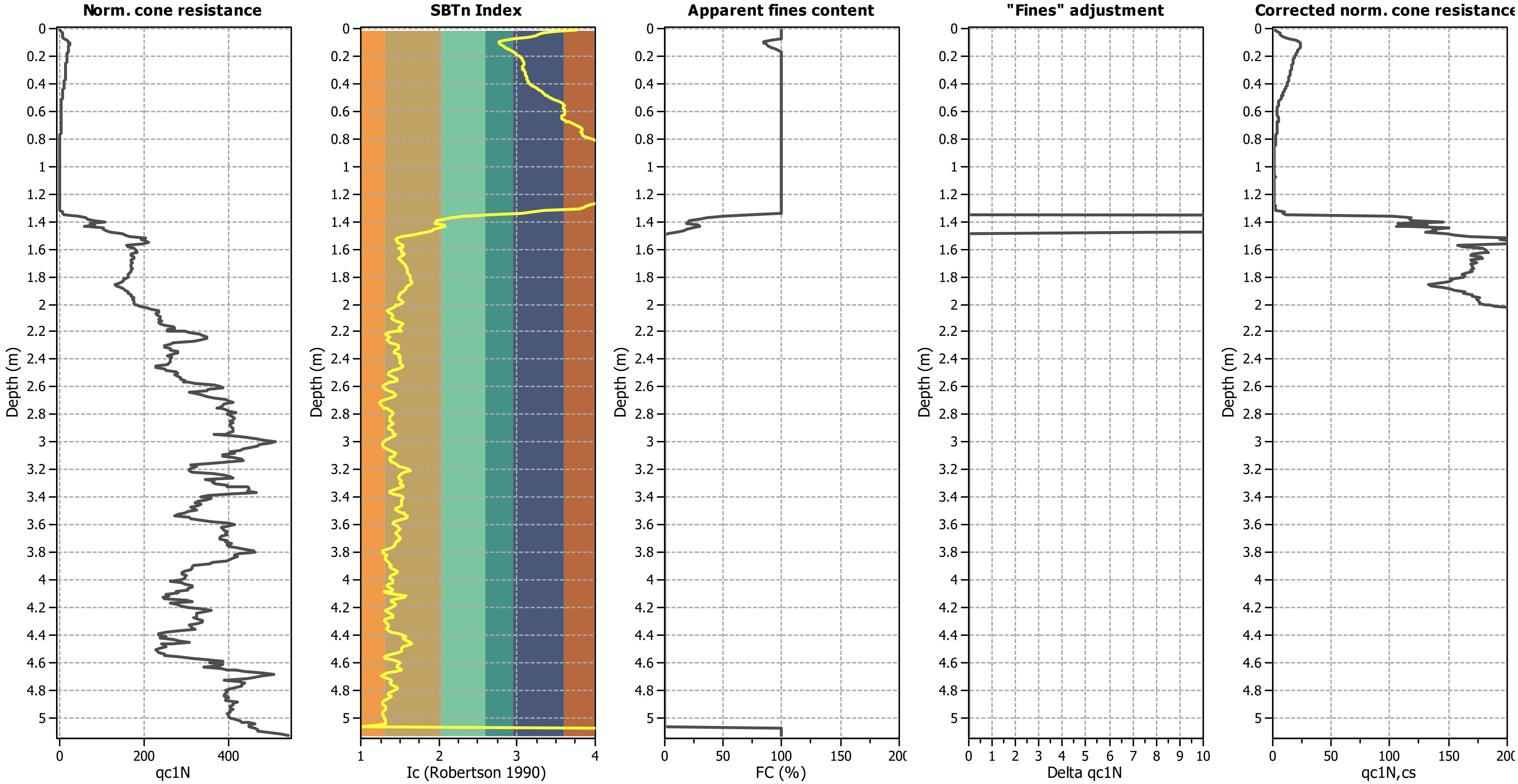






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

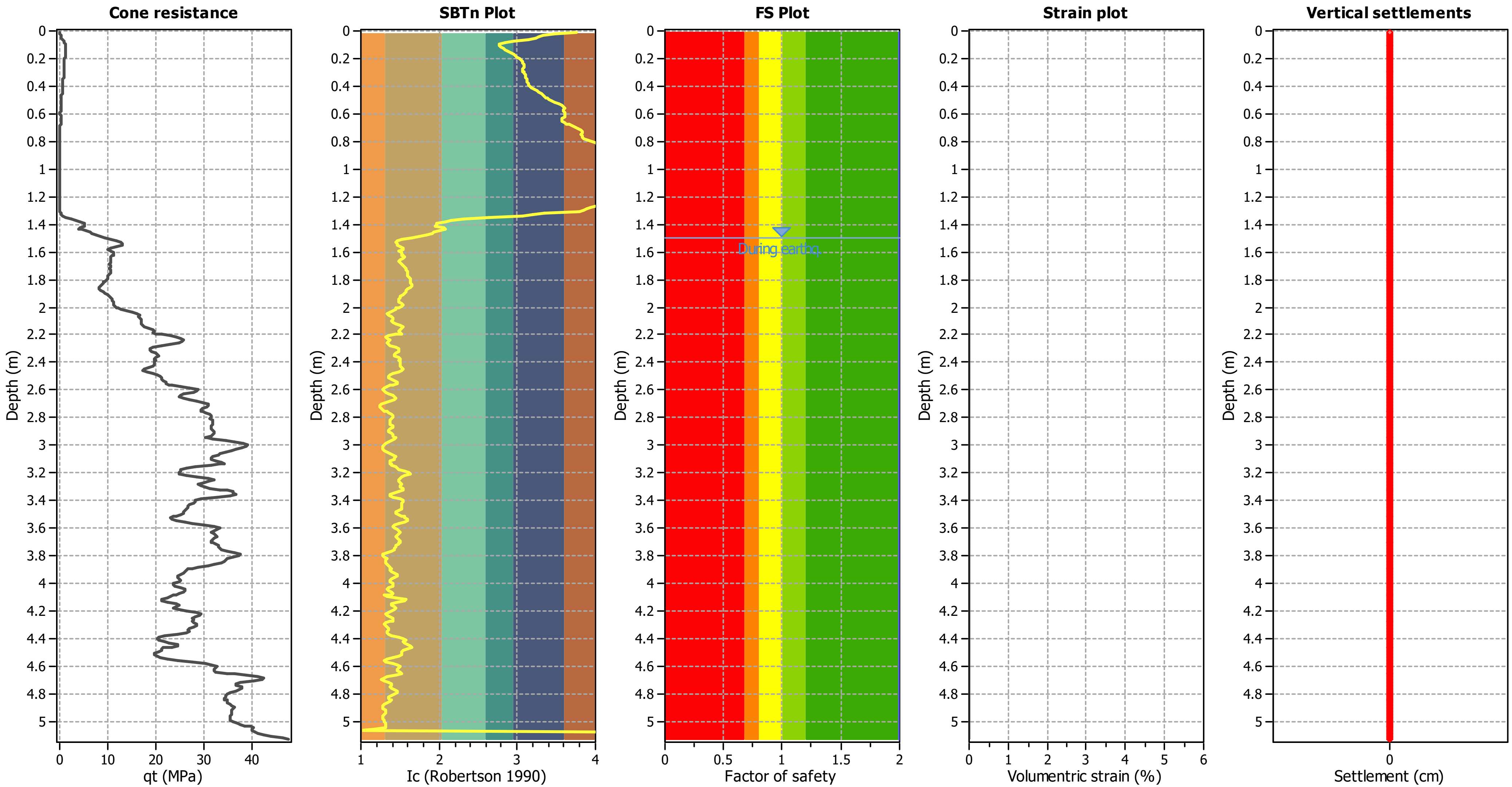
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

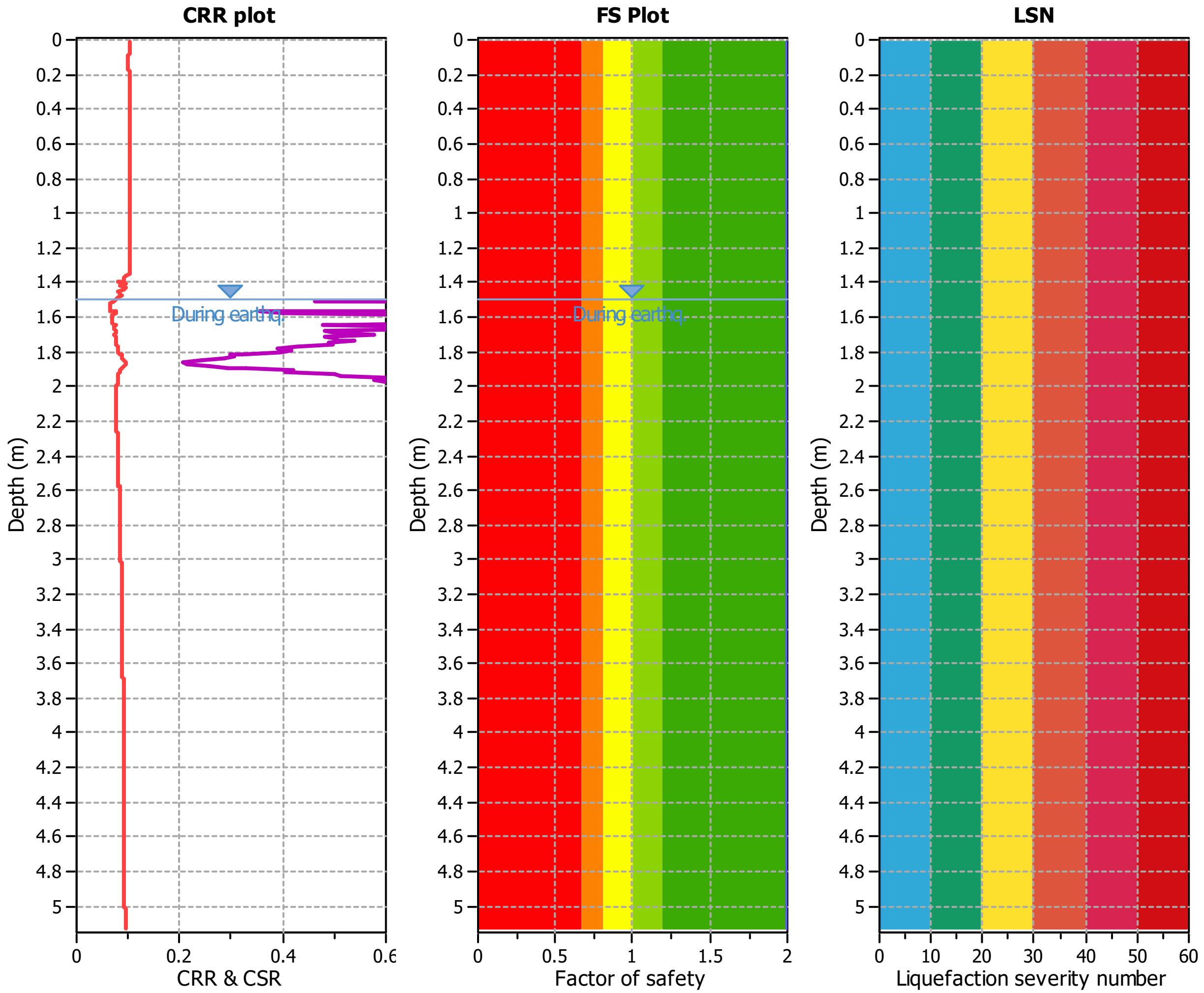


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT4
Total depth: 5.13 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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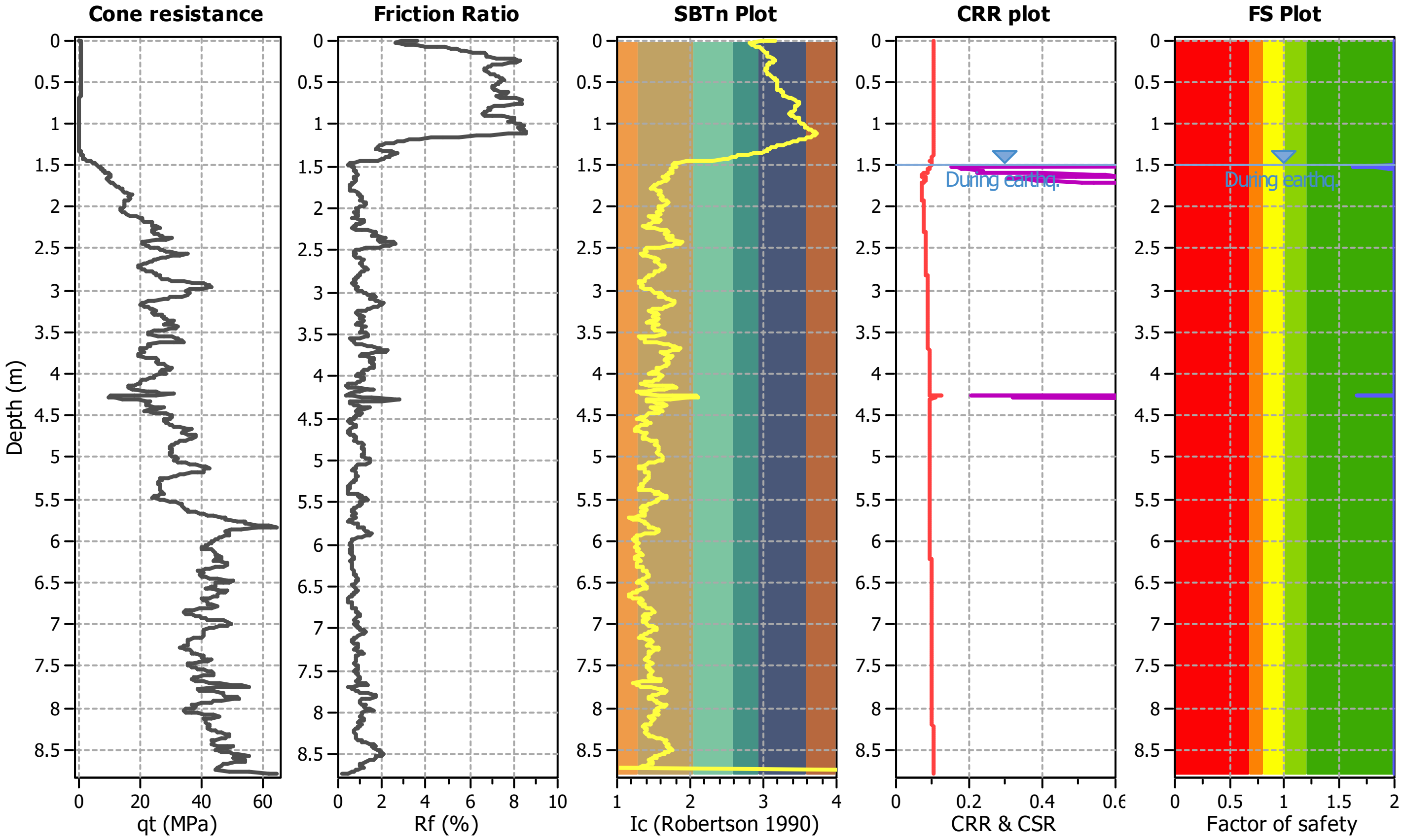
LIQUEFACTION ANALYSIS REPORT

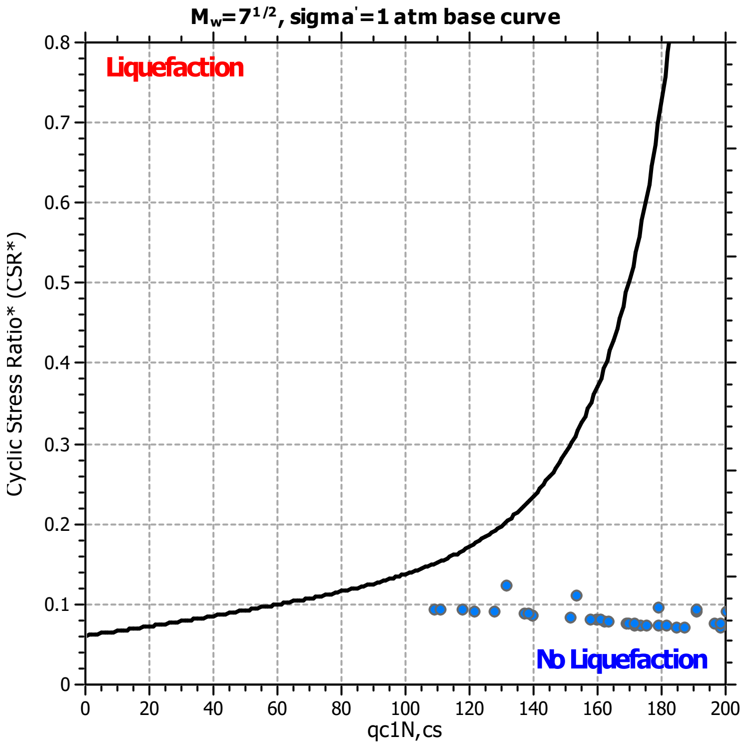
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

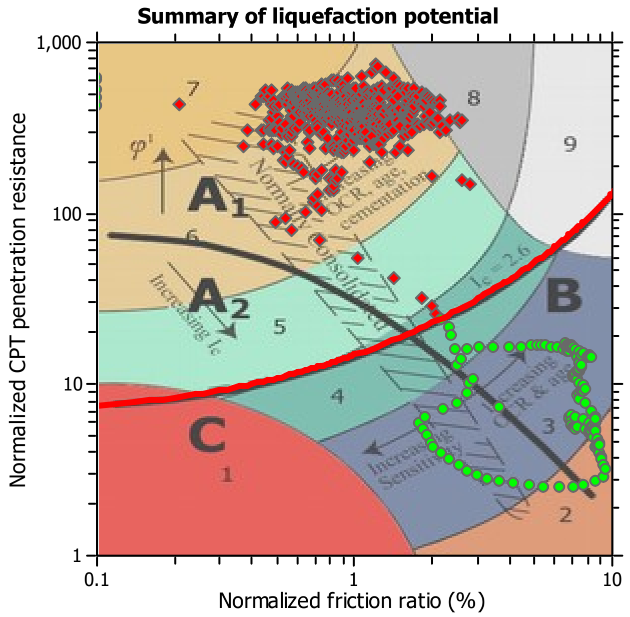
CPT file : CPT5

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A		
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	10.00 m
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

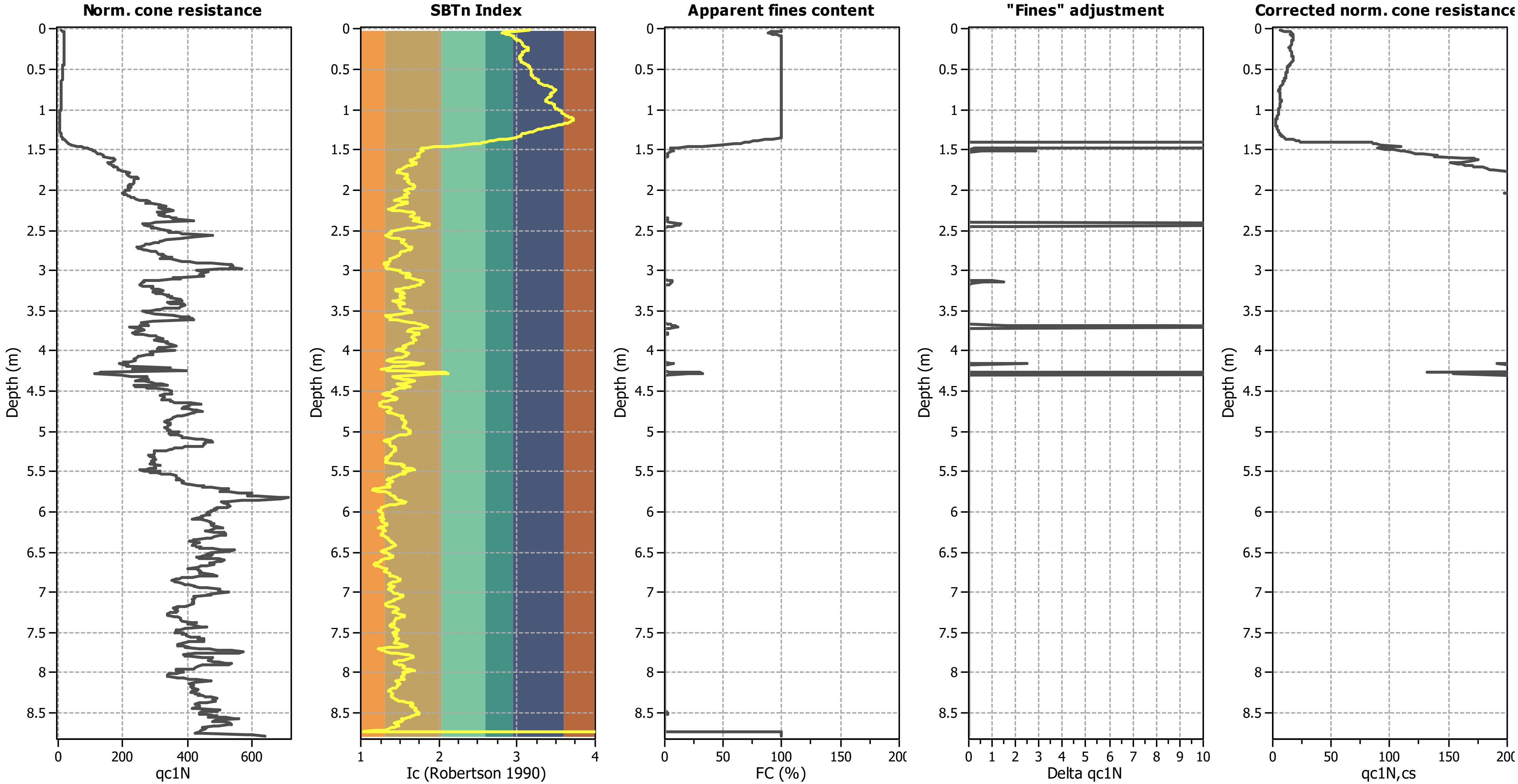






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

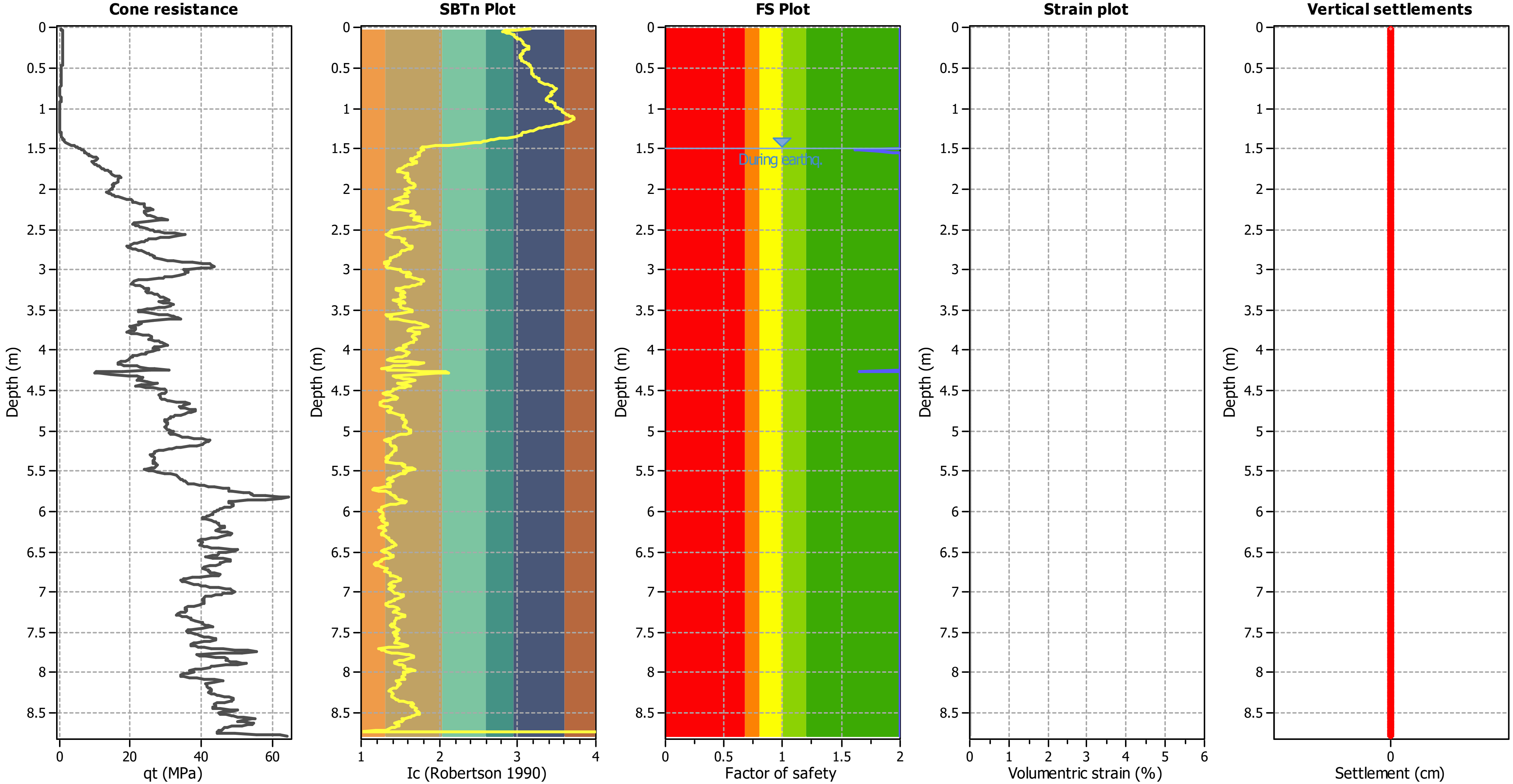
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

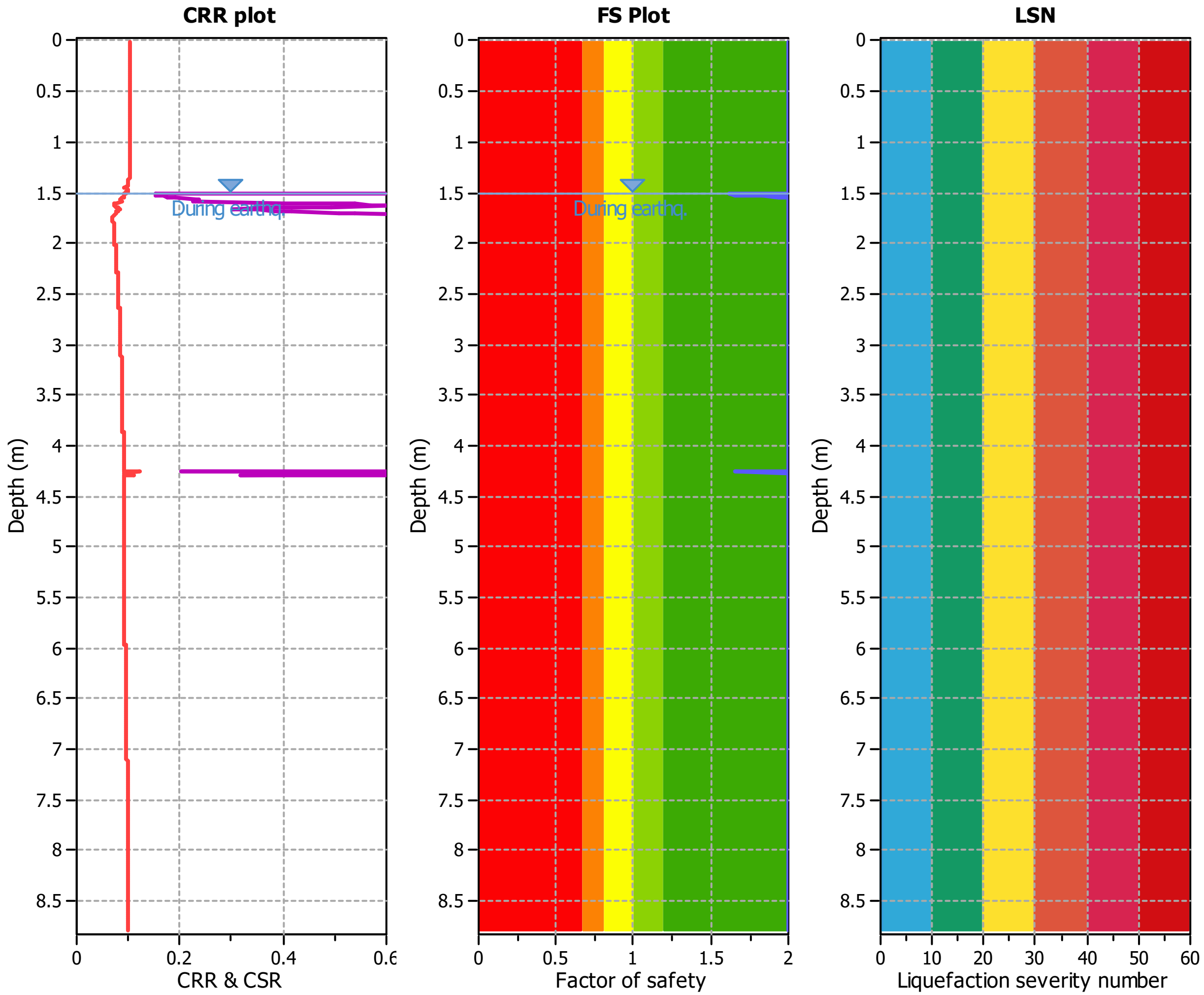


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT5
Total depth: 8.79 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

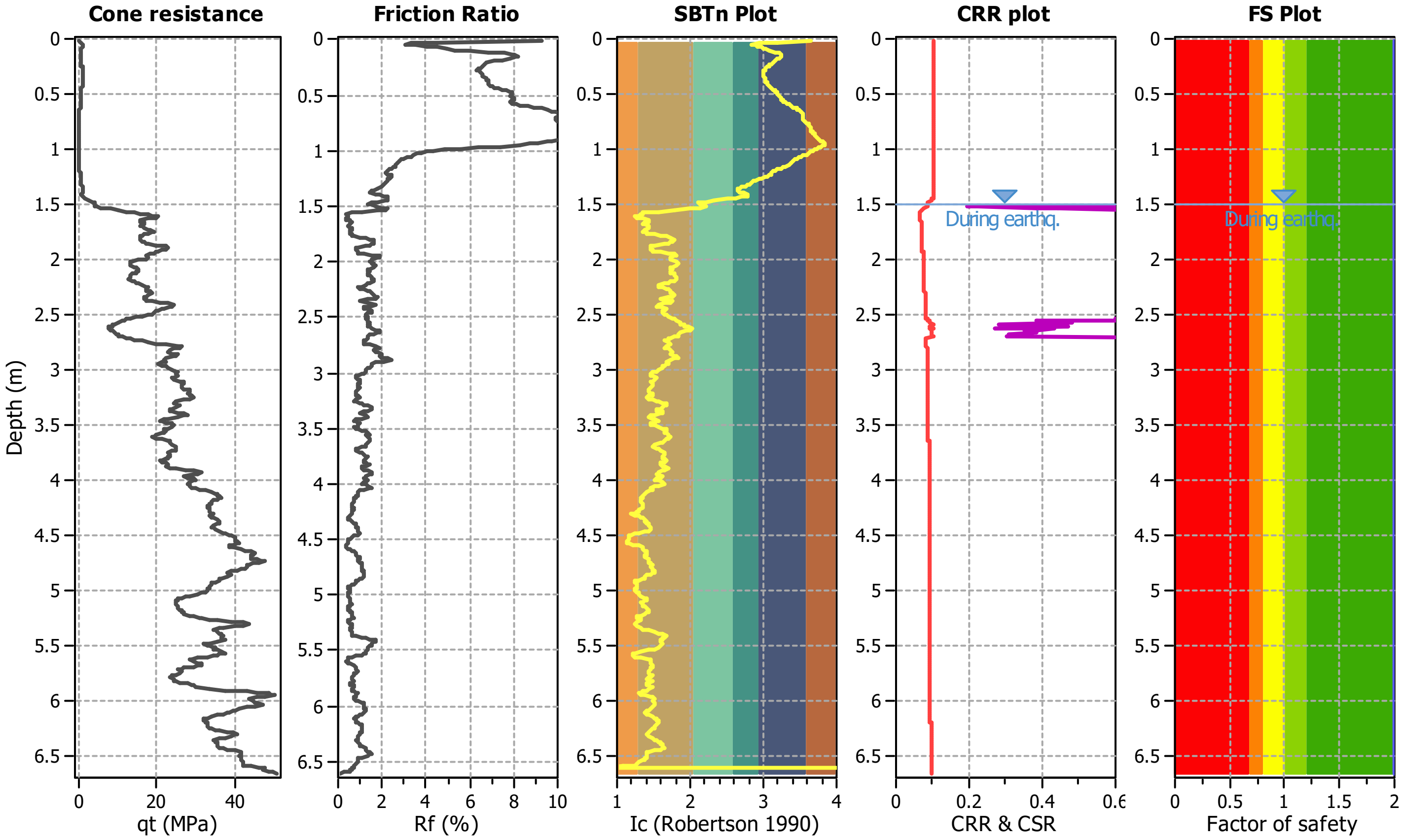
LIQUEFACTION ANALYSIS REPORT

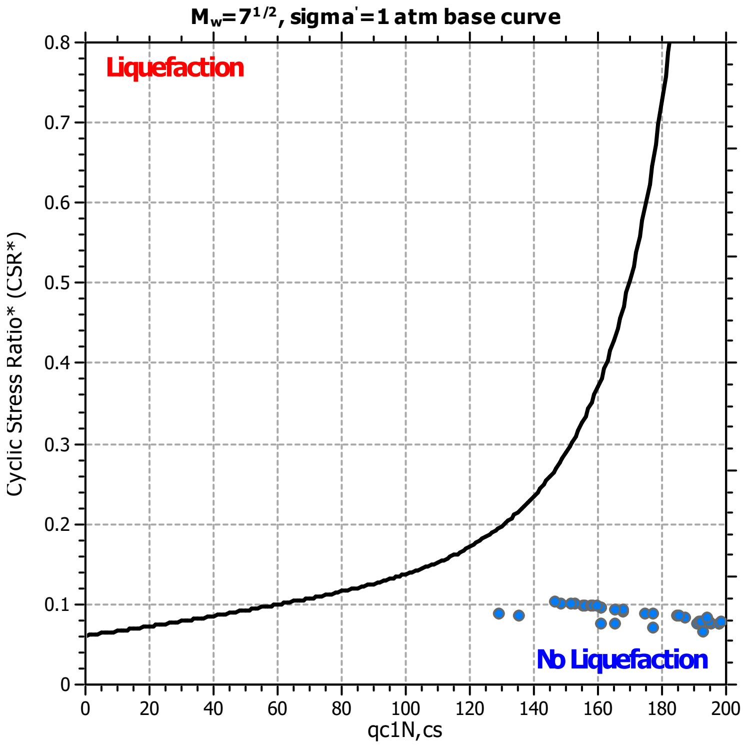
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

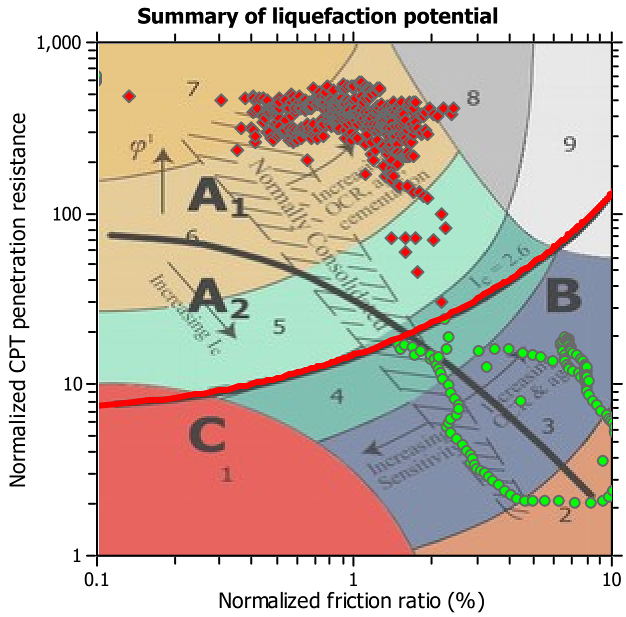
CPT file : CPT6

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

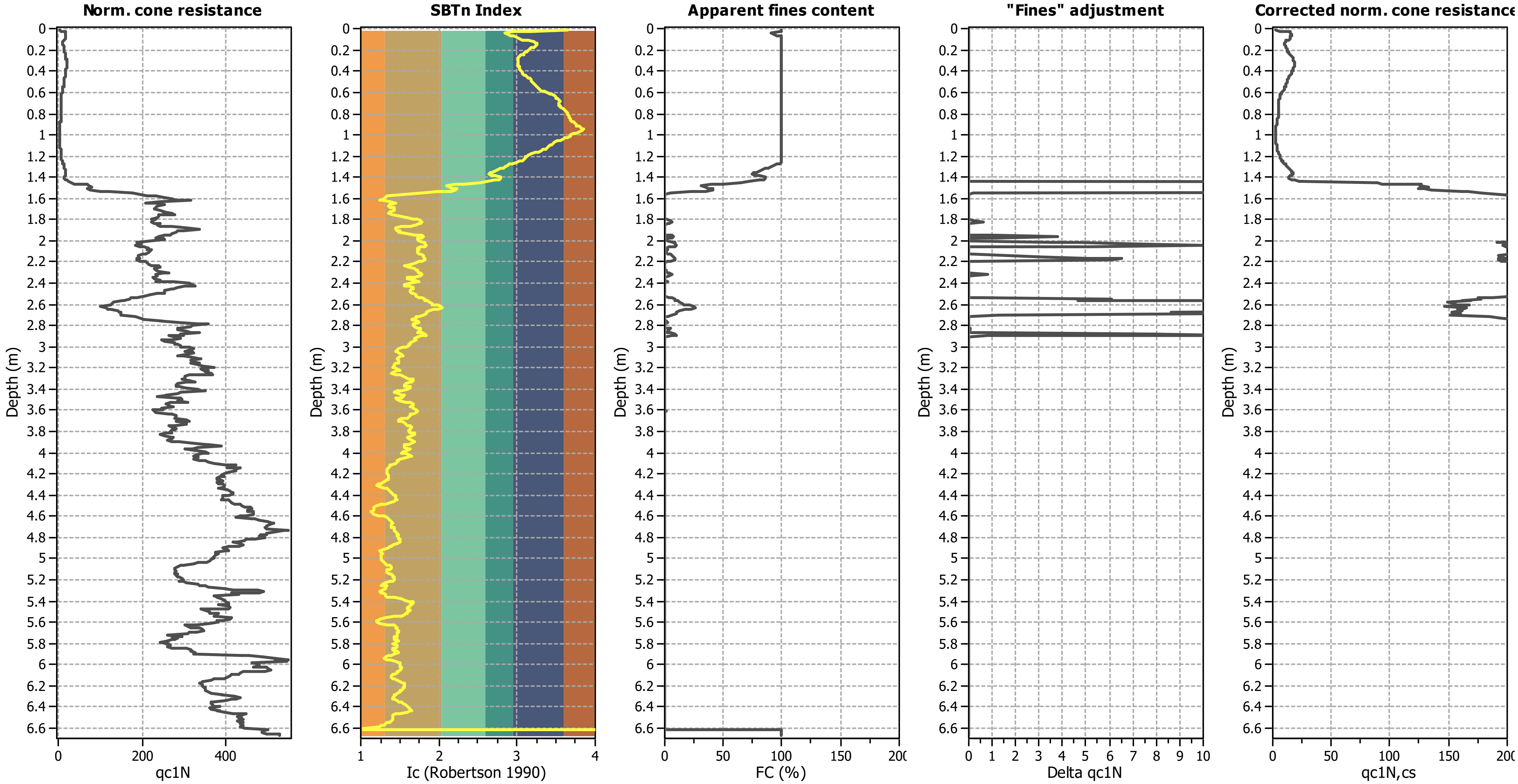






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

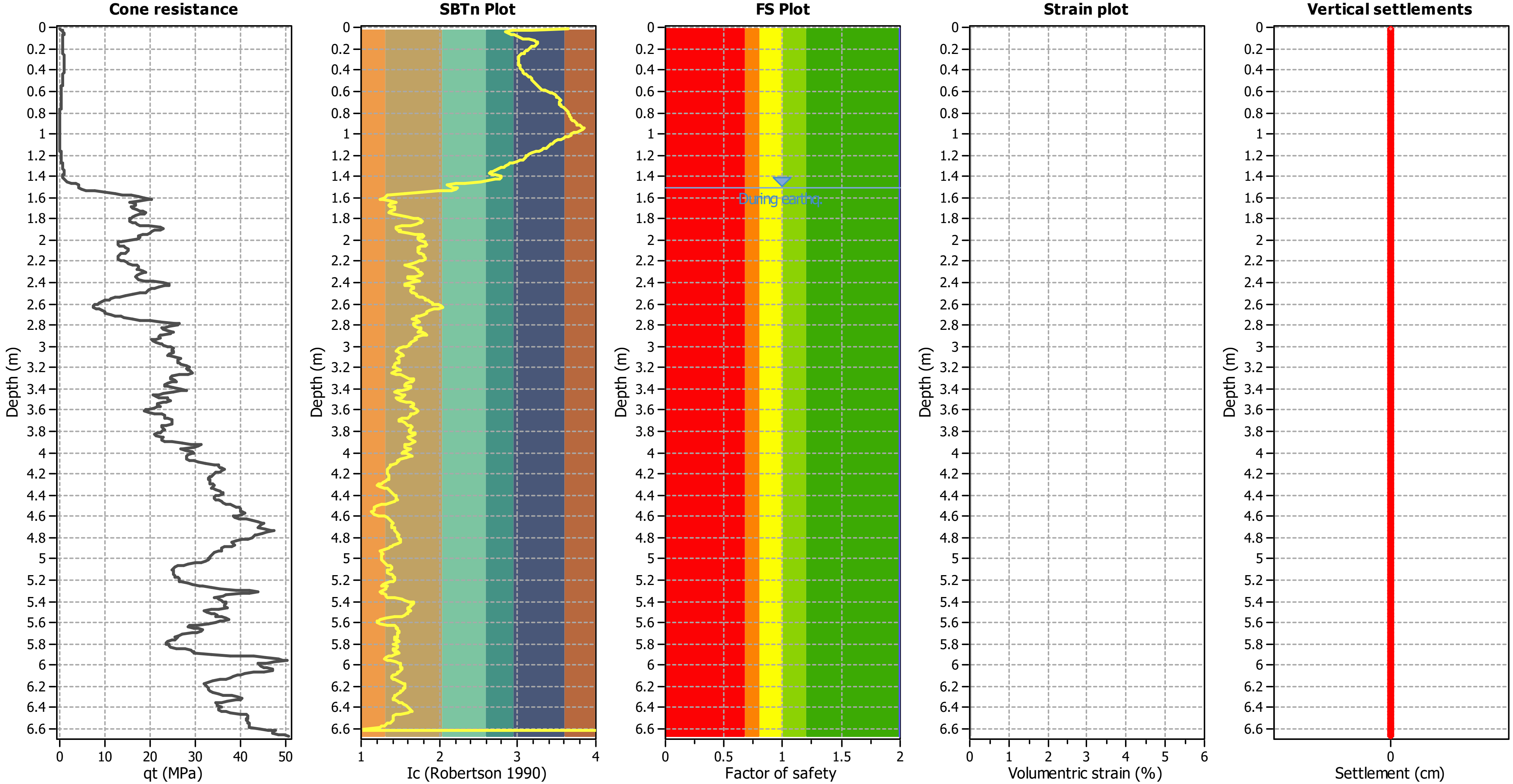
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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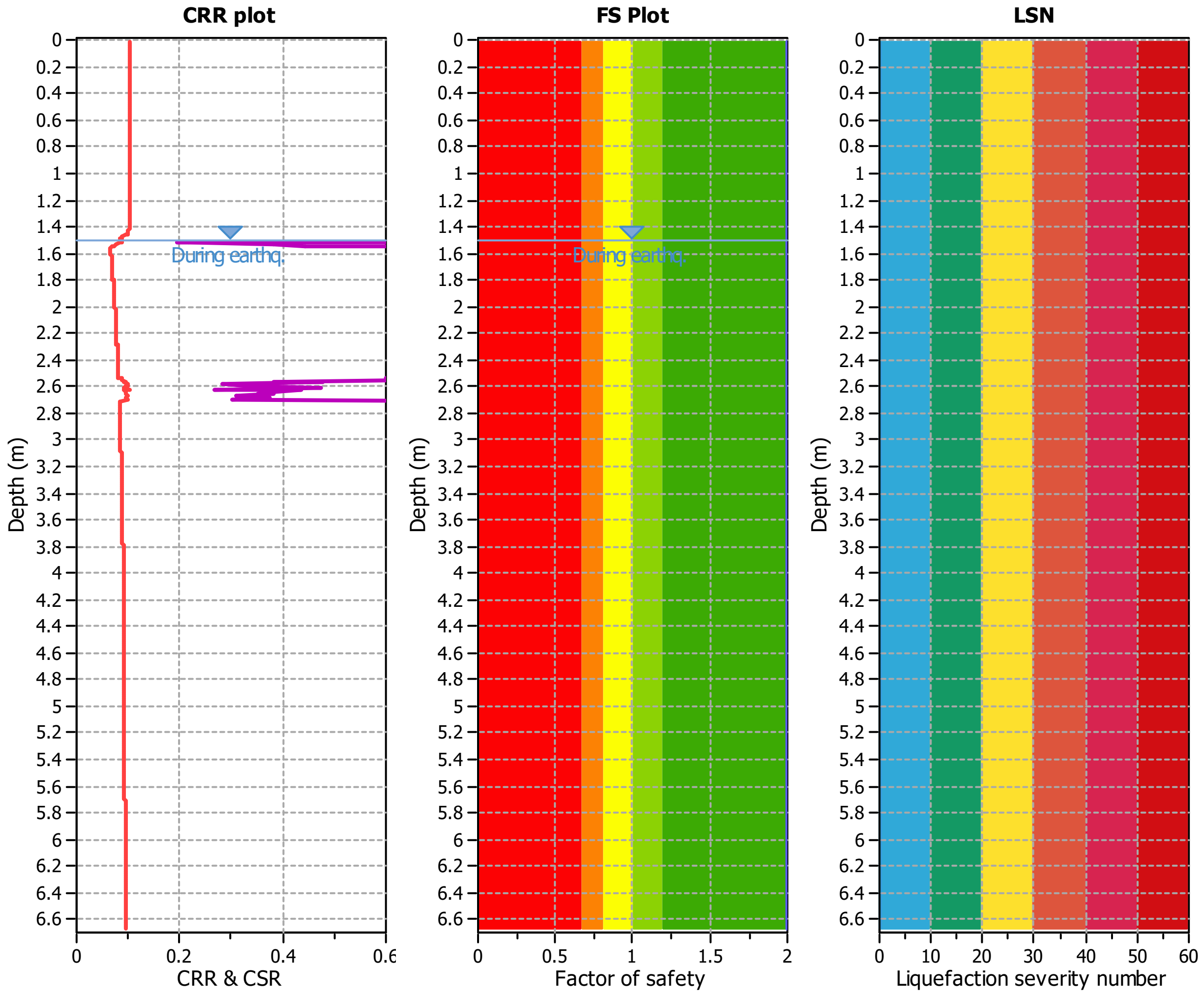
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT6
Total depth: 6.67 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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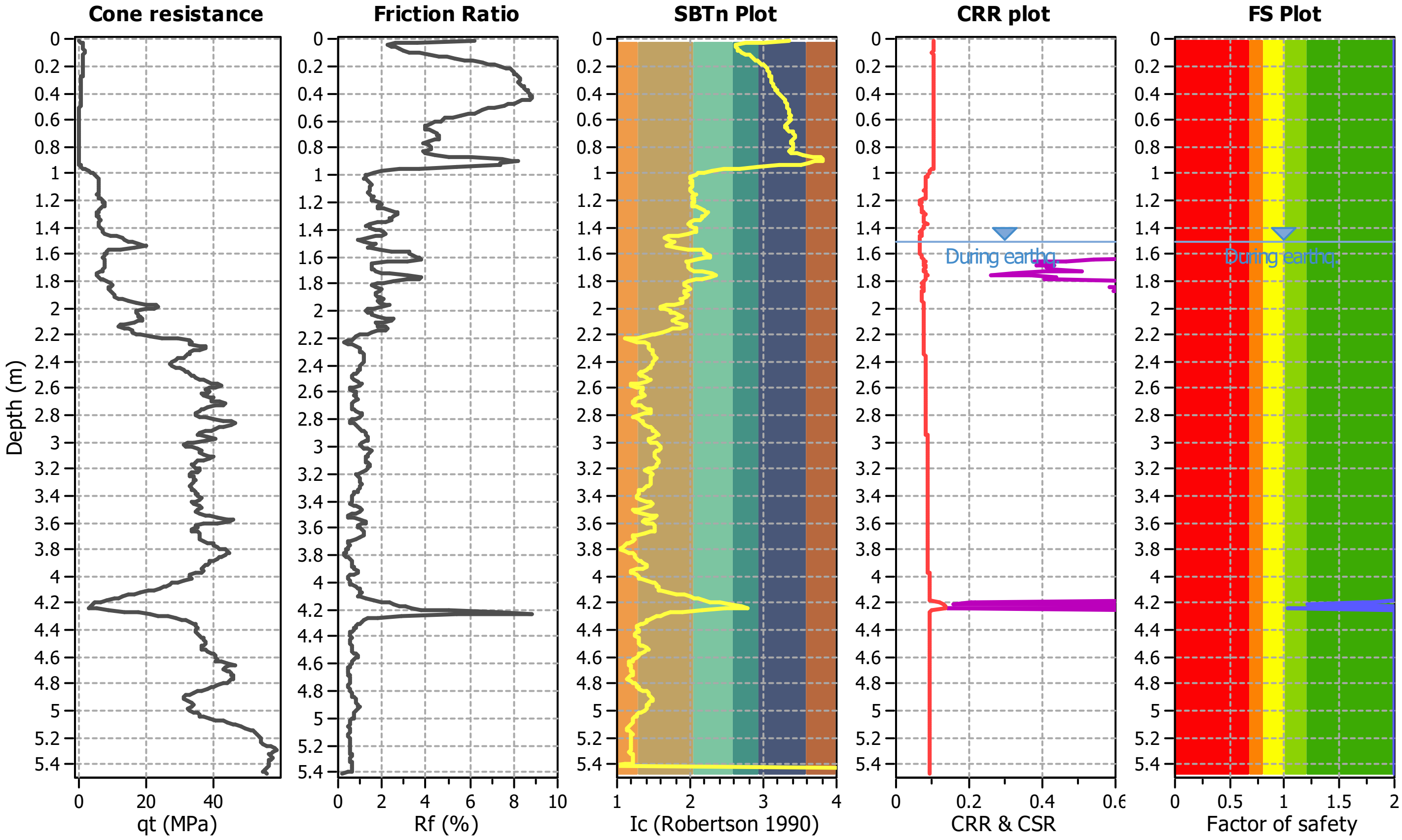
LIQUEFACTION ANALYSIS REPORT

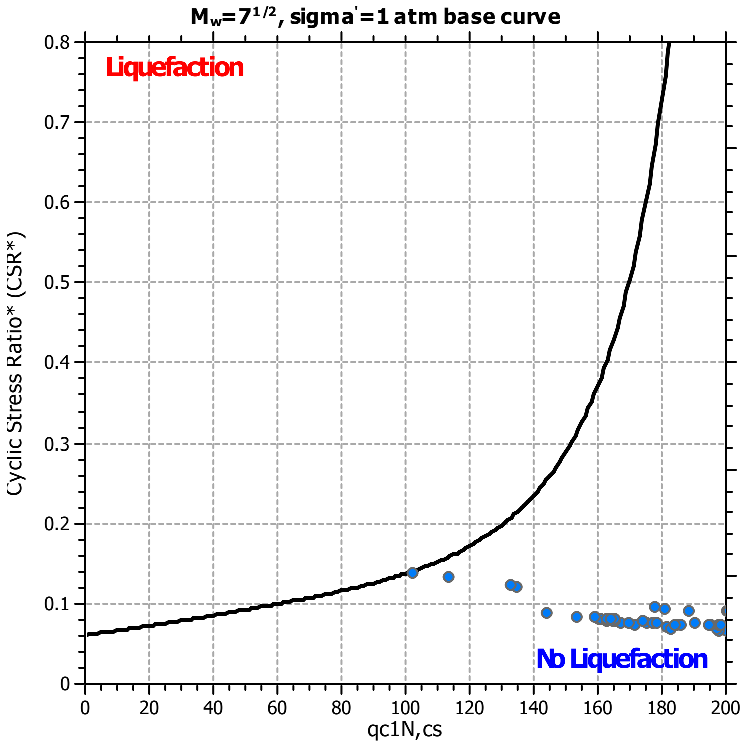
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

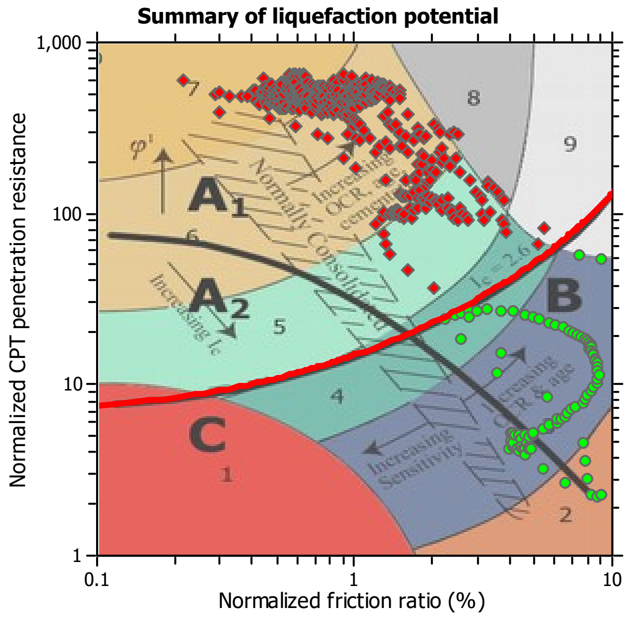
CPT file : CPT7

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A		
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	10.00 m
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

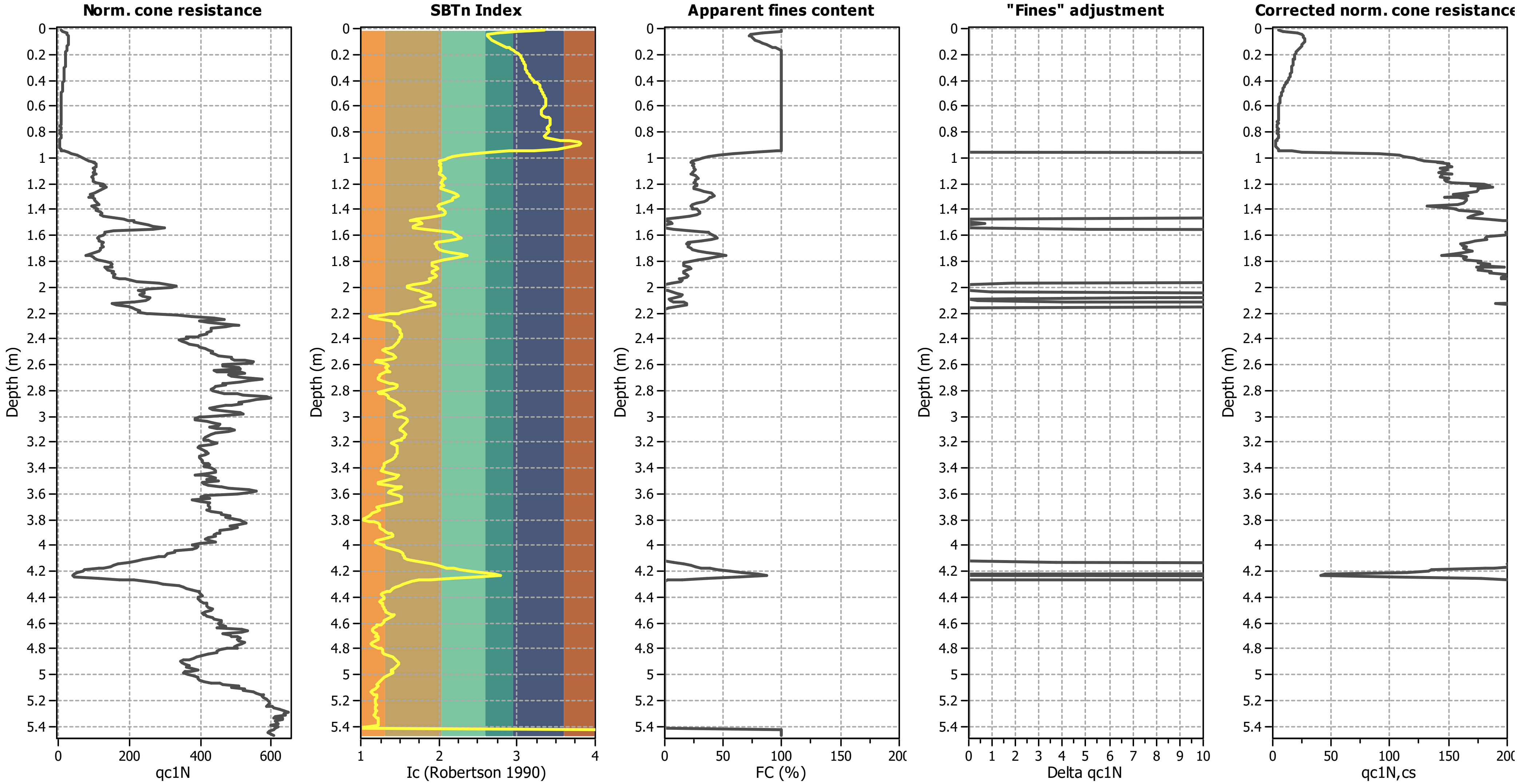






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

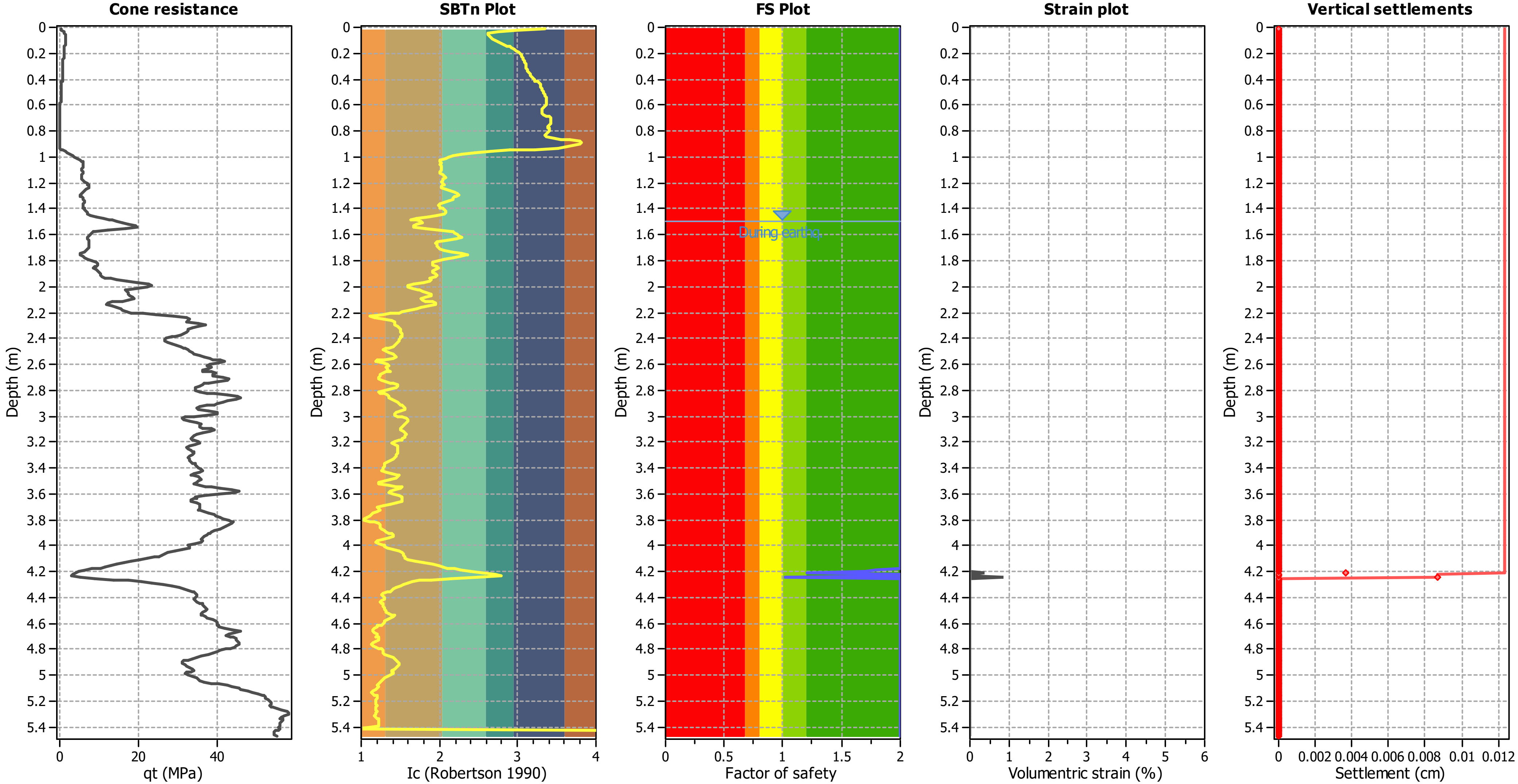
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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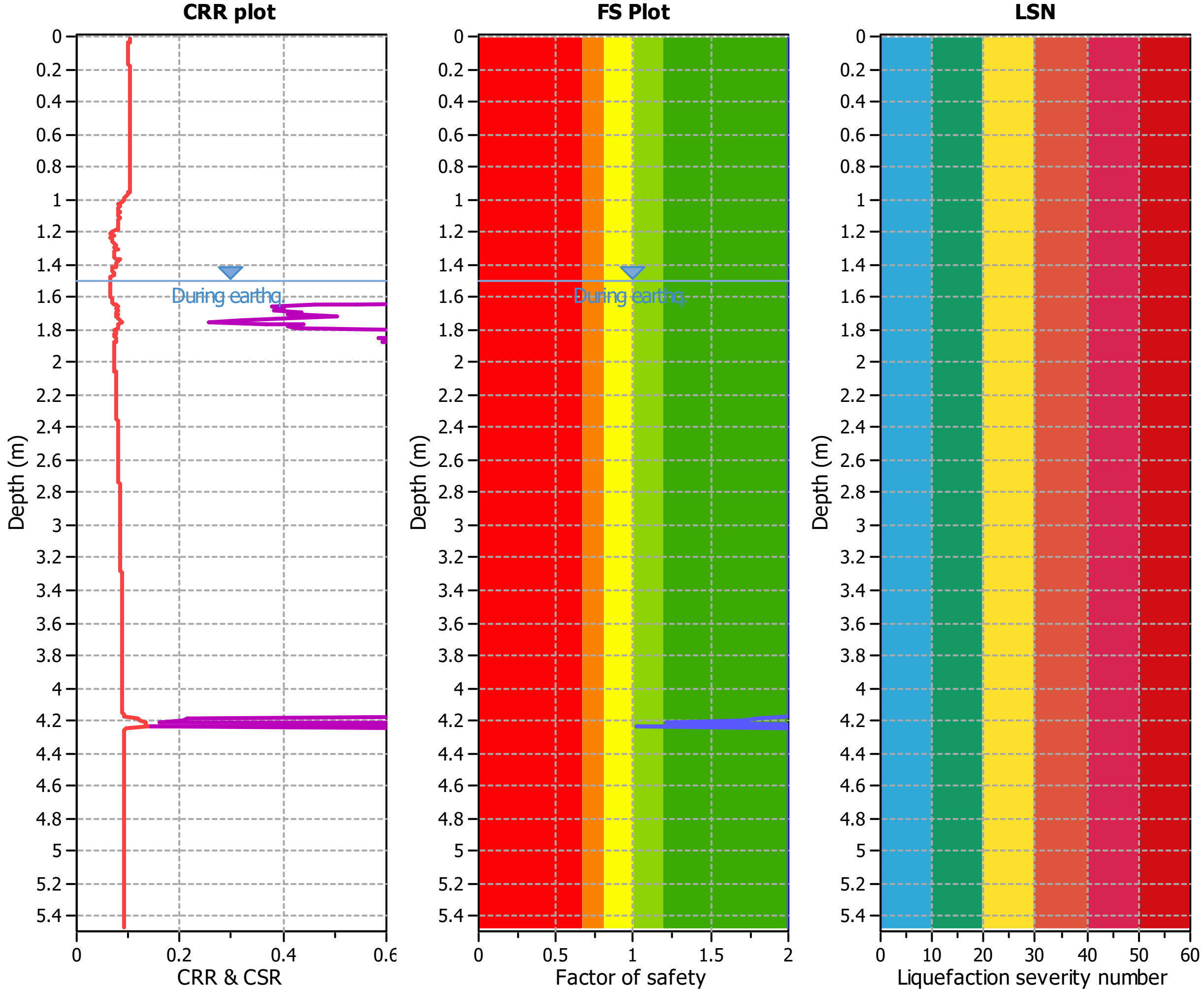
Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT7
Total depth: 5.47 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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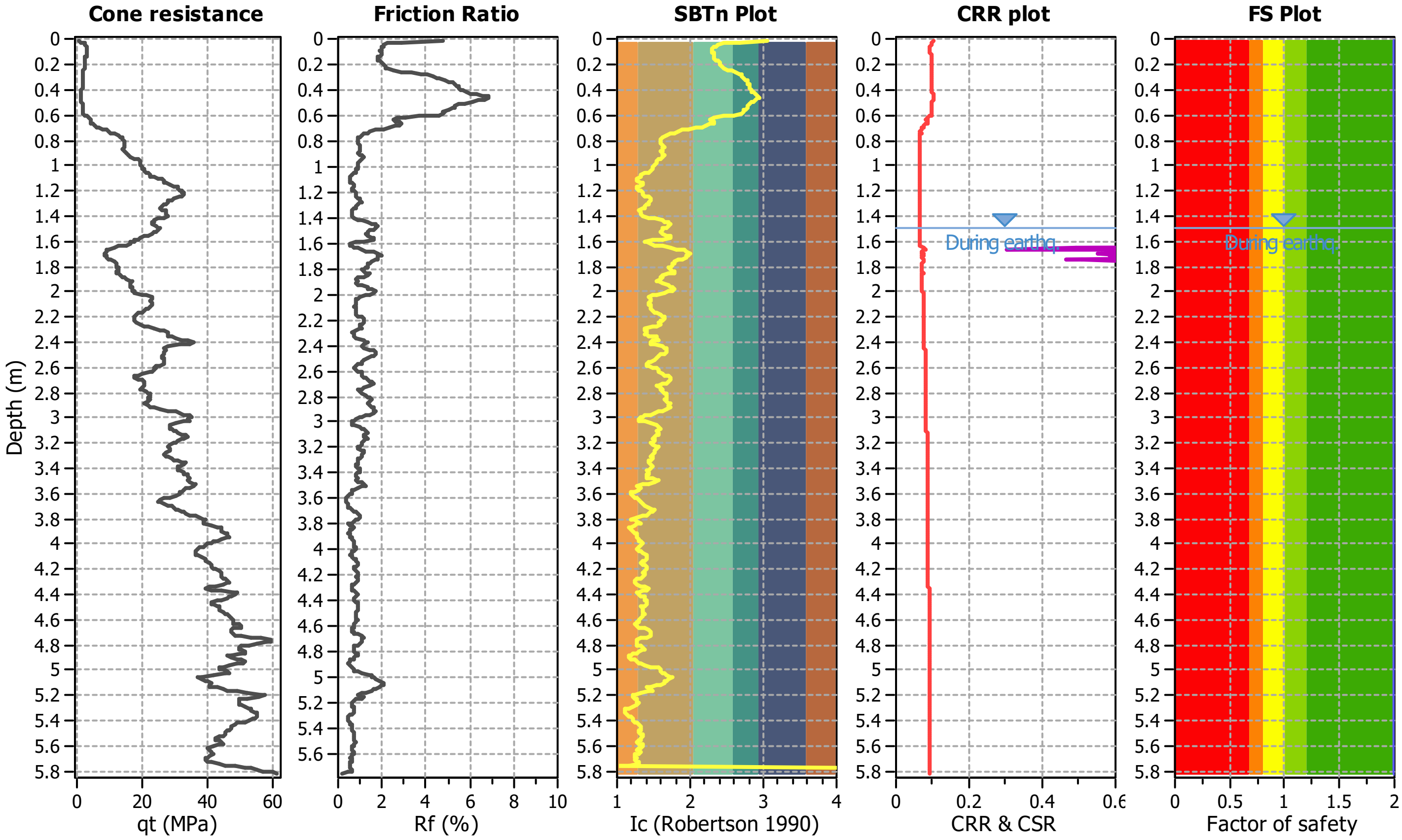
LIQUEFACTION ANALYSIS REPORT

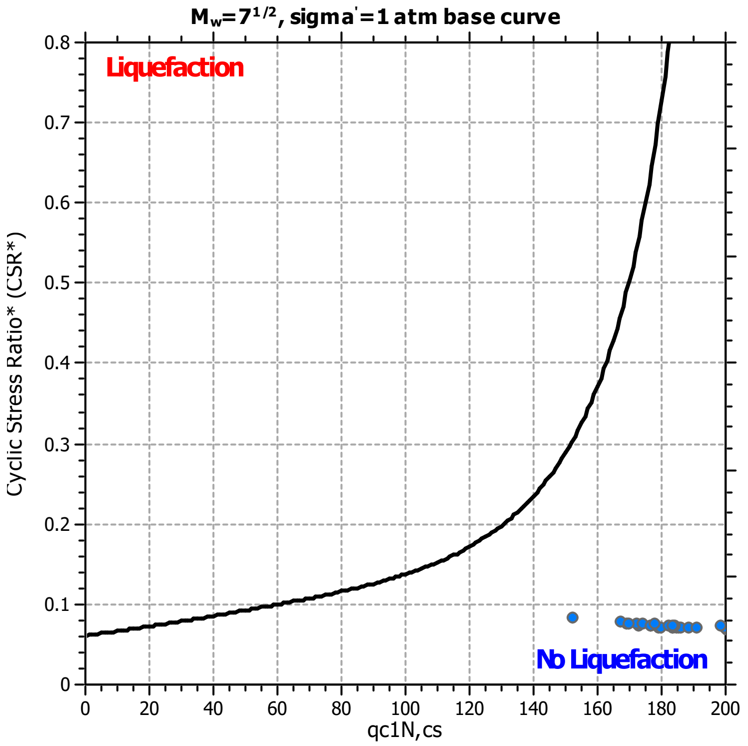
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

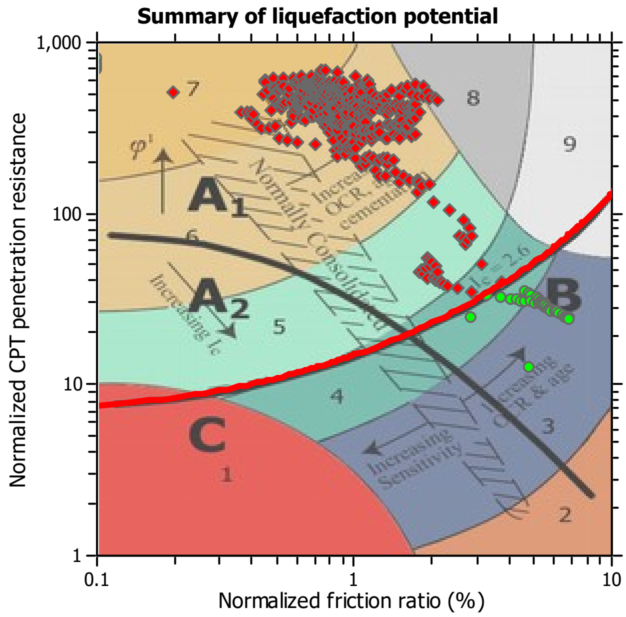
CPT file : CPT8

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

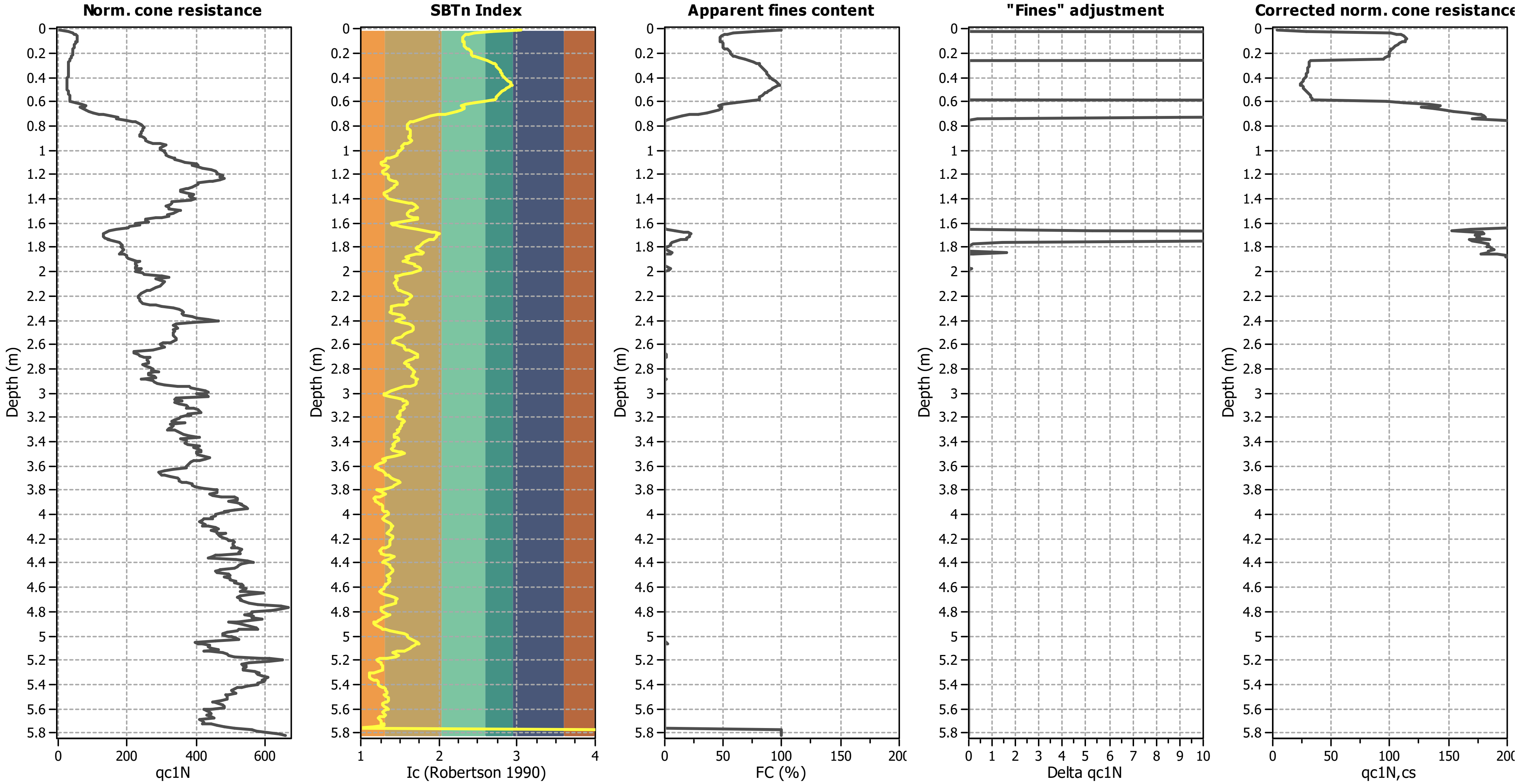






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

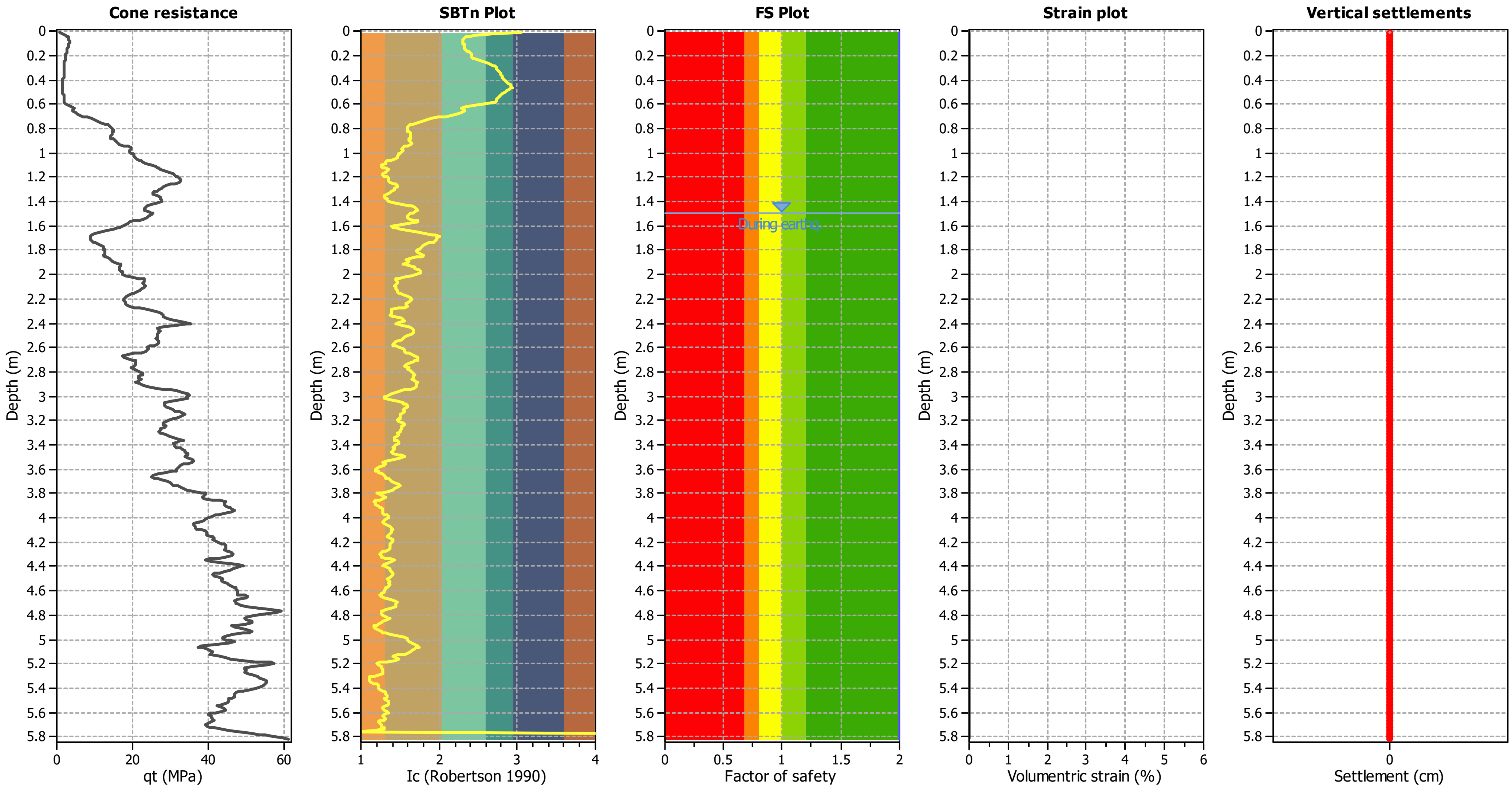
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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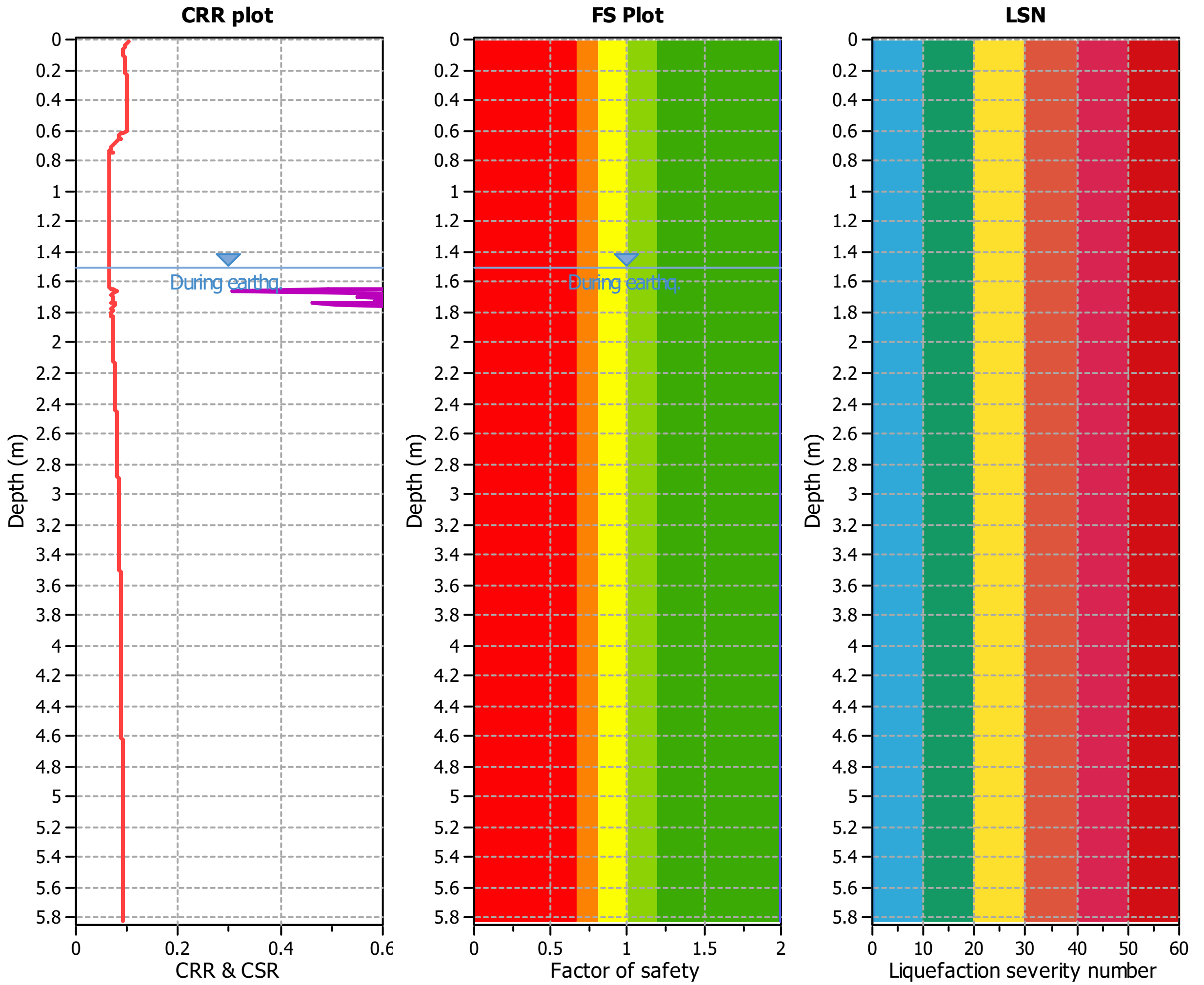
Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT8
Total depth: 5.82 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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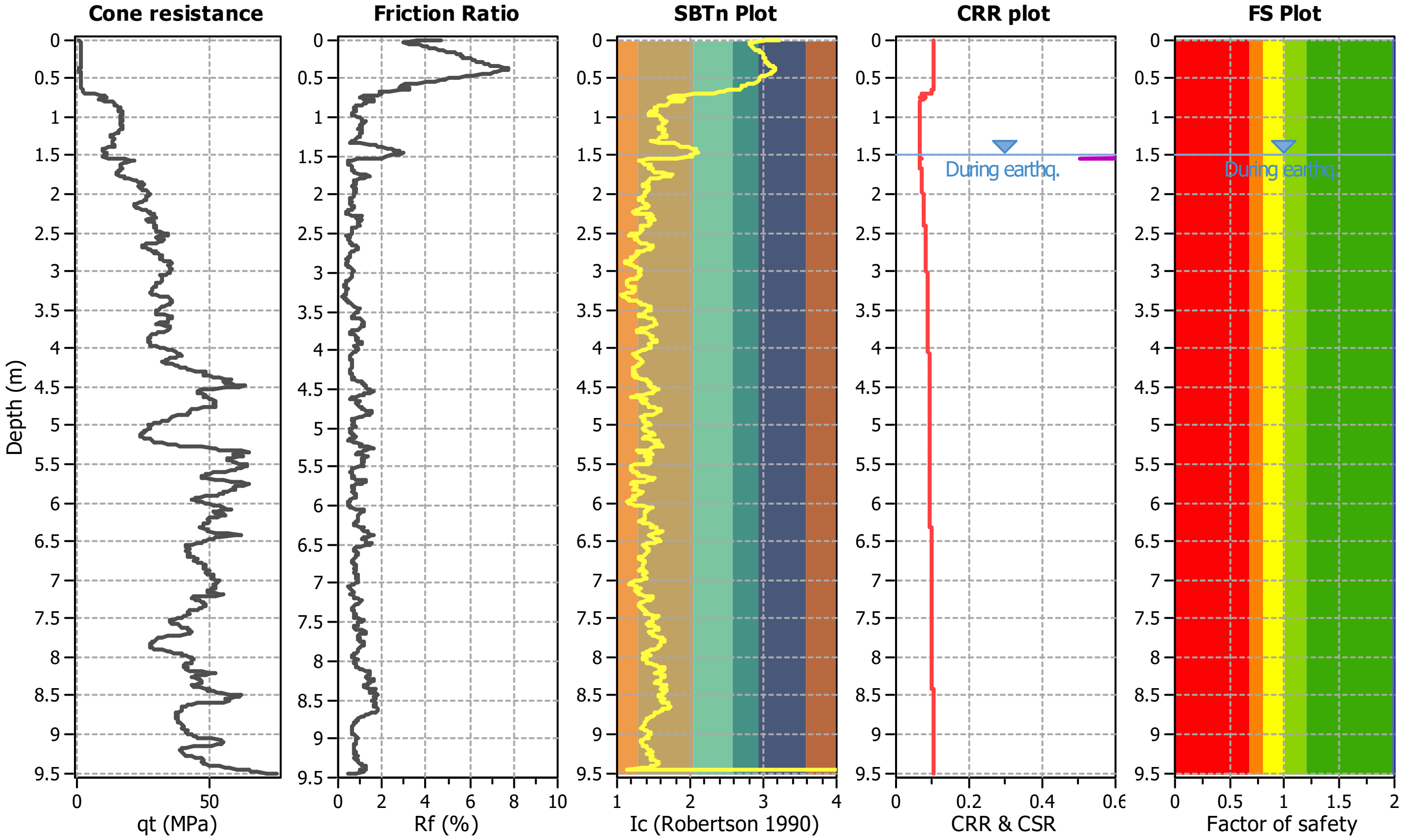
LIQUEFACTION ANALYSIS REPORT

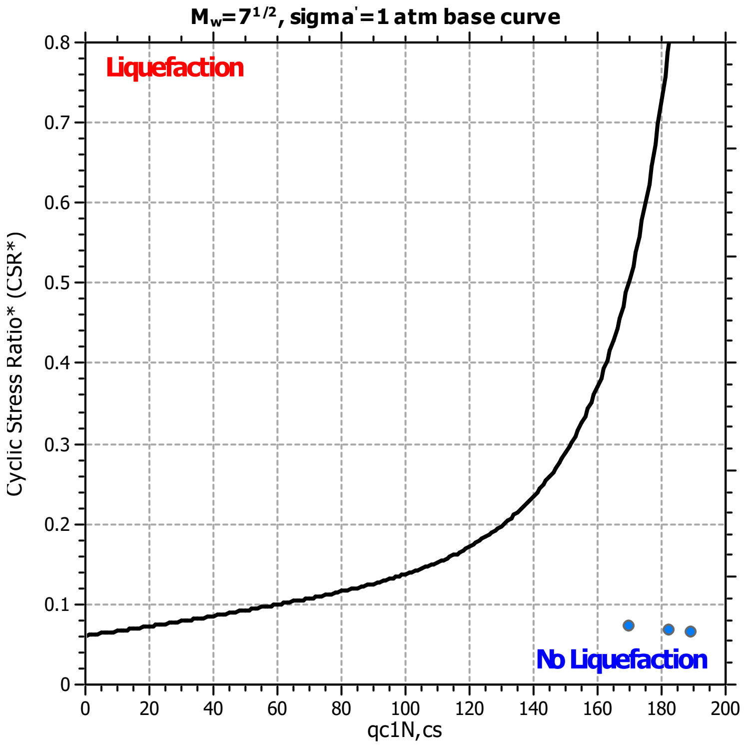
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

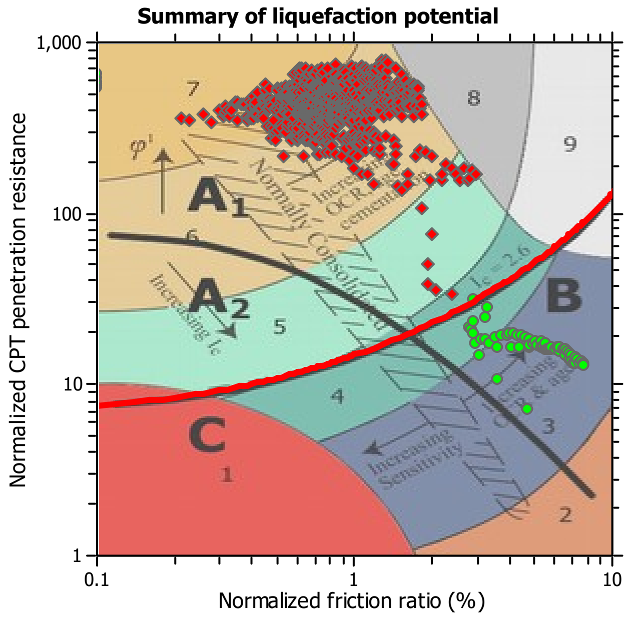
CPT file : CPT9

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

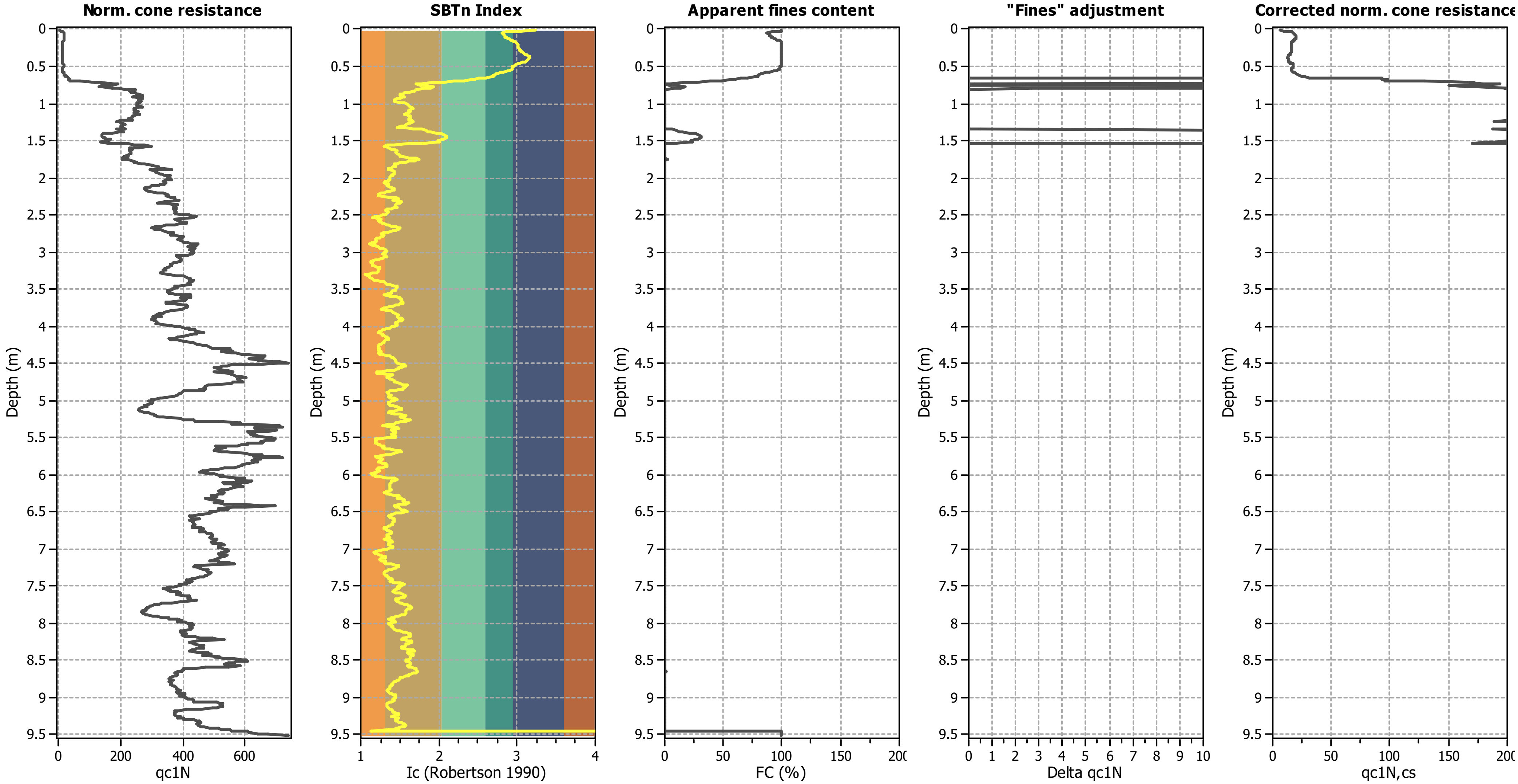






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

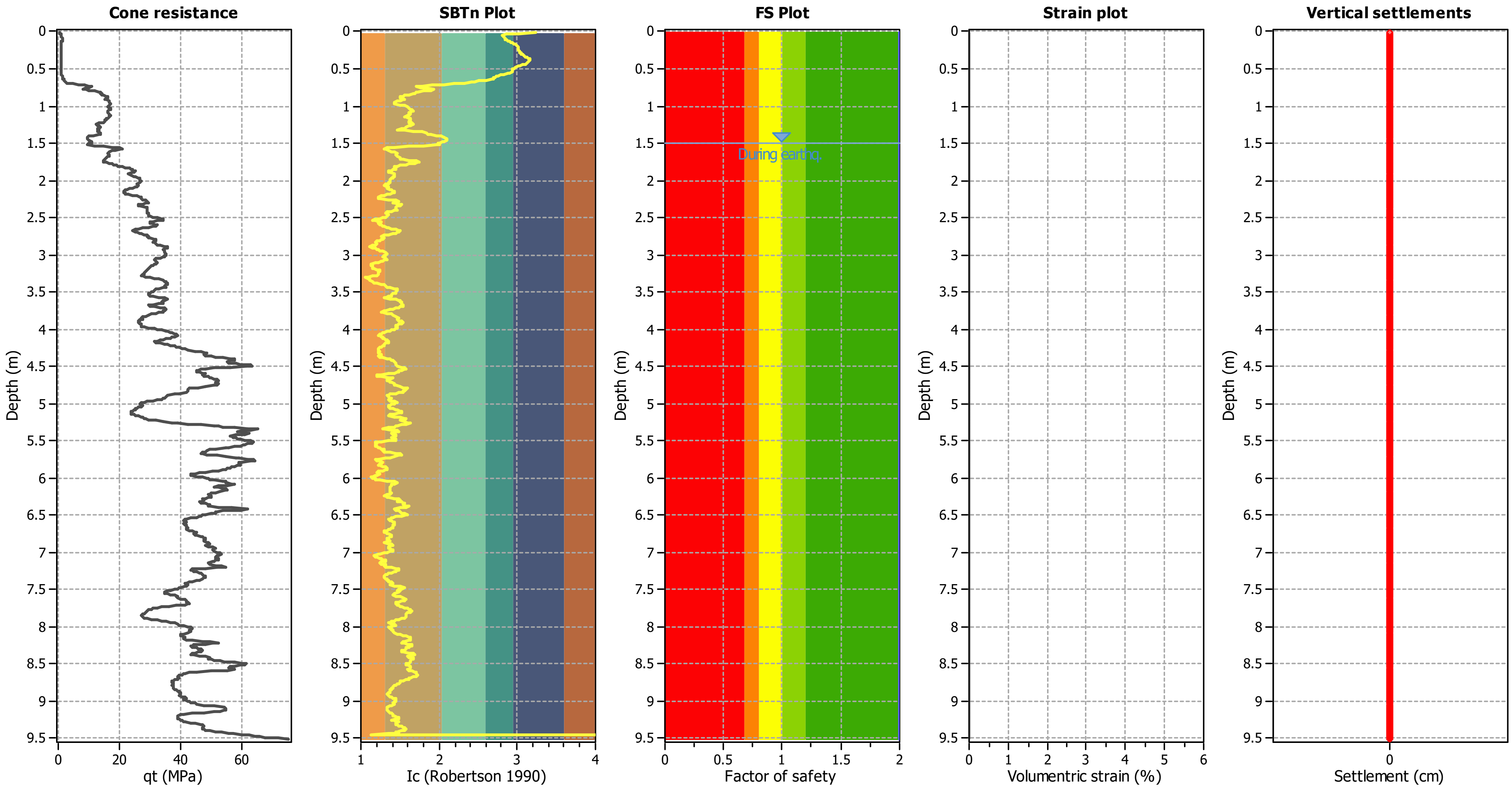
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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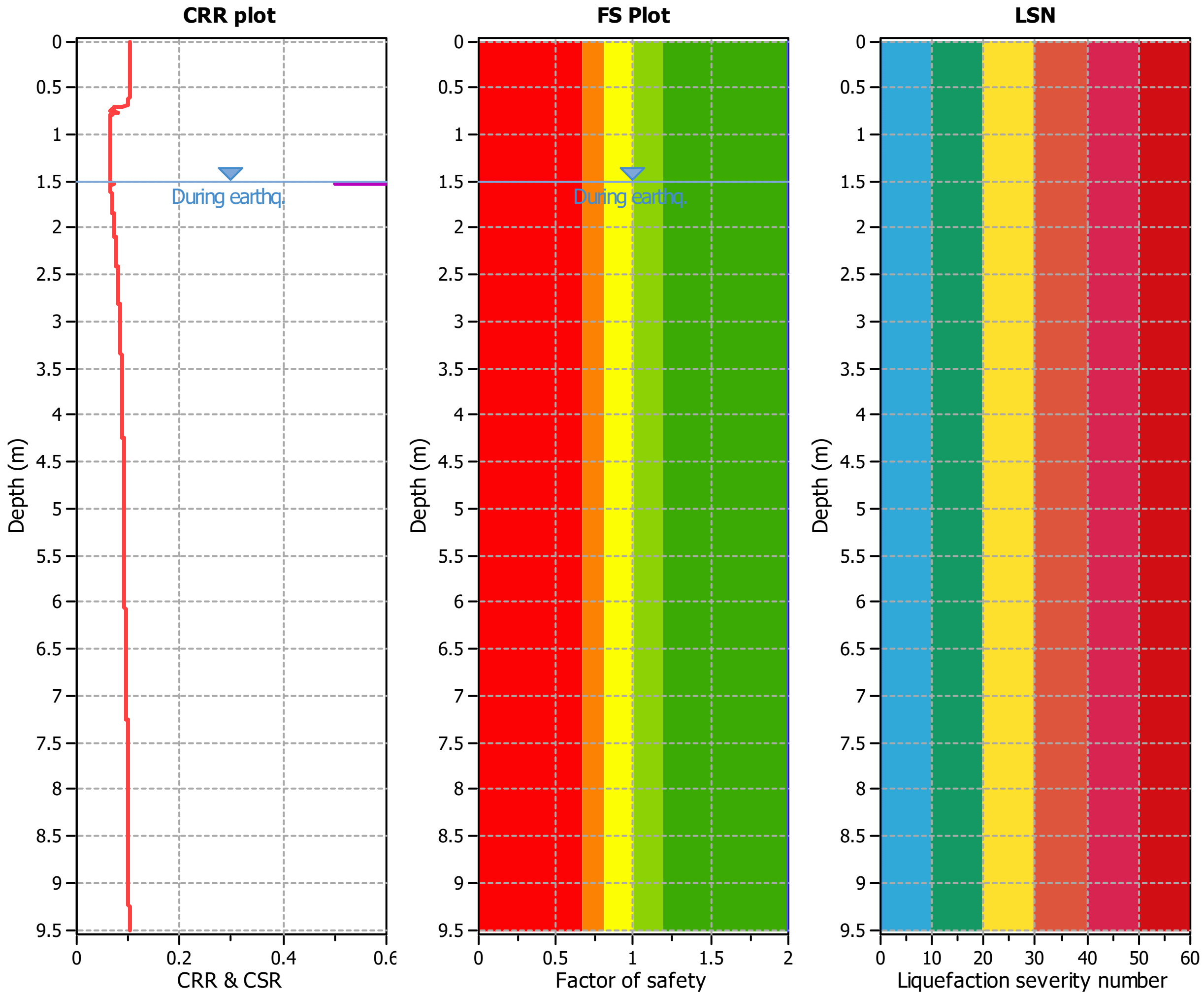
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT9
Total depth: 9.51 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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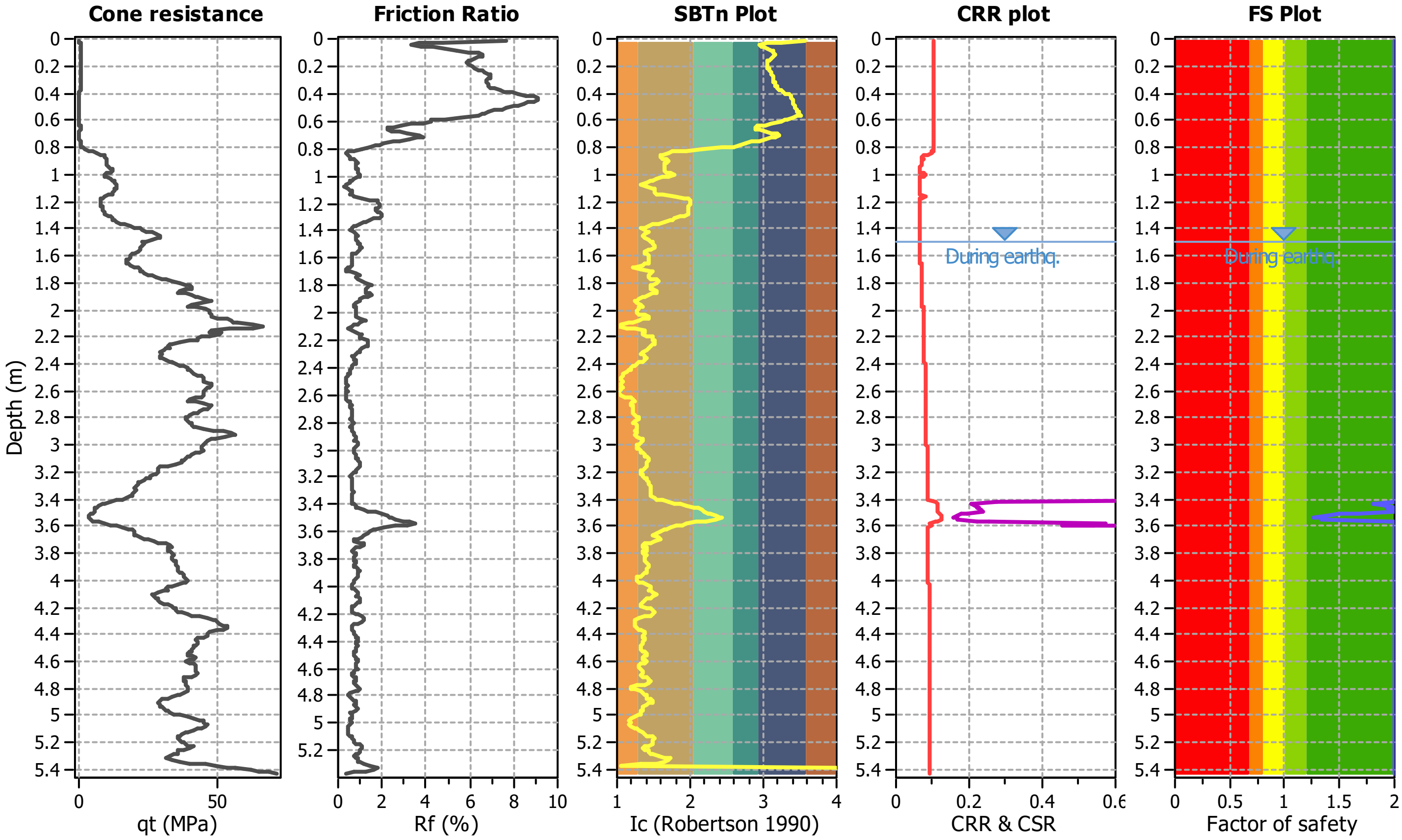
LIQUEFACTION ANALYSIS REPORT

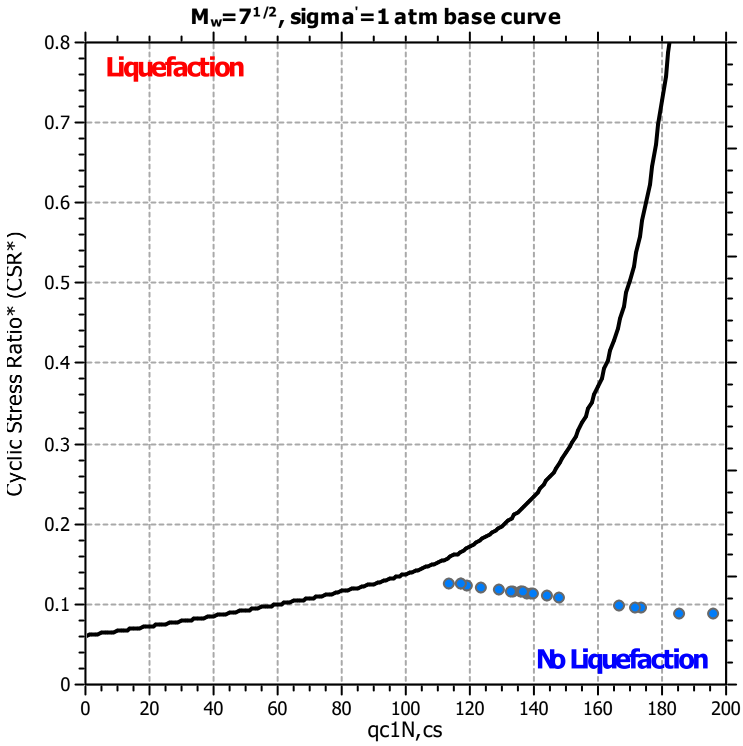
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

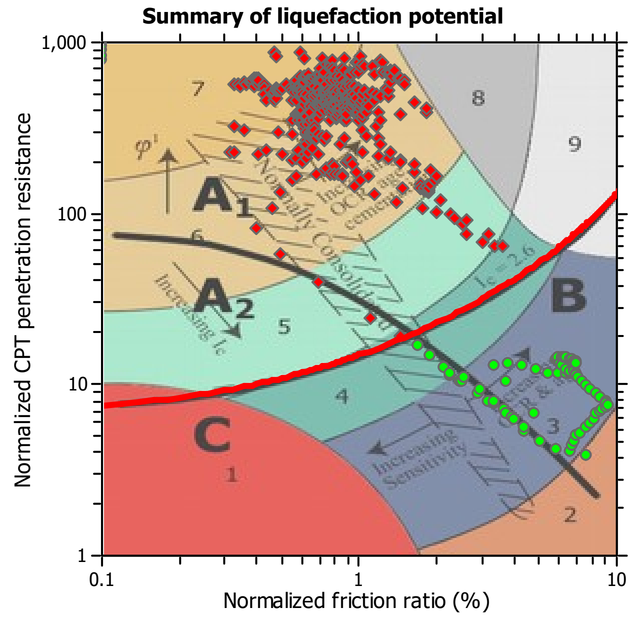
CPT file : CPT10

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

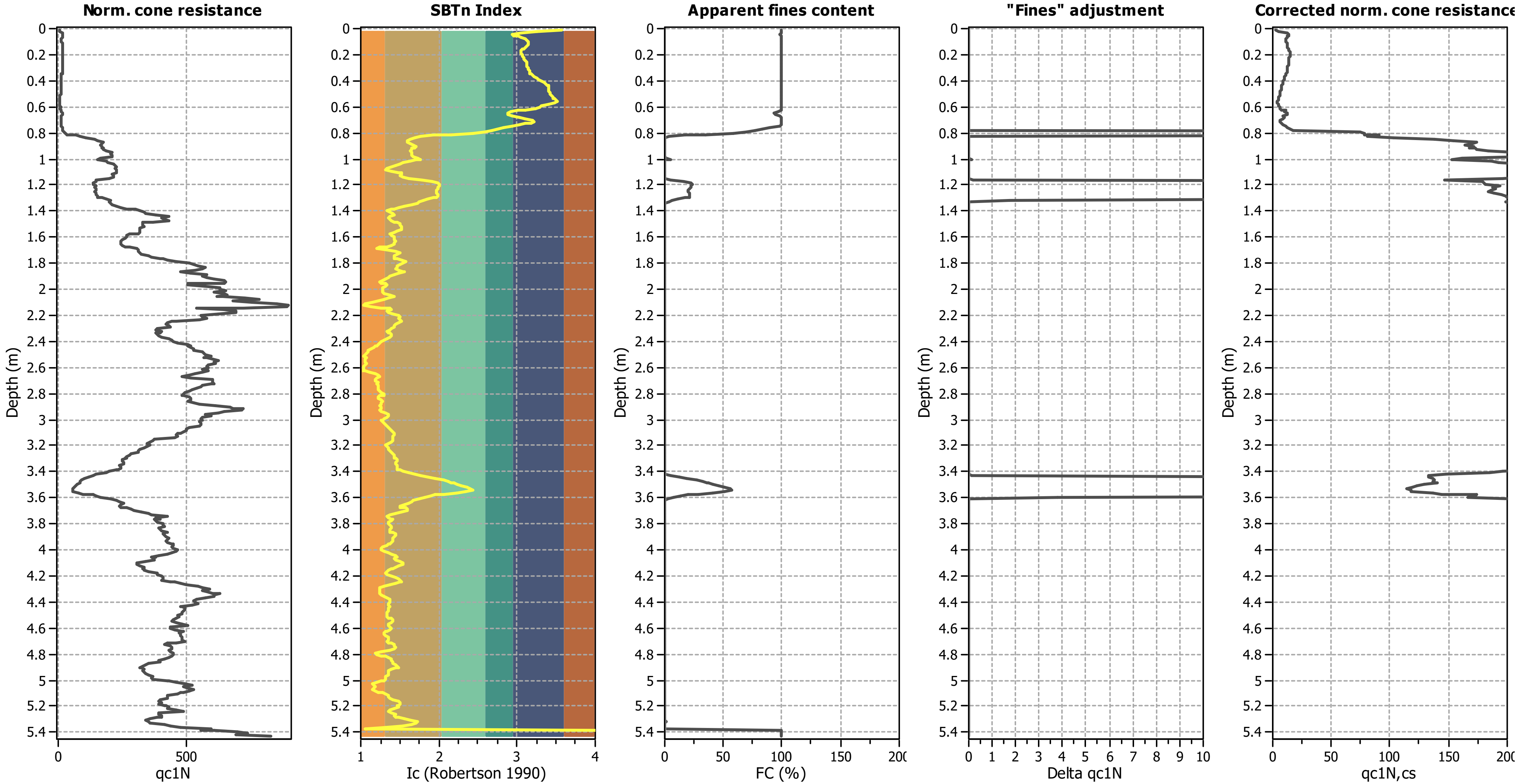






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

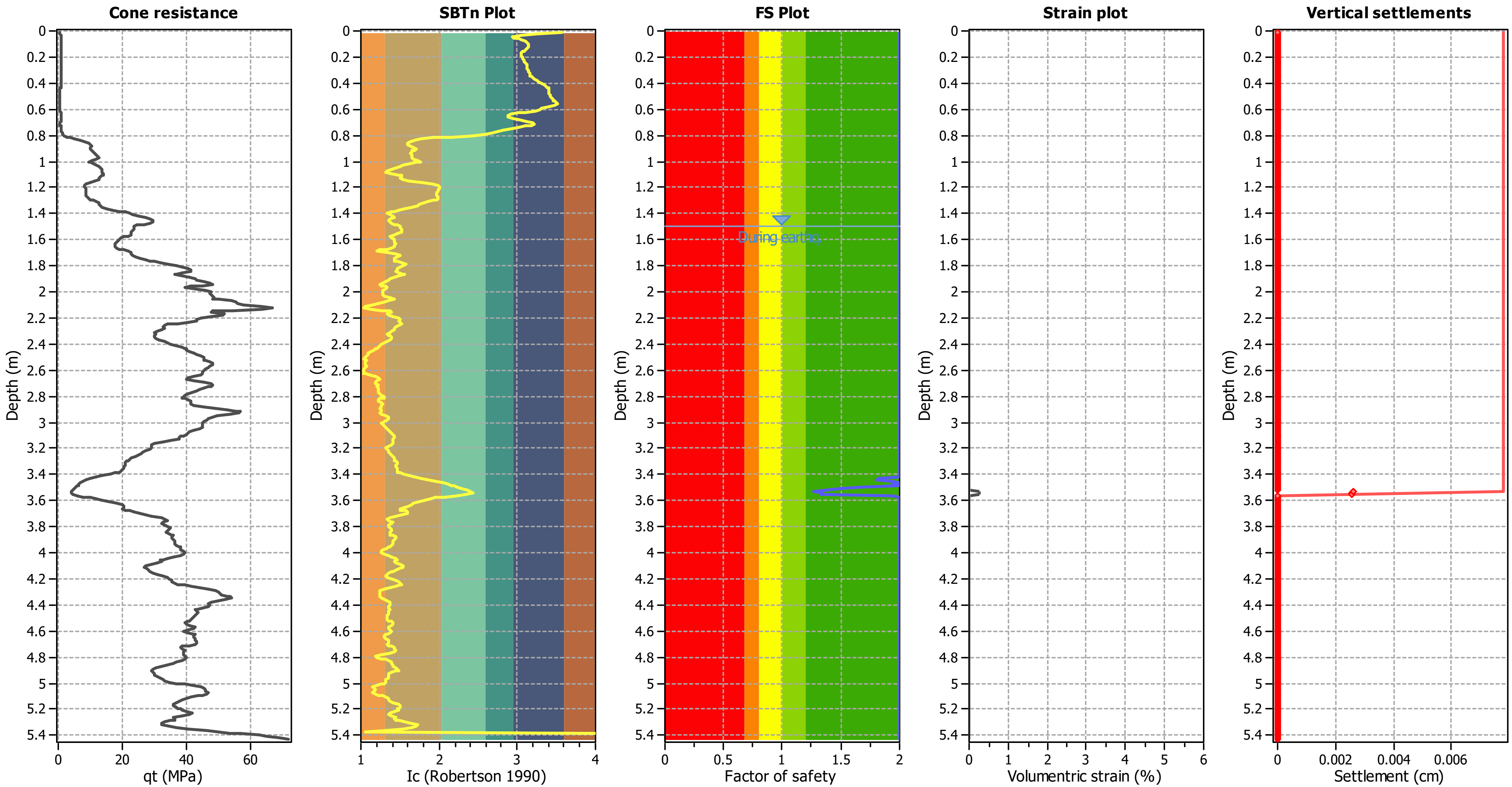
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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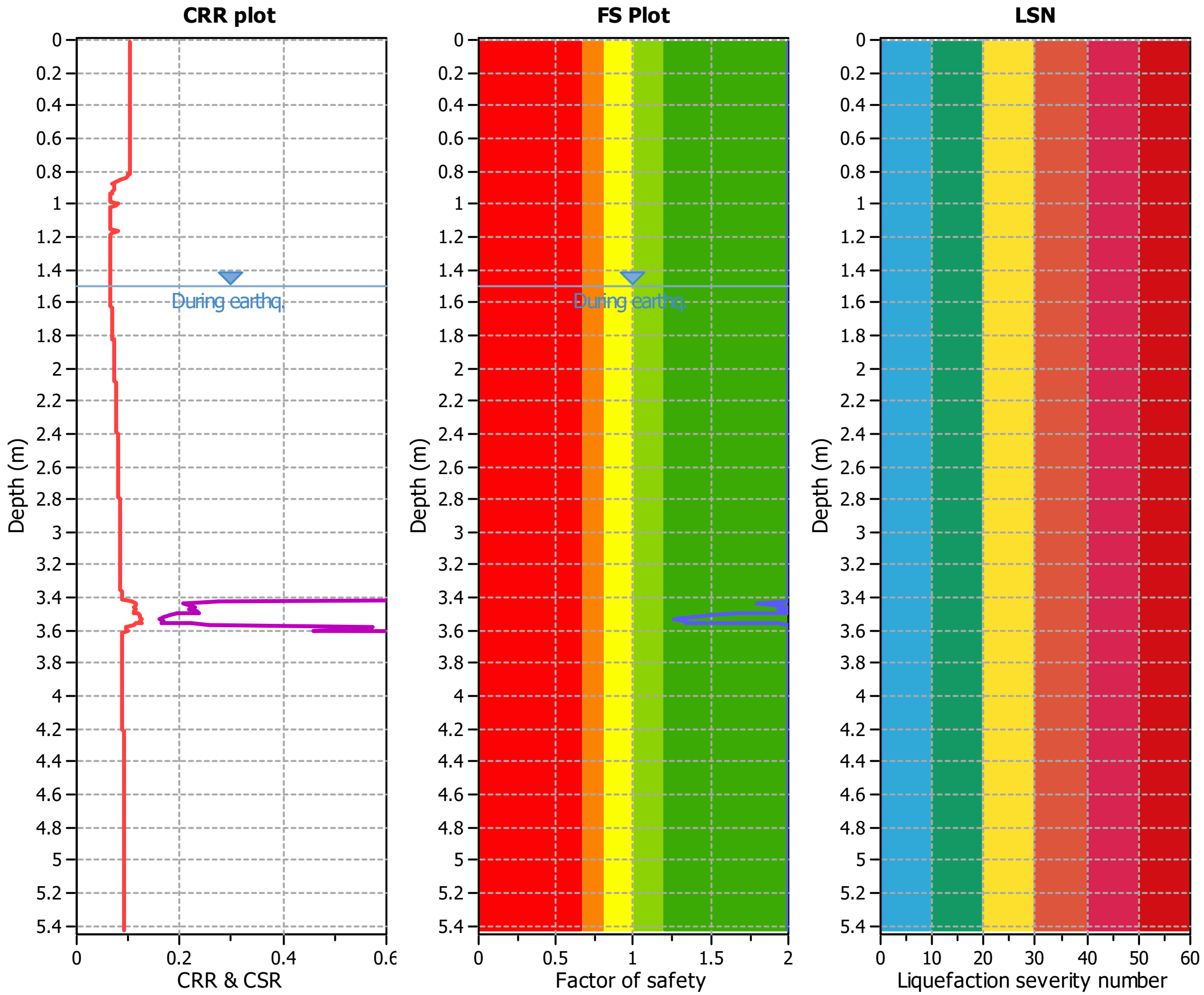
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT10
Total depth: 5.43 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

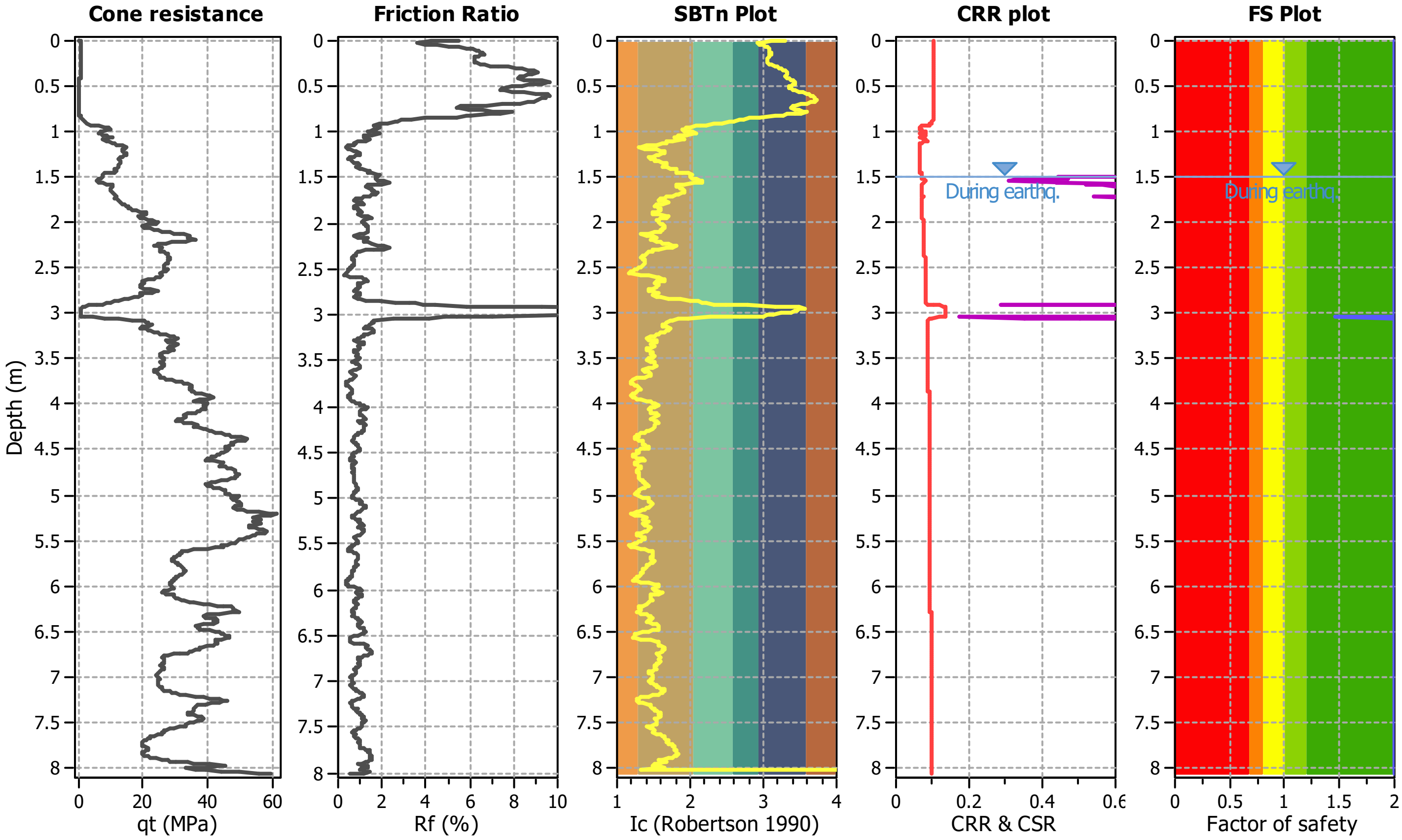
LIQUEFACTION ANALYSIS REPORT

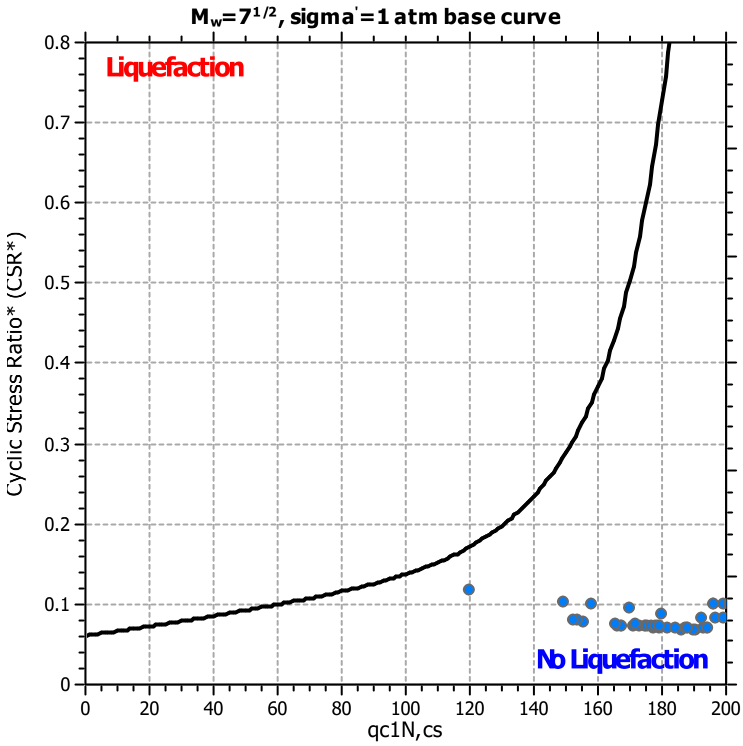
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

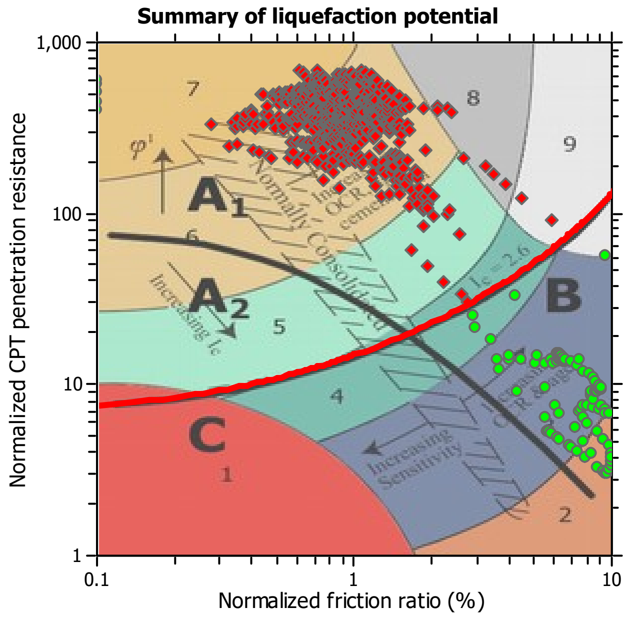
CPT file : CPT11

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

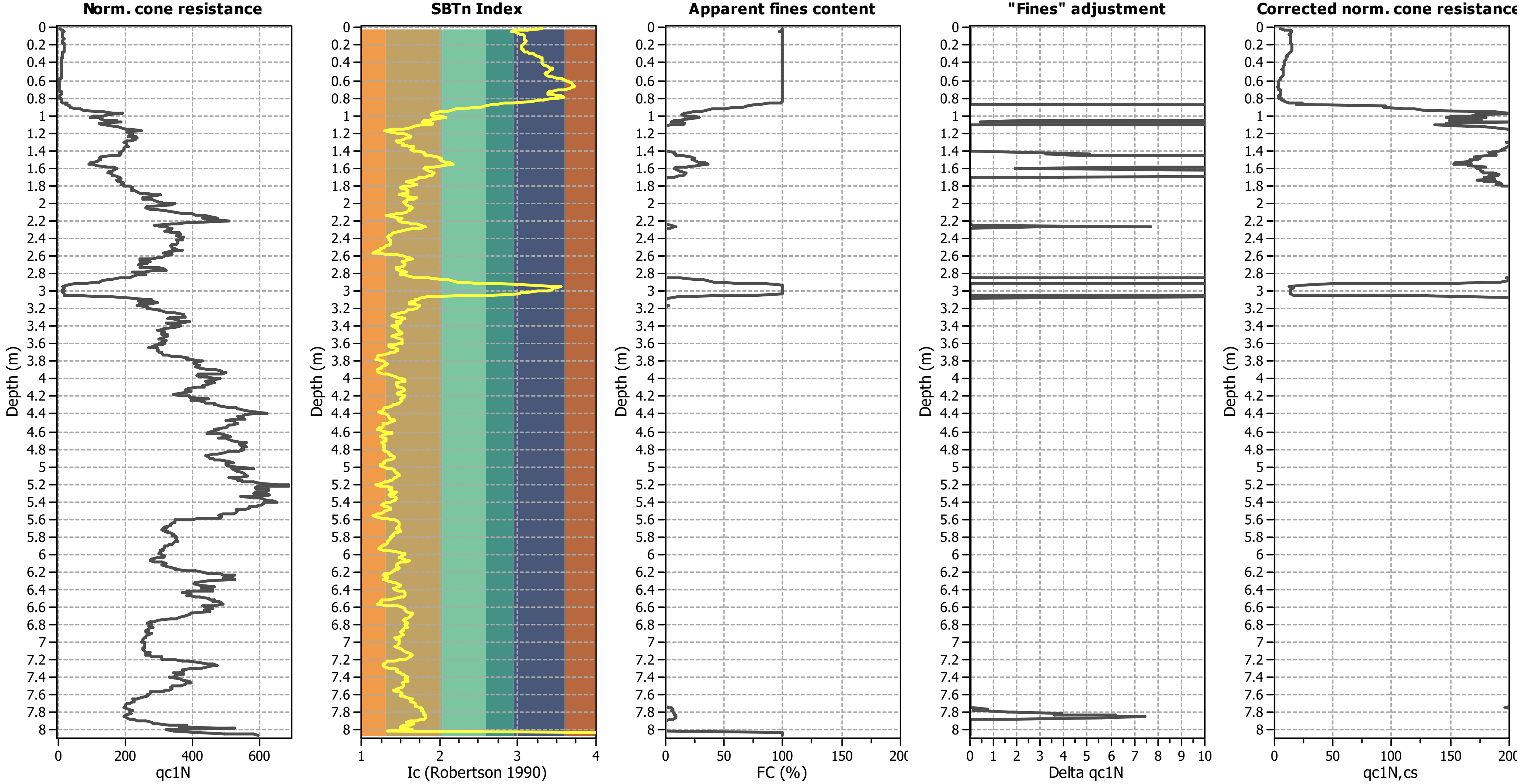






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

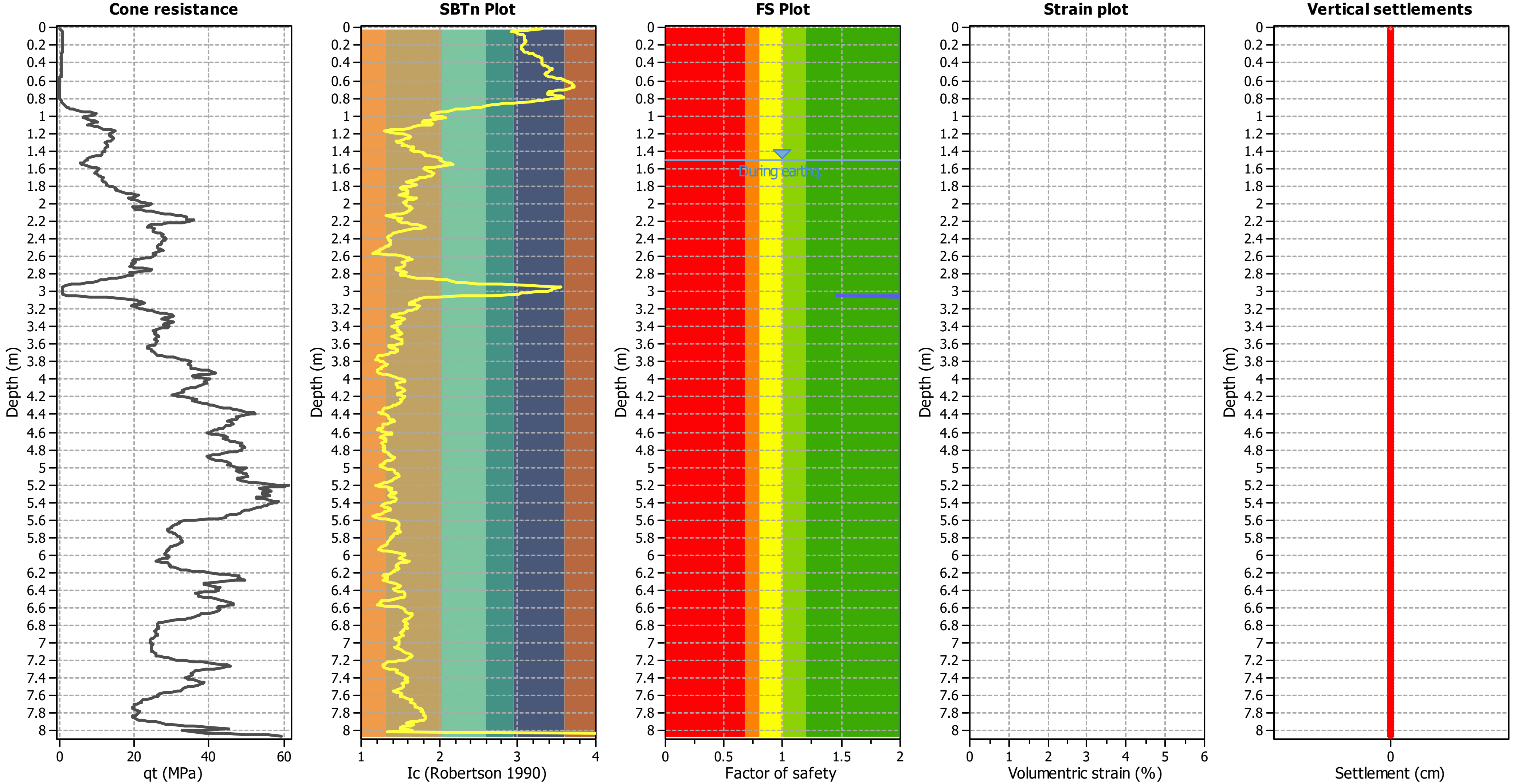
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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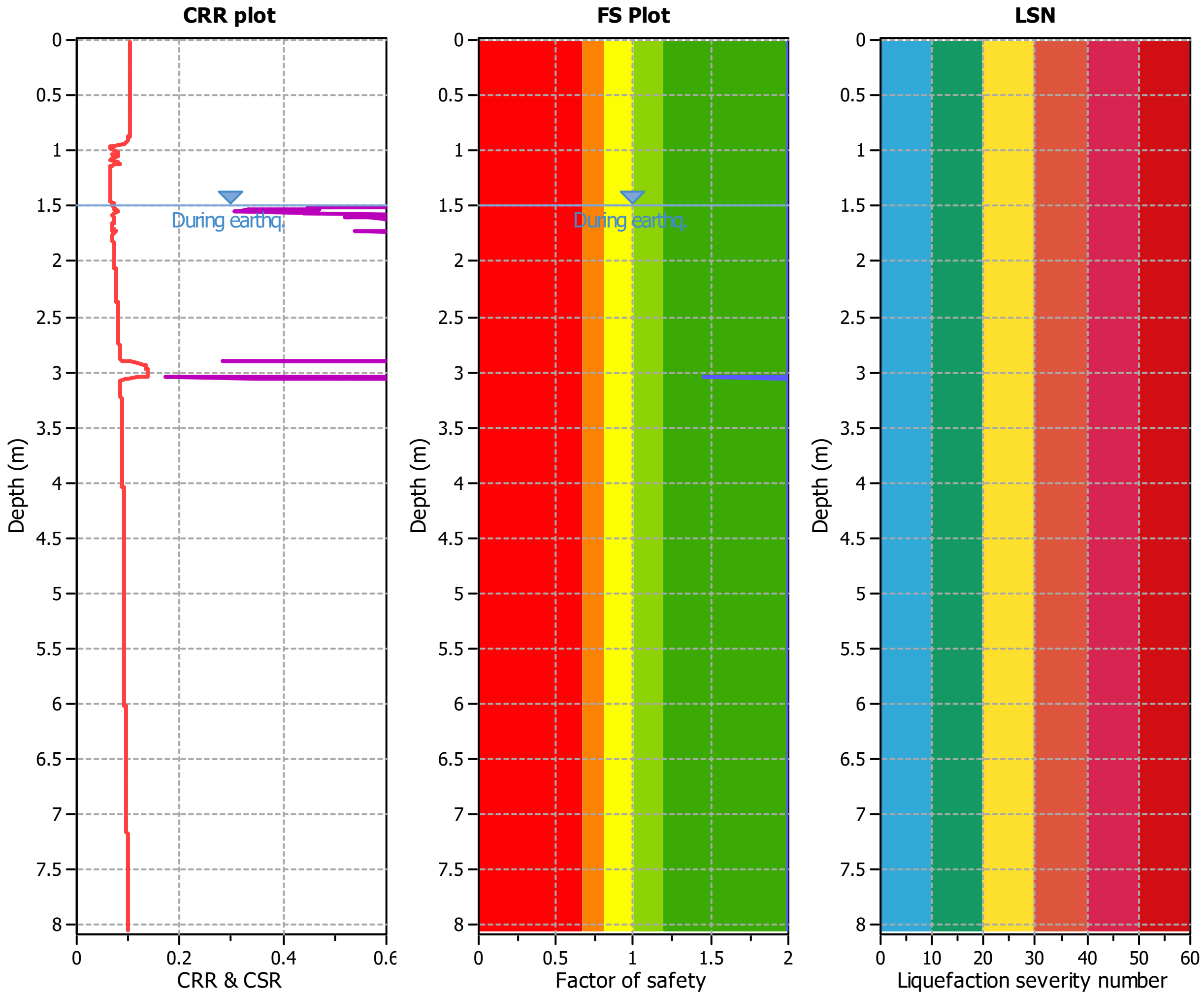
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT11
Total depth: 8.06 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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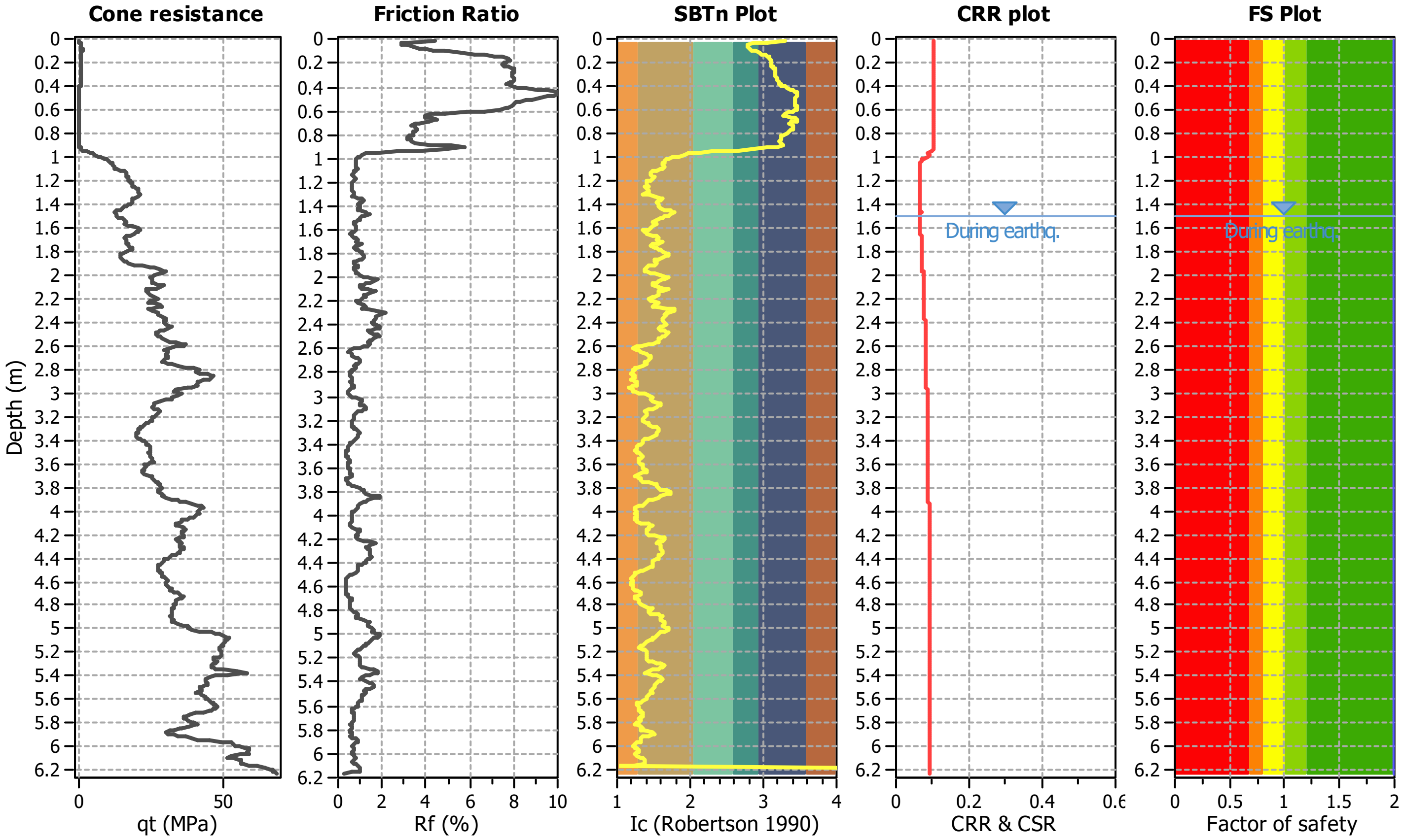
LIQUEFACTION ANALYSIS REPORT

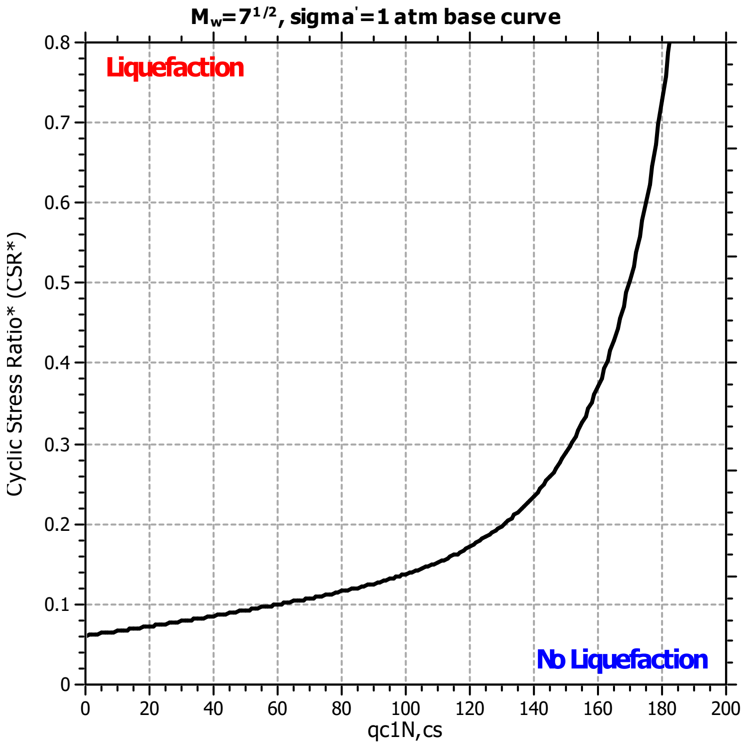
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

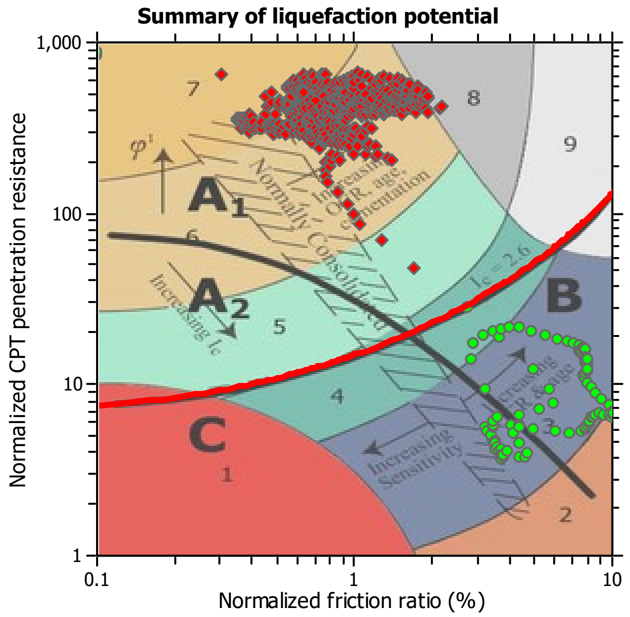
CPT file : CPT12

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

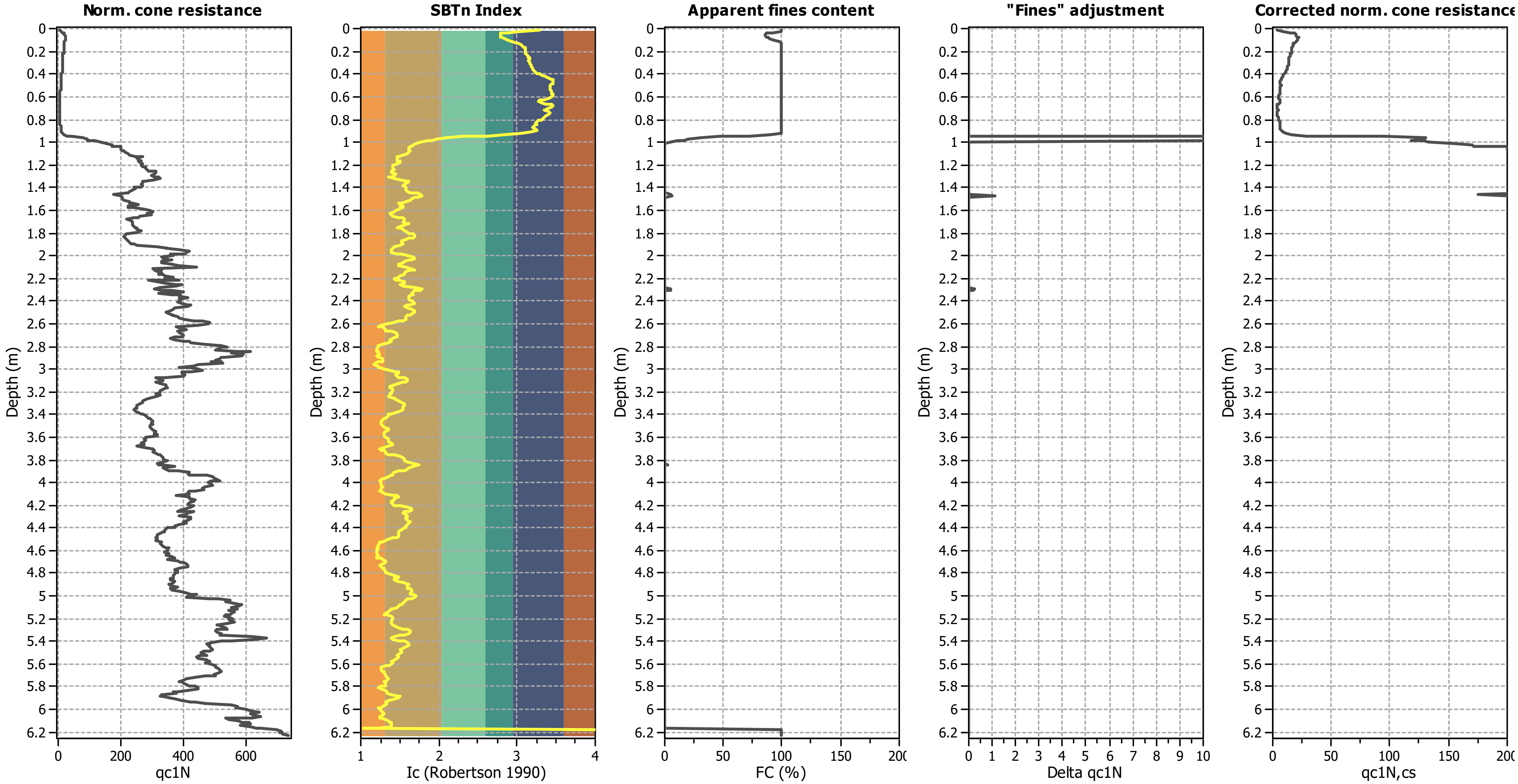






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

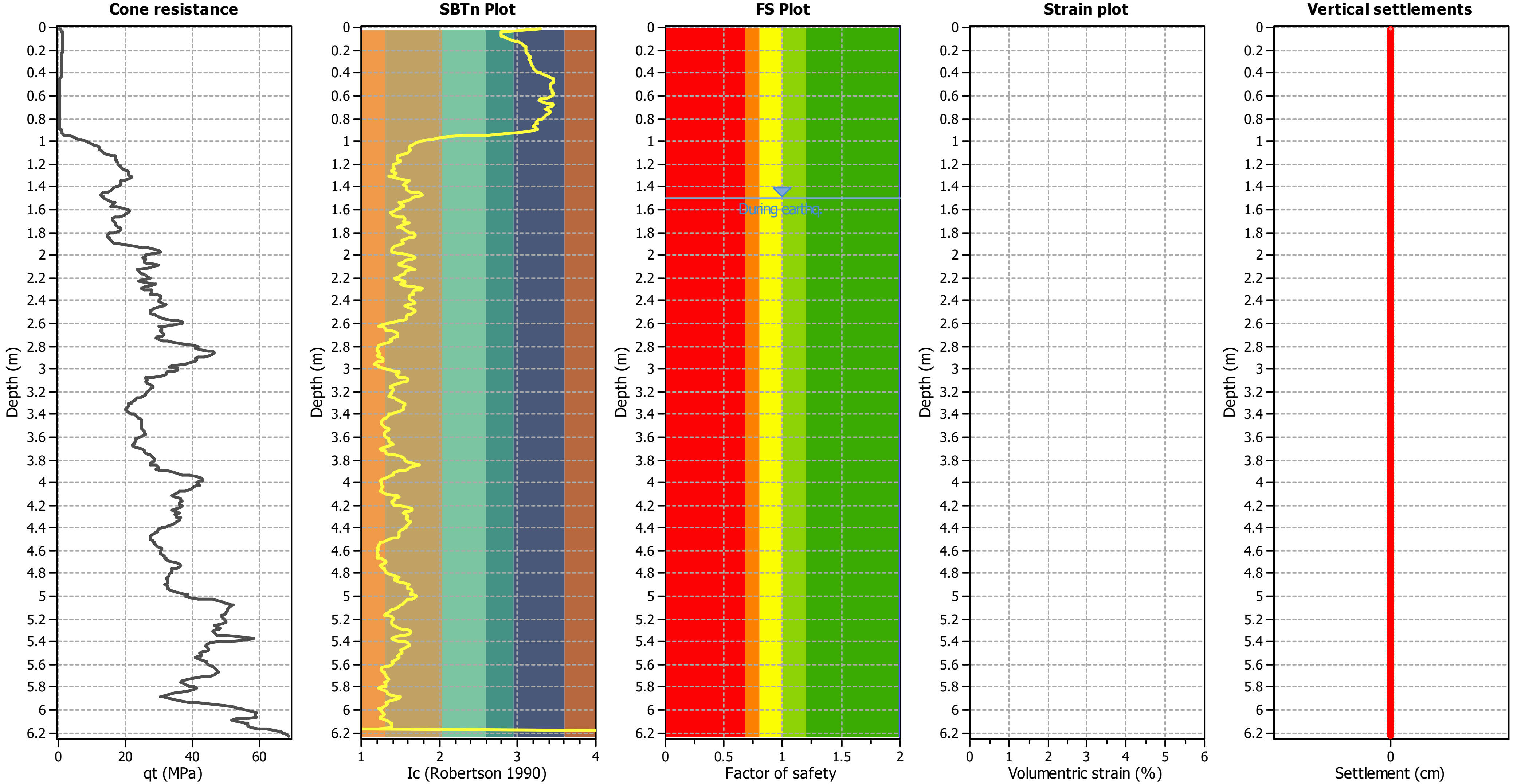
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

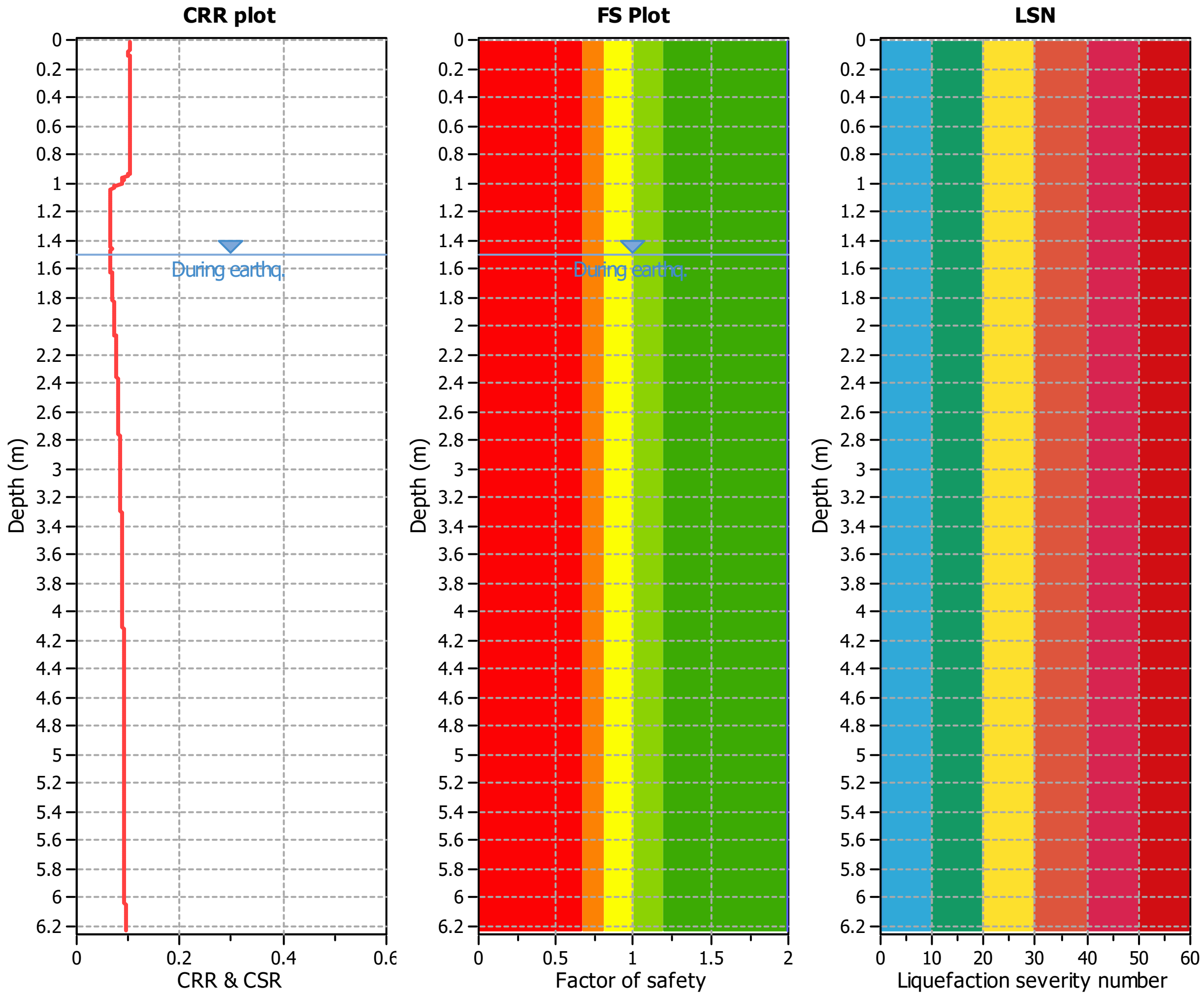


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT12
Total depth: 6.23 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

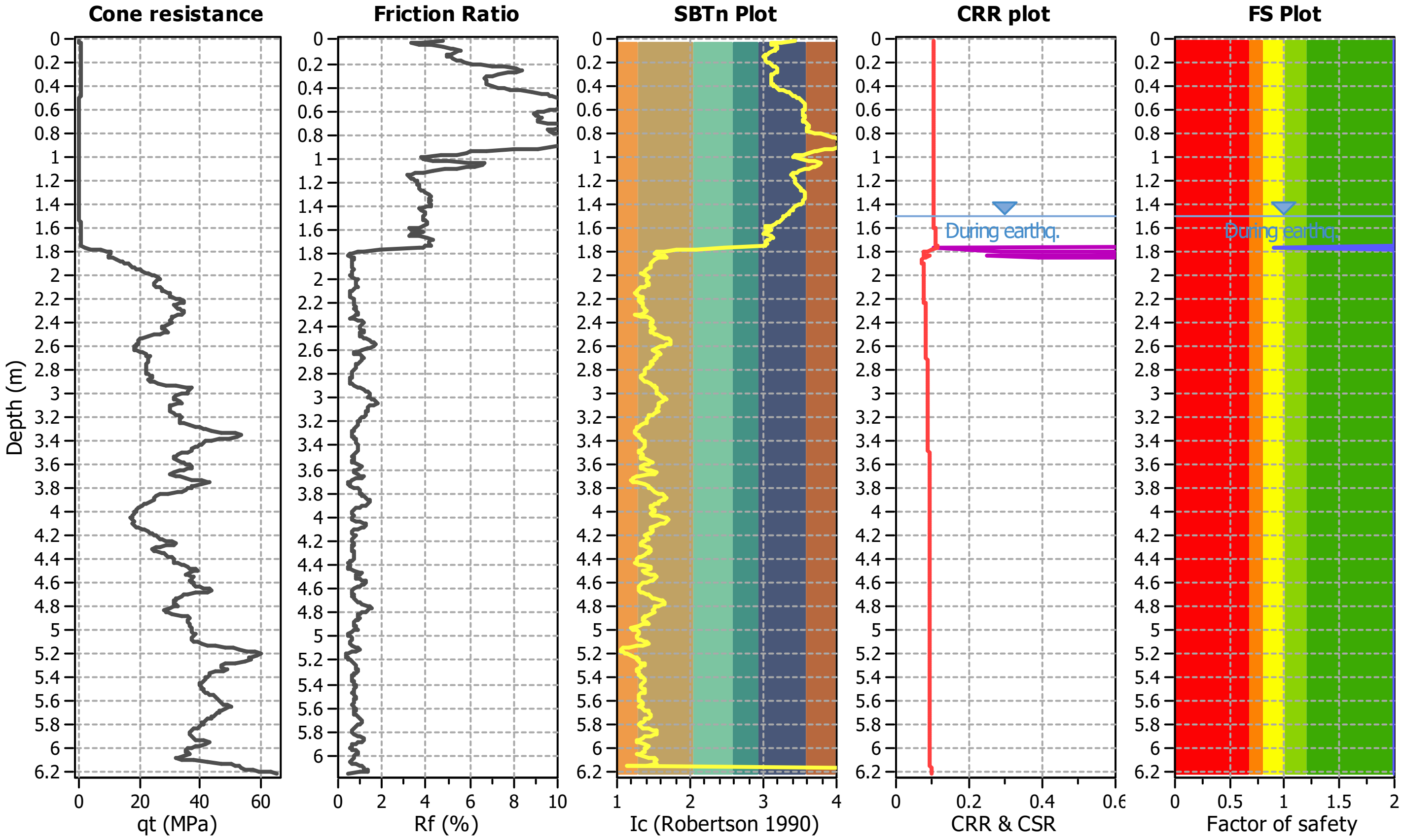
LIQUEFACTION ANALYSIS REPORT

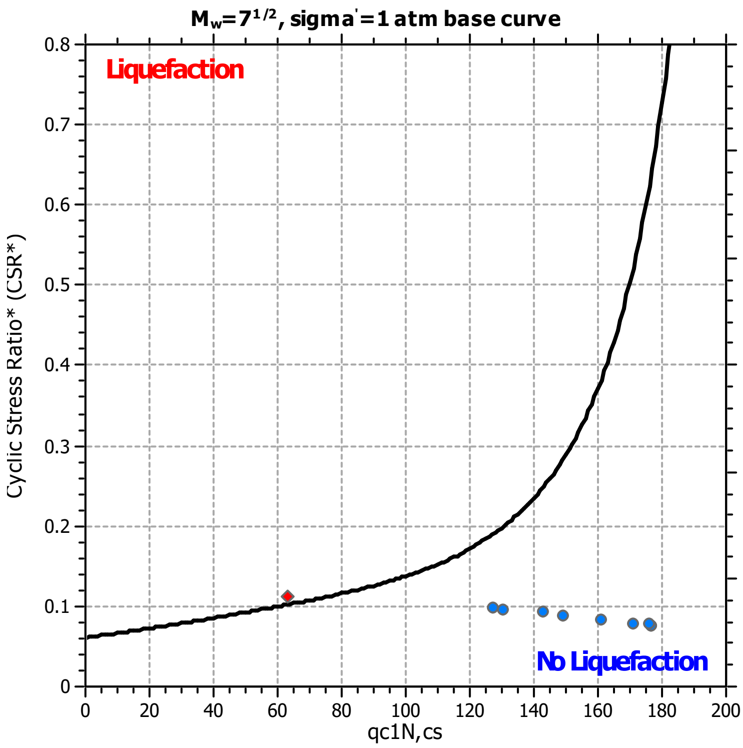
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

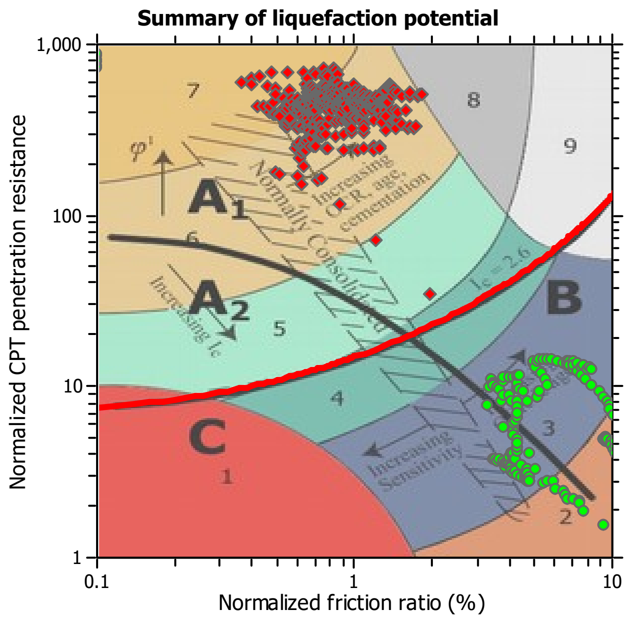
CPT file : CPT13

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

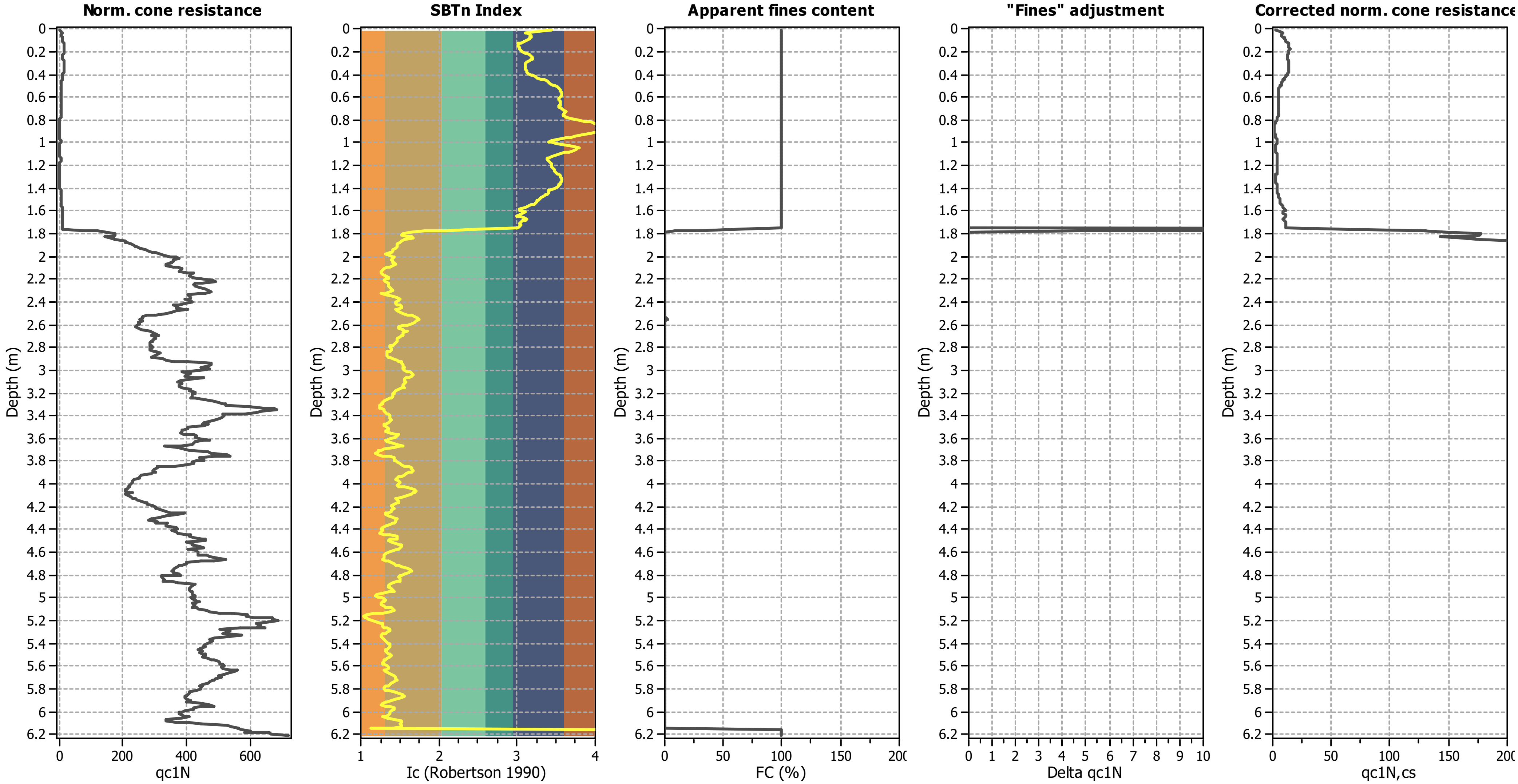






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

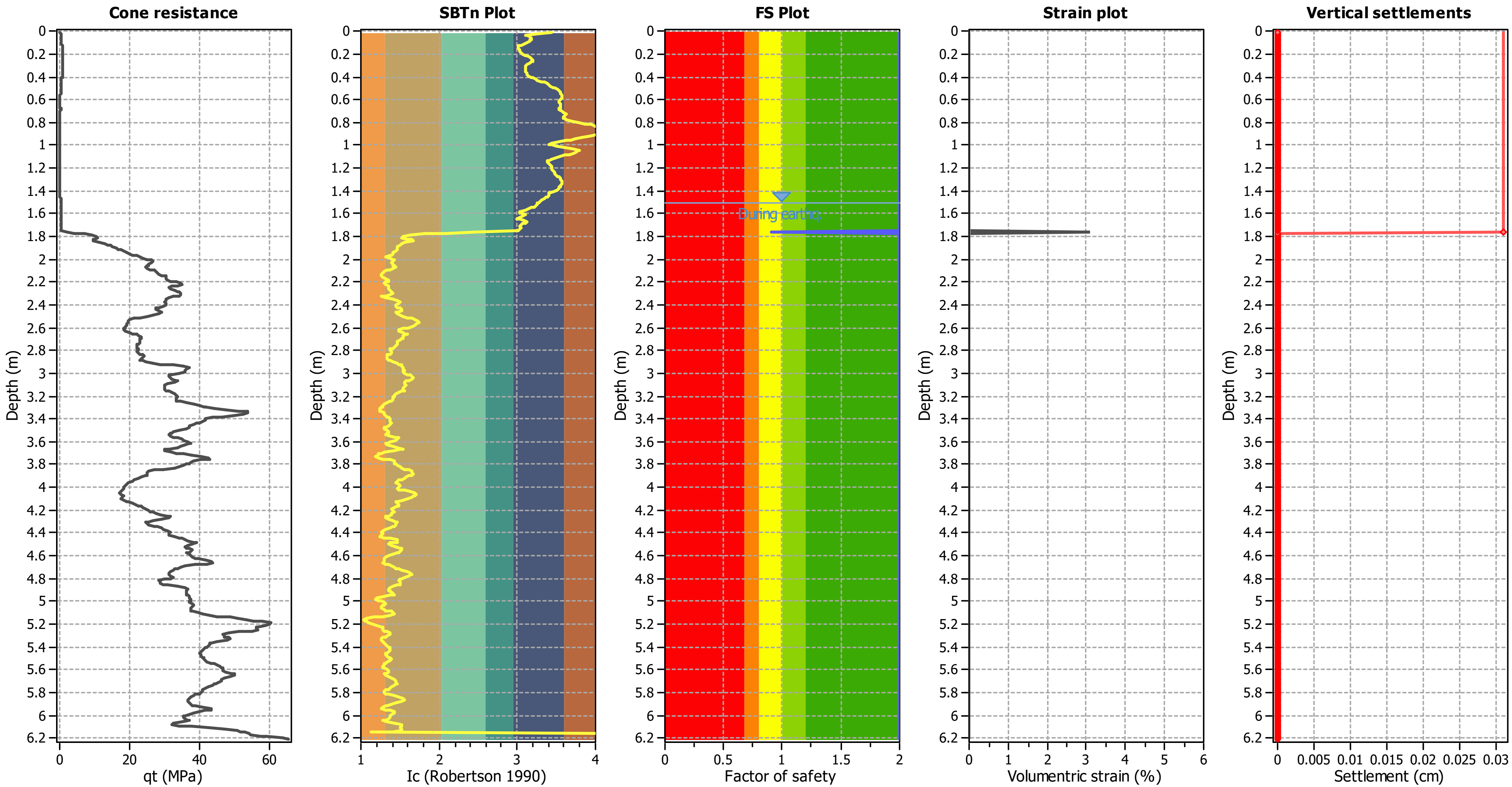
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.19	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

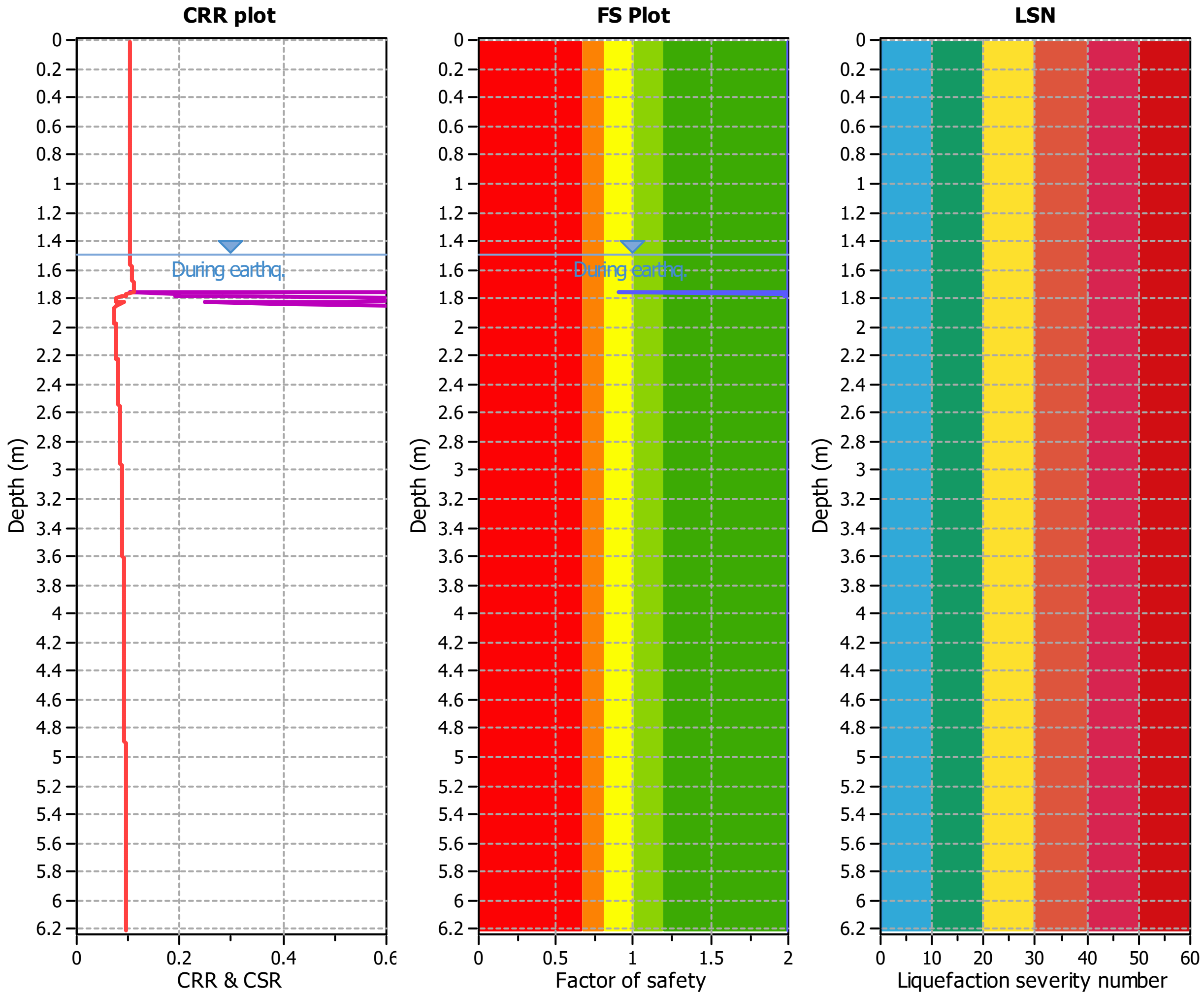


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT13
Total depth: 6.21 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	6.00	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.19	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

Ultimate Limit State (ULS) Design Earthquake Event

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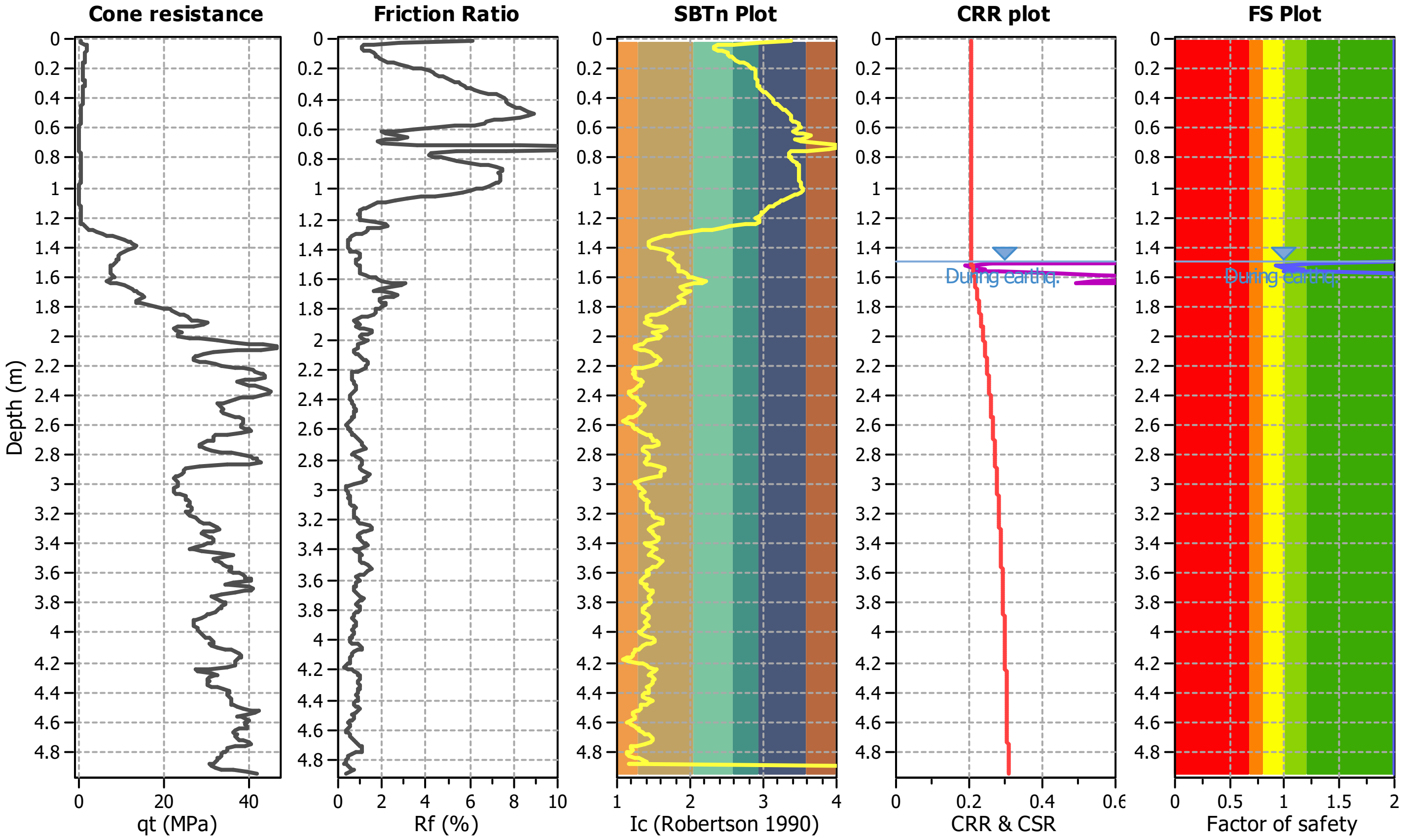
LIQUEFACTION ANALYSIS REPORT

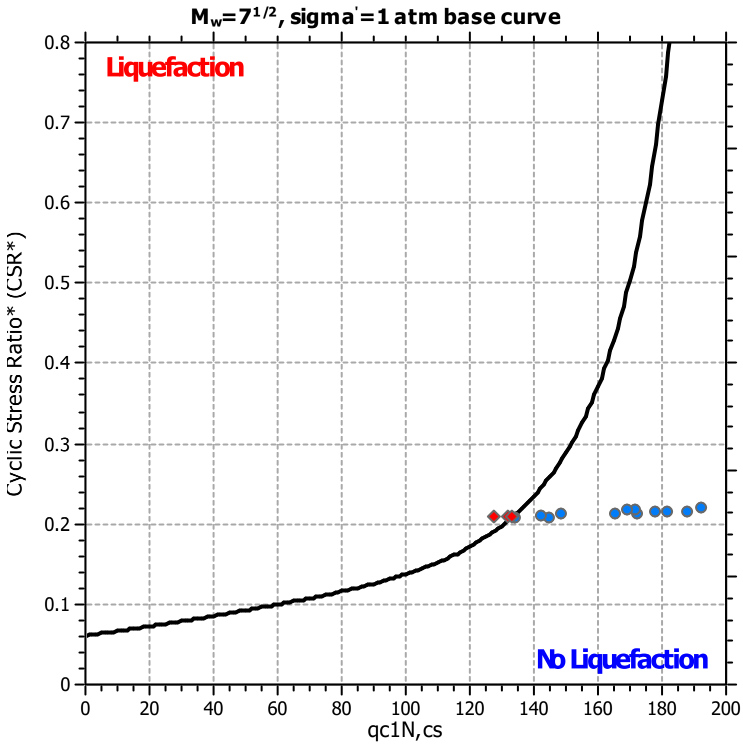
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

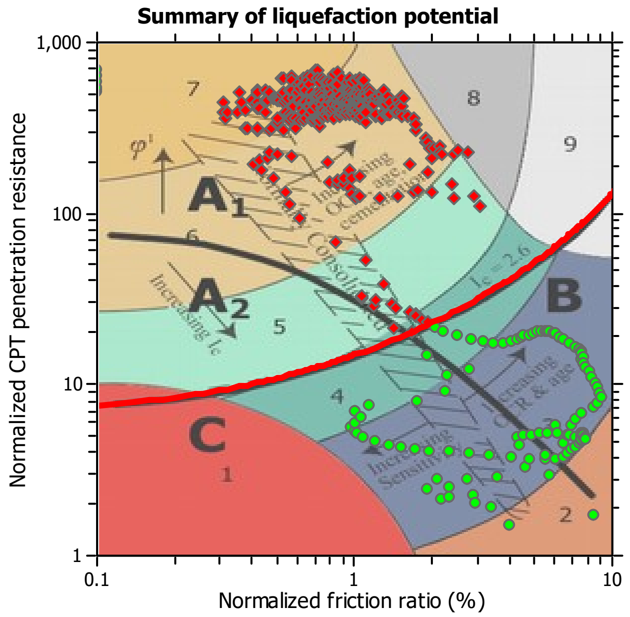
CPT file : CPT1

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

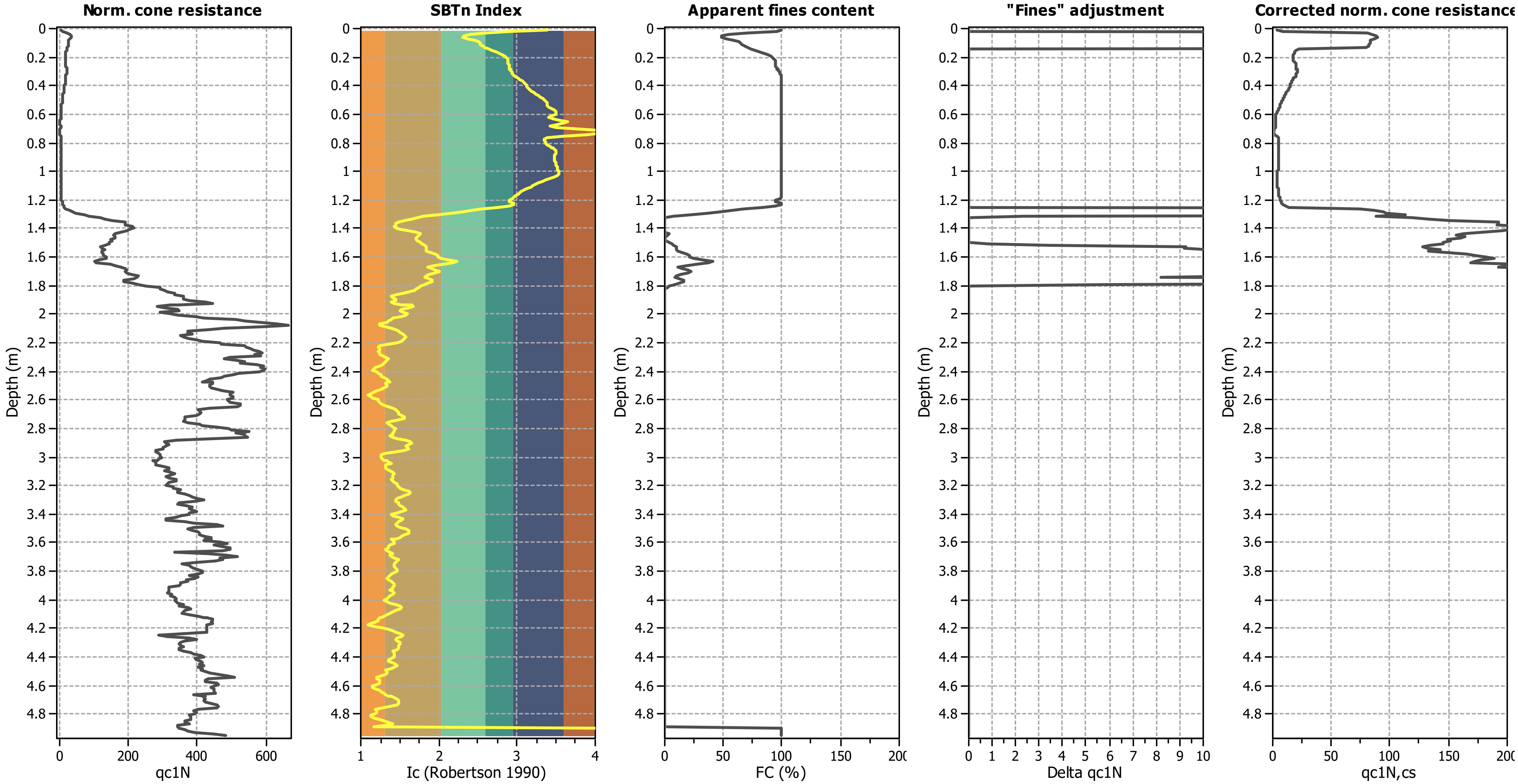






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

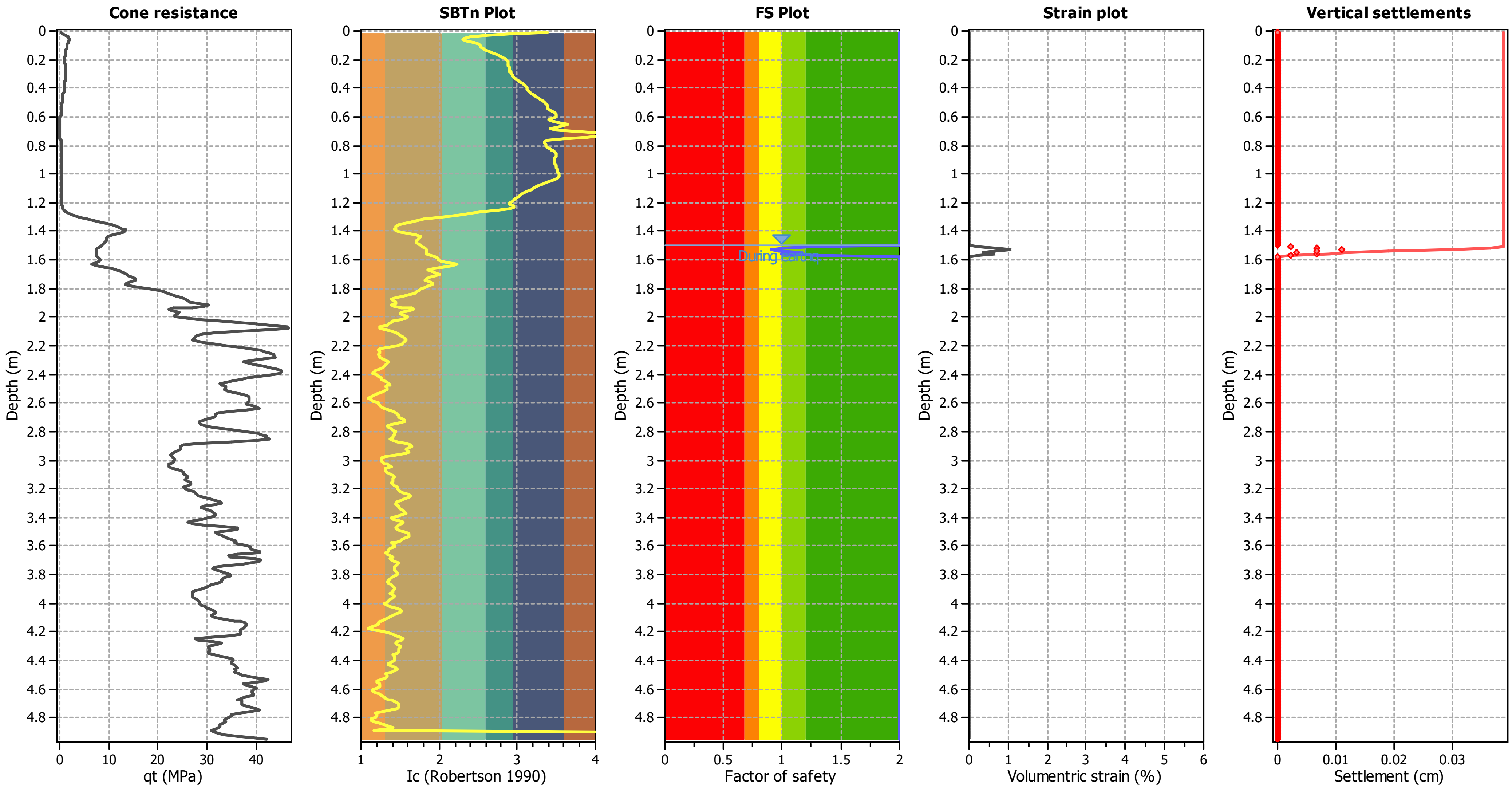
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

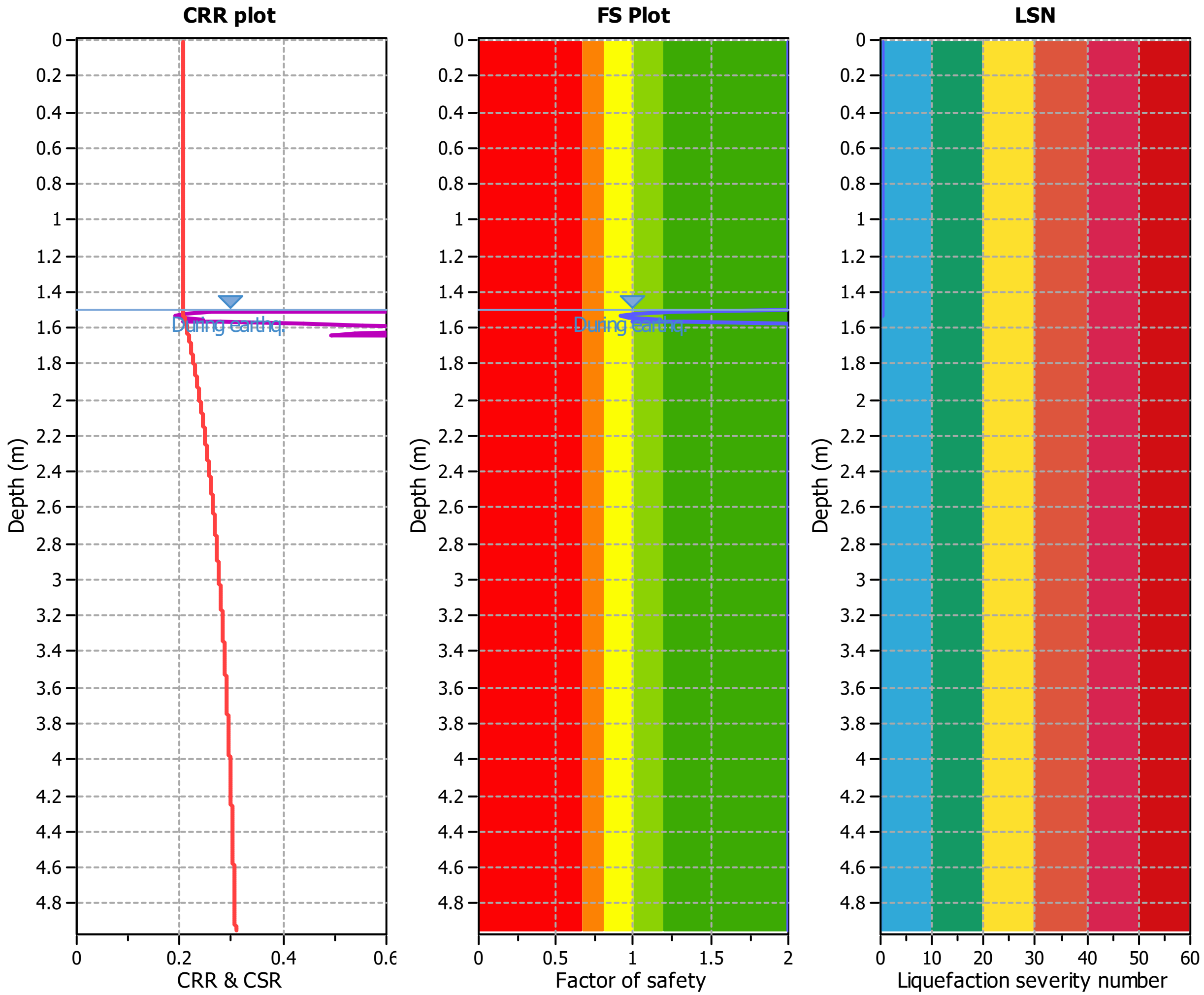
q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark

Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT1

Total depth: 4.95 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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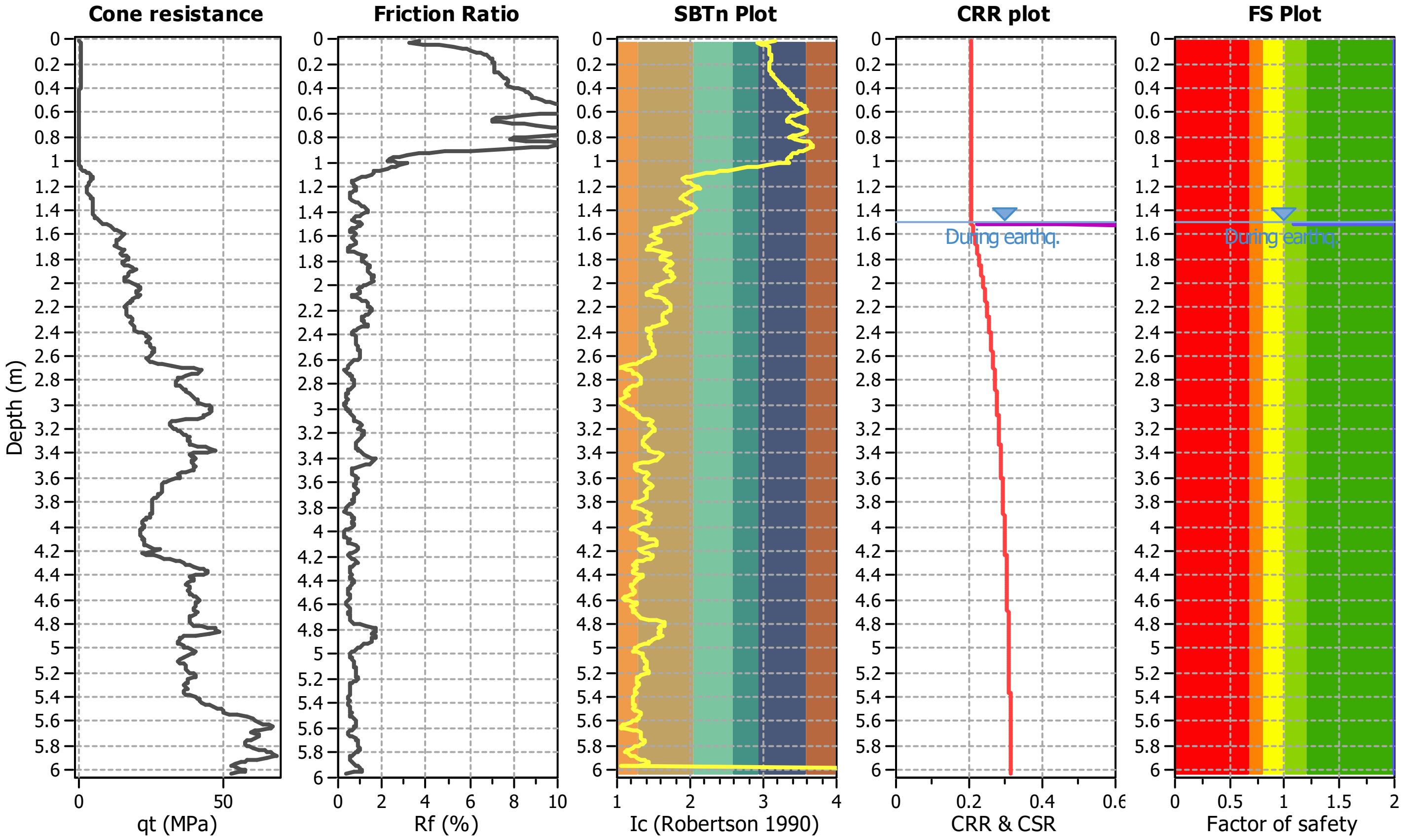
LIQUEFACTION ANALYSIS REPORT

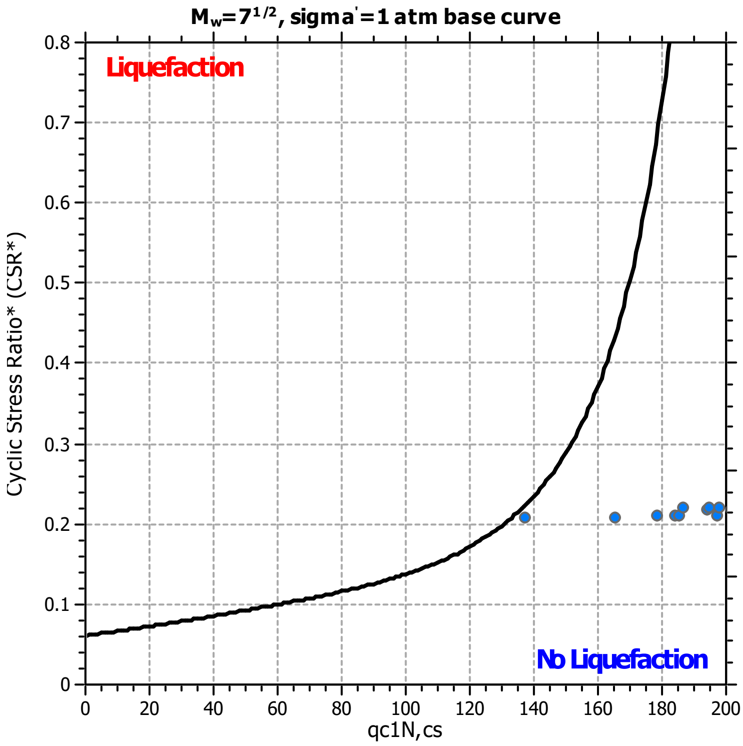
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

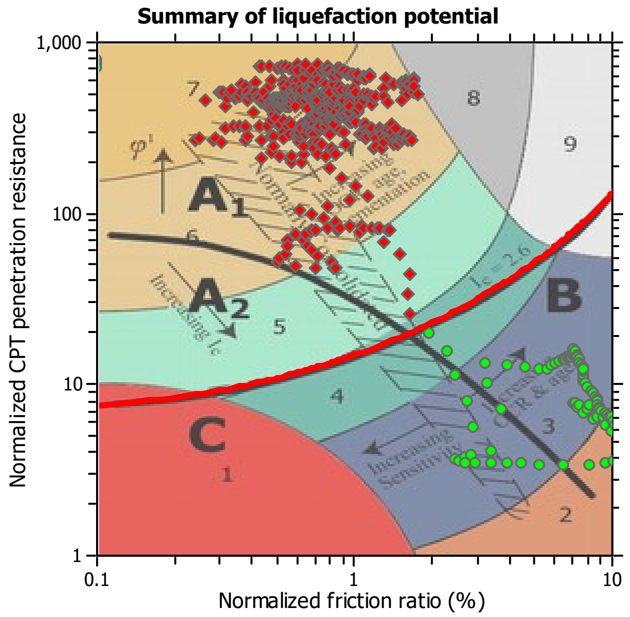
CPT file : CPT2

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

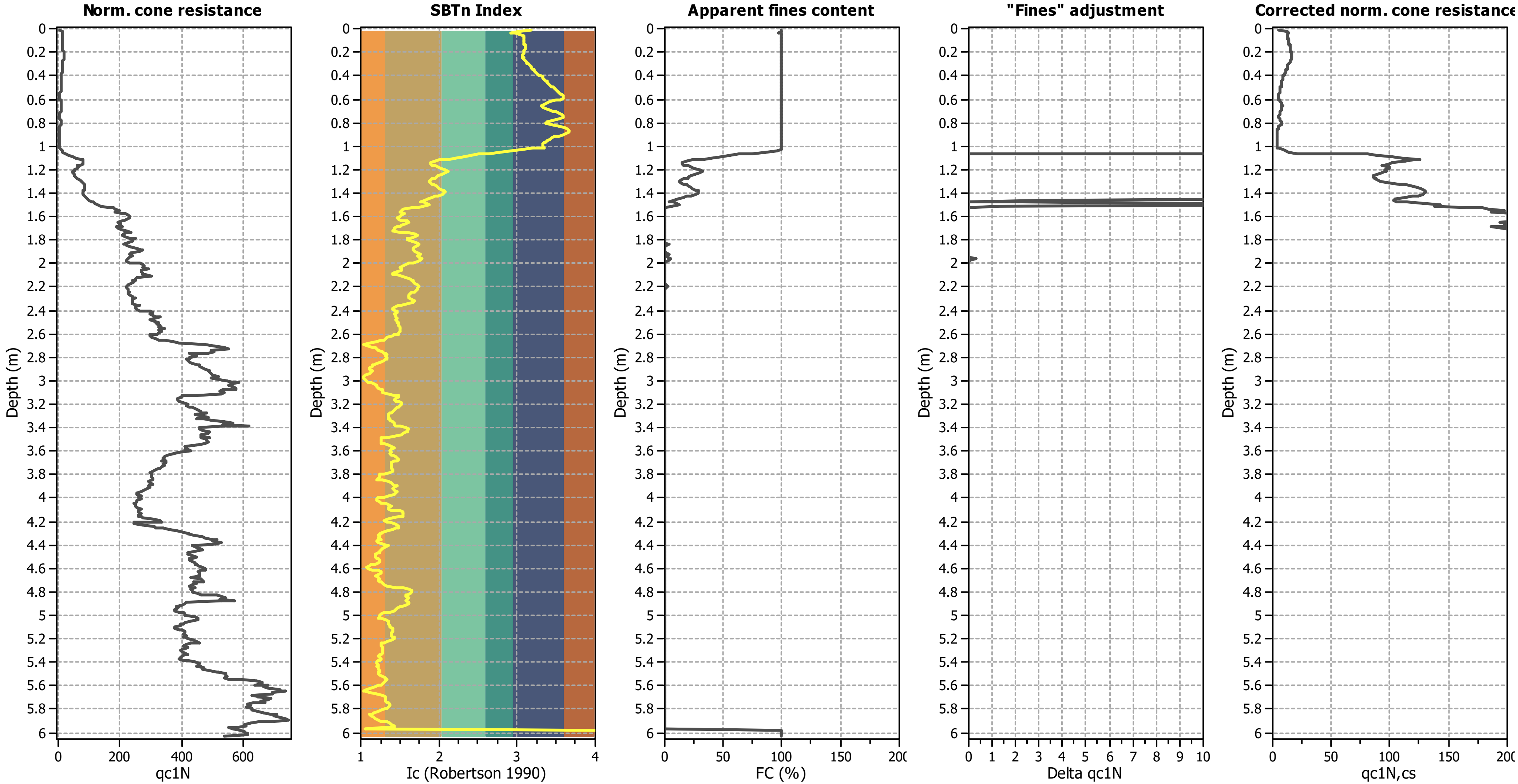






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

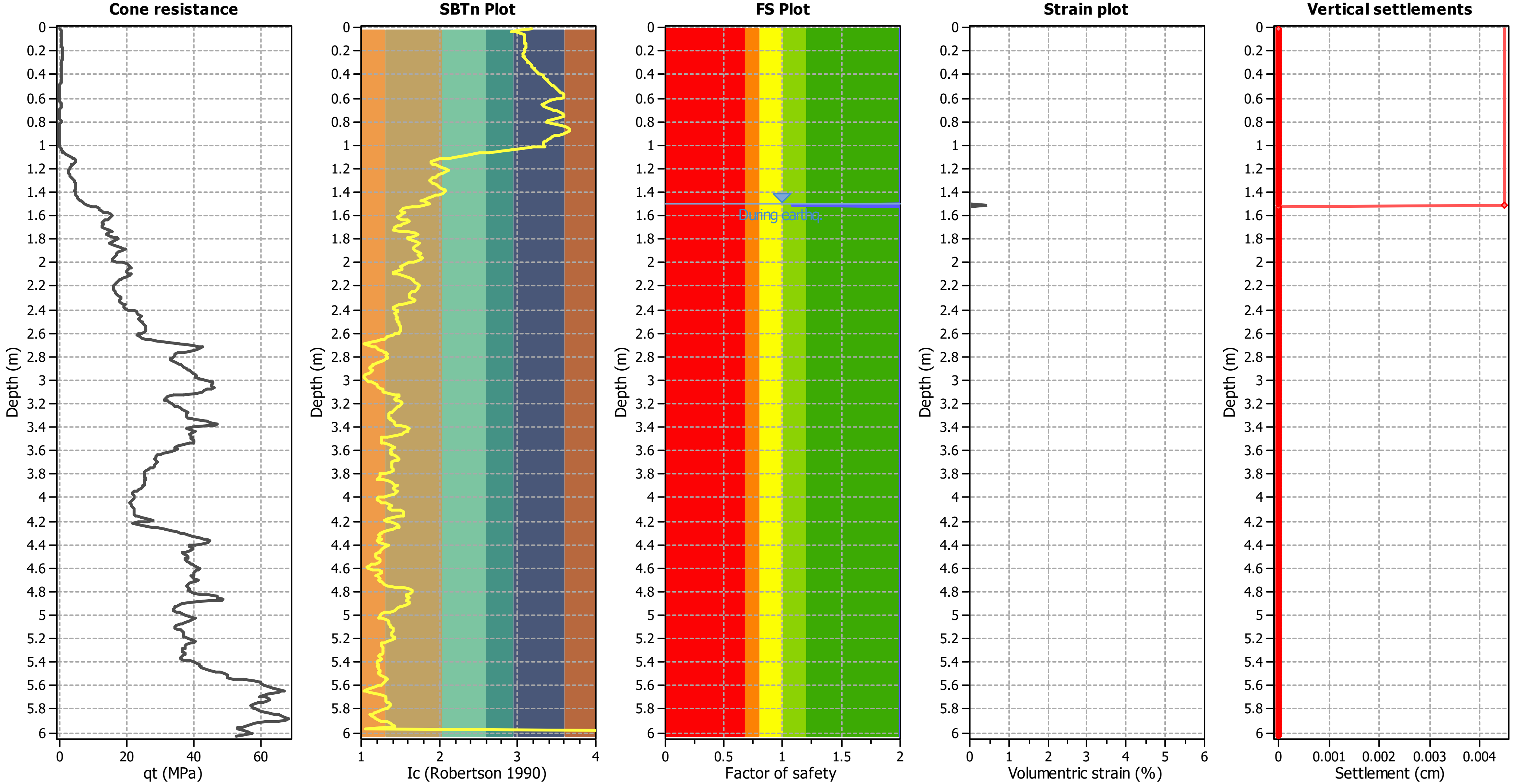
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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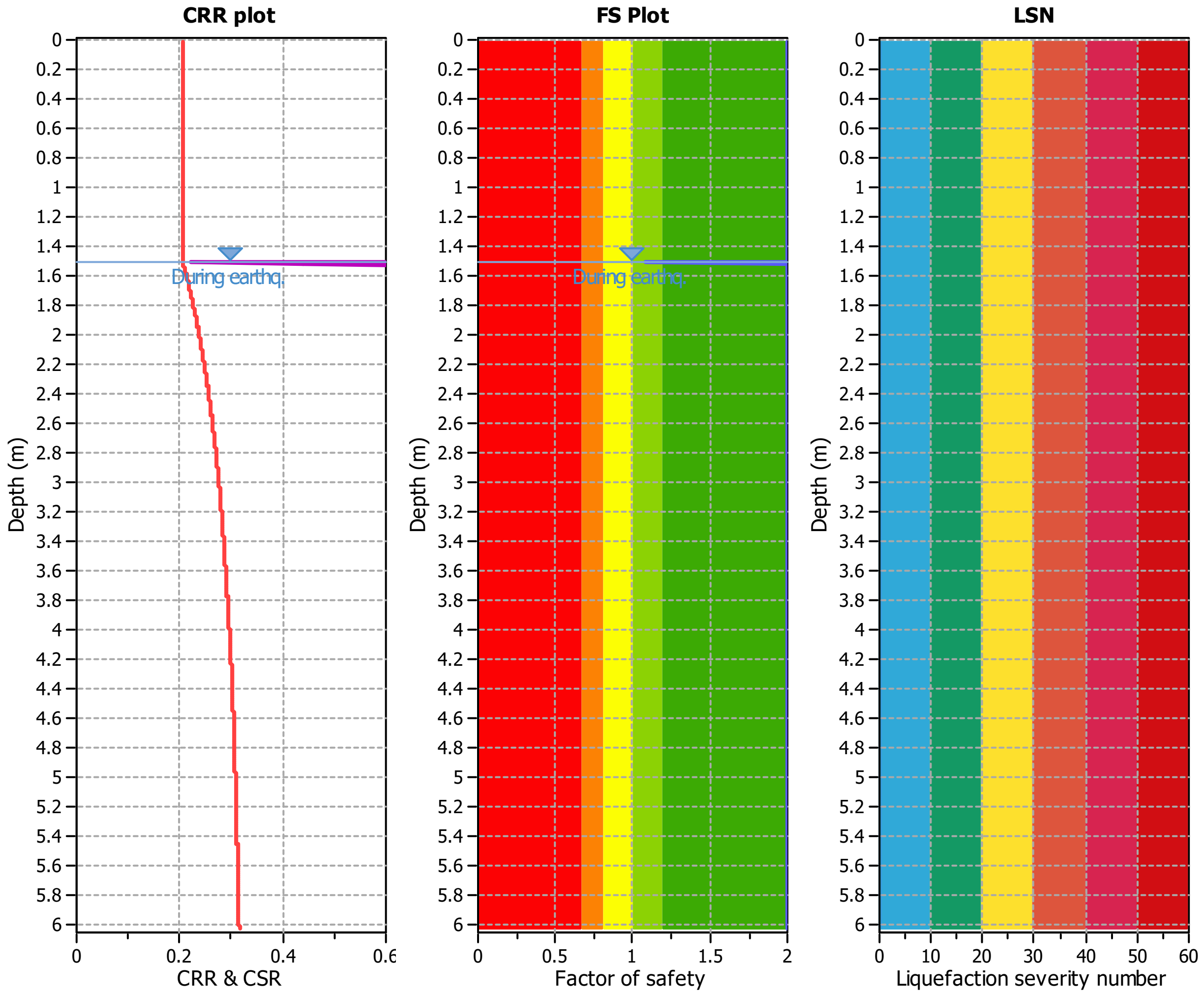
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT2
Total depth: 6.03 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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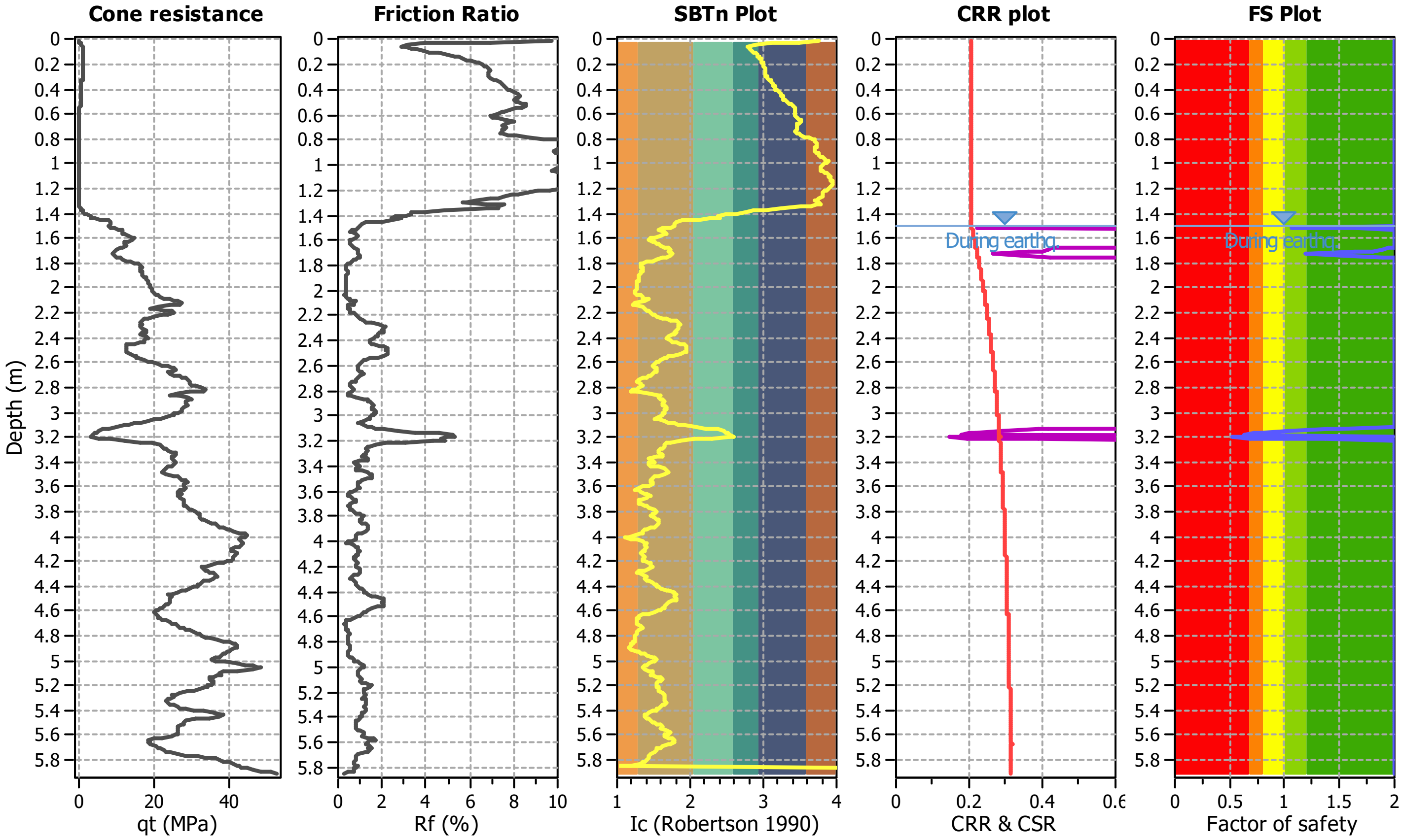
LIQUEFACTION ANALYSIS REPORT

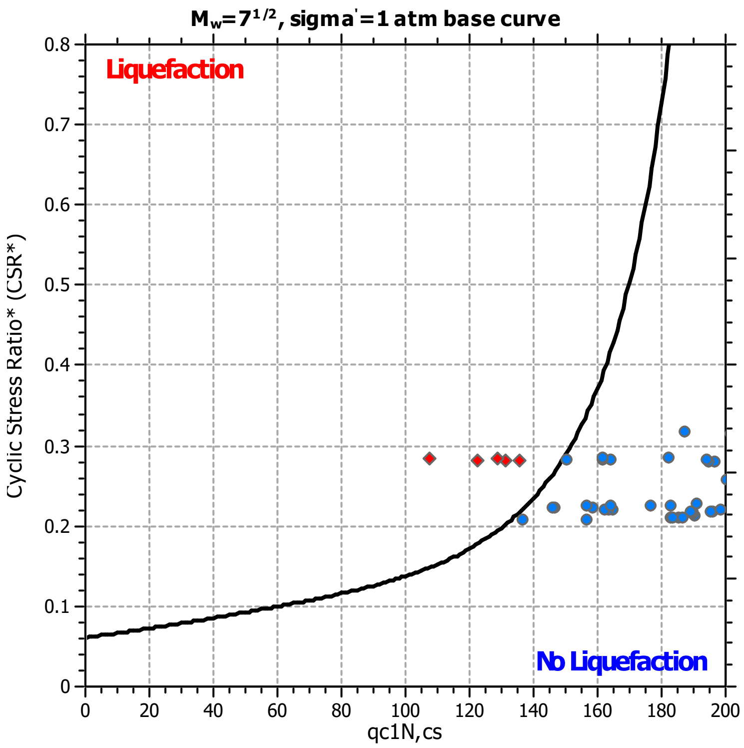
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

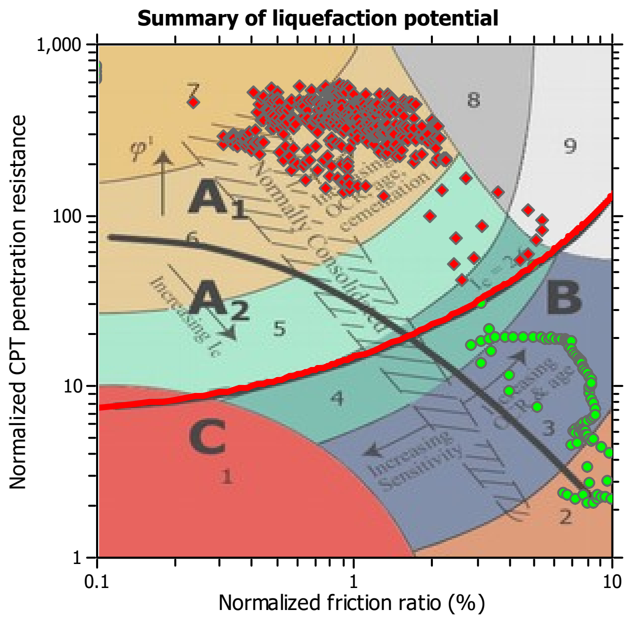
CPT file : CPT3

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

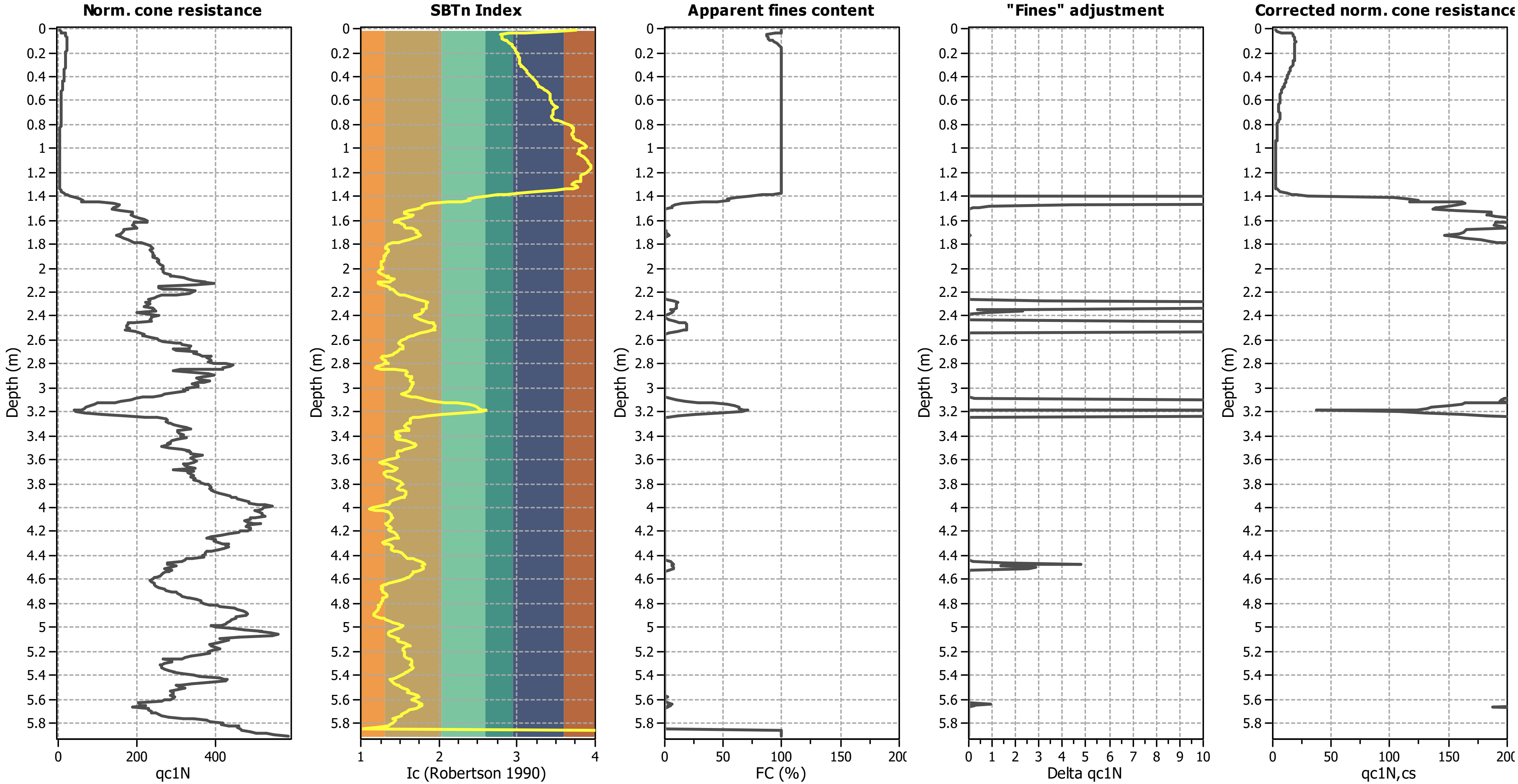






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

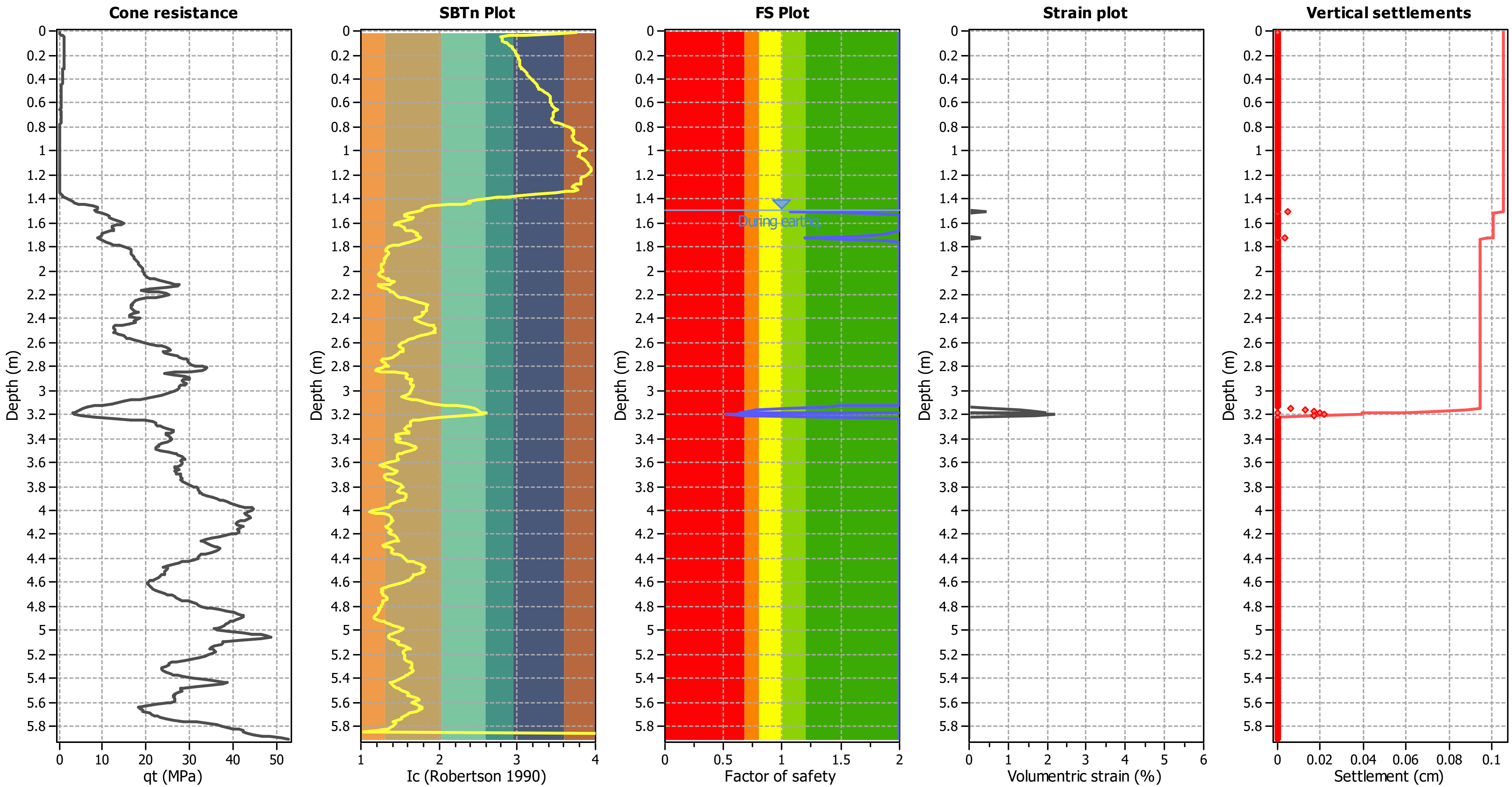
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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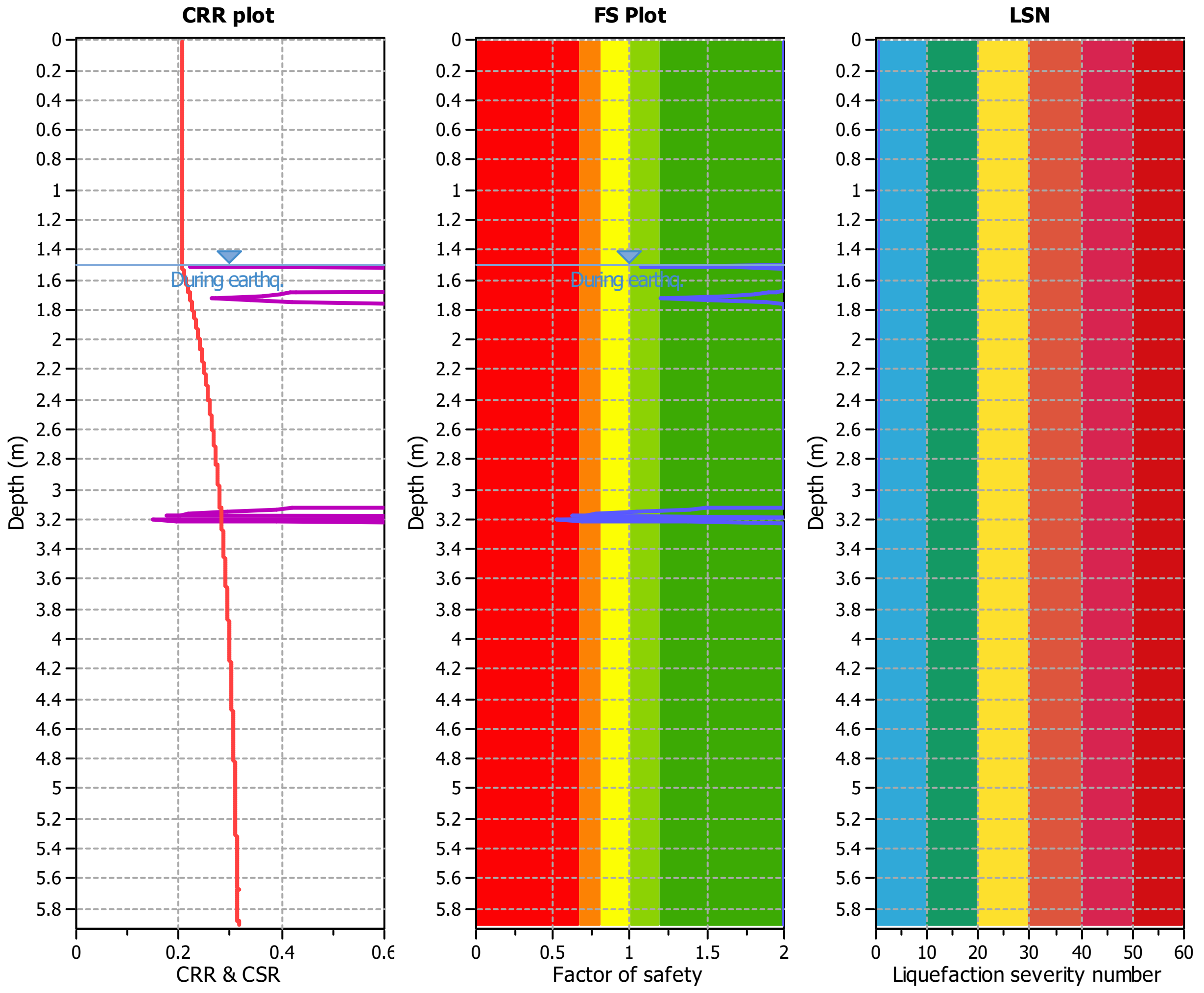
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT3
Total depth: 5.91 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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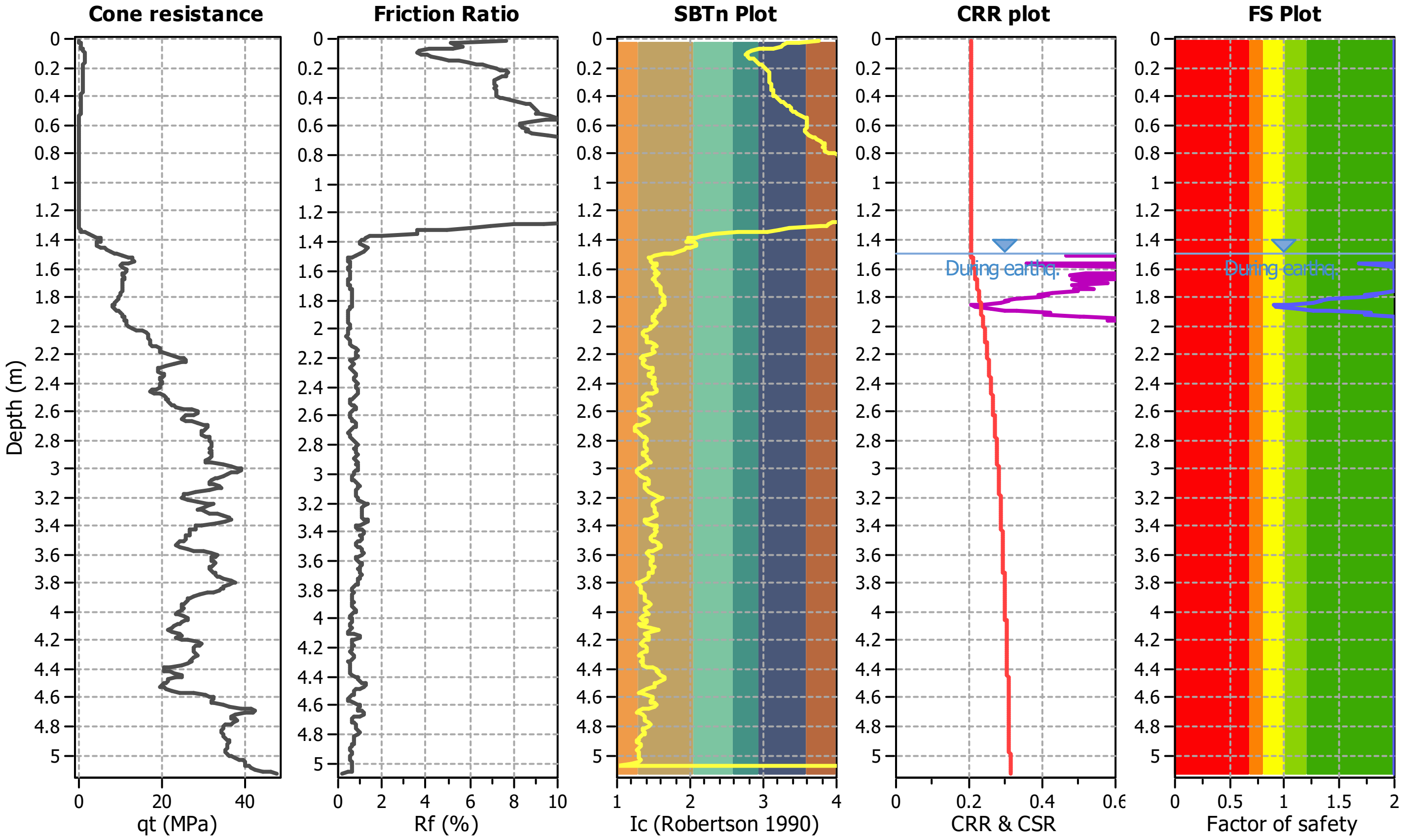
LIQUEFACTION ANALYSIS REPORT

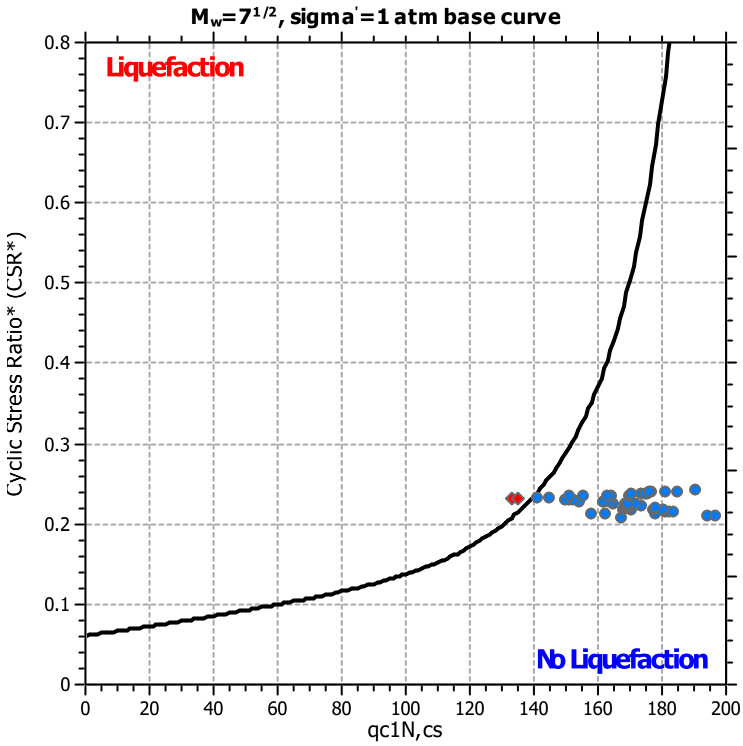
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

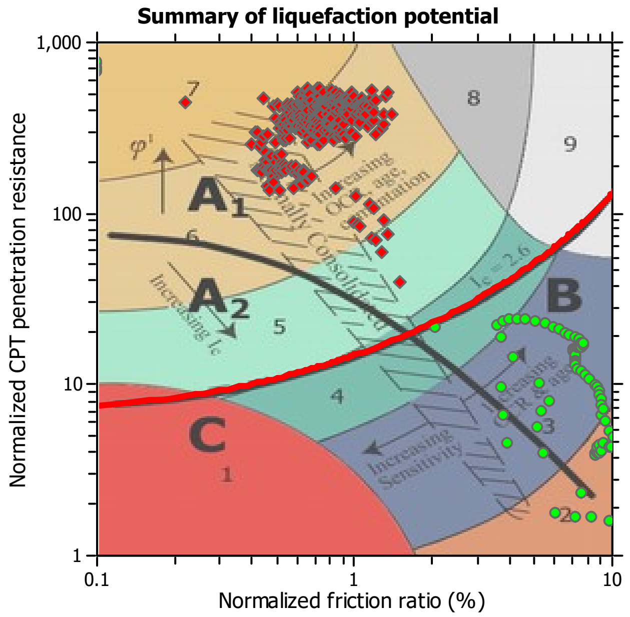
CPT file : CPT4

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

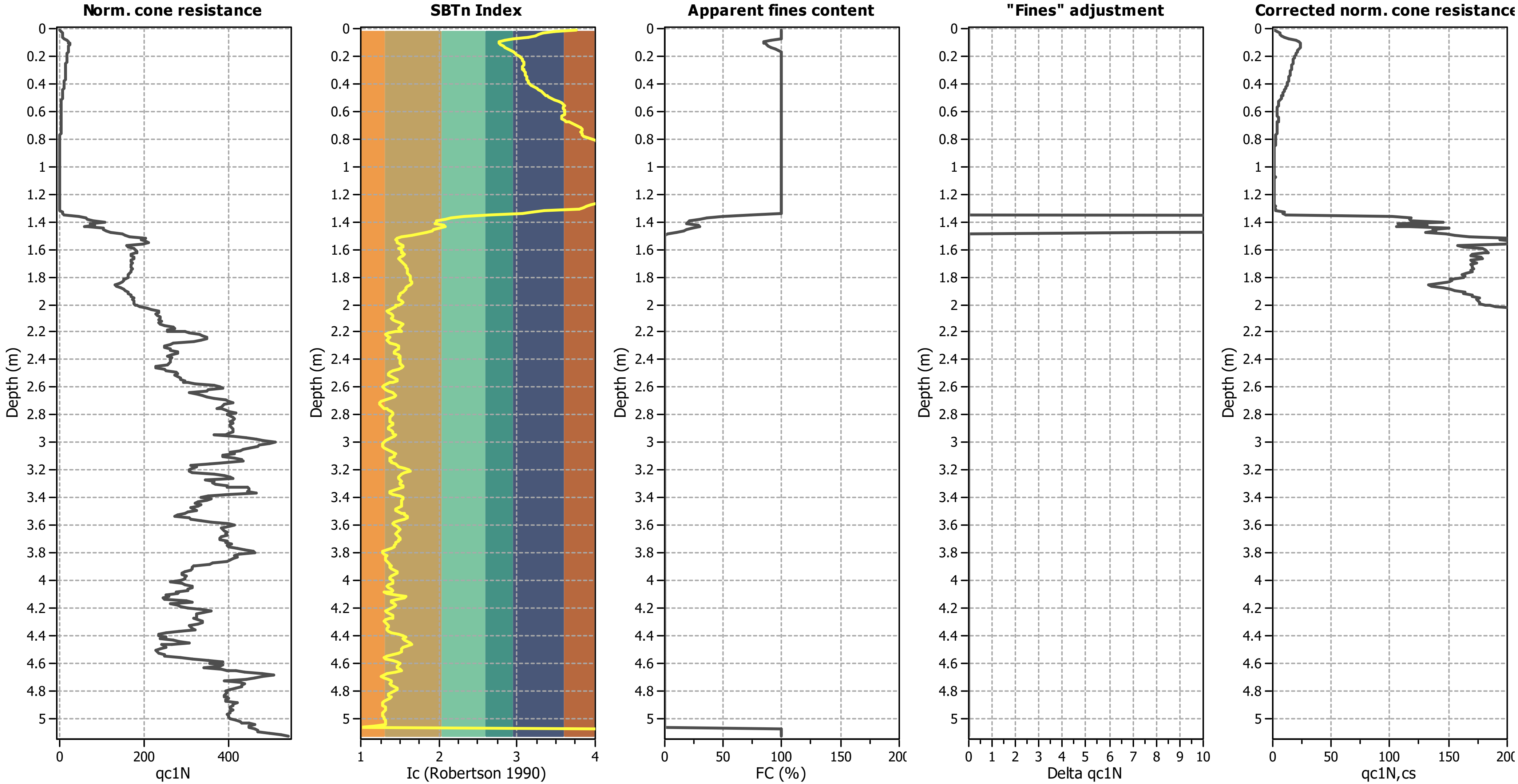






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

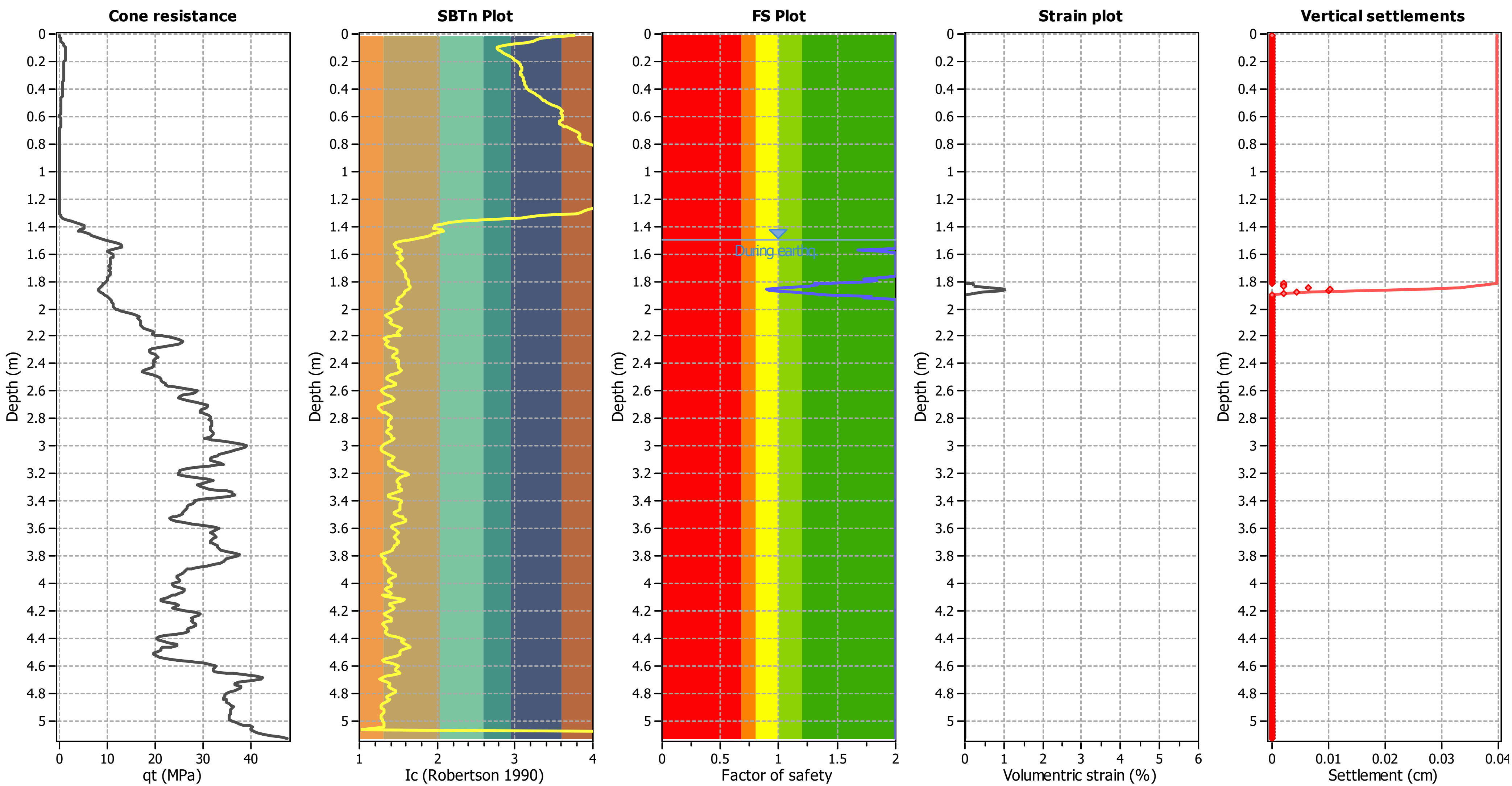
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

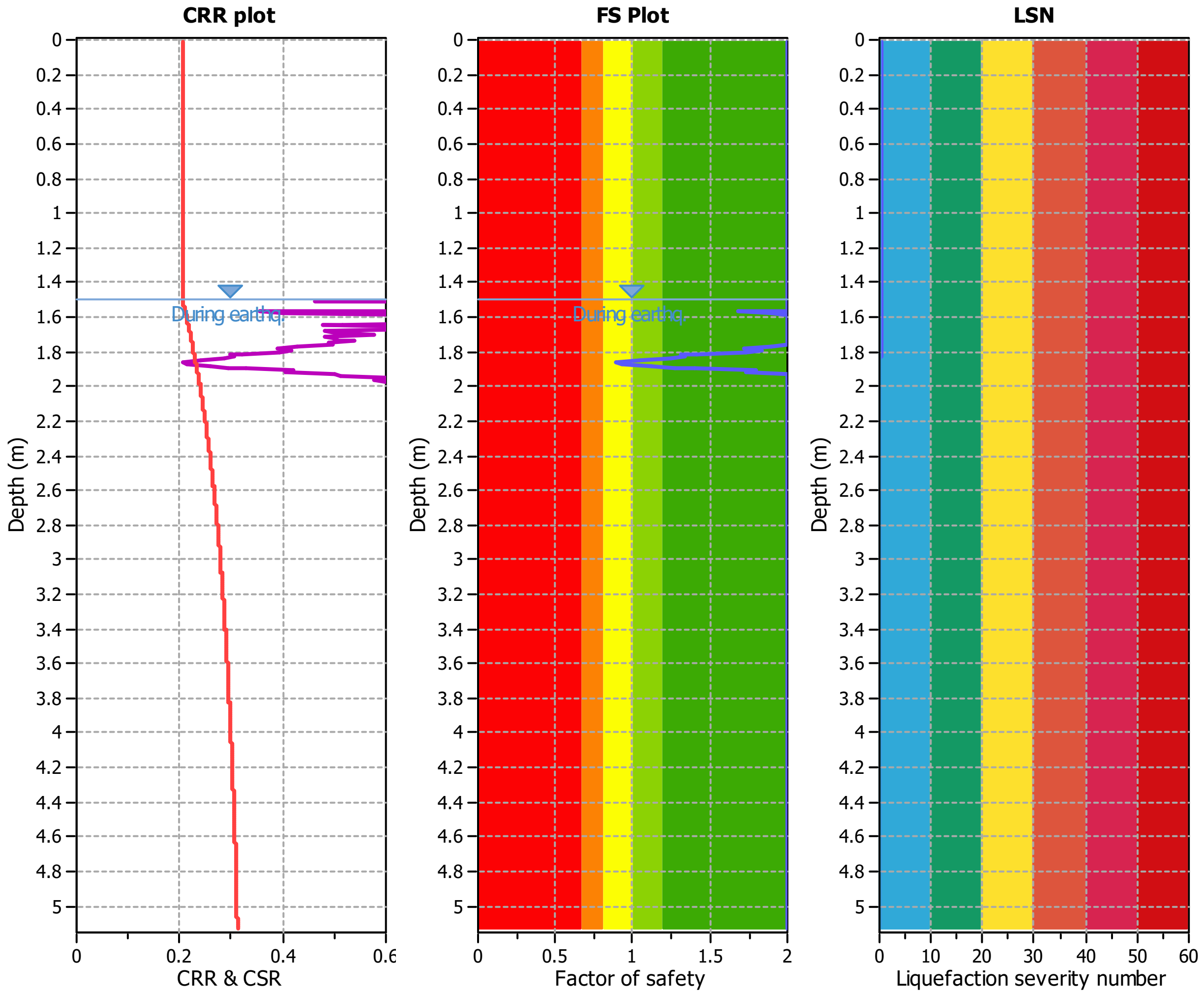


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT4
Total depth: 5.13 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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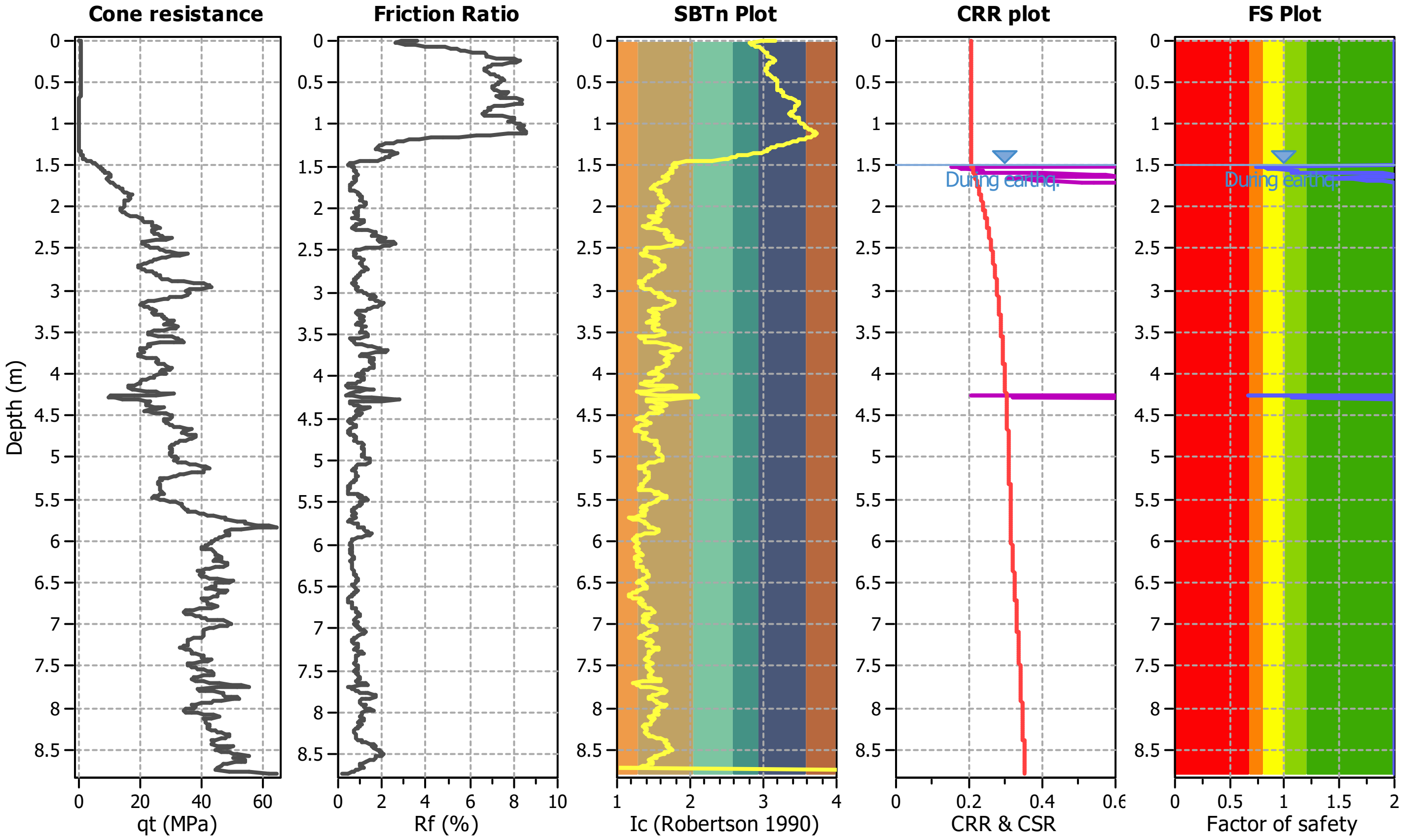
LIQUEFACTION ANALYSIS REPORT

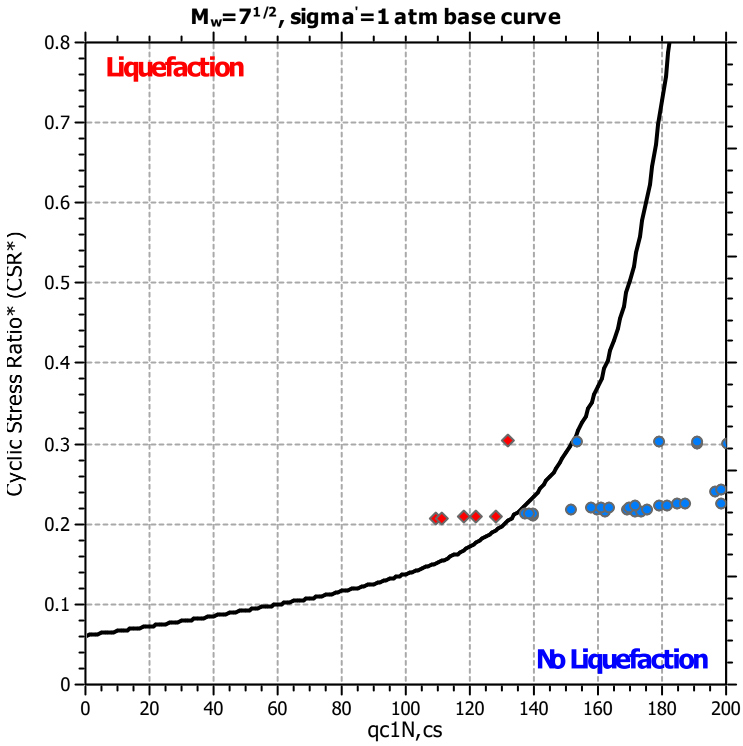
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

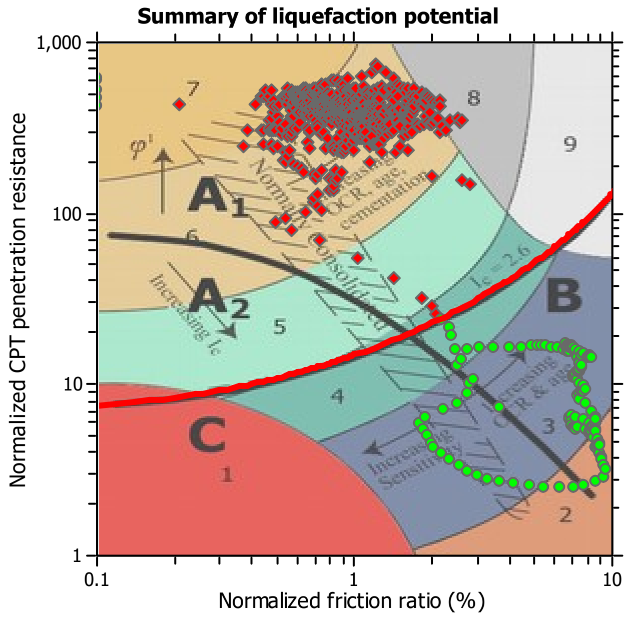
CPT file : CPT5

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

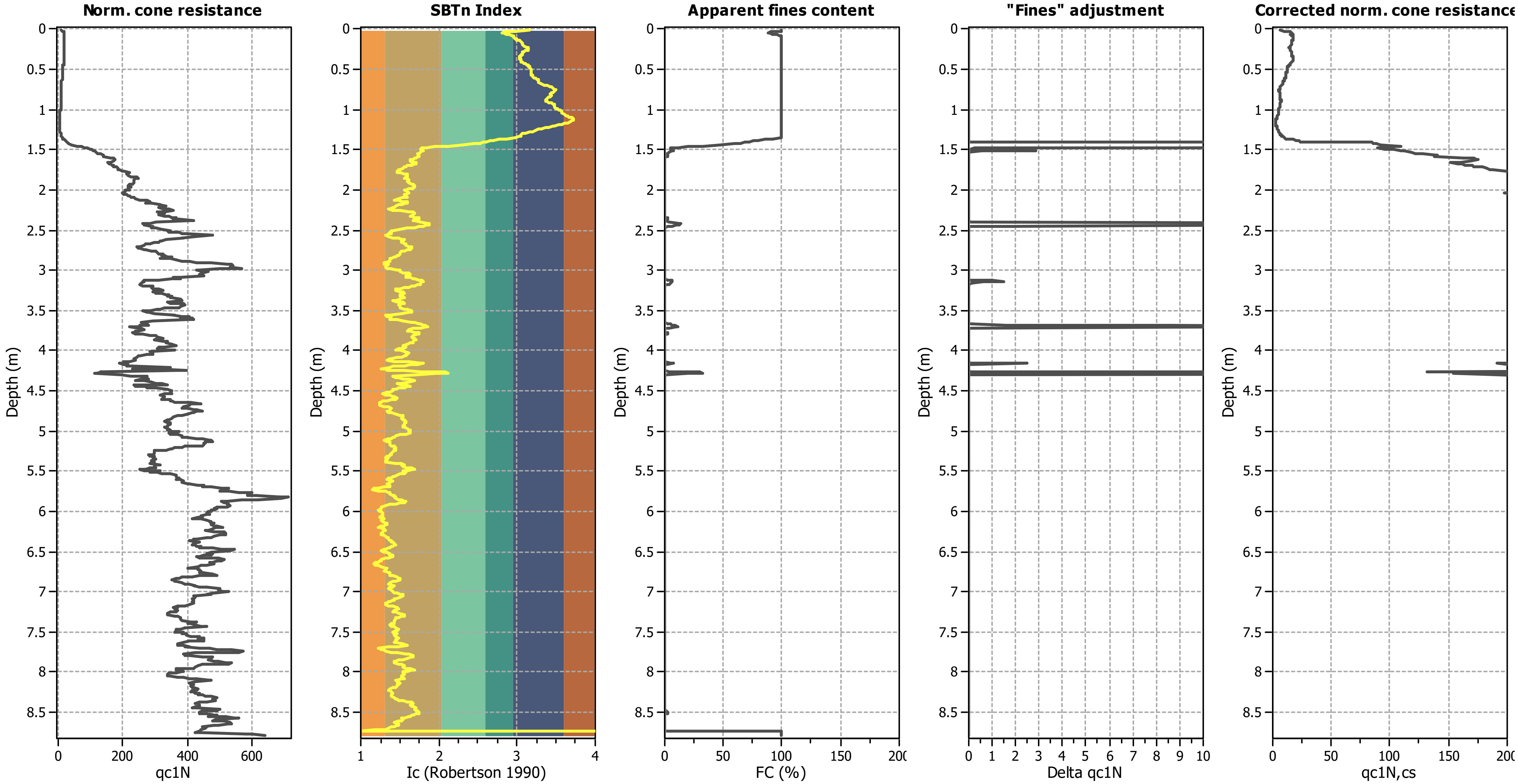






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

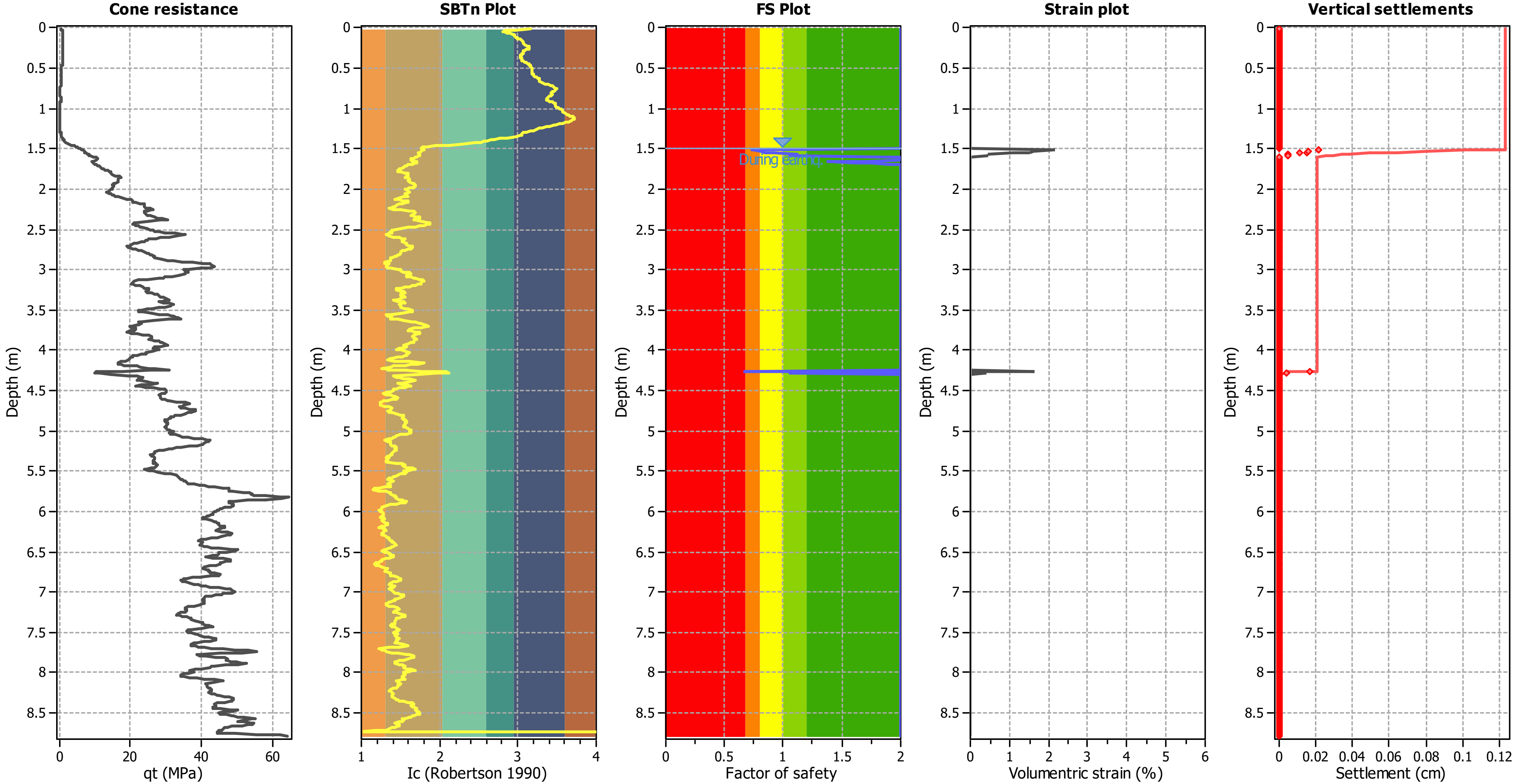
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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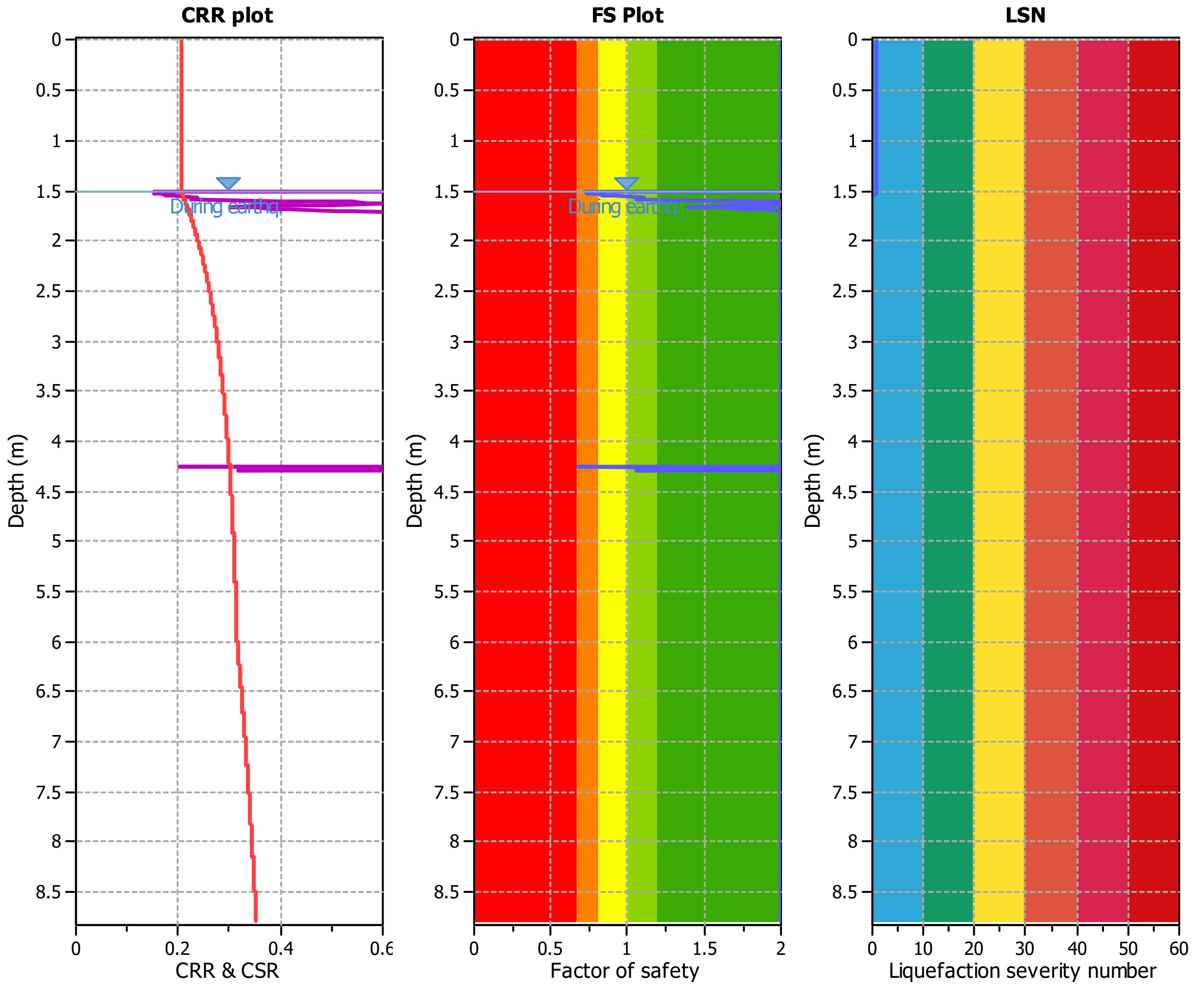
Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT5
Total depth: 8.79 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

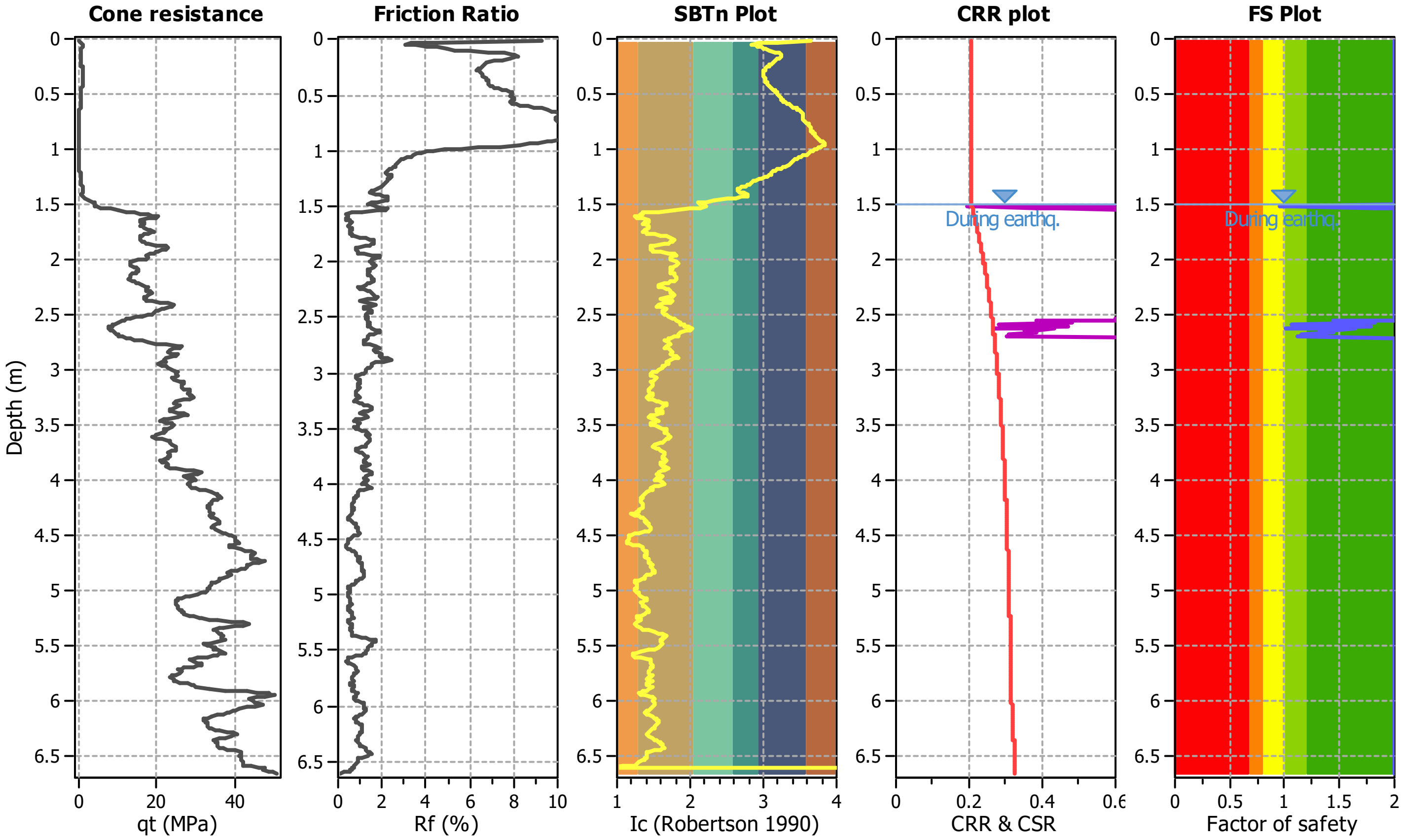
LIQUEFACTION ANALYSIS REPORT

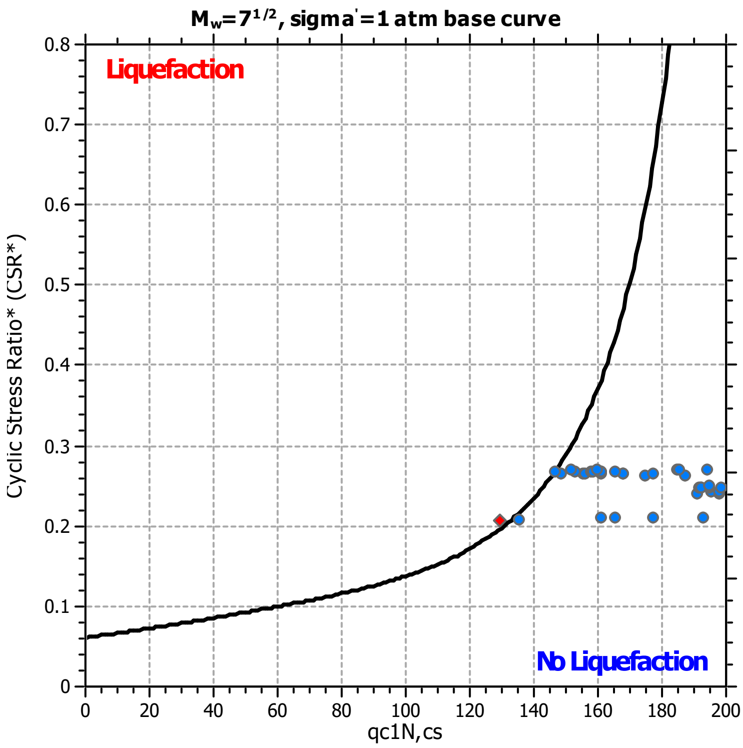
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

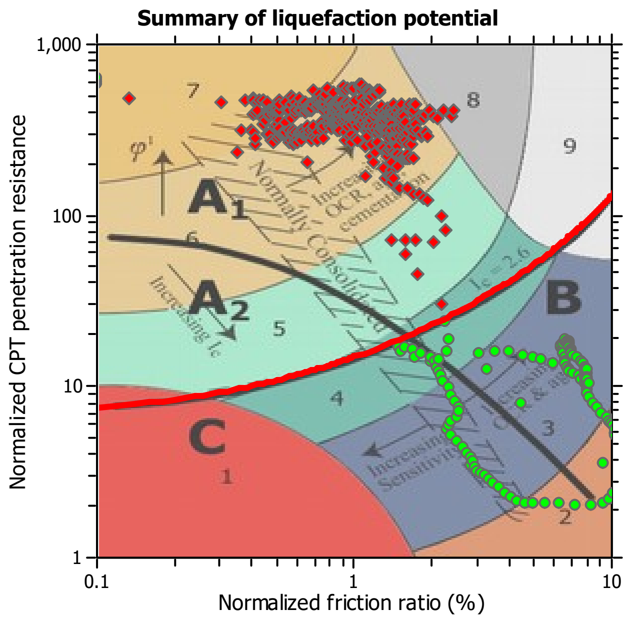
CPT file : CPT6

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

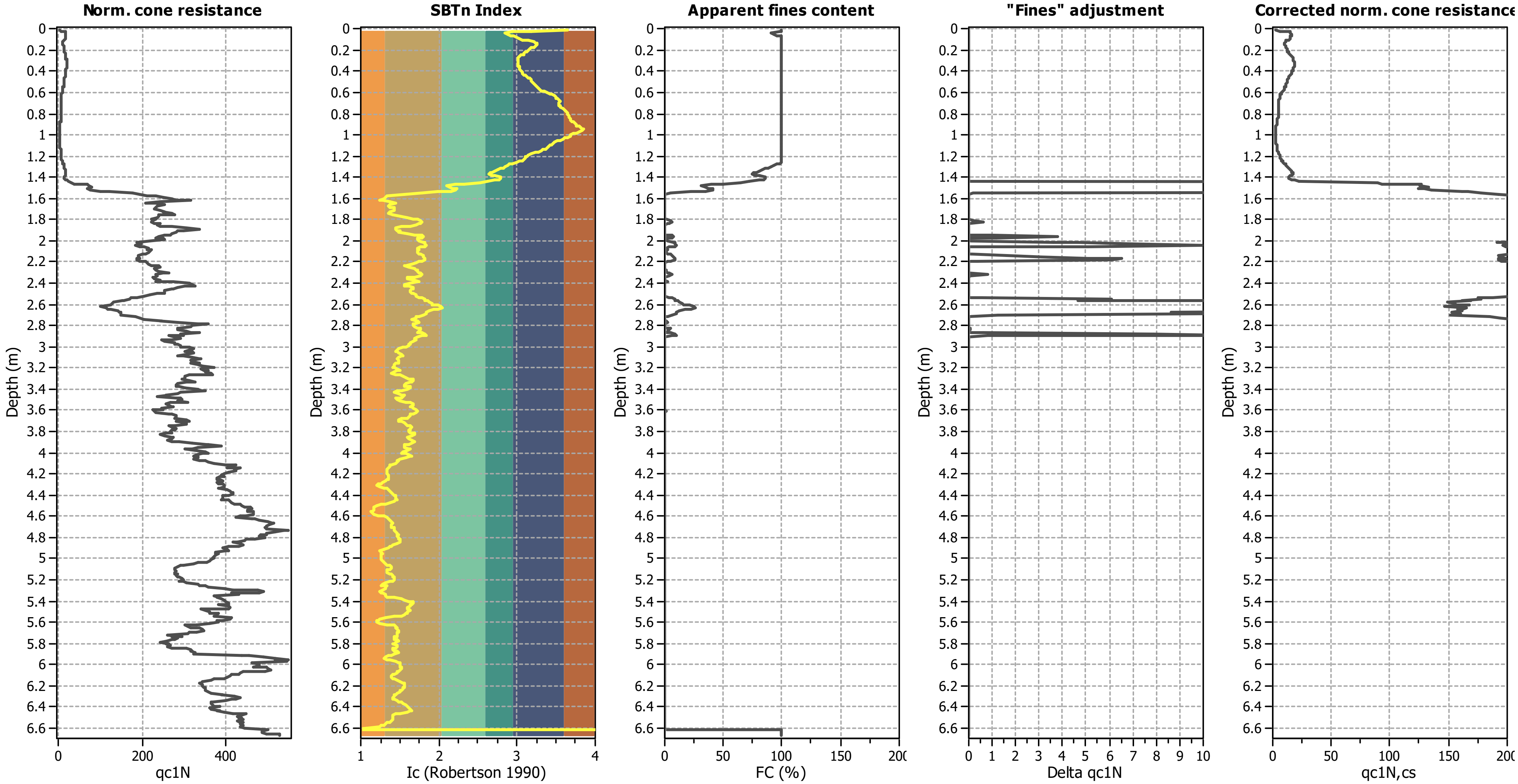






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

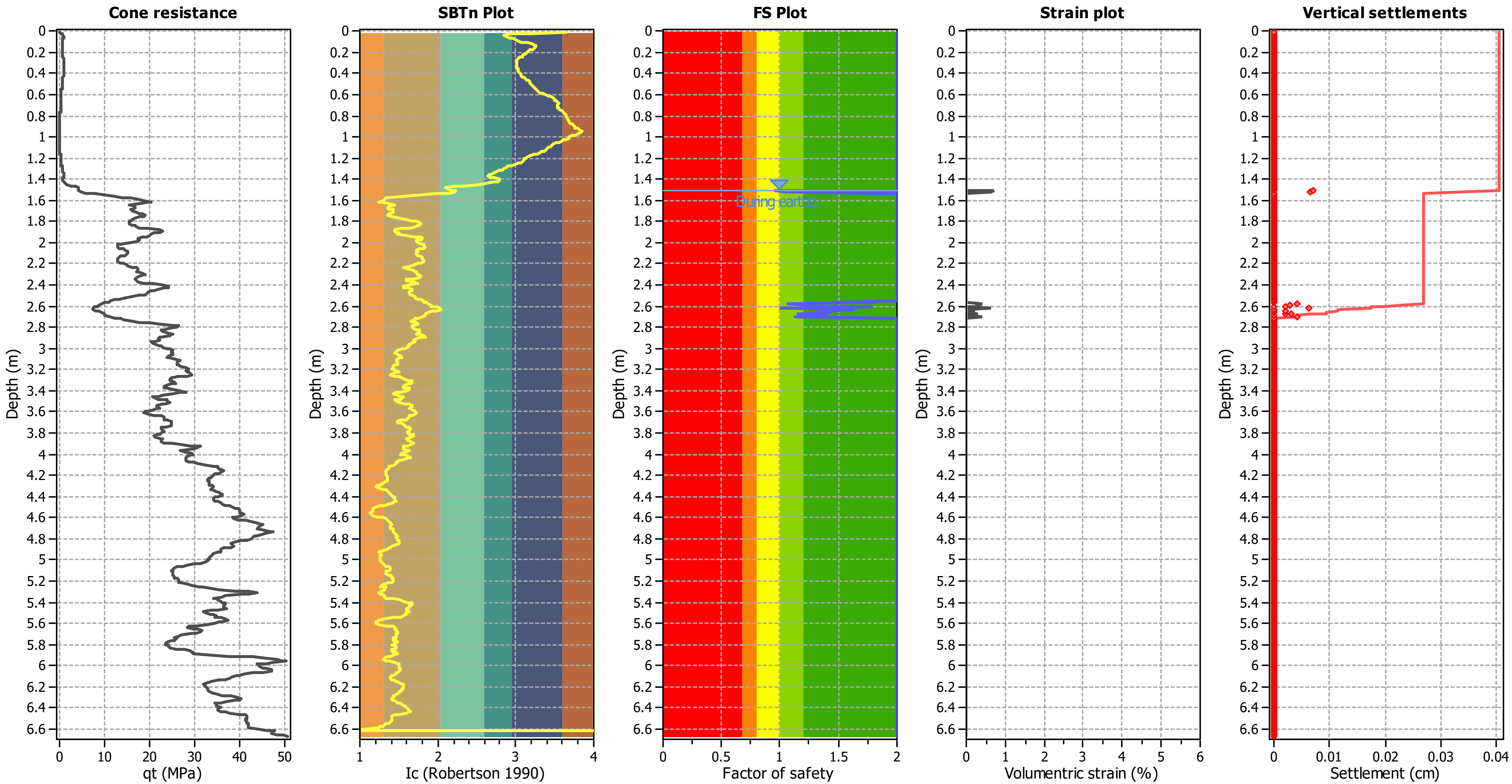
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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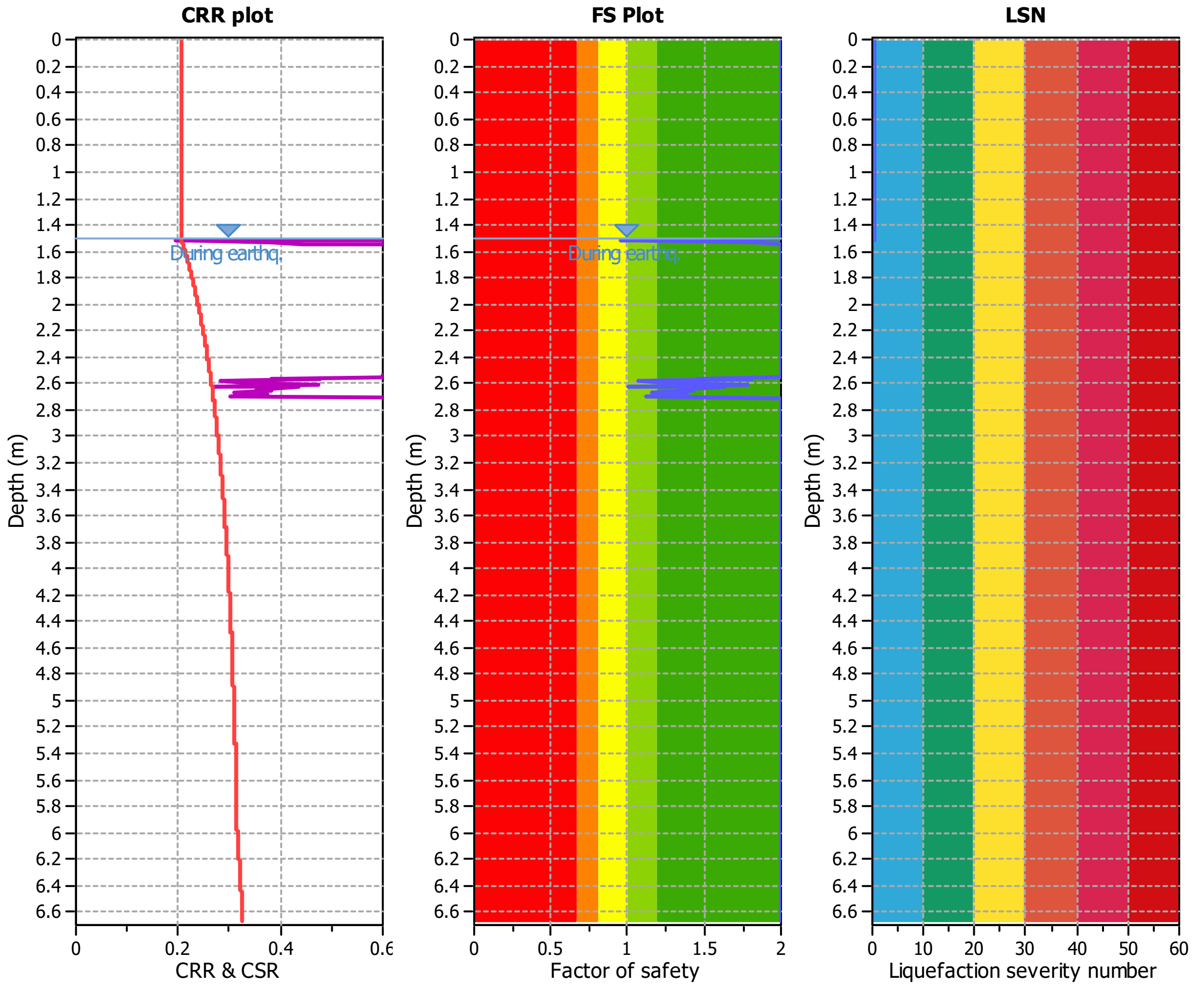
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT6
Total depth: 6.67 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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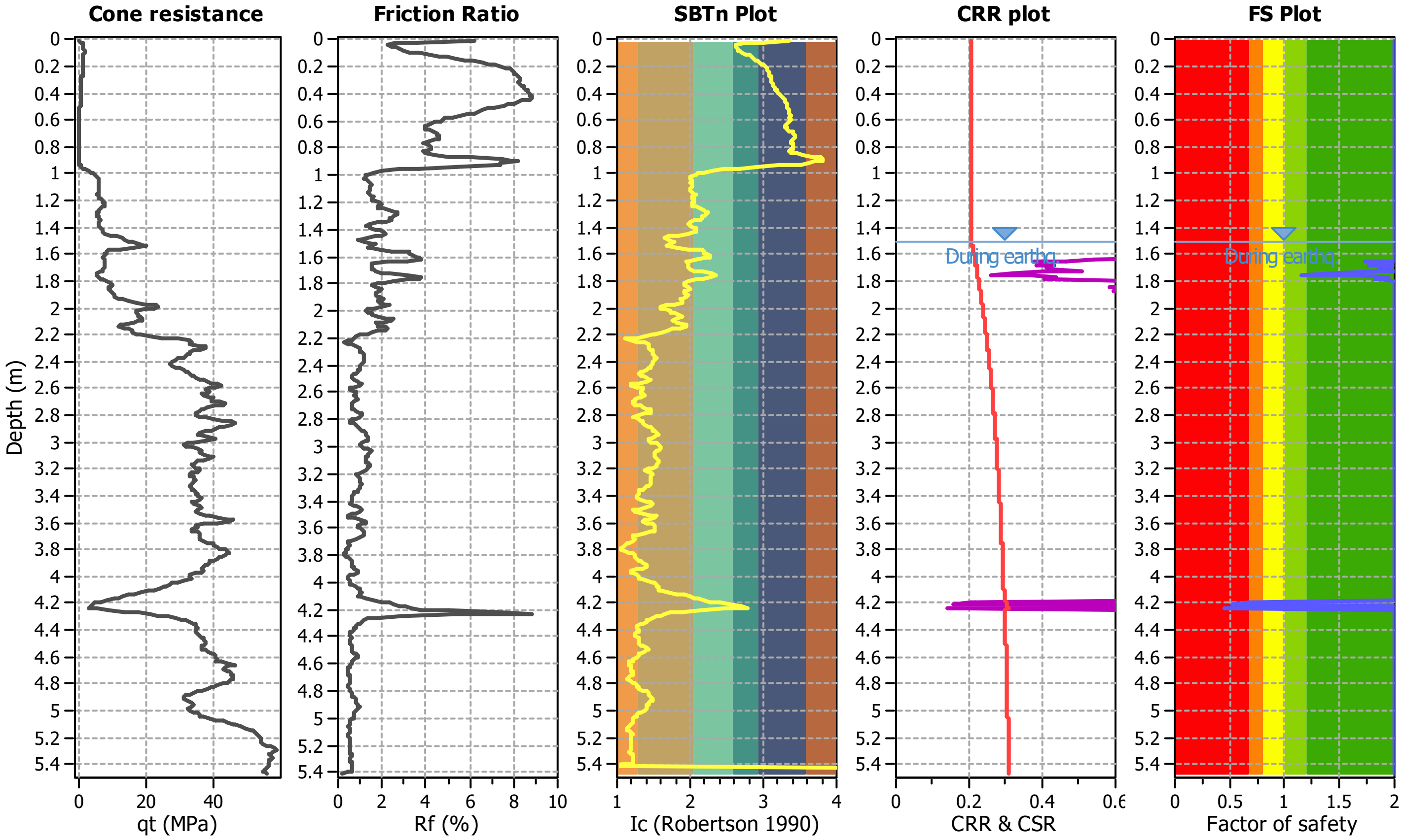
LIQUEFACTION ANALYSIS REPORT

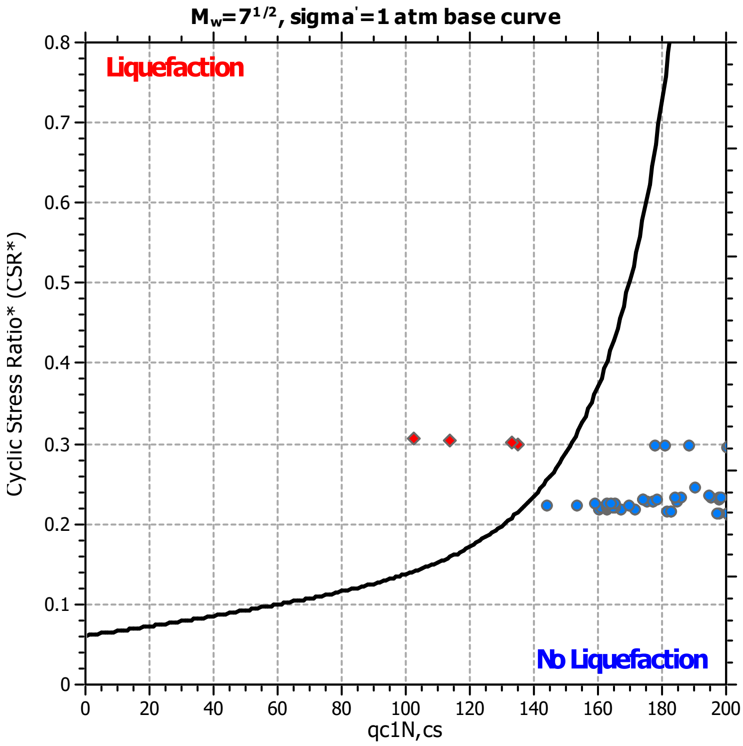
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

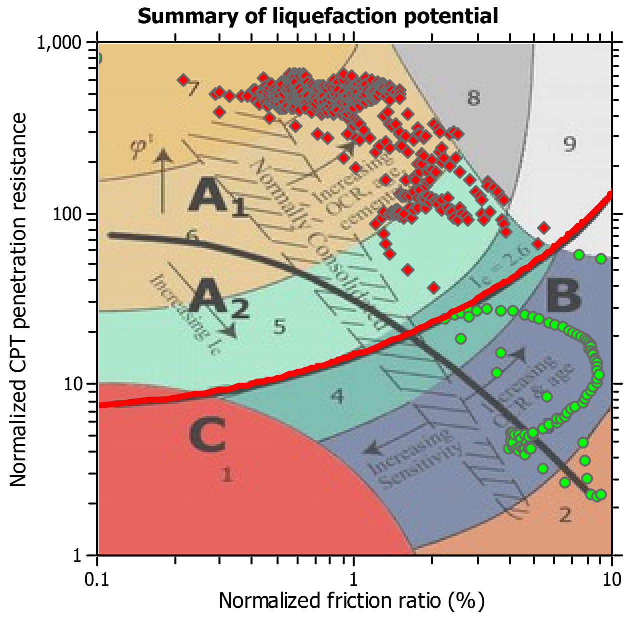
CPT file : CPT7

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A		
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	10.00 m
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

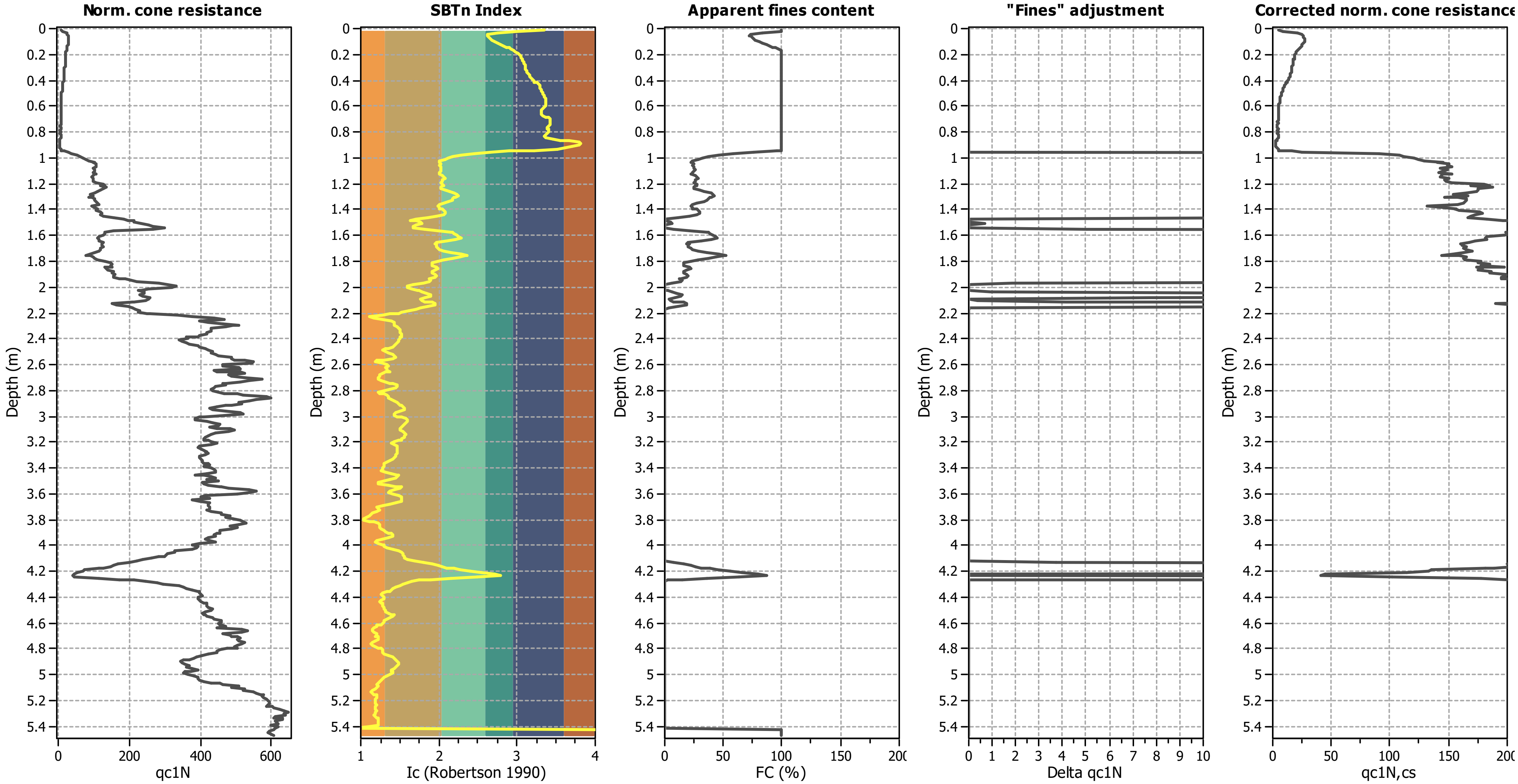






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

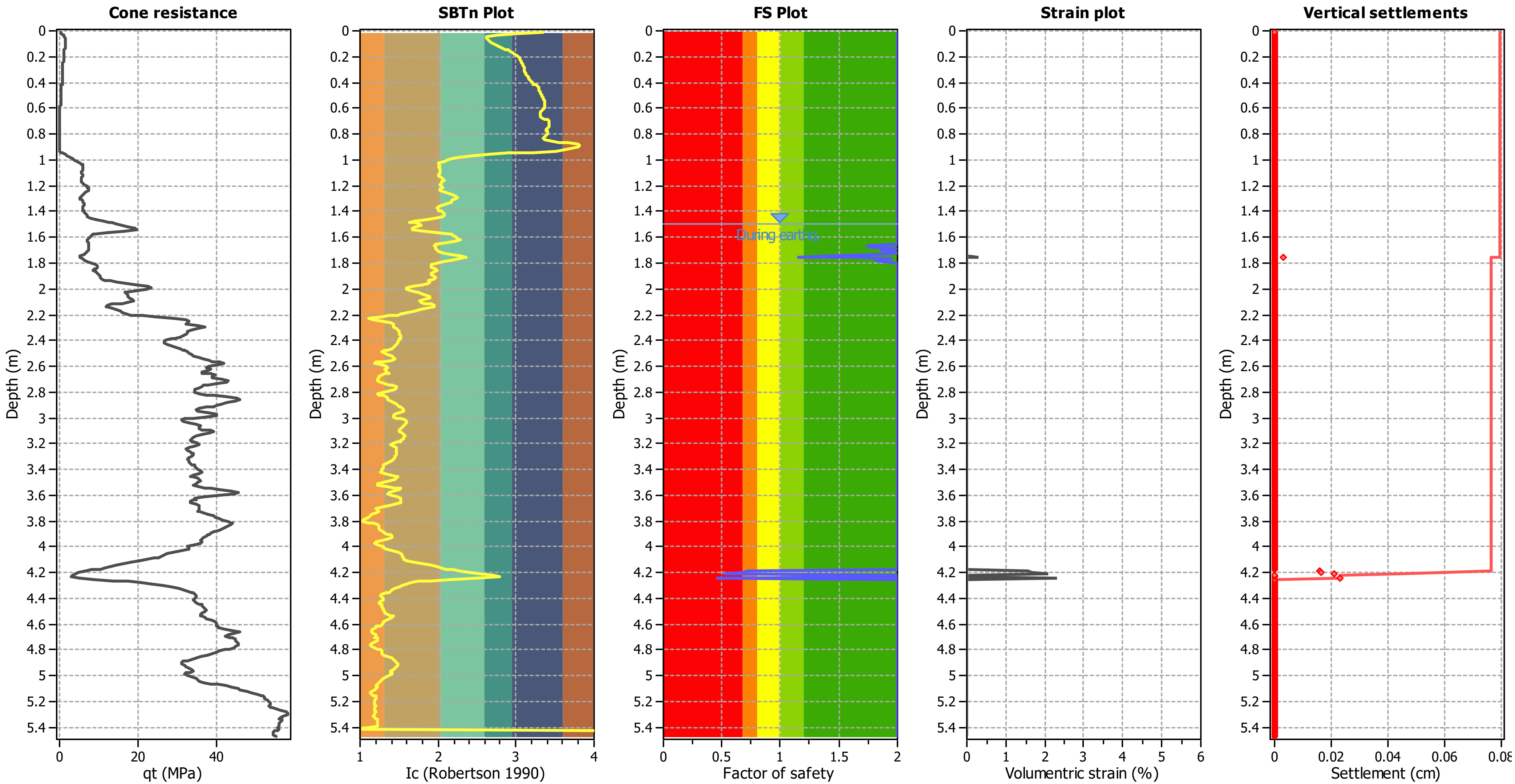
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

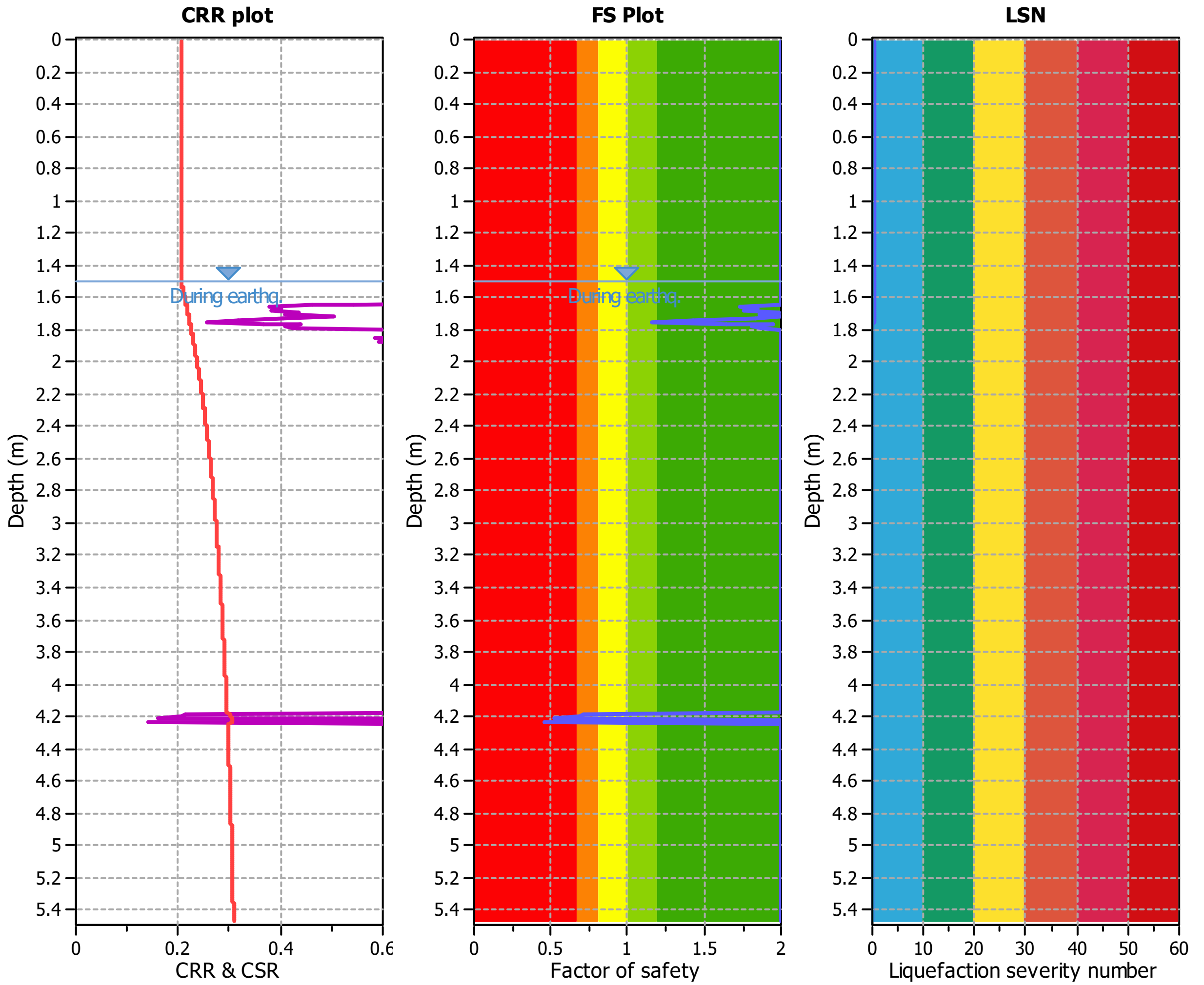


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT7
Total depth: 5.47 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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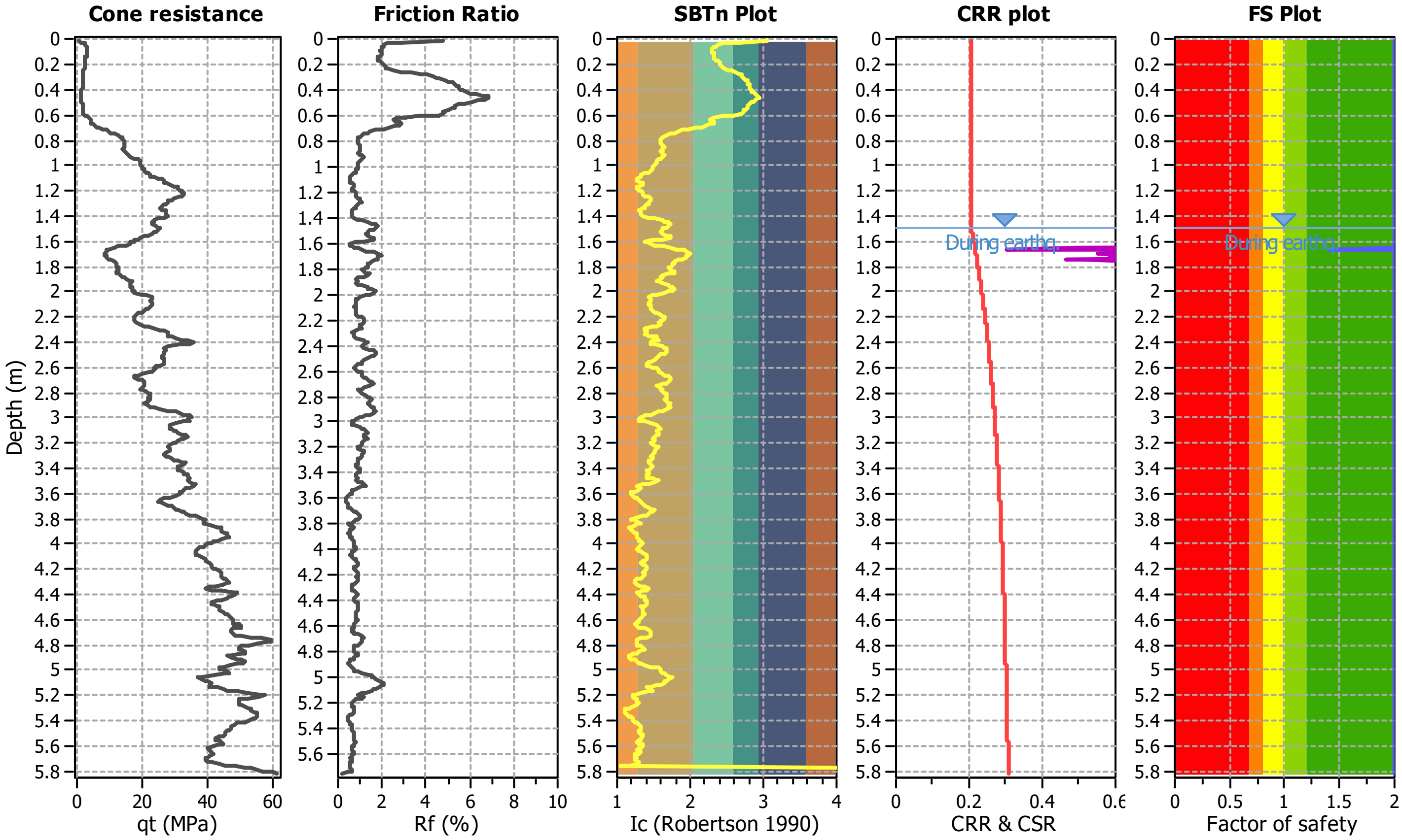
LIQUEFACTION ANALYSIS REPORT

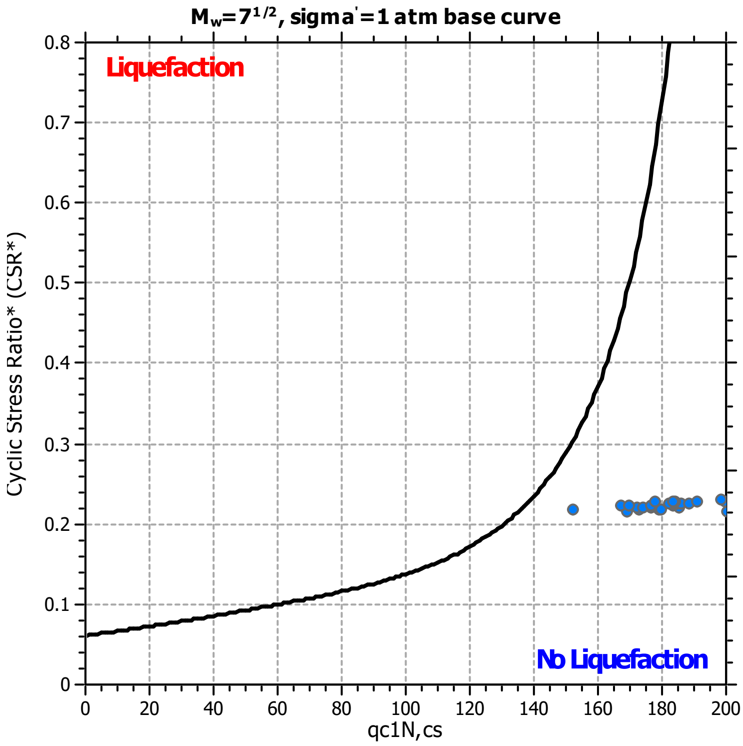
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

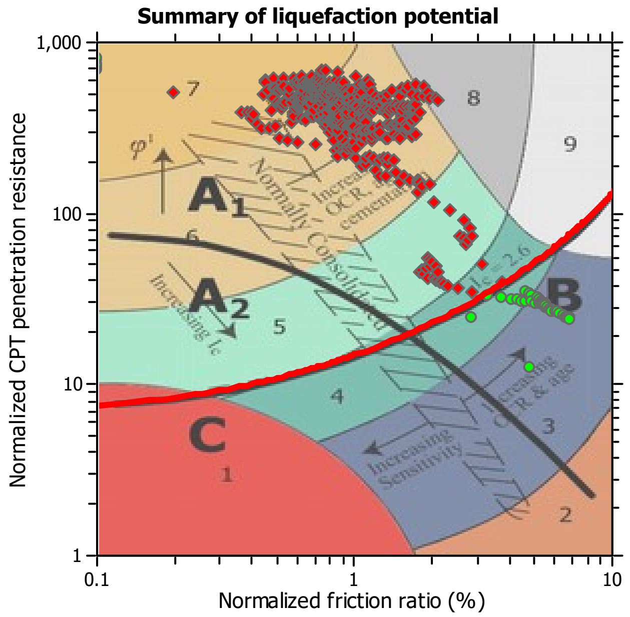
CPT file : CPT8

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A		
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth applied:	Yes
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	Limit depth:	10.00 m
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes	MSF method:	Method based

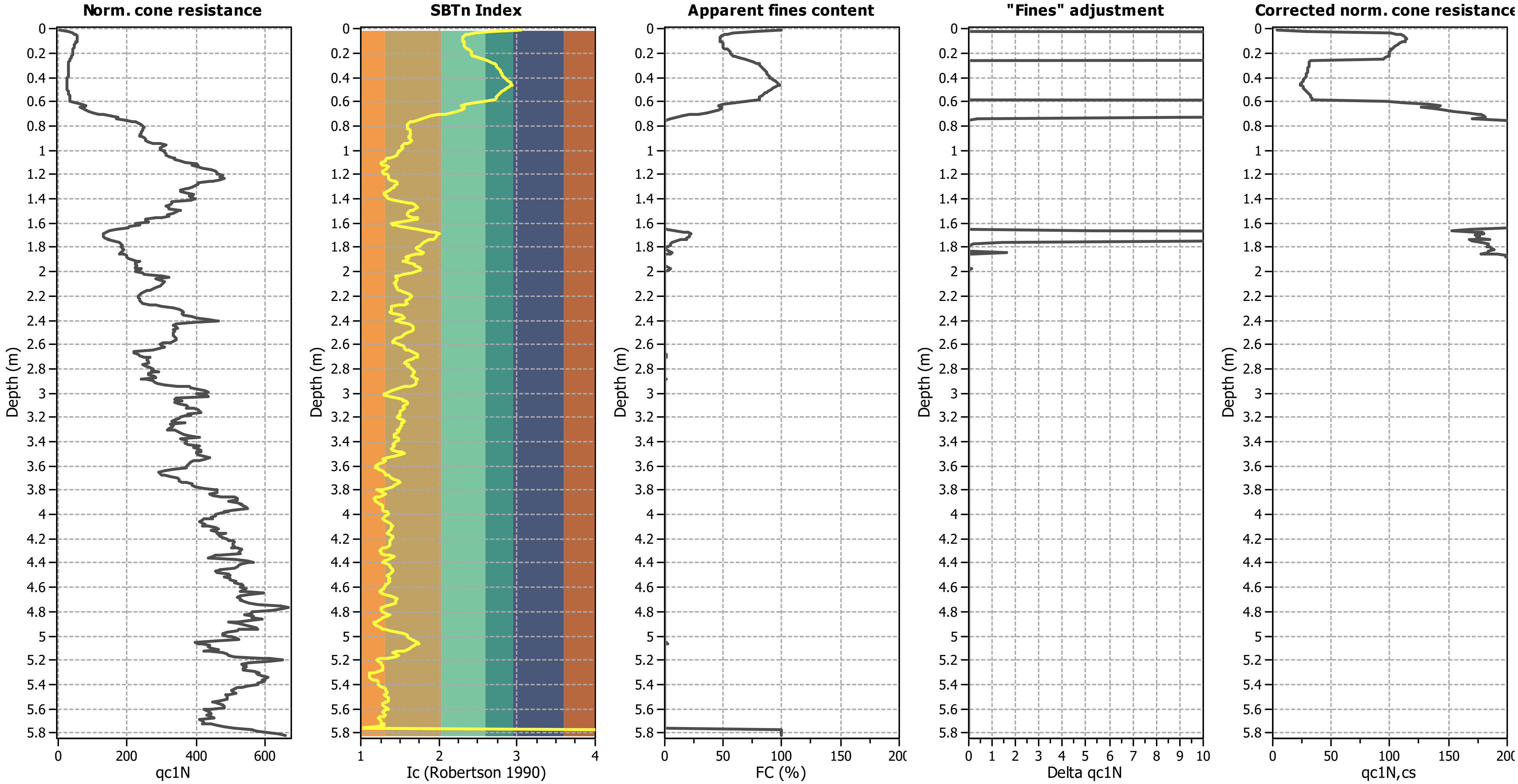






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

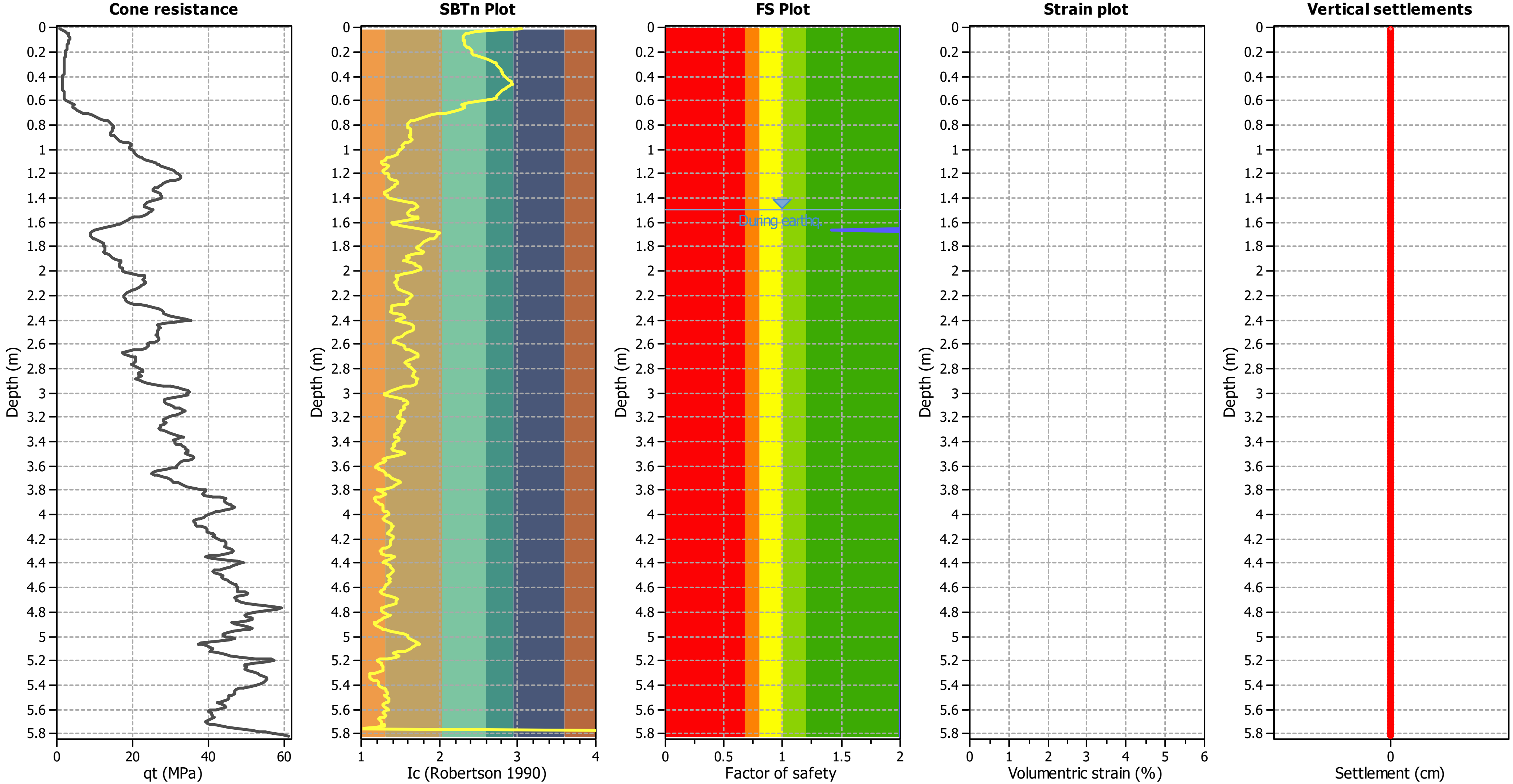
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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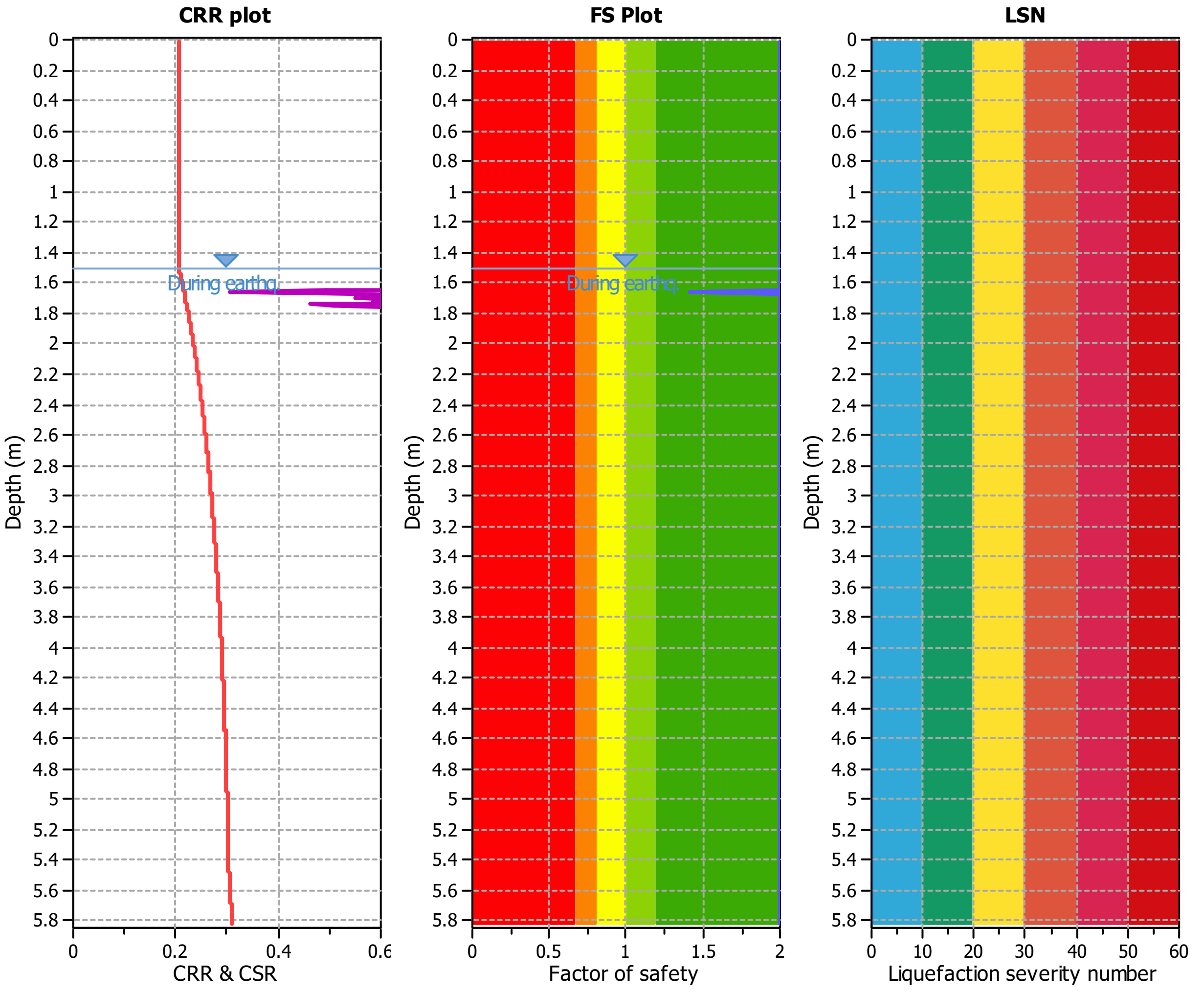
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT8
Total depth: 5.82 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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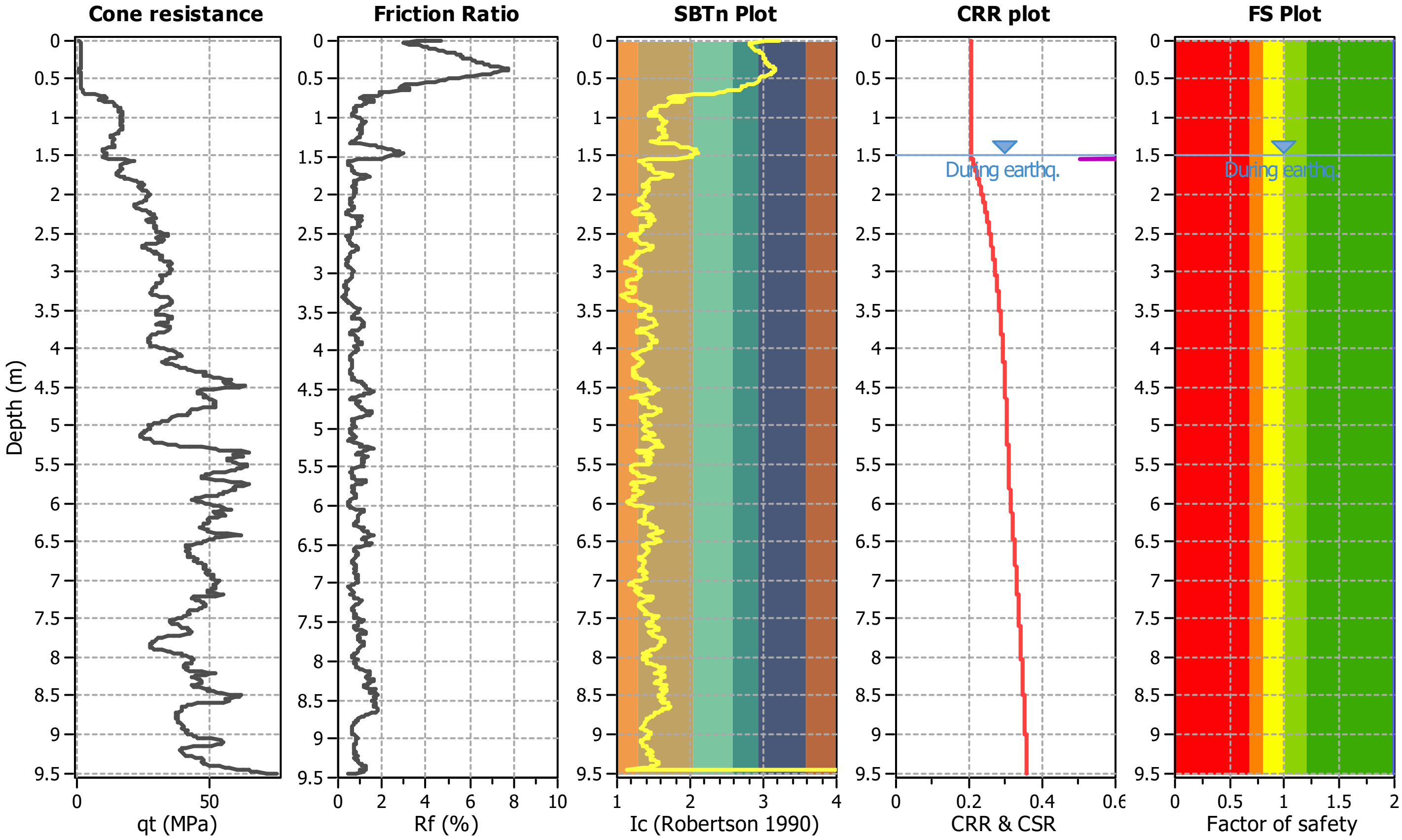
LIQUEFACTION ANALYSIS REPORT

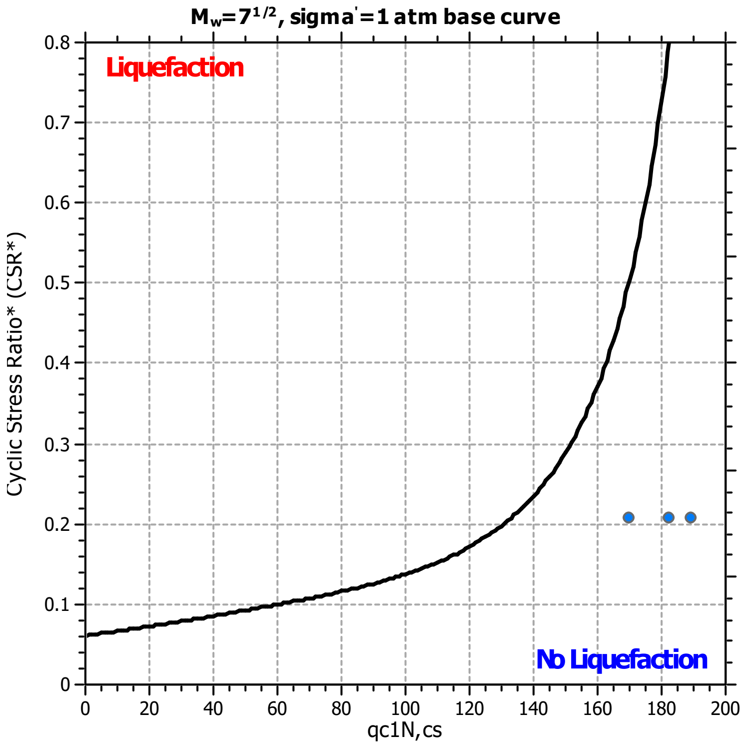
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

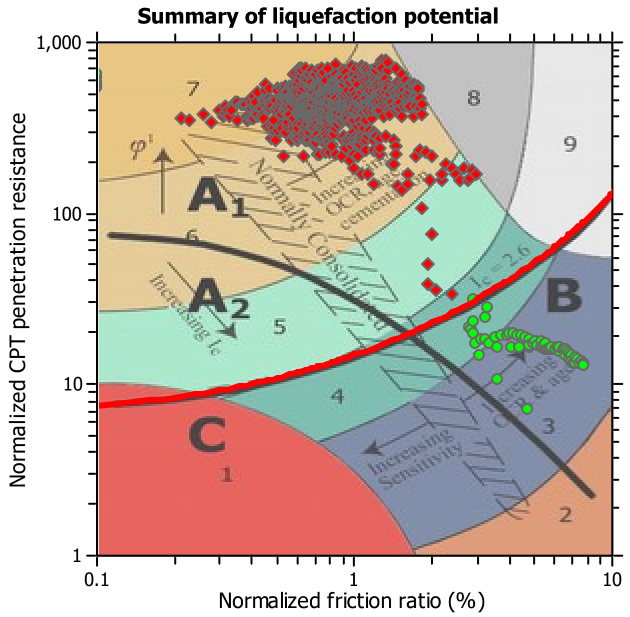
CPT file : CPT9

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

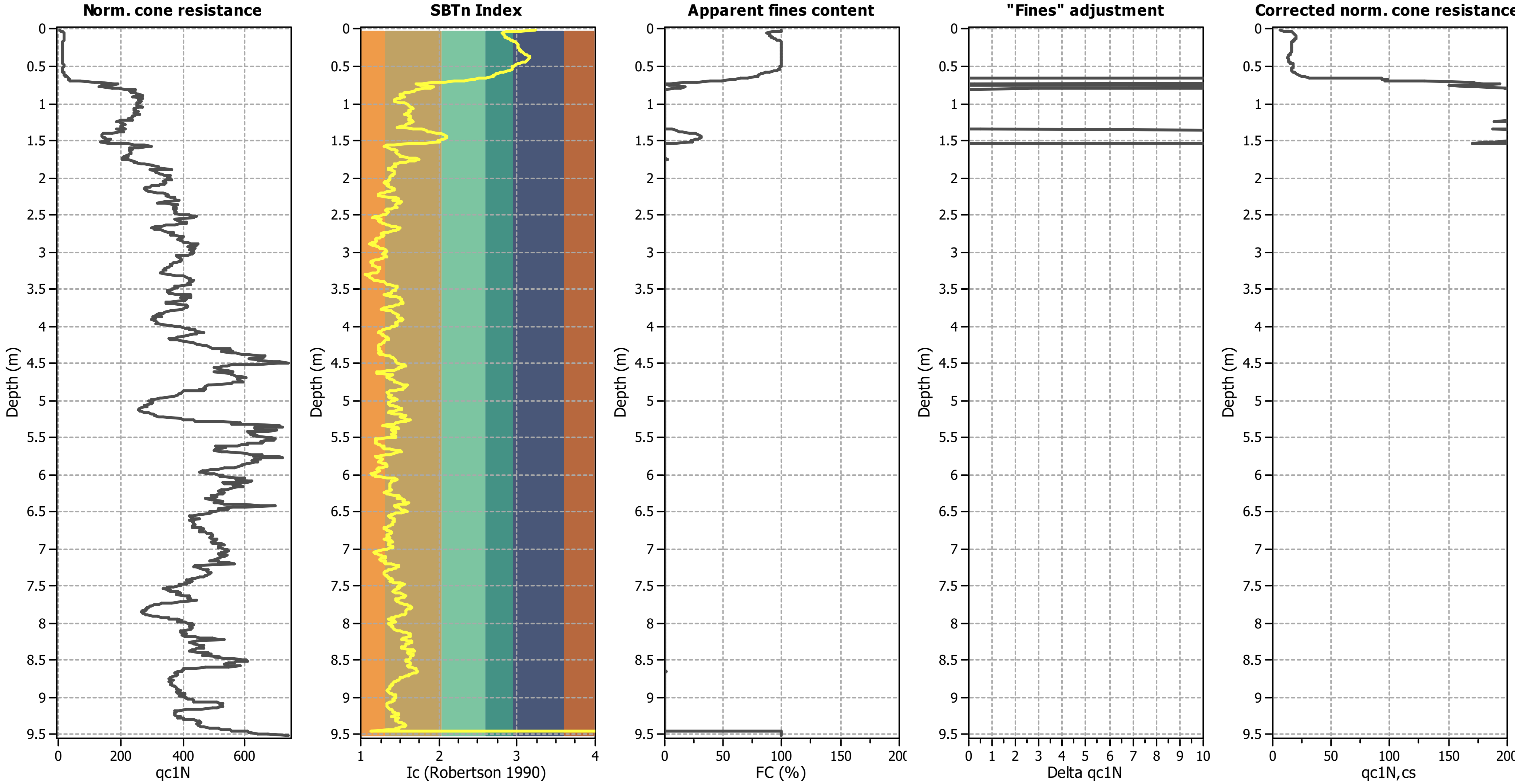






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

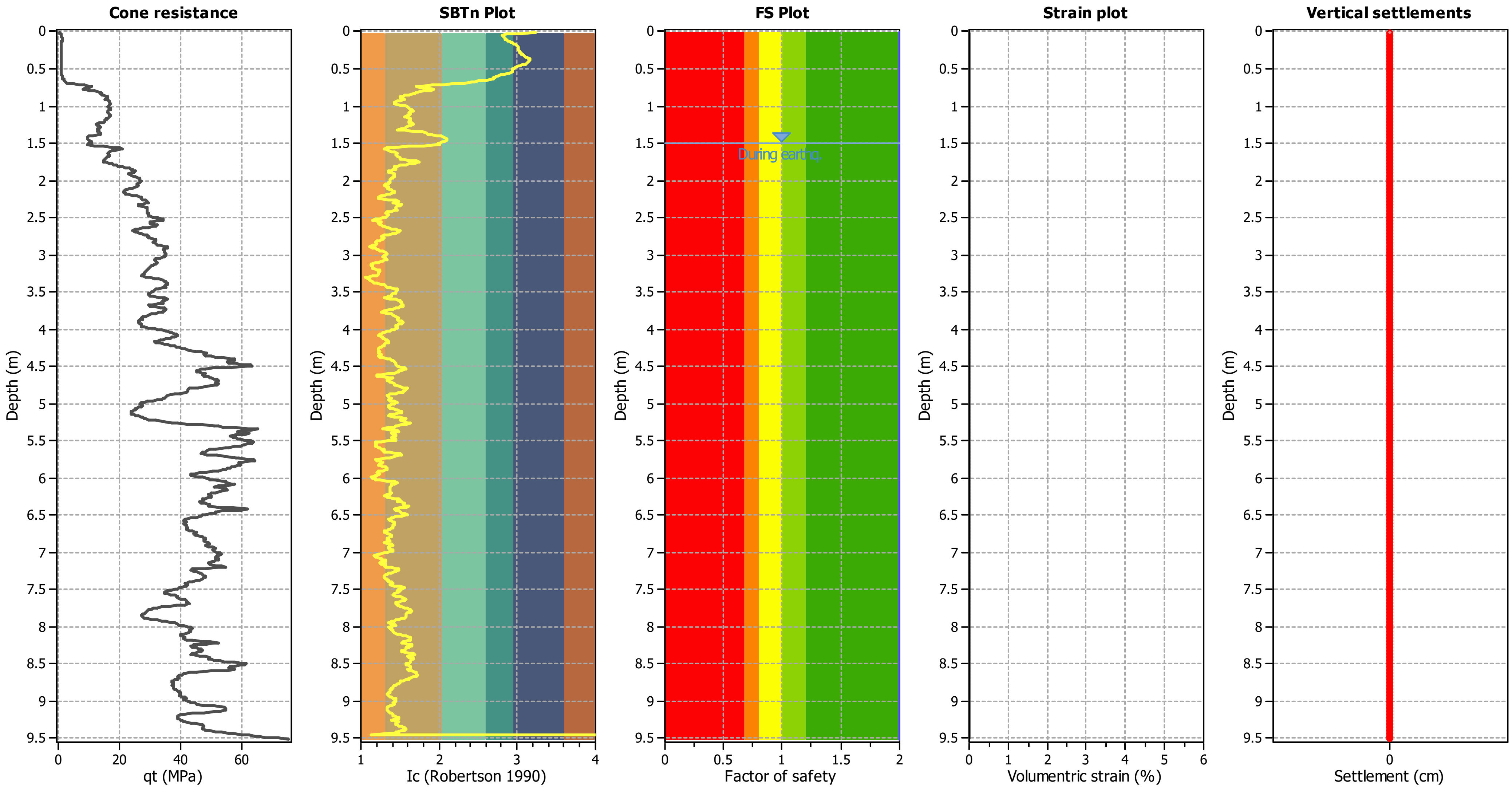
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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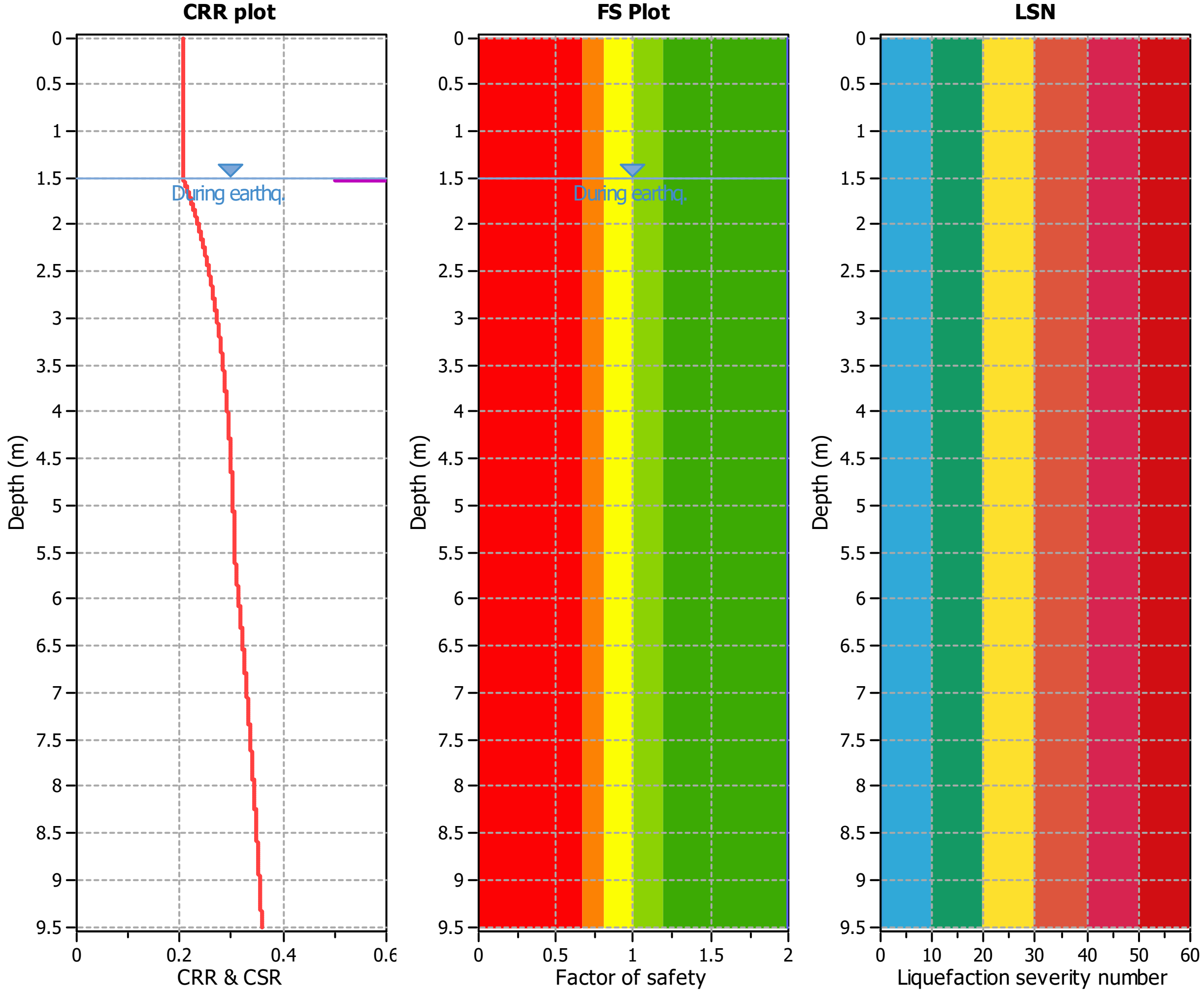
Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT9
Total depth: 9.51 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

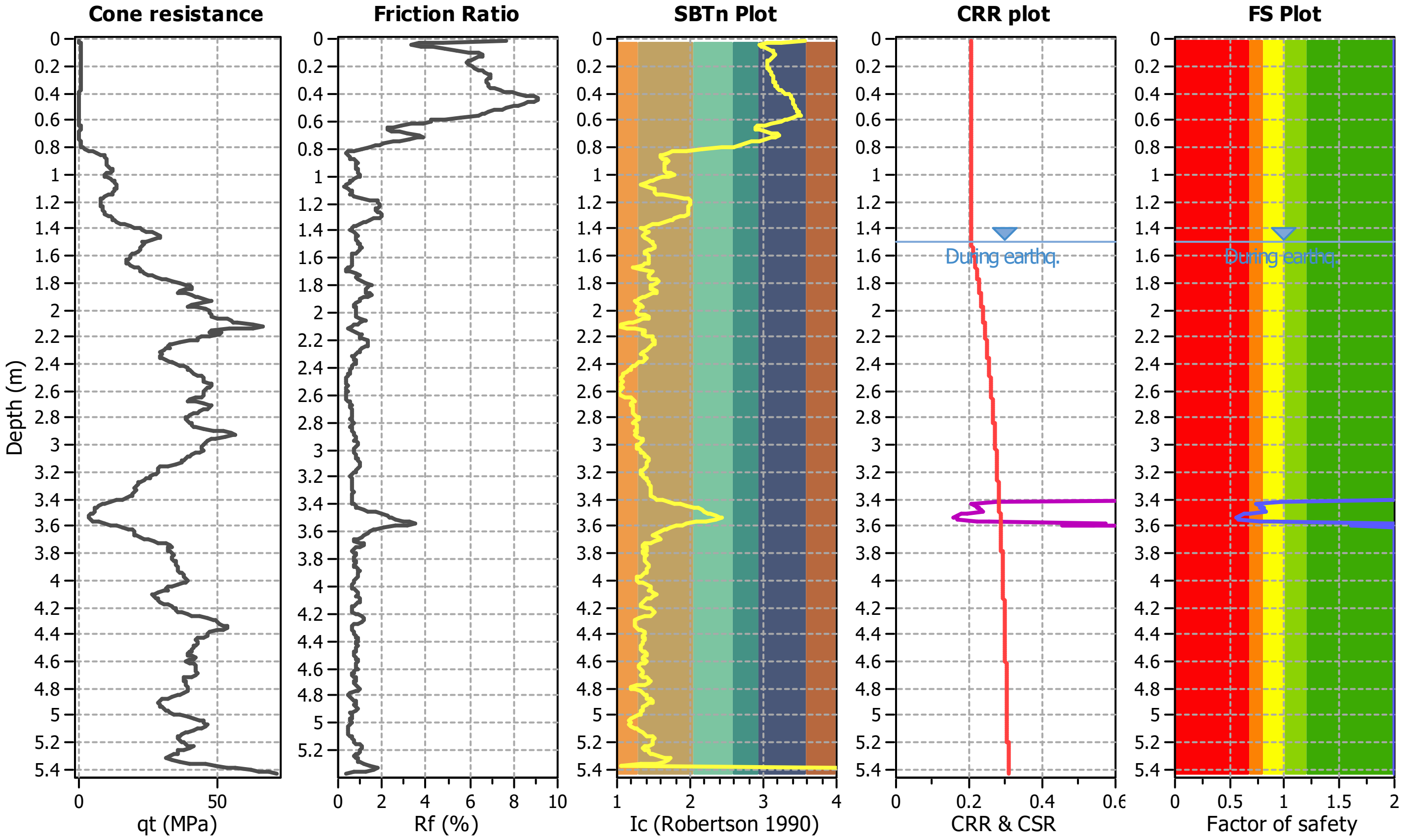
LIQUEFACTION ANALYSIS REPORT

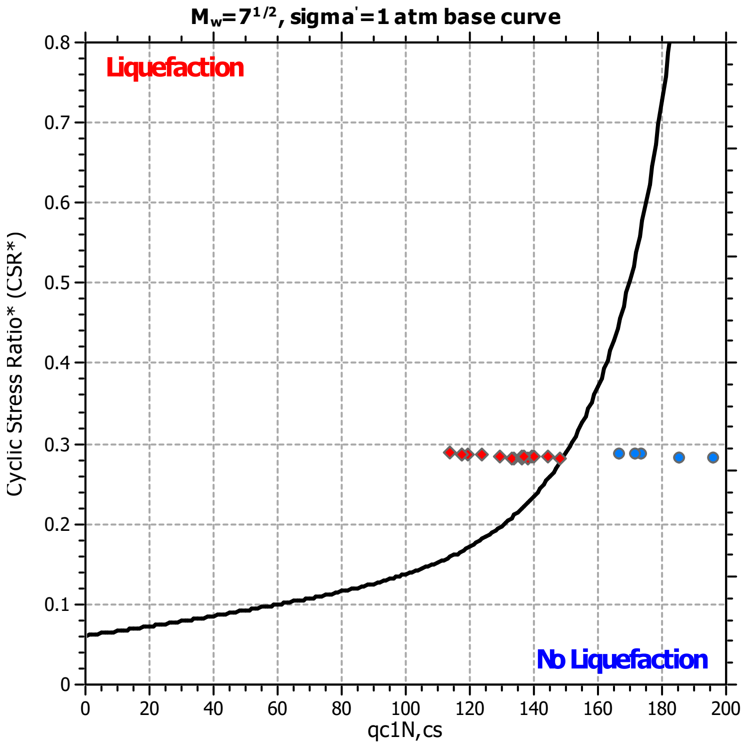
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

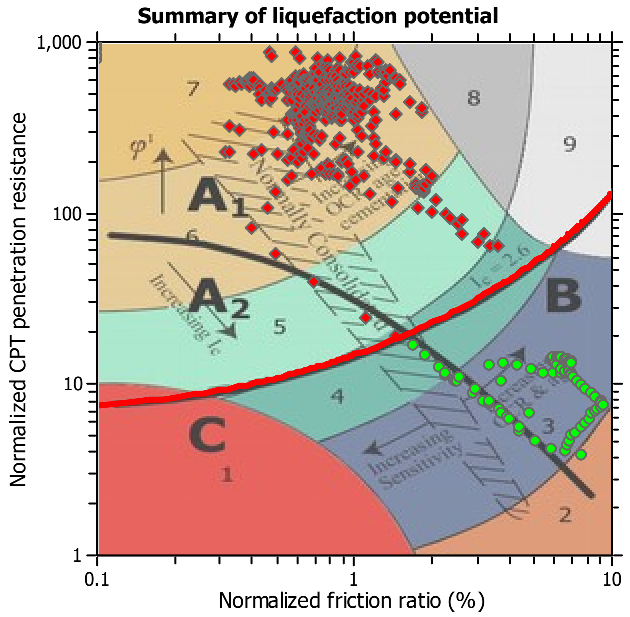
CPT file : CPT10

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		







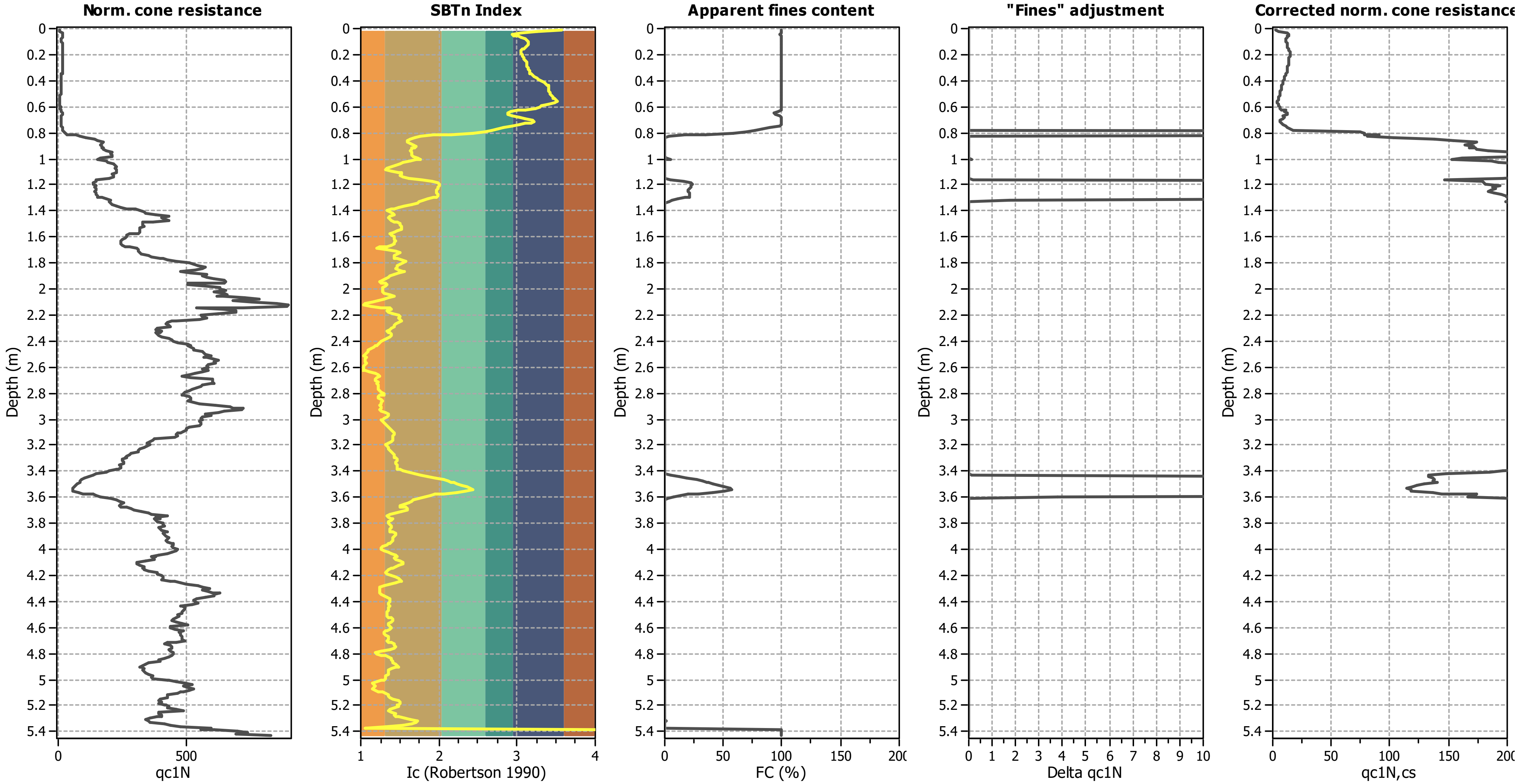
Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading

Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry

Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening

Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

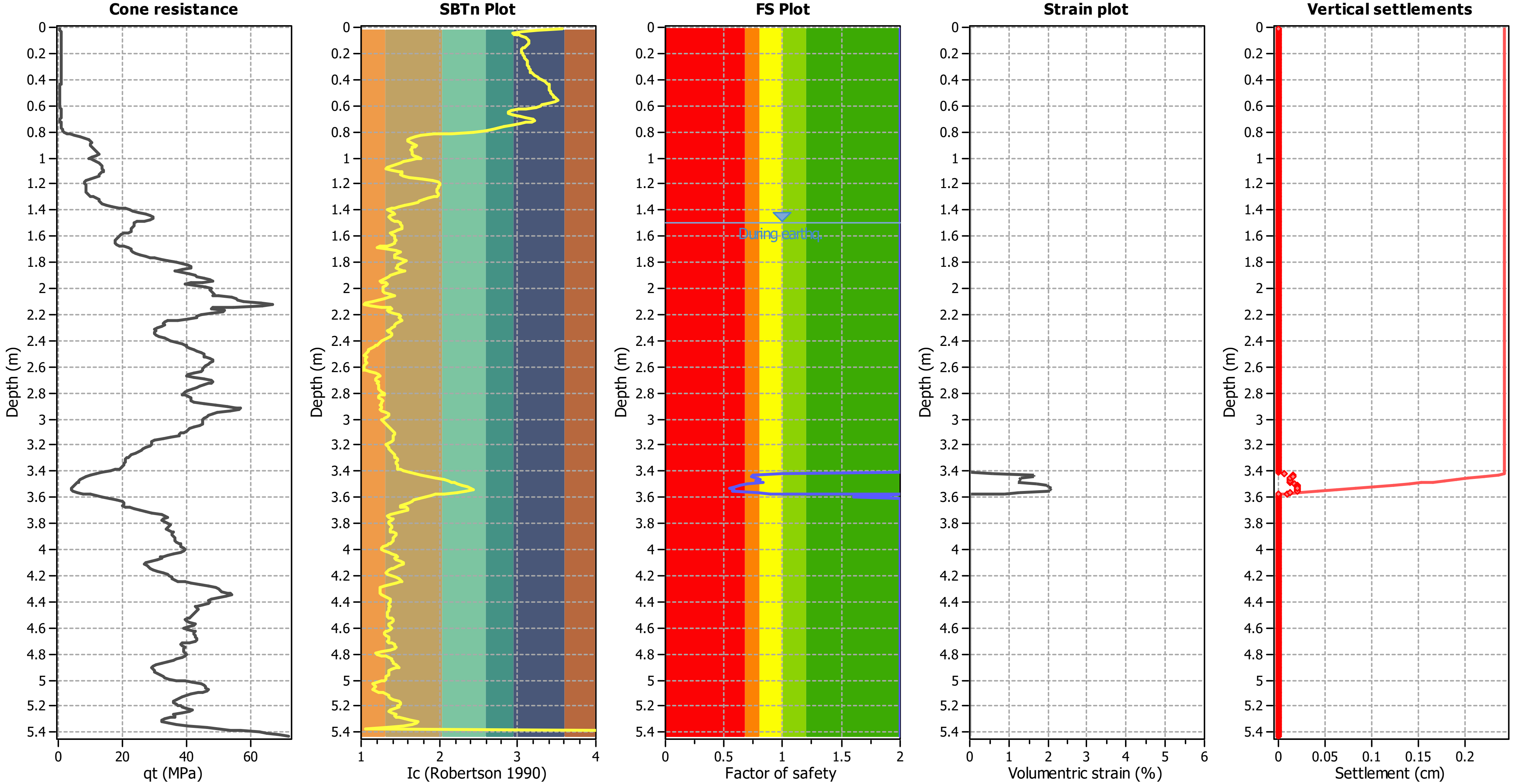
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

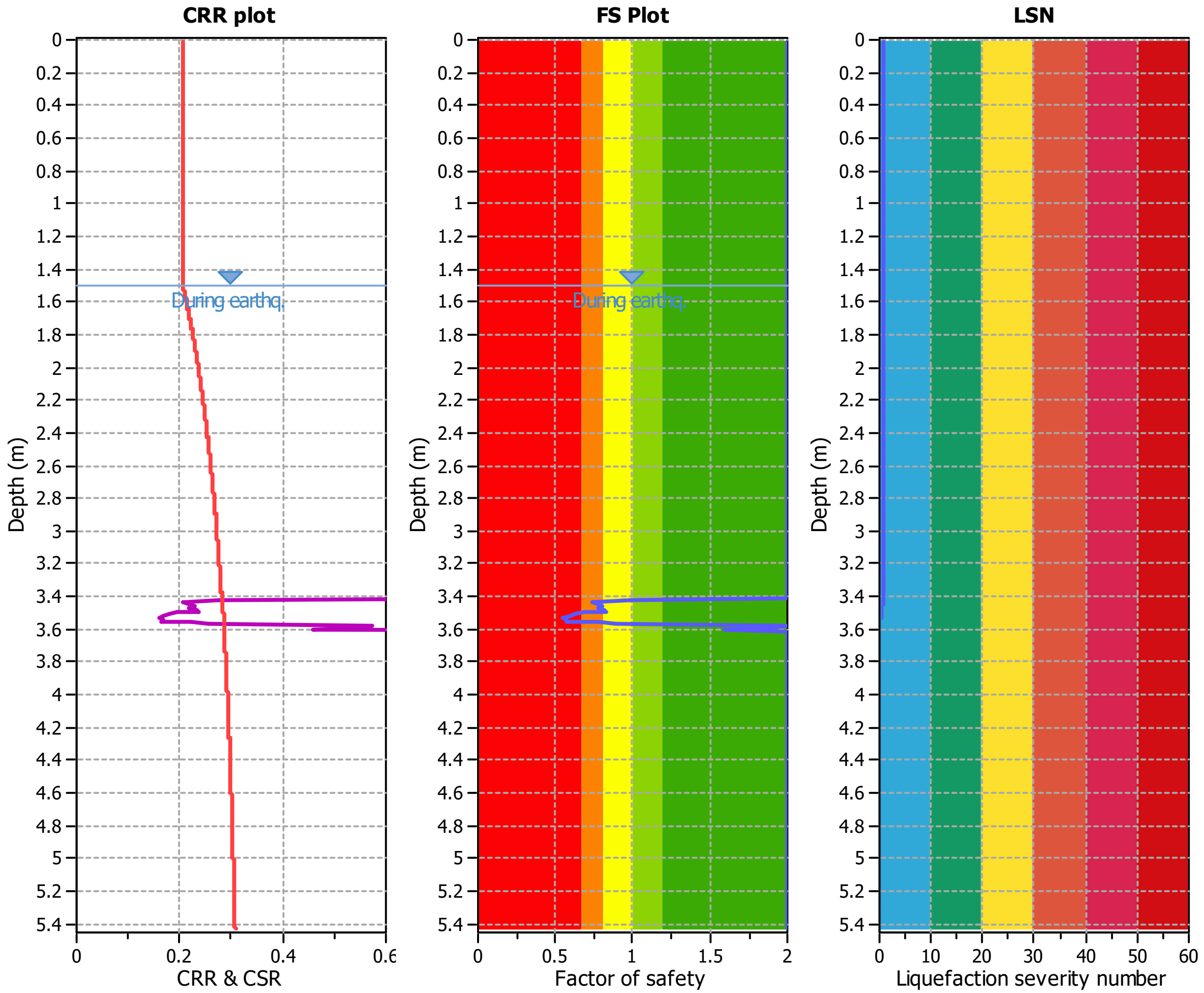
q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: **Richard and Geoff Spark**

Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT10

Total depth: 5.43 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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Consulting Engineers and Surveyors
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LIQUEFACTION ANALYSIS REPORT

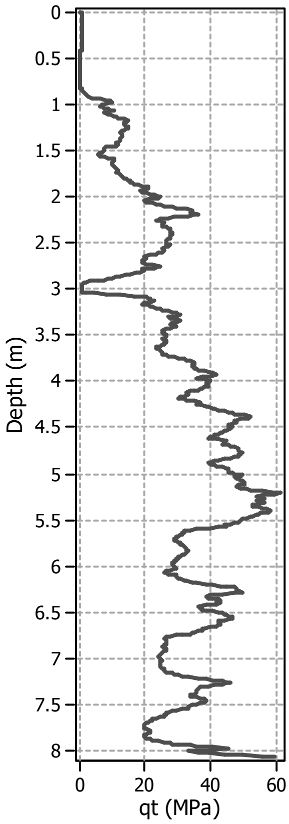
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

CPT file : CPT11

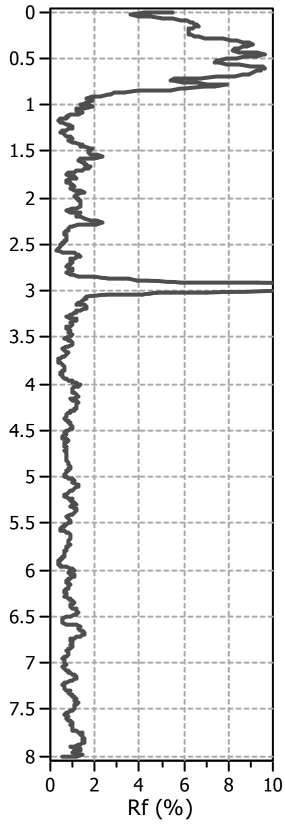
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

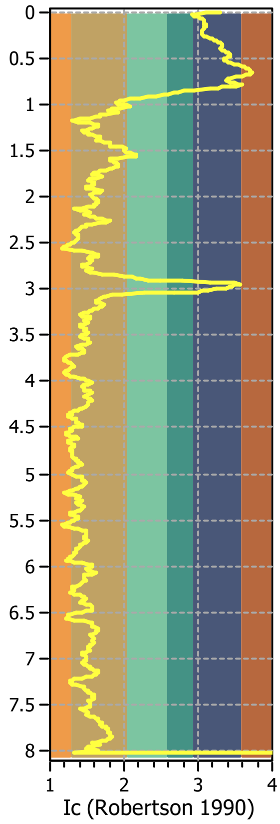
Cone resistance



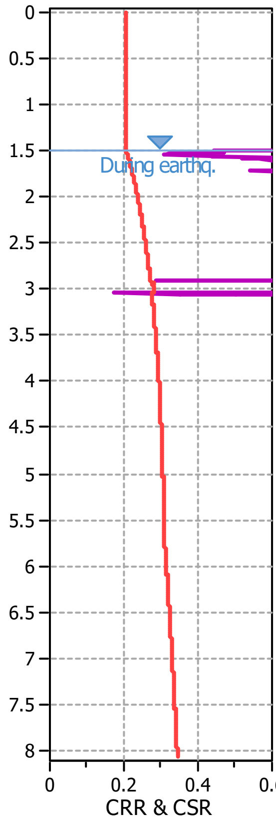
Friction Ratio



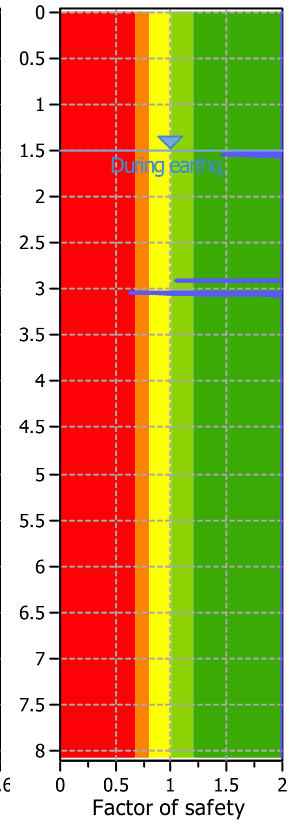
SBTn Plot



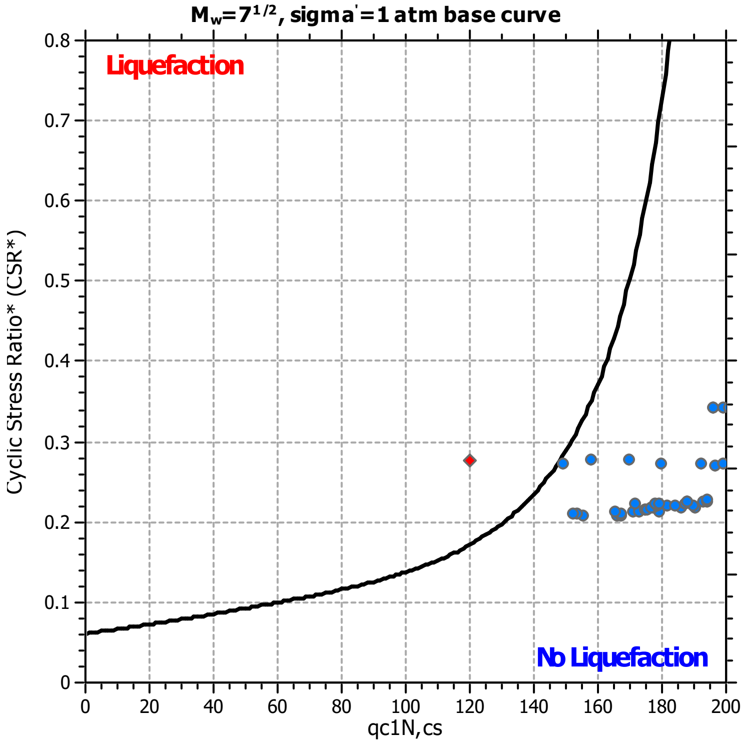
CRR plot



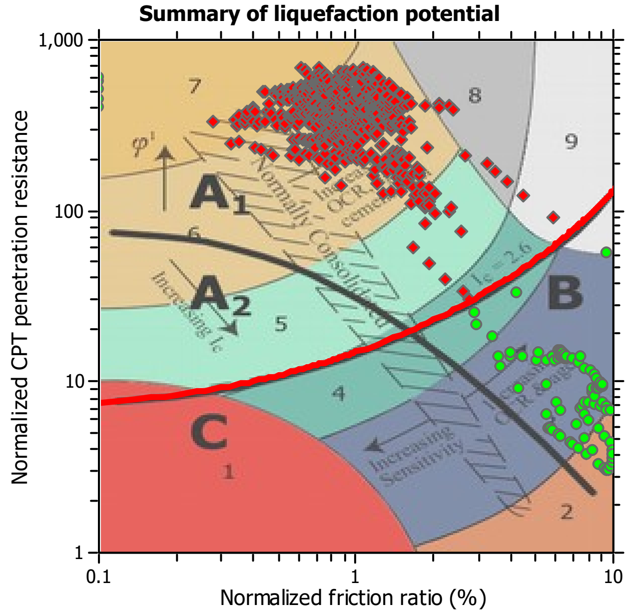
FS Plot



$M_w=7^{1/2}$, sigma'=1 atm base curve

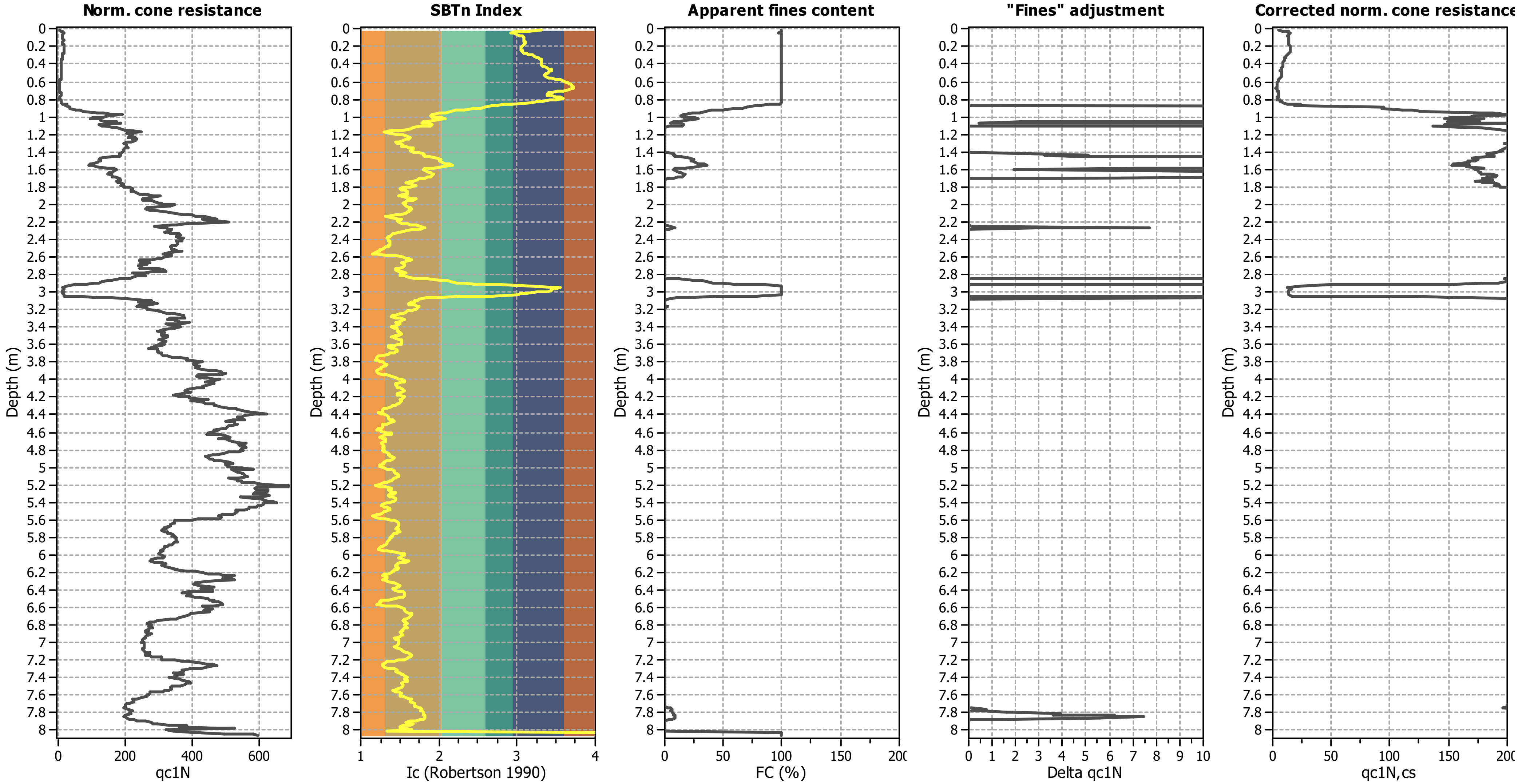


Summary of liquefaction potential



Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

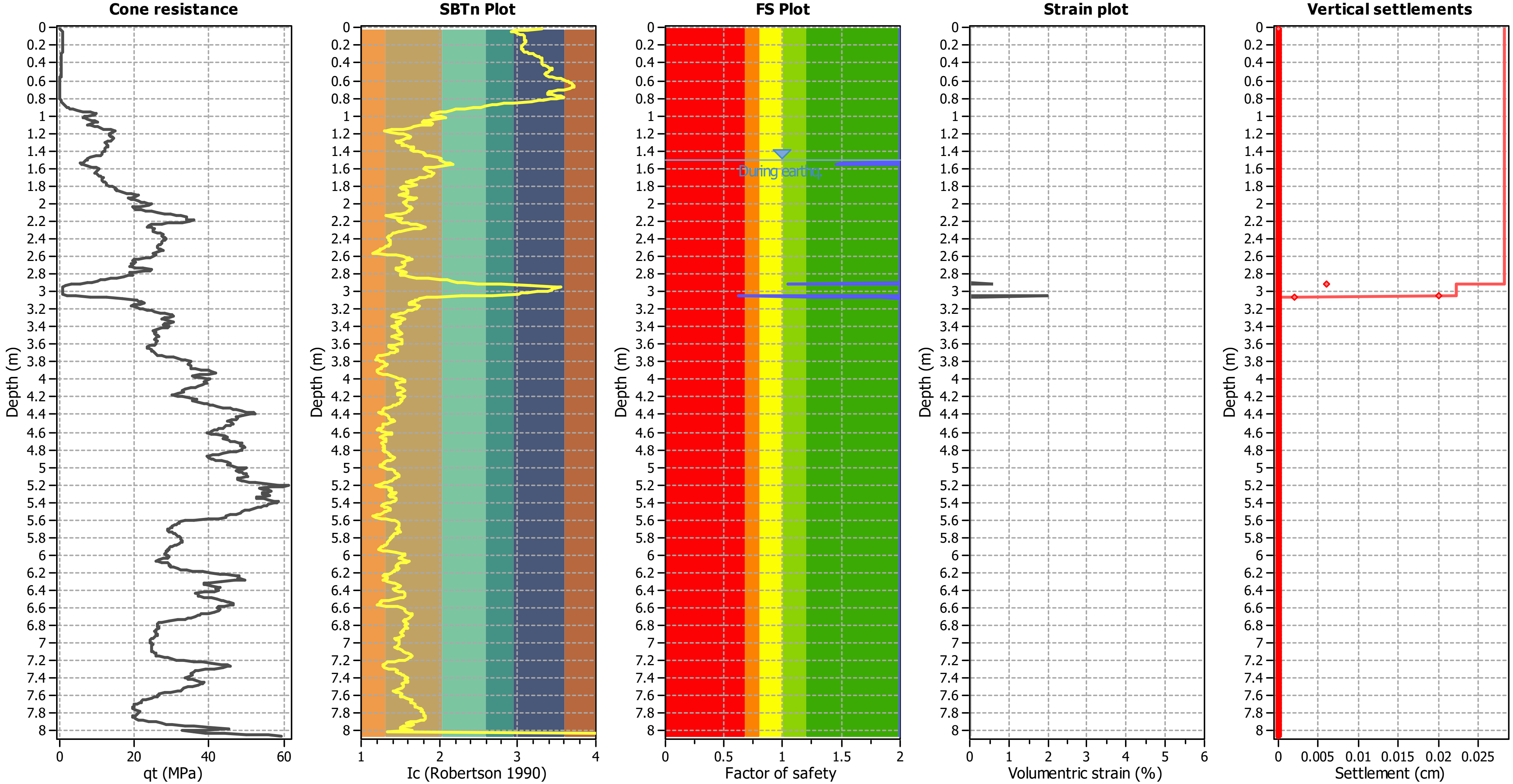
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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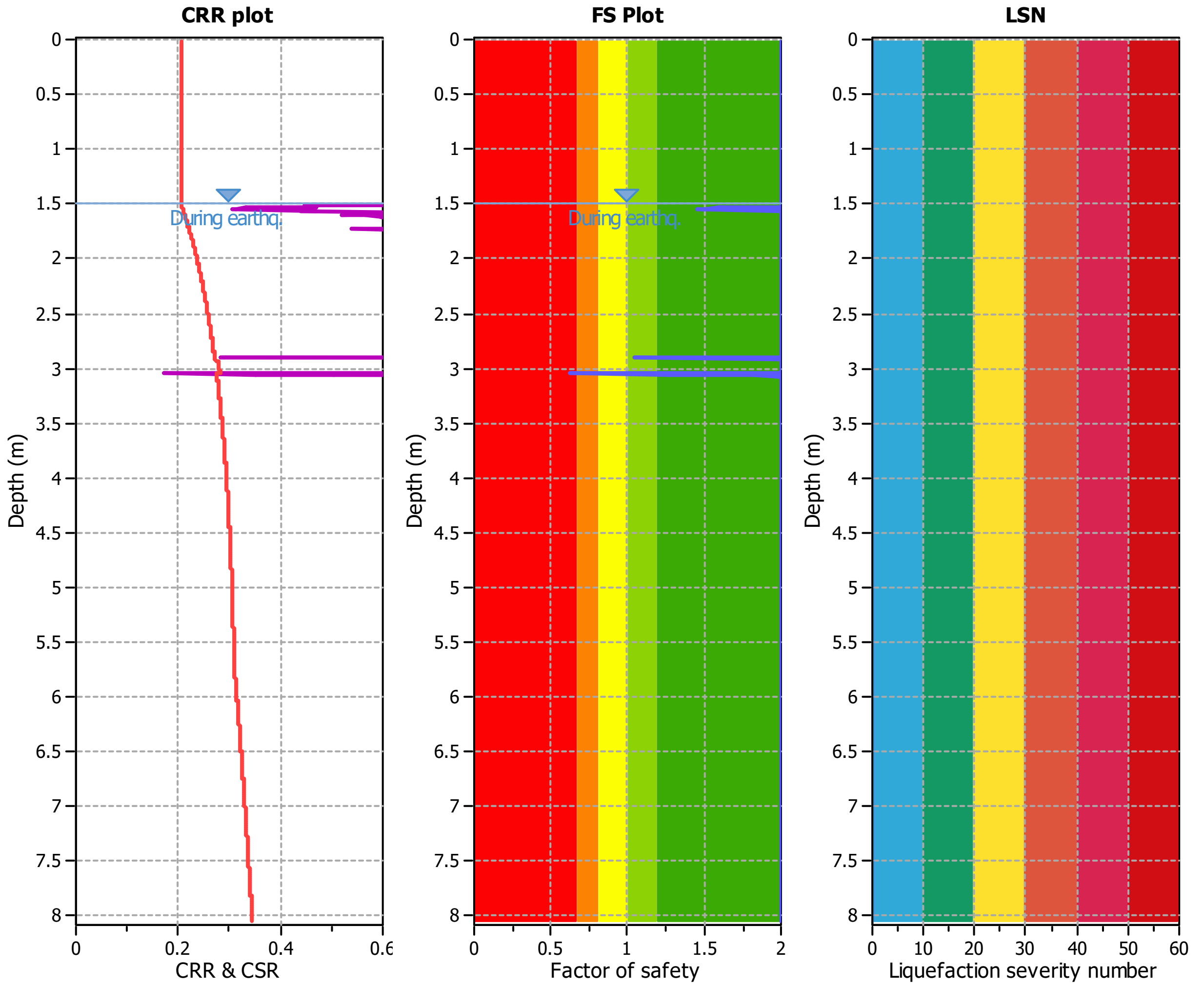
Consulting Engineers and Surveyors
https://fraserthomas.co.nz/

Project: **Richard and Geoff Spark**
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT11
Total depth: 8.06 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

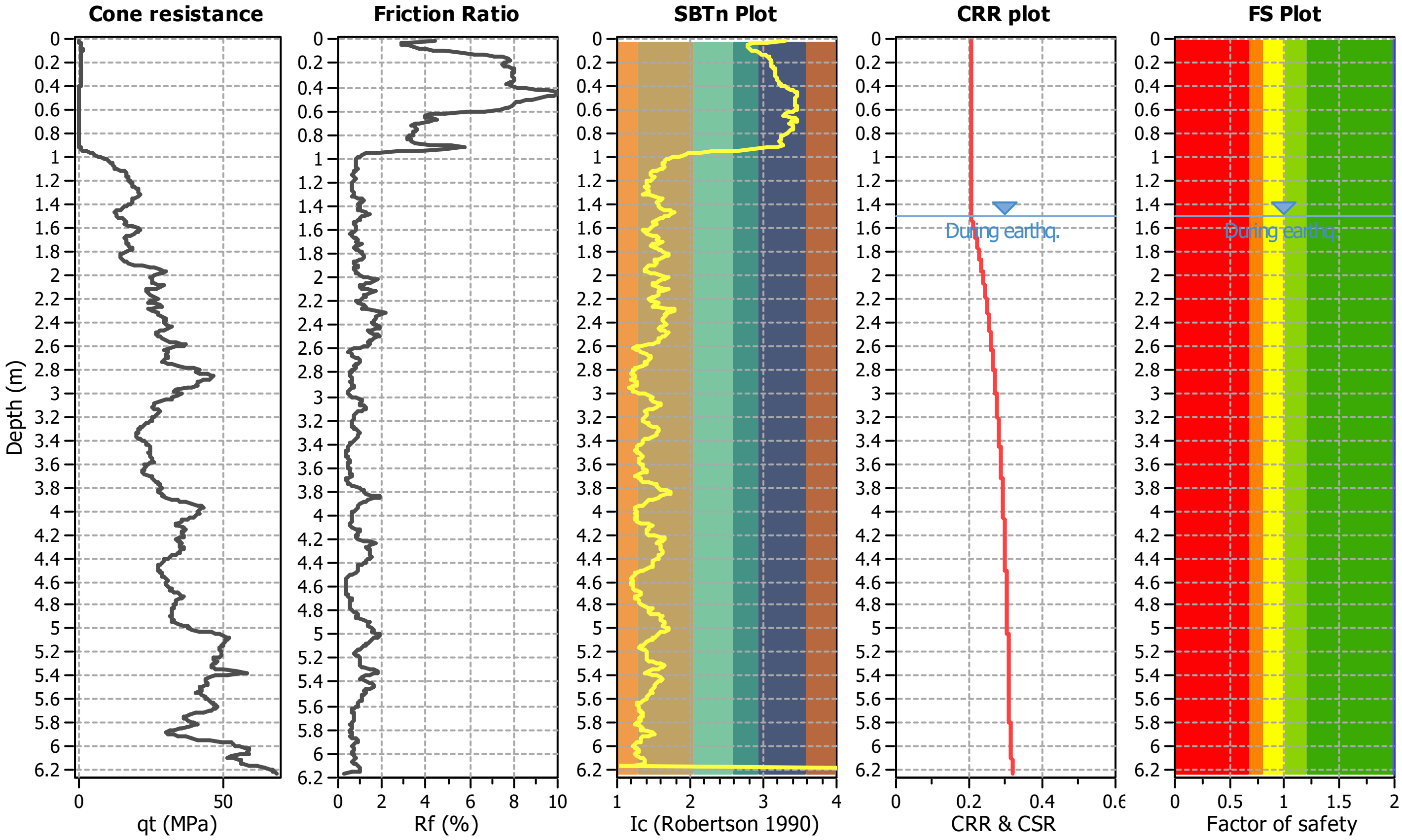
LIQUEFACTION ANALYSIS REPORT

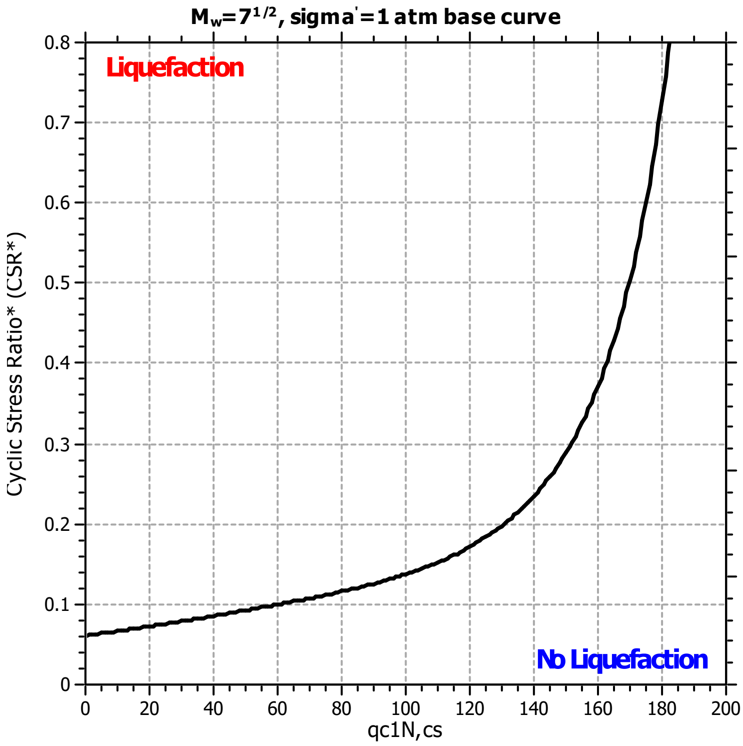
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

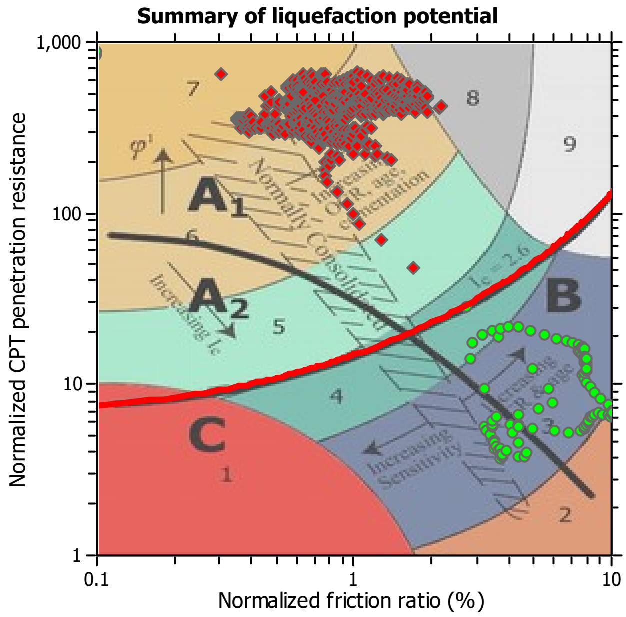
CPT file : CPT12

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

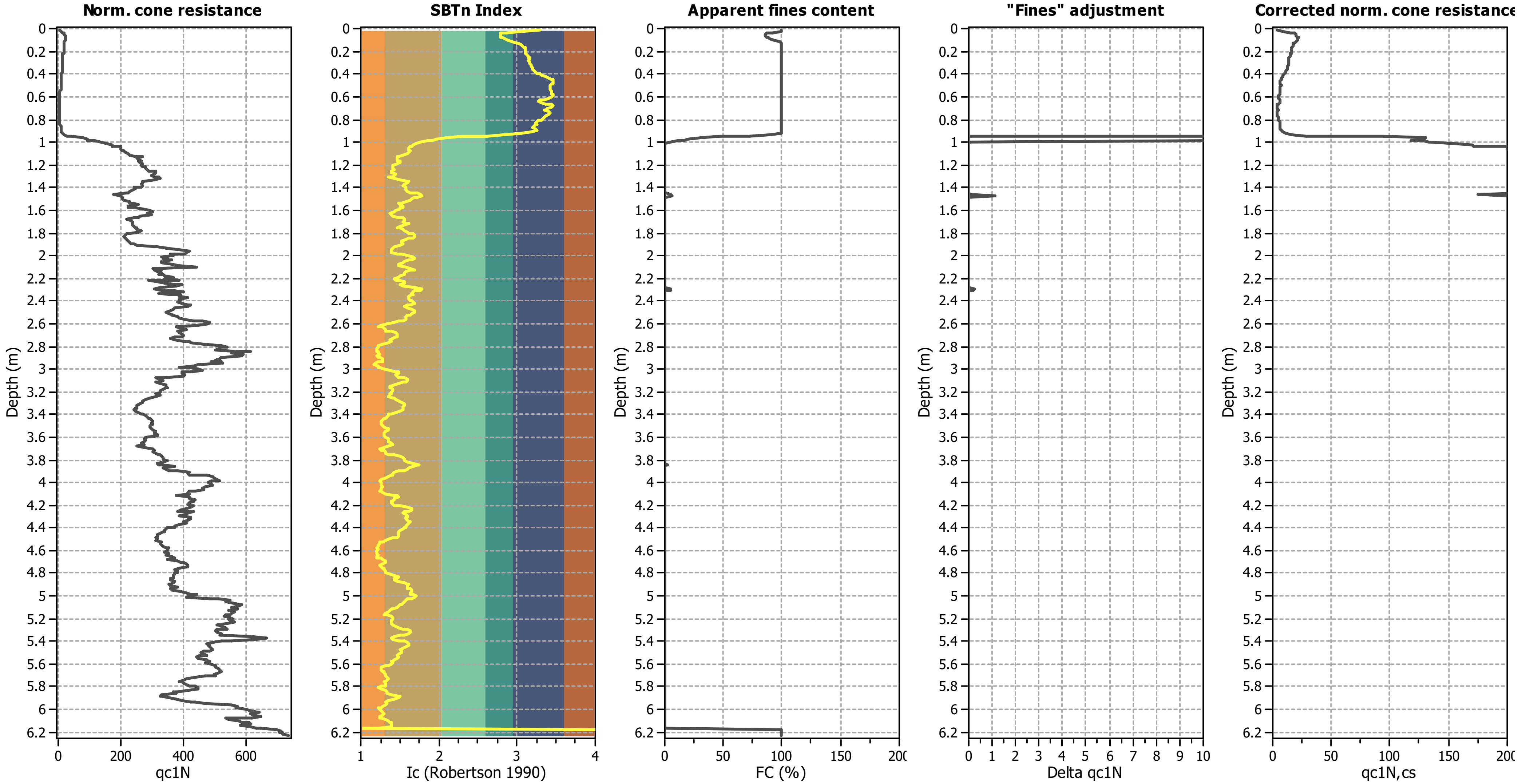






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

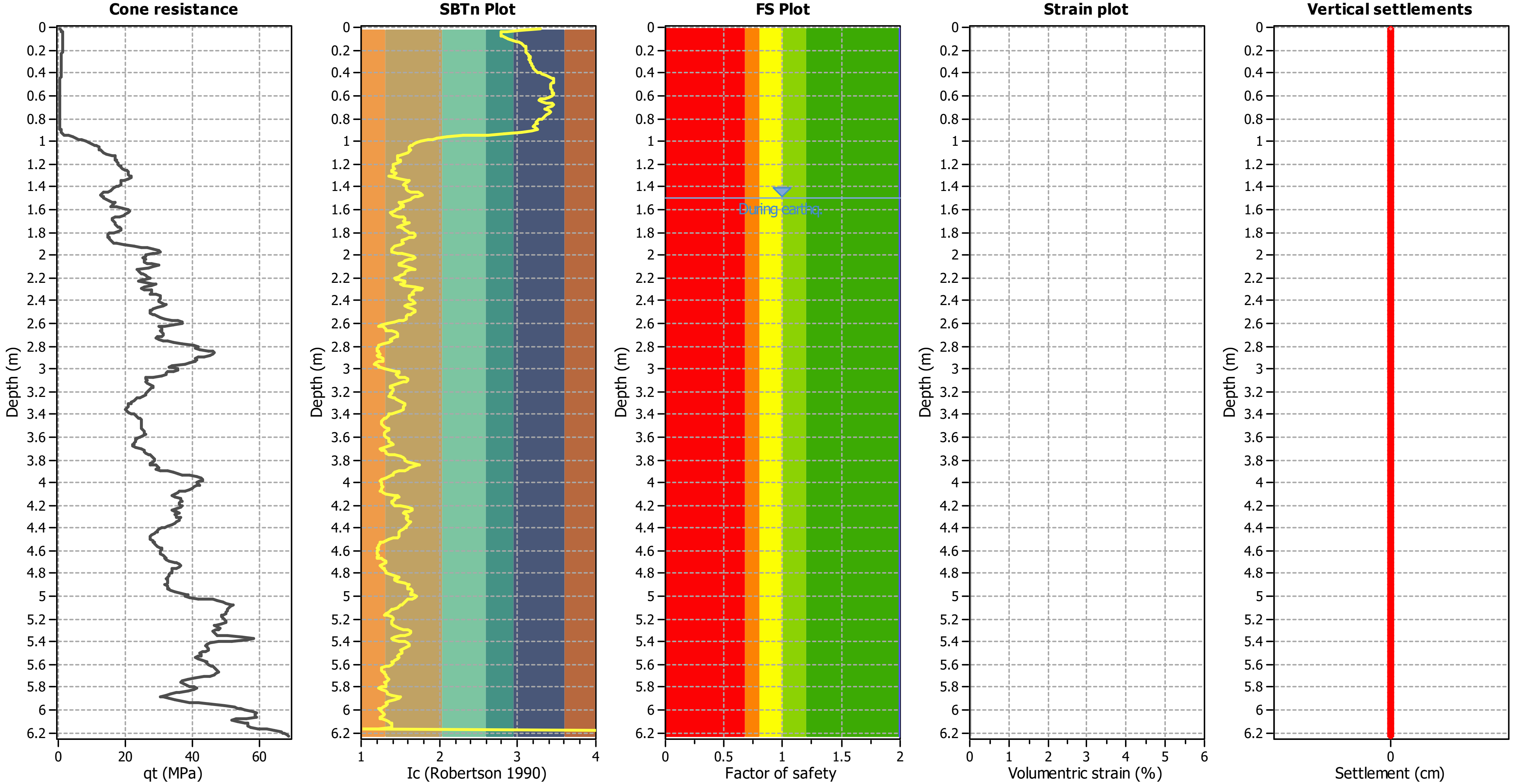
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements

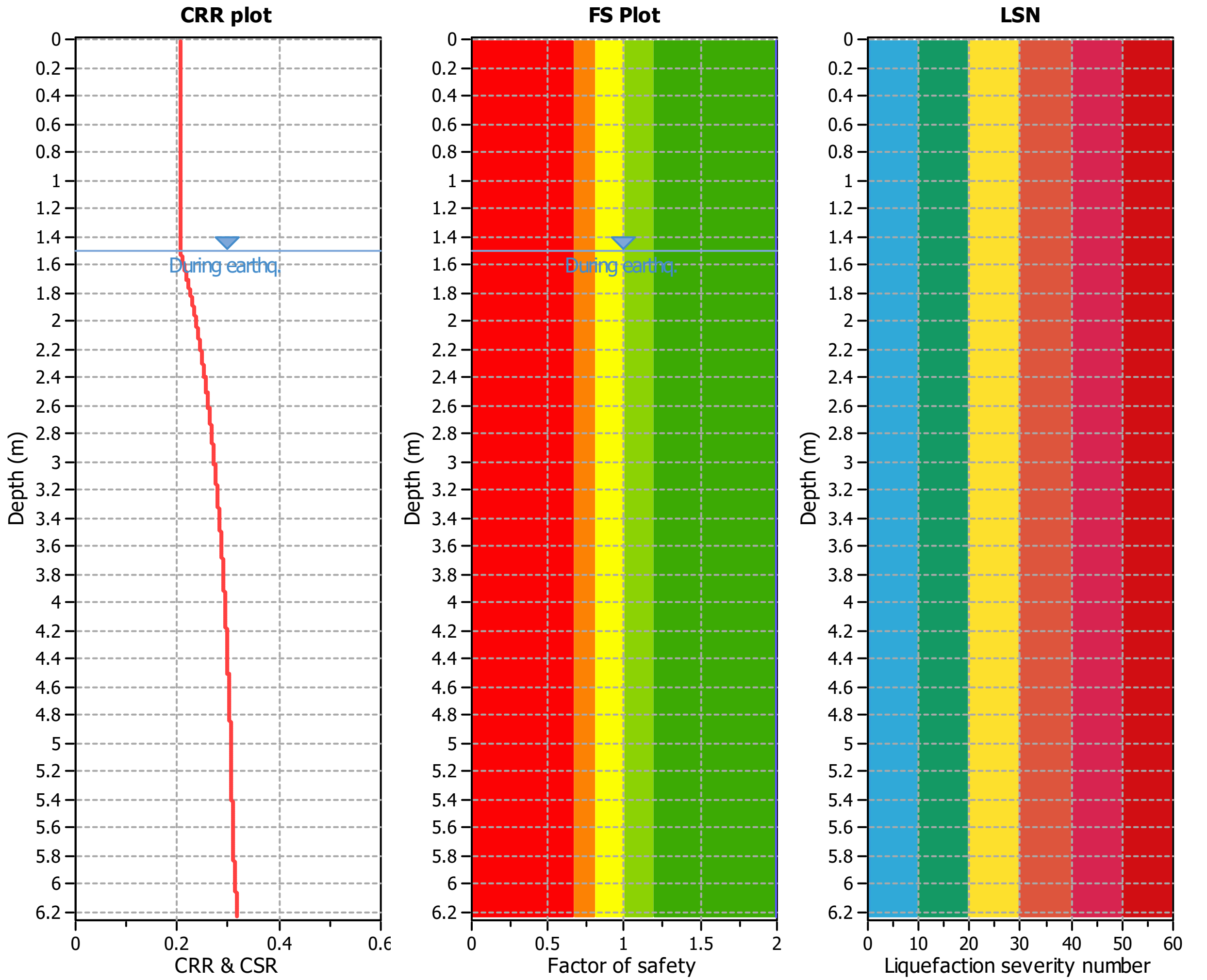


Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Project: Richard and Geoff Spark
Location: Spark Dairy Farm, Boys Road, Rangiora

CPT: CPT12
Total depth: 6.23 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

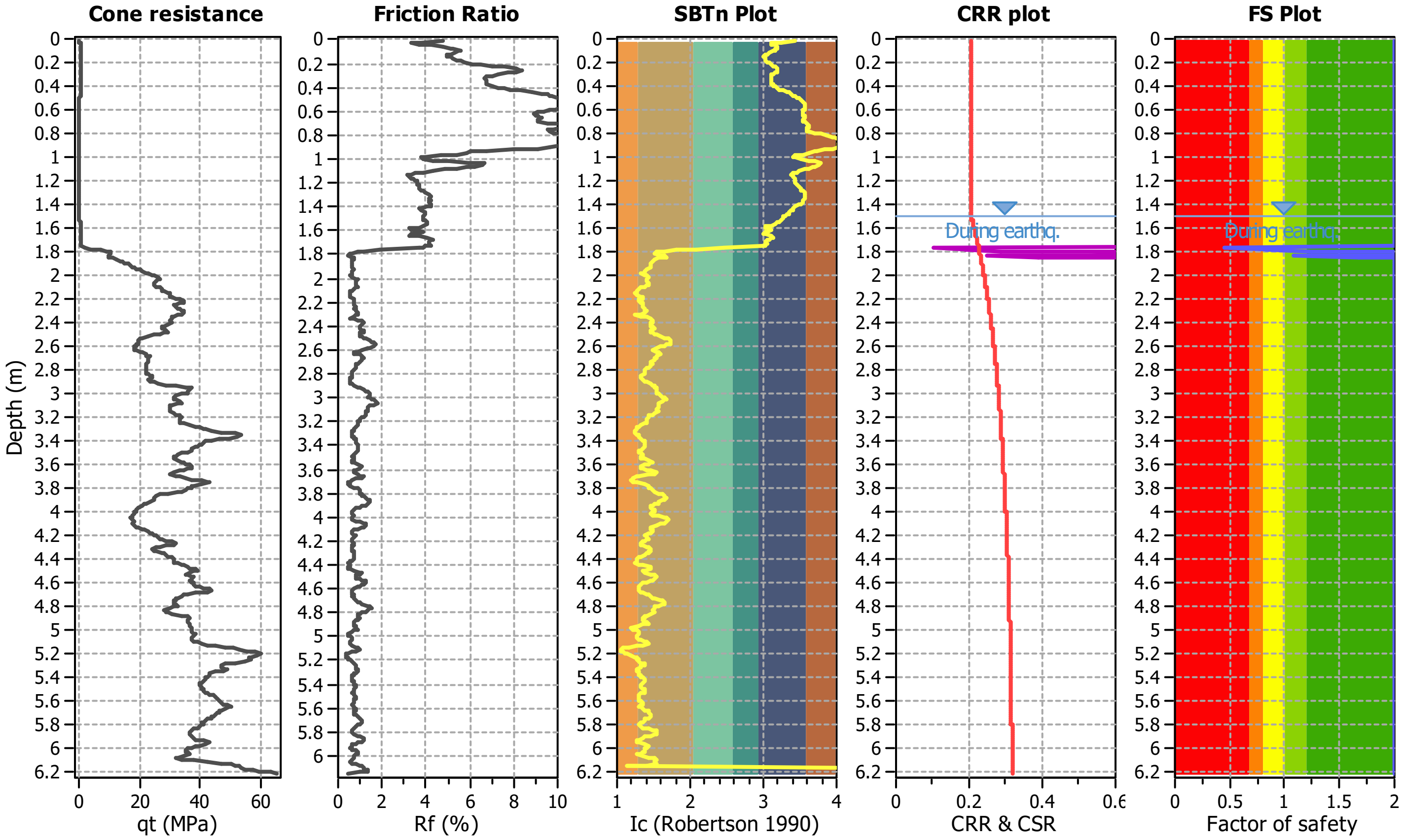
LIQUEFACTION ANALYSIS REPORT

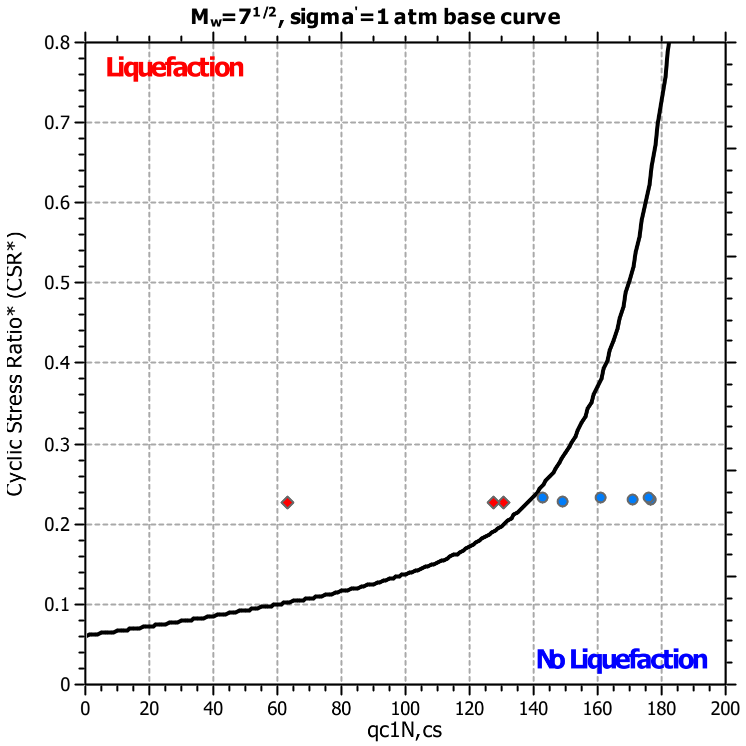
Project title : Richard and Geoff Spark **Location : Spark Dairy Farm, Boys Road, Rangiora**

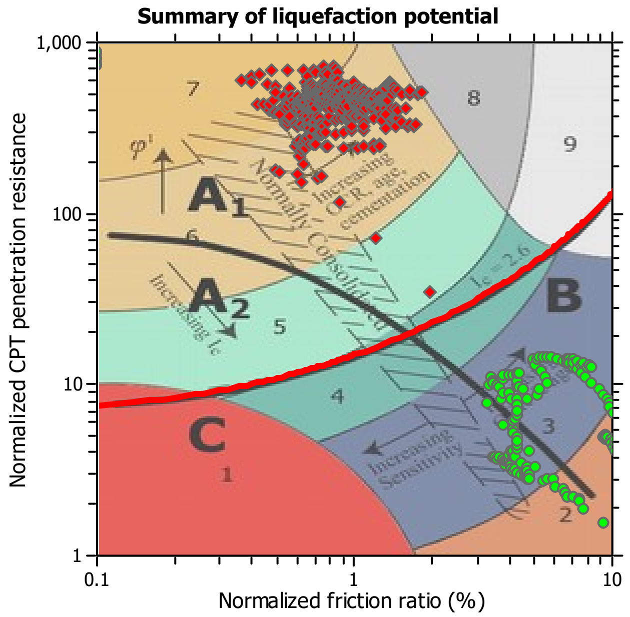
CPT file : CPT13

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

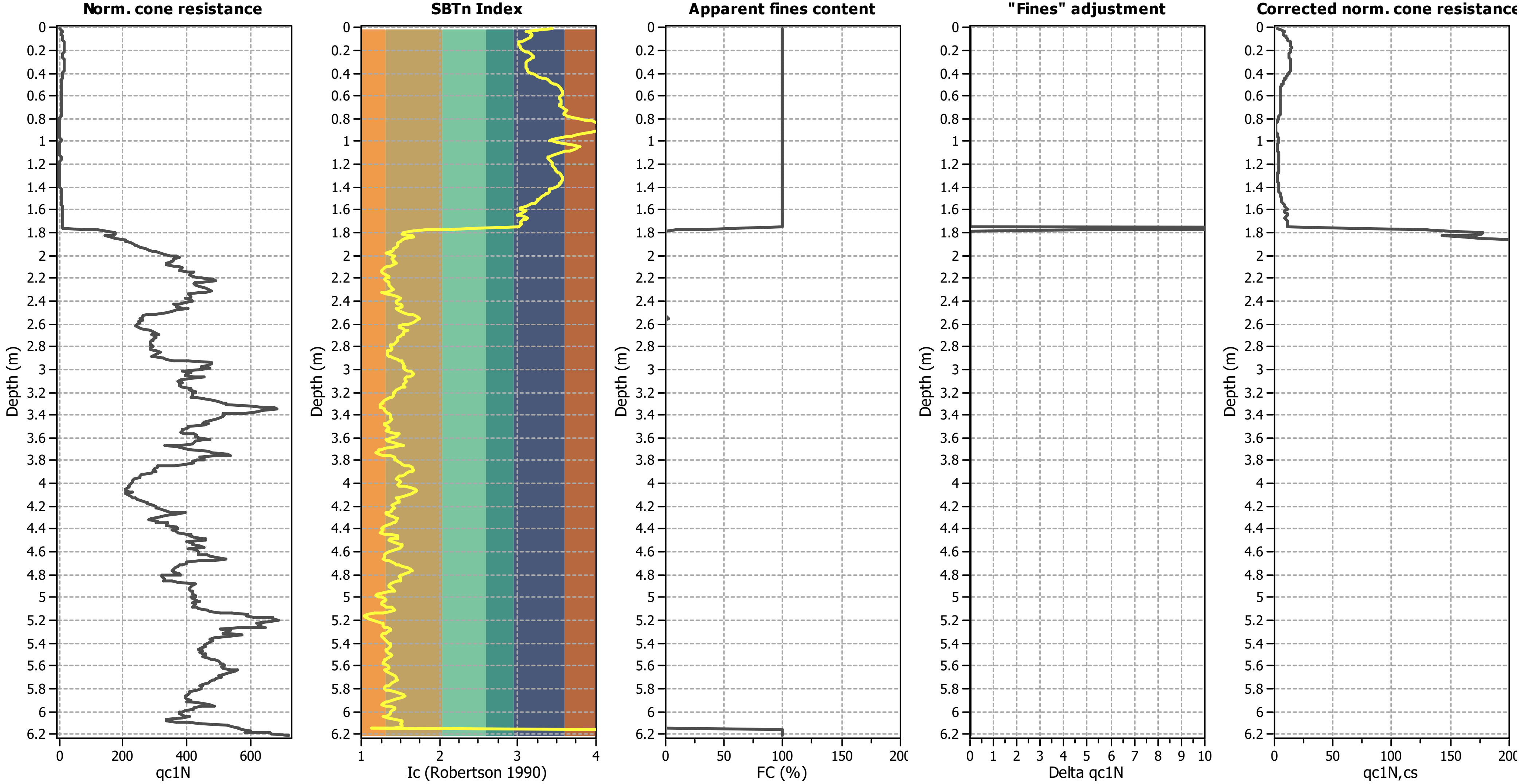






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

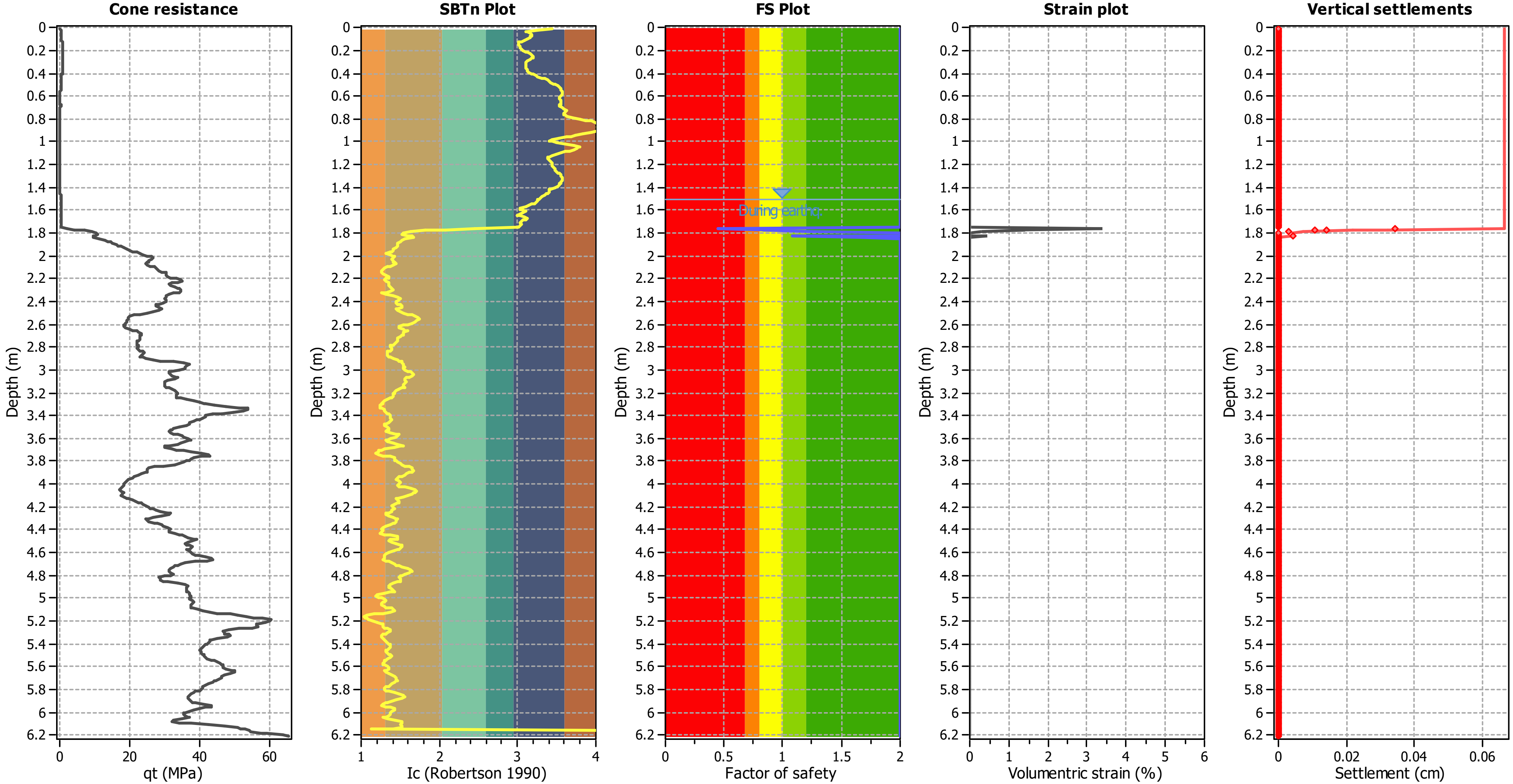
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	10.00 m

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

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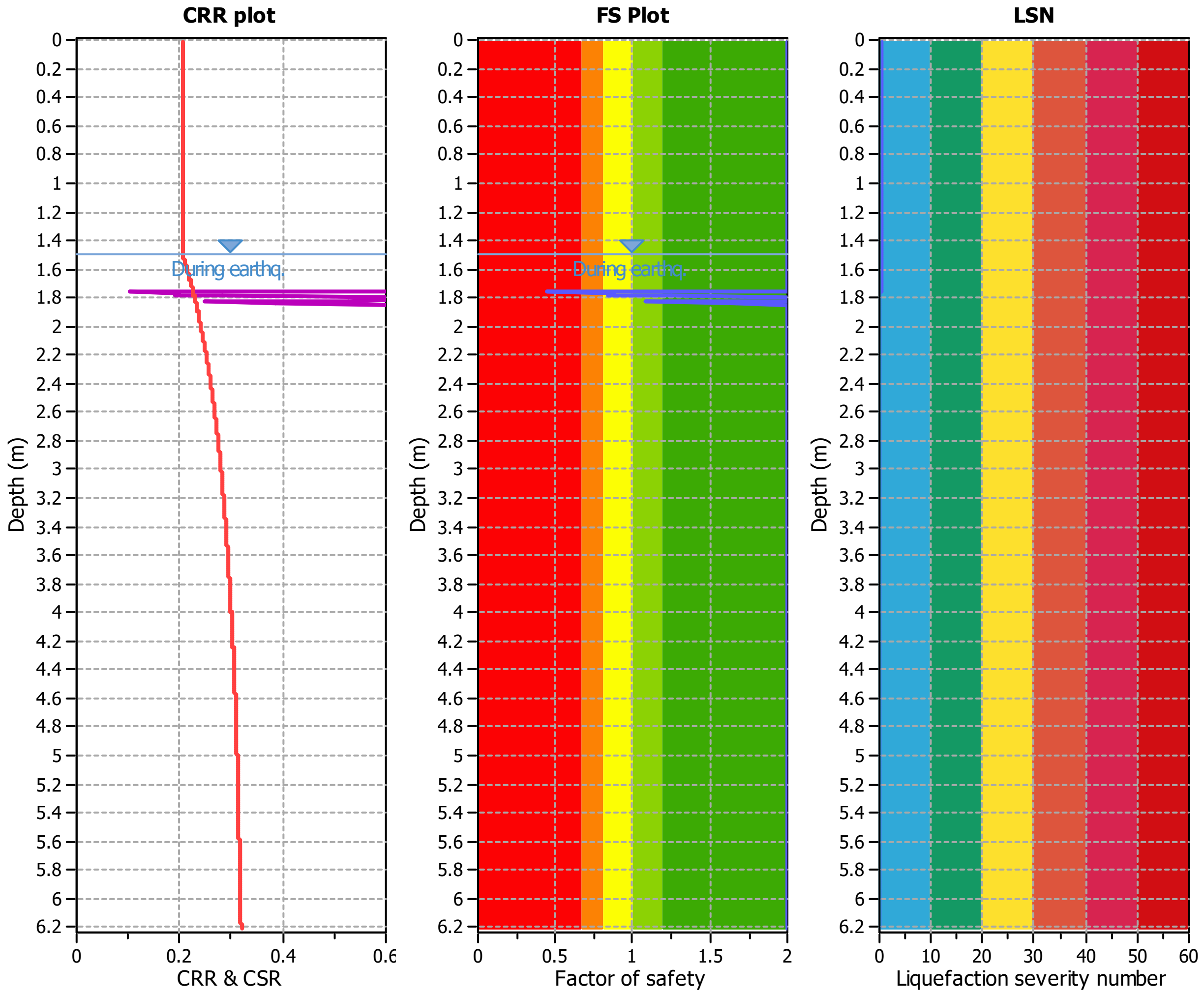
ENGINEERS · RESOURCE MANAGERS · SURVEYORS

Project: **Richard and Geoff Spark**

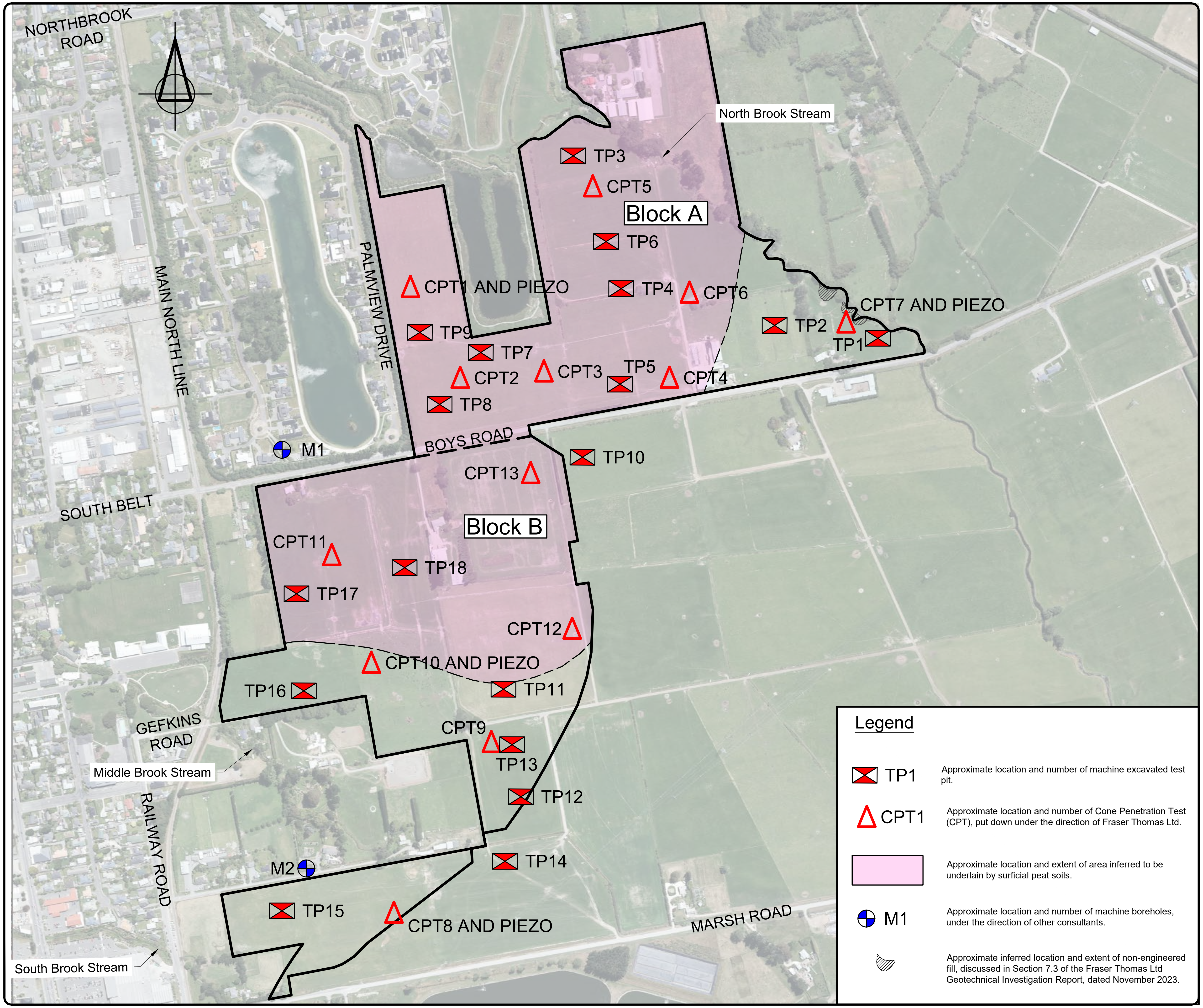
Location: **Spark Dairy Farm, Boys Road, Rangiora**

CPT: CPT13

Total depth: 6.21 m



Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	.
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		



SURVEYED	FTL	25/11/22	APPROVED: MVR
DESIGNED			
DRAWN			
CAD	MC	30/01/23	
CHECKED	KT	01/11/22	

REVISION	CHANGES	CHECKED	DATE

NOTES

1. The location and extent of the site boundaries have been adopted from Landonline and from the available Council road designation information.

CLIENT

RICHARD AND GEOFF SPARK

PROJECT

REZONING REQUEST
SPARK DAIRY FARM,
BOYS ROAD, RANGIORA

TITLE

SITE PLAN

Fraser Thomas

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AUCKLAND 09 278 7078
HAWKE'S BAY 06 211 2766
CHRISTCHURCH 03 358 5936
BLENHEIM 03 428 3292
NELSON 03 222 1132

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SCALE 1:6000 (A3)

DRAWING No CH01508-G-02 REVISION

SHEET 1 of 1