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Preface

This document has been written by Tonkin & Taylor Ltd and is intended as a field investigation code of practice and reference guide to methodologies for all parties involved in the Earthquake Commission Geotechnical Investigation Project (EQC GI Project).

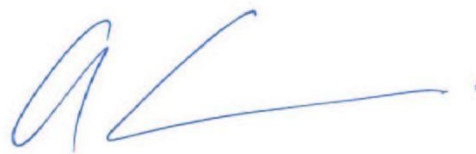
The main impetus for this document is to standardise field practices employed throughout the EQC GI Project and provide a reference for field staff engaged in the various key investigation duties. Although not a conclusive text it is perceived that the majority of processes, common duties and issues that may arise have been covered. Any other process, test or complication is to be referred back to the Engineer overseeing the investigation for further clarification.

This document has been reviewed by the following key members of the EQC GI Project team and the Engineers Collaboration Group (ECG) and the comments and feedback received from these persons has been incorporated as appropriate.

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Purpose of EQC Geotechnical Investigation Project

As a result of the extensive land damage caused by the 2010 – 2012 Canterbury Earthquake Series, the Canterbury Earthquake Recovery Authority (CERA), with assistance from the Department of Building & Housing (DBH), has divided Canterbury residential green zone into three technical categories with respect to future requirements for the investigation, repair and/or replacement of foundations (TC 1, TC 2 and TC 3). Residential properties located in areas where over 100mm of liquefaction settlement has occurred, and/or where severe and widespread liquefaction induced lateral spread damage to land and properties has occurred have been zoned residential “RED” by CERA.

EQC commissioned their 2012-2013 “deep” geotechnical investigation program as a direct consequence of the M6.3 earthquake that occurred on 22nd February 2011. Table 1 below provides a summary of the investigation type and locations which have been completed under this program. Detailed records for each of the investigations which are listed in Table 1 have been uploaded to the Canterbury Geotechnical Database (CGD) as soon as all appropriate QA/QC checks have been completed.

Table 1: Summary of the 2012-2013 EQC Geotechnical Investigation Program

Stage	Description	Number Of Investigations		
		Machine Drillholes	CPT's	Dynamic Probe Tests
1A	Machine drillhole and CPT investigations in TC3 zones to support residential repair and rebuild works which are completed as part of the FEQR program. In general, the target depth of these investigations was 20.00 m bgl	720	2,379	40
1B	Additional machine drillholes and CPT investigations in TC3 zones to provide information in-between stage 1A investigation locations. The target depth of these investigations was 10.00 m bgl	70	1,264	-
1C	Machine drillhole and CPT investigations within the residential Red Zone and immediately adjacent to TC3 land. The target depth of these investigations was 10.00 m bgl	19	186	-
1D	Machine drillhole and CPT investigations within TC2 land and adjacent to TC3 land. The target depth of 10.00 m bgl	41	418	-
TOTAL		850	4247	-

It is anticipated the EQC will commission a limited number of additional deep geotechnical investigations during 2013-2014 to supplement the information which is obtained from the above program. These investigation results will also be published on the CGD immediately after all appropriate QA/QC checks have been completed. These investigations are to be known as the Stage 1E and Stage 1F EQC investigations.

The primary purpose of the EQC GI programme is to expedite collection of the geotechnical data necessary to permit foundation repair / replacement options for “under-cap” properties to be scoped, designed, costed and constructed.

There are a number of subsidiary benefits to the investigations being undertaken, including:

- Significant programme and cost reductions from undertaking area wide investigations rather than individual properties on an ad hoc basis. This is expected to reduce the overall number of the investigations required and improve the quality and consistency of the data which is obtained.
- By completing area wide investigations and making this data available via the Canterbury Geotechnical Database (CGD), Engineers and other organisations who are involved in the rebuild process are able to review and analyse the data which is collected by the EQC GI Project. This has the potential to result in cost and program savings to the wider earthquake recovery process.
- The information being collated and uploaded to the CGD will form one of, if not the, largest database of geotechnical data relating to liquefaction susceptible soils in the world. This information will not only have a direct benefit to Christchurch residents affected by the recent earthquakes, but will also contribute to international research and understanding of land damage resulting from earthquakes; particularly with respect to prediction of, and damage resulting from, liquefaction and lateral spreading in similar geotechnical environments.

Role and Responsibilities of Field Staff

The primary responsibility of all field staff, through application of the methodologies outlined in this manual is intended to ensure that the raw geotechnical data is of a high quality and is collected in a systematic, consistent and reproducible manner. The information collated will be made available to third parties through inclusion on the CGD and will be subject to a high level of scrutiny from geotechnical specialists using the information directly to design foundation repair / replacement options, as well as national and international peer reviewers acting on behalf of key stakeholders (such as the major insurers / reinsurers) and research institutions. It is imperative that field staff commit to undertake their work with a full understanding of the purpose and outcomes that will stem from the data obtained.

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1 Introduction

1.1 Definitions

ASTM	Means the American Society for Testing and Materials International. An international voluntary consensus standards body that develops the standards in use on the EQC GI Project.
BCPT	Means Borehole Cone Penetration Test. This borehole replaces a CPT shallow refusal.
BS	Means British Standard.
CERA	Means the Canterbury Earthquake Recovery Authority.
CPT	Means Cone Penetrometer Test.
CPTB	Means a CPT investigation located specifically within 2 meters of a borehole (or a maximum of 5 meters in cases of difficult access). This CPT is designed to tie other CPT investigations in the area to the observed geology of a borehole.
DBH	Means the Department of Building and Housing, a division of the New Zealand Government, recently restructured to become a branch within the Ministry of Business, Innovation and Employment (MBIC).
Dissipation Test	Means an additional CPT procedure to measure groundwater pressure and improve the accuracy/correctability of CPT measurement.
DPH	Means Dynamic Probe Heavy (often referred to under the umbrella colloquial term 'HDCP').
DPSH-B	Means Dynamic Probe Super Heavy B (often referred to under the umbrella colloquial term 'HDCP').
ECan	Means Environment Canterbury.
EQC	Means The Earthquake Commission.
EQC GI Project	Means the Canterbury EQC Geotechnical Investigation Project.
Engineer	Means a specified employee of Tonkin & Taylor Ltd or authorised representative who is responsible for management of all or part of the EQC investigation and directing the Contractor. This may refer to other geotechnical engineering companies from time to time.
FEQR	Means Fletchers Earthquake Recovery.
Field Staff	Means the Engineers appointed representatives and seconded staff, variously charged with marking out, services clearance, traffic control, supervision, logging of the works, etc.
GPR	Means Ground Penetrating Radar. For the purpose of this project GPR is used for the detection of buried service lines, but may be used as a geotechnical investigation tool in its own right.
HQTT	Means HQ size Triple Tube drilling method / technology. Borehole is logged from rock/soil core that is recovered during the process.

ISO	Means International Standards Organisation.
m bgl	Means Meters Below Ground Level at the time the investigation was carried out.
PDCPT	Means Predrill Cone Penetration Test. This forms part of the CPT shallow refusals procedure.
Rotary Mud	Means Rotary open hole drilling techniques using a recirculated flush/mud. The borehole is logged from highly disturbed cuttings.
Rotary Sonic	Means Rotary Sonic Drilling method's / technology. Borehole is logged from rock/soil core that is recovered during the process.
Site	Means the location of the geotechnical investigation and the surrounding subcontractors working area.
SPT	Means Standard Penetration Test as completed in accordance with the methodology stipulated in ASTM D1586-11.
Subcontractor	Means subcontractors engaged by the Earthquake Commission to undertake Investigative work.
TC3	Means land which has been designated by CERA and DBH as "Technical Category 3". A full description of the location of this zone and the assessment criteria in provided in DBH ^{1, 2, 3} and CERA ⁴ publications.
TC2	Means land which has been designated by CERA and DBH as "Technical Category 2". A full description of the location of this zone and the assessment criteria in provided in DBH ^{5, 6, 7} and CERA ⁸ publications.
TC RED or Red Zone	Referred to as RED zone for the purpose of this document. Means land which has been designated by CERA and DBH as "Residential RED Zone". A full description of the location of this zone and the assessment criteria in provided in DBH ^{9, 10, 11} and CERA ¹² publications.
T&T	Means Tonkin & Taylor Ltd.
Wand	Means an Engineer approved, specified Service Location Detector (Cable Avoidance Tool (CAT) or similar)

¹ Revised guidance in repairing and rebuilding houses affected by the Canterbury earthquake sequence, Department of Building and Housing, November 2011 ISBN: 978-0-478-38131-3 (website)

² Interim guidance for repairing and rebuilding foundations in Technical Category 3, Department of Building and Housing, 27 April 2012, ISBN: 978-0-478-38163-4 (website)

³ CERA website: <http://cera.govt.nz/residential-green-zone-technical-categories>

⁴ Guidelines for the geotechnical investigation and assessment of subdivision in the Canterbury region, Department of Building and Housing, 14 November 2011, ISBN: 978-0-478-38131-3 (website)

⁵ Revised guidance in repairing and rebuilding houses affected by the Canterbury earthquake sequence, Department of Building and Housing, November 2011 ISBN: 978-0-478-38131-3 (website)

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¹¹ CERA website: <http://cera.govt.nz/residential-green-zone-technical-categories>

¹² Guidelines for the geotechnical investigation and assessment of subdivision in the Canterbury region, Department of Building and Housing, 14 November 2011, ISBN: 978-0-478-38131-3 (website)

1.2 General

This manual has been prepared to provide guidance to Field Staff responsible for work being carried out as part of the EQC GI Project. Procedures to be adopted, as outlined in this manual, relate to the principal tasks outlined in the following subsections.

Please note: all lengths and depths referred to in this field manual are to be recorded using metric units.

Investigations which are completed as part of the EQC GI Project have different target depths dependant on which phase of investigation they are assigned to. The Engineer will specify a phase for all planned investigation locations provided to the Field Team. Phase 1a investigations and any Fletchers Earthquake Recovery (FEQR) additional Phase 1e investigations have a target depth of 20.00 m bgl, however the Engineer may specify or accept a minimum target depth of 15.00 m bgl⁴ in exceptional circumstances. Phase 1b, 1c and 1d investigations have a target depth of 10.00 m bgl, however the Engineer may specify or accept a minimum target depth of 8.00 m bgl⁴ or request additional meterage in exceptional circumstances.

1.2.1 Marking Out

Marking out the proposed investigation locations at the addresses and approximate locations provided by the Engineer shall be completed by Field Staff, with due consideration of:

- a. the need for suitable access to the investigation location by the plant required to undertake the physical works, whilst minimising potential disruption to the landowners and damage to the site.
- b. to ensure investigation points are located clear of any live underground or overhead services to permit drilling / testing from the ground surface, where possible, or completion of inspection pits where this is not possible
- c. locating the investigation points such that disruption to pedestrians and vehicles is kept to a minimum

1.2.2 Machine Boreholes

Field staff will supervise the drilling of machine boreholes to a typical target depth for Phase 1a/1e of 20.00 m bgl, or 10.00 m bgl for other phases. Principal duties of a fieldwork supervisor include:

- a. To monitor the performance of the drilling contractor, with particular primary attention to achieving high quality core recovery in the case of sonic, HQ Triple Tube or Direct Push drilling methods, and reliable Standard Penetration Test (SPT) results in the case of rotary mud drilling investigations;
- b. Ensure accurate and consistent procedures and reporting of in situ testing is completed by the Subcontractor, with particular attention paid to the correct methodology for undertaking Standard Penetration Tests (SPTs) within potentially liquefiable materials;
- c. Compile detailed engineering logs, take good quality core photographs, to select and bag suitable samples for subsequent laboratory testing, during the site works;
- d. Ensure all drill core and SPT samples are appropriately boxed, bagged, sealed and transported to the EQC core storage facility, where high resolution core photographs will be taken and the core stored for a fixed period;

- e. Reinstate the borehole and site clean-up to a high standard, backfilling in accordance with the standard ECan approved details provided in this manual. Where a standpipe piezometer is scheduled for inclusion at the borehole location, supervise the installation undertaken by the Subcontractor and record the as-built condition;
- f. Maintain detailed site records to include, as a minimum:
 - i. Unusual or unexpected results, such as low SPT blow counts which may have resulted from “base heave”;
 - ii. Sufficient detail of the Subcontractors work to permit appropriate payment;
 - iii. A proposed laboratory testing schedule on the collected core samples for consideration by the Engineer;
- g. From time to time, the Engineer may specify additional testing, sampling and/or instrumentation within the boreholes, such as thin walled push tube or piston samples, installation of casing for subsequent geophysical testing, etc.

The machine boreholes represent a significant cost for the EQC GI Project. The information obtained from the boreholes and subsequent laboratory testing and groundwater monitoring, will be used to calibrate the Cone Penetration Tests (CPTs) and the resulting liquefaction analyses. It is imperative that all care is taken when supervising and reporting the results of the machine borehole investigations.

Each sonic borehole forming part of Phase 1a will be accompanied by an adjacent piezocone (CPT with pore pressure measurement (CPTu)). It is envisaged that the piezocone will be completed first (except in areas identified as likely to include shallow gravel layers), such that the results can be used to assist in directing the advancement of the boreholes, including in situ testing, sampling for laboratory testing and installation of standpipe piezometers. Guidance from the Engineer on the required testing, sampling and instrumentation, based on the piezocone results, will be provided where possible. Where boreholes are advanced in lieu of the piezocone, the field staff member shall also record the presence of any layers that may cause premature refusal of the piezocone and report to the Engineer the possibility of pre-drilling required to achieve the target depth of 20.00 meters.

1.2.3 Cone Penetration Tests

The principal responsibilities of field staff supervising the CPT rigs are to ensure compliance with the technical specification for this test (refer to section 4 of this document) and maximum efficiency without compromising the quality of the data obtained. This will include:

- a. Ensuring the rigs can move quickly between test locations by assisting with access and logistics
- b. Identifying where dissipation tests may be of value and direct the Contractor to undertake these at the depths specified
- c. Inform the Engineer as soon as possible where target depths are not being achieved due to refusal within shallow dense / gravel layers, such that predrilling of these locations can be completed (if necessary) and similar issues can be anticipated at adjacent investigation locations
- d. To inform the Engineer as soon as possible where the density of the materials encountered at depth (>10m below ground level) are consistently high across an area, such that consideration may be given to reducing the target depth of subsequent holes in the immediate vicinity if similar materials are encountered.

1.2.4 Interpretation and Direction by Field Staff

It is anticipated that all Field Staff will gain a high degree of experience and understanding of the 'typical' ground conditions encountered in different areas of the city (individual pods or suburbs). Due to the volume of data being collated and requiring processing, the Field Staff are encouraged to discuss with the Engineer at an early stage, where the ground conditions encountered at specific sites vary from what is 'typical' or 'expected'. More detailed review of the data coming from these locations can then be completed and the testing programme reviewed and updated, as appropriate.

1.3 Specification Exclusions

This specification excludes details of the following aspects of the works:

- The field teams/subcontractor's preliminary and general obligations including, but not limited to, extent of subcontractors working area;
- The field teams/subcontractor's health and safety requirements ;
- The field teams/subcontractors requirements for confidentiality, and dealing with residents and members of the public;
- The field teams/subcontractor's resource consent and environmental compliance including matters associated with management of dust, noise, and light impacts, and water and sediment control and discharge obligations;
- Basis of payment;
- Temporary works including access;
- Surface reinstatement techniques, including details of third party procedures, and,
- Minor associated works as directed by the Engineer.

1.4 Induction of Field Staff

To ensure a consistent approach to the supervision, reporting and health & safety of Field Staff, a formal induction process will be followed. This will include an introduction to the marking out and supervision procedures, an overview of the aims and structure of the EQC investigations and a short mentoring period during which new staff will accompany more experienced Field Staff until they are confident and competent to undertake the role independently.

All employees of subcontractors working on a site must have attended an EQC Drilling Induction provided by the Engineer's representative. The induction includes the reading, understanding and signing of an EQC project generic Health and Safety form. A copy of the Health and Safety form will be maintained on site by the subcontractor at all times.

The existence of the generic Health and Safety form shall not excuse the Contractor from exercising their Health and Safety responsibilities for the Site operations.

It is expected that all Field Staff will have a good appreciation of the procedures and requirements set out in this Field Manual and the referenced guidelines and standards detailed in Section 1.10.

1.5 Health and Safety

All field staff shall be fully familiar with the project-specific health and safety plan and manual. Full details of this are provided in a separate document. This Field Manual is to be read in conjunction with the project-specific health and safety manual¹³.

1.6 Emergency procedures

It is the responsibility of the supervising field staff to ascertain the availability of appropriate emergency services and equipment prior to the start of works. These will include:

- The location of the nearest telephone;
- Location of the nearest first aid kit;
- Emergency response and evacuation procedures, including provisions for notifying and managing neighbouring site users; and,
- Appropriate local medical emergency numbers.

The Engineer shall be immediately notified of any injury or accident occurring at the site. If serious harm occurs OSH must be notified as soon as practical once all emergency incidents have been appropriately addressed.

1.7 Interference with Traffic and Public

The subcontractor shall liaise closely with the Field Staff in order to ensure a minimum interference or hindrance to traffic and the public. Vigilance is required when manoeuvring rigs on the public highway and if necessary field staff will assist with flagging traffic and controlling the area. Vehicles will be placed in defensive positions utilising hazard lights with the aim of protecting staff during tracking of machinery on the public highway.

1.8 Advertising

No advertising or any information shall be displayed at the Site other than the approved EQC information boards and Health and Safety information that the Contractor may require under the appropriate Health and Safety Plan.

1.9 Public Statements

No employee or any representative of the Contractor shall release any press statements or information to the public regarding the EQC Field Investigation, or work completed at any Site, without written permission from EQC.

¹³ Health and safety documentation is sourced from the EQC GI Projects Overseeing Company

1.10 Guidelines and Standards

Unless specifically noted otherwise, all testing standards referenced in this specification are the latest version of the ASTM International standards for drilling and sampling.

All Field Staff shall have a good working knowledge of this manual and all of the following associated documents.

- Field Description of Soil and Rock. Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes. NZ Geotechnical Society Inc. December 2005.
- Test Method for Determining the Vane Shear Strength of a Cohesive Soil using a Hand Held Shear Vane. NZ Geotechnical Society. 2001
- Guidelines for Hand Shear Vane Testing. NZ Geotechnical Society Inc. December 2005.
- ASTM D1452, 2009. "Standard Practice for Soil Exploration and Sampling by Auger Borings". ASTM International, West Conshohocken, PA, 2012. DOI: 10.1520/D1452-09.
- ASTM D1586, 2011. Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils. ASTM International, West Conshohocken, PA, 2012. DOI: 10.1520/D1586-11.
- ASTM D2573, 2008. "Standard Test Method for Field Vane Shear Test in Cohesive Soils". ASTM International, West Conshohocken, PA, 2012. DOI: 10.1520/D2573-08.
- ASTM D4220, 1995 (Reapproved 2007). "Standard Practice for Preserving and Transporting Soil Samples". ASTM International, West Conshohocken, PA, 2012. DOI: 10.1520/D4220-95.
- ASTM Standard D4633, 2010. "Standard Test Method for Energy Measurement of Dynamic Penetrometers". ASTM International, West Conshohocken, PA, 2010. DOI: 10.1520/D4633-10.
- ASTM Standard D5778, 2012. "Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils". ASTM International, West Conshohocken, PA, 2012. DOI: 10.1520/D5778-12.
- ASTM D6066, 2011. Standard Practice for Determining the Normalized Penetration Resistance of Sands for Evaluation of Liquefaction Potential. ASTM International, West Conshohocken, PA, 2012. DOI: 10.1520/D6066.
- ASTM D7400, 2008. "Standard Test Method for Downhole Seismic Testing". ASTM International, West Conshohocken, PA, 2012. DOI: 10.1520/D7400.
- BS EN ISO 22476-2:2005, 2005. "Geotechnical investigation and testing – Field testing – Part 2: Dynamic probing". British Standard, 2005. EN ISO 22476-2:2005.
- ISO 22476-1, 2012 (including technical corrigendum 1, 2013). "Geotechnical Investigation and testing – Field testing – Part 1: Electrical cone and piezocone penetration test". International Standard, 2012. ISO 22476-1:2012(E)

2 Set Out, Location and Inspection of Site

2.1 EQC Geotechnical Investigation Locations

All Field Staff must be familiar with the basis of borehole and CPT site selection, services clearance procedures and the EQC Permit to Drill process.

Design Drawings for the EQC geotechnical investigations may change from time to time based on parameters defined by EQC and the Engineer. The Engineer will provide the Field Team with drawings and/or lists of investigation locations for each week or part thereof of work, so the Field Staff can provide day to day direction. The EQC Permit to Drill is an essential part of the Site identification documentation.

The CPT and machine borehole locations will have been identified by Field Staff and marked by a locating peg and/or paint marks. Services identification and clearance will be carried out by the Field Team in accordance with the procedure developed and recorded on the EQC Permit to Drill, using trained Ground Penetrating Radar (GPR) and cable locating subcontractors where applicable.

Locations are to be marked out within a 5.00 meter radius of the illustrated investigation location provided by the Engineer. Where this is not possible due to terrane constraints or service proximity the mark out team will assess the whole property area and attempt to find a useable location. Investigations moved more than 5.00 meters are to be referred to the Engineer for approval prior to drilling. Investigations are to remain within the boundary of the original property, and as close as possible to a specific address in the case of flats or large buildings.

2.2 Markout Induction

All field staff must complete the EQC geotechnical investigation markout induction before commencing any work involving locations of investigations or the moving of marked positions to facilitate drilling. A copy of the induction document can be found in Appendix A of this document.

2.3 EQC Geotechnical Investigation Permit to Drill

For all investigation locations field staff should utilise the EQC GI Project Permit to Drill. A blank proforma of this document is contained in Appendix A. A summary of the process for filling out this document follows below.

Prior to a rig arriving at any particular investigation site a thorough assessment of services near to the intended investigation location should have been completed by a markout team. Field Staff will review the EQC Permit to Drill, service plans and location marks with the contractor onsite immediately prior to commencing each and any intrusive investigation. The field team shall determine that the contractor is satisfied that service location has been carried out. No penetrative investigation such as drilling, testing or auger anchoring is to take place before the EQC Permit to Drill has been issued to the contractor and signed off by the supervising field team member responsible for site works.

At each premarked investigation location the field staff shall consult a full set of service drawings and compare these to the markout on the ground. The location shall be double checked by the field team using a wand. The field operative will request the site is rescanned using GPR if any uncertainty remains.

Should a borehole location not be satisfactory and/or safe, work shall **NOT** commence until an alternative borehole location has been approved in writing by the Engineer, and services identified in the new location. If a CPT location is not satisfactory and cannot be safely relocated within 5.00 meters of the original position the field staff shall redirect the contractor to the next available investigation position until an alternative CPT location has been approved in writing by the Engineer and services identified in the new location.

2.4 Vacuum Excavation Service Clearance

Where excavation is required to clear for services, a hand auger shall be completed and logged in accordance with ASTM D1452-09 to the required depth (see section 5.3). The hole formed shall then be widened to greater than the diameter of the subsequent borehole or CPT test required using vacuum excavation to the depth reached by auguring. The hole shall then be backfilled with sand. The depth of the predrill shall be reported on the markout sheet and clearly marked at the site so that this can be recorded on the BH or CPT log.

Hand shear vane testing shall be conducted within cohesive materials at one meter centres maximum and at each change to a cohesive stratum within the hand auger hole.

If the ground is too compact to complete hand auguring to the required depth, a field logger shall monitor the arising's from the vacuum excavation and log the materials exposed in the side of the pits.

2.5 Contaminated Land

It is possible that during the course of the EQC intrusive geotechnical investigations that some field staff will encounter contaminated materials. The majority of contaminated areas are likely to be adjacent to commercial or industrial zones but there are a number of small scale, unlined landfills around the fringes of some residential areas. Any contaminants encountered by the field team are expected to be mild in nature.

A wide range of contaminants may be present in the ground as a result of either current or historic land uses¹⁴. These could include, but are not limited to:

- Asbestos;
- Agrichemicals (pesticides, herbicides and fungicides);
- Heavy metals and metalloids (lead, copper, arsenic etc.);
- Hydrocarbons (fuels, oils and greases); and
- Solvents;

In addition, the earthquakes have resulted in widespread damage to the city's infrastructure meaning that soils and/or groundwater may also have been contaminated by sewage effluent which could include bacteria and viruses that are harmful to health.

Many of the contaminants listed above may not be evident visually, or based on odour. On this basis, from a health and safety perspective, all soils and groundwater encountered during the works should be considered to be contaminated until proven otherwise. In addition, particular caution should be taken if any of the following are noted:

¹⁴ TC3 SHEP Plan

- A hydrocarbon odour (typically smells like petrol, diesel, kerosene etc);
- Other abnormal odours not normally associated with soil;
- Discoloured soil (i.e. areas of soil with dark staining, abnormal or unnatural colouring);
- Soil with waste material or building debris (i.e. plastics, metal, bricks, timber etc) indicating the material is fill; or
- An oily substance or sheen on the surface of soil, or on the surface of water in excavations.

The ECan maintained 'Listed Land Use Register (LLUR)' has been utilised to identify known and potentially contaminated land within EQC Geotechnical Investigation areas. Each intrusive investigation location will be checked for its proximity to potentially contaminated land. If an intrusive investigation falls within 50.00 meters of a known old landfill area the field staff will be notified by the Engineer. In such cases the following additional health and safety precautions are to be enforced by the supervising field staff.

- No food or drink to be consumed within the work area
- No smoking within 100.00 meters of the work area
- Hand sanitizer to be available at all times and to be used when leaving the work area, and before consuming food or drink, applying sunscreen etc.
- Mobile phones are not to be used in the work area.
- Gloves must be worn by all staff at all times within the work area and whilst handling core or equipment before it has been cleaned.
- Core boxes are to be CLEARLY labelled with the acronym "P.C." (Potentially Contaminated).
- Eye protection is to be readily available for use if mild contamination is encountered
- All tools, equipment, rigs, boots etc. are to be washed down before leaving site wherever possible.

If obvious signs of contamination are observed and judged to be of a more serious nature by the field staff, the supervisor will halt the investigation and seek the immediate advice of the Engineer.

3 Specification for EQC GI Boreholes

3.1 Preamble

Part of the observing Field Staff's duty is to check that the contractor's procedures approve or exceed the requirements of this manual and that all work is carried out in an efficient manner. The observing Field Staff must maintain a record of the rate of advancement, depth and testing being undertaken in the borehole. This requires regular discussion and checking with the driller.

Initially an understanding of the driller's method of measuring the hole depth should be reached by the supervising field staff. The length of the rod string (subs, core barrel, shoe etc), measurement datum, relative stick up measurement, sequence of adding rods etc should be understood and recorded. This allows the observing field staff to independently assess and/or check the hole depth at any time.

3.2 General

Before unloading a rig at a borehole location a pre-start meeting (toolbox talk) should be held. This should confirm H&S aspects, including requirements for contaminated land, special requirements relating to the site in question and permit to work. Field team supervisors will also instruct drillers on the specification and purpose of each hole as appropriate.

The field team will assure Before and After photographs are taken at every investigation location. These photographs should contain a photo board with relevant location information and several angles should be captured with particular shots taken of existing cracks or damage. These photographs are important for future dispute resolution.

Boreholes will be drilled to complement the other ground investigation methods being used:

- Safety is a priority and no investigation should be undertaken without Service checks and location documentation.
- Boreholes provide an indication of the soil profile, to correlate against CPT and geophysical testing
- Boreholes provide investigation coverage at depths not reached by other techniques
- Drilling retrieves soil samples for laboratory testing
- Standard Penetration Tests (SPT) can be performed in boreholes to provide an indication of the insitu density of the ground
- After completion of a borehole the installation of piezometers for groundwater monitoring or casing for down-hole seismic testing may be requested by the Engineer.

All measurements relating to boreholes are to be recorded as 'meters below existing ground level' (m bgl). Relative level for borehole will be calculated using the Mount Pleasant Datum.

3.2.1 Borehole Drilling Technologies

The drilling rigs will be capable of meeting the requirements of the borehole and in particular shall be able to drill to a minimum depth of 30.00 m bgl. Continuous sampling, in situ testing and Shelby push-tube sampling should also be within the plants abilities. HQT, Direct Push and Rotary OH / Mud drilling and sampling equipment shall generally comply with the requirements of ASTM D6066-11. The requirements for Rotary Sonic Drilling shall be as specified in this document.

Plant shall be maintained in good condition and serviced as necessary to minimise downtime due to equipment breakdown. The subcontractor shall carry sufficient stock of common replacement items / consumables to prevent delays in work.

The following four different borehole drilling technologies are currently employed on the EQC geotechnical investigation Project:

- Rotary Sonic Drilling
- HQ Triple Tube Drilling
- Direct Push Drilling/Boring
- Rotary Open Hole / Rotary Mud Drilling

Additionally Low frequency sonic drilling has been used previously. Combined drilling and CPT sounding rigs and/or rotary mud drilling techniques are in consideration for future use in geotechnically complex and/or difficult areas.

3.2.2 Order of Importance of Borehole Data Collection

It is known that the different drilling techniques employed on the EQC geotechnical investigations have individual strengths and weaknesses in relation to complete data compilation. Wherever possible field teams will endeavour to gather full and reliable information however, if an order of importance needs to be applied to a borehole the following should be followed:

1. High levels of core recovery in Sonic and HQT holes are preferential wherever possible to enable geological review, laboratory analysis and important comparison with local CPT traces/data.
2. Reliable SPT measurements in sonic holes are to be achieved but not at the expense of core recovery.
3. Reliable SPT measurements in Rotary Mud holes are to be achieved using open hole techniques as specified in ASTM D6066-11. Material descriptions will be drawn from logging cuttings

3.2.3 Obstructions and Abandoning Boreholes

Should unnatural obstructions to drilling be encountered, the Engineer shall be informed immediately so that a decision may be made regarding the use of any special technique, including chiselling, percussion, diamond drilling or termination of the borehole. Boreholes terminated with the consent of the Engineer shall be fully measured and documented.

Under no circumstances shall the contractor abandon or terminate a borehole without the approval of the Engineer. Boreholes so abandoned or terminated will not be measured.

However, should the Contractor be unable to complete any borehole due to encountering underground services or structures which cannot be reasonably foreseen the completed boreholes may be allowed to be measured.

3.2.4 Driller's daily field logs

The observing Field Staff shall observe and make sufficient notes to enable detailed review and certification of the Subcontractor's Daily Report for each Site. The drillers daily report should, at a minimum, identify the following for each location:

- rig type and I.D.;
- name of supervisor;
- site(s) occupied;
- hours worked, including rig stand-by time and reason(s) for stand-by;
- depths drilled;
- number and type of samples and tests undertaken;
- consumables used;
- time travelling between sites;
- any other information relevant for the Engineer's assessment of payments;
- Water levels at start and end of shift;
- Drillers stratigraphic observations and depths of changes recorded as a log;
- SPT results, and,
- "Base heave" at the start of each SPT.

3.2.5 In situ testing

It is important to characterise the near surface (i.e. upper 0.5m) soils at the site so the first SPT should be as shallow as possible. If service proximity dictates vacuum excavation, the contractor will undertake hand auger holes to characterise the ground conditions to the required predrill depth. If cohesive soils are encountered then vane shear testing shall be undertaken at each change of soil horizon or 0.5m maximum vertical spacing. This work will be completed by the field team and approved subcontractors prior to driller mobilising to site.

SPTs will generally be undertaken at 1.0 to 1.5m centres to suit the casing length being used. Where non-metric drilling rods are utilised, this shall be noted on the field log and the precise depths of the SPTs shall be clearly recorded.

SPT results should be reported as per the standard on final borehole logs as the number of blows for each 75mm penetration, followed by the uncorrected SPT-N value (e.g. 3 / 2 // 3 / 5 / 4 / 3 N=15). Where a test has refused the amount of penetration for the refusal increment must be recorded as blows over penetration in mm (e.g. 15 blows/40mm).

Where organic silt layers are encountered, consideration should be given to pushing a Shelby push-tube for possible future laboratory testing. Lubricating the internal surface of the push-tube is desirable to minimise compression during sampling. Where possible a pre-lubricated tube will be used. If lubrication is required the supervising field staff will confirm the availability of appropriate lubricant with the driller before commencement.

When organic layers are expected to be encountered in submitted locations, this will be notified in writing to the field team.

Where samples of cohesive soils are obtained in sample tubes, field hand shear-vane testing may be undertaken in the end of the tube at the direction of the Engineer. Measurement is to be undertaken in accordance with the NZGS publication "Guideline for Hand Held Shear Vane Testing". Corrected shear strength results are to be reported on the final log sheets. The methodology for performing this test can be found in ASTM D2573, 2008. "Standard Test Method for Field Vane Shear Test in Cohesive Soils". To preserve sample moisture, drillers will seal the ends of all sample tubes before the end of the shift using either wax or double layered plastic wrap sealed with double elastic bands and tape at either end of the tube. Field staff will confirm the presence and effectiveness of seals before transporting samples off site.

Depending on the method of ground-treatment undertaken in each area, or if groundwater flow issues are identified, there may be benefit in undertaking insitu permeability testing. This testing would be most applicable for ground-treatment methods which rely on drainage effects, such as earthquake drains or some design implementations of gravel columns. If the need for permeability information is identified for a particular area during the design process then insitu rising/falling-head testing could be undertaken in the previously installed standpipe piezometers, or new boreholes could be drilled specifically for this testing. These will be requested in writing to the field team. If insitu permeability tests are to be undertaken, these tests and the data to be reported will be specified in writing by the Engineer.

3.3 Standard Penetration Testing (SPT)

Standard Penetration Tests (SPTs) are generally to be carried out at 1.5m intervals in the machine boreholes. The testing procedure will follow ASTM standards D1586-11 and D6066-11. Field records shall be kept by the observing Field Staff to allow the SPT results to be used for the assessment of liquefaction potential. Split spoon SPT samplers, which are **NOT** machined for liners, are to be used in all tests unless the driller is specifically instructed otherwise by the attending supervising field team member. Split spoons should be used in all soils, including coarse soils. Where a solid cone is specified at a specific centre the driller will revert to using a split spoon sampler unless instructed otherwise by the field team.

3.3.1 SPT Hammer Efficiency

Drilling rig operators must provide the Field Team / Engineer with a current, measured Hammer Efficiency for every SPT hammer / rig employed on the EQC GI Project. Hammer efficiencies are used to correct SPT N values and are essential for the engineering use of SPT data. There is considerable variation in the measured efficiency of different types of hammer.

SPT Hammer Efficiency testing must be conducted in accordance with ASTM D4633-10.

3.3.2 Obtaining a Clean Hole for Testing

Disturbance checks shall be made after each run, cleanout or upon insertion of the split spoon sampler. Regular checks will help to evaluate levels of heave disturbance within the hole.

The driller will use any and all methods at their disposal to minimise base heave effects. This may include the use of Engineer approved drilling mud. Percussive actions and wash boring are not acceptable methods for obtaining a clean hole in loose sands.

If an obstruction is encountered such as cobbles, boulders or debris the borehole should be progressed below the obstruction before a test is attempted.

3.3.3 Records for each borehole:

The following details will be recorded by the field staff in consultation with the subcontractor and will also appear on driller's daily logs:

- Hole ID
- borehole diameter;
- casing diameter and depth at time of test;
- Drill fluid used (i.e., water, polymer mud, bentonite, etc.);
- size of SPT rods (i.e., AJ, BW); See Appendix B
- whether the SPT split spoon sampler has space for liners (35mm inside diameter if no liner / 38.1mm behind driving shoe if space for liners), or if a solid tip is used (as in gravel);
- Type of SPT hammer being used (donut, safety, automatic) and the measured energy for efficiency of the specific hammer being used (as per approved test results).
- Description of location – i.e. 2m from kerb, 2.7m from south edge of building at number 123 geo street.

3.3.4 Additional Records For each SPT:

The following details will be checked and recorded by the field staff in consultation with the subcontractor:

- Confirm the depth of the borehole;
- rod stick-up above ground surface to nearest 0.05 meters;
- Record water level before inserting SPT rods;
- Confirm presence and operation of the ball valve at top of SPT;
- Amount of heave measured in hole to nearest 0.05 meters. Record null results, i.e. if no heave, then record 'no heave' on the field log;
- Record self-weight penetration in mm once the SPT rod string is loaded with the hammer. This self-weight penetration should be included as part of the test i.e. 0/0// 0/1/1/2;
- If ball valve vents become covered the test is to be abandoned at that centre and the hole cleaned out before another attempt is made. In this case a full test is to be undertaken at the new centre;
- Record hammer blow counts per 75.00 mm increment that will have been marked on the rods by the driller;
- If recognised to be in gravel type materials, blow counts per 25mm increment should be recorded; i.e. 5/6/6, 3/2/2(seating) //1/2/6, 6/2/3, 8/8/9, 1/2/1 (main drive). Note that this represents a total drive of no more than 450.00 mm;

- Hammer blows to be monitored between 20 to 40 blows per minute. Issues such as sticking hammer weight and speed of blows should be noted and rectification. Discuss with the driller as appropriate, and,
- Length of sample recovered from the split spoon sampler.

If refusal occurs during seating drive (25 blows for the initial 150.00 mm) the supervising field team member will halt the test and measure the penetration achieved for the increment the test has refused on. This will be recorded in mm. The driller will re-mark the main drive increments and continue the test for the remaining 300.00 mm or to refusal. A test which refuses on its seating drive will be recorded 5 / 20/50mm // 5 / 8 / 9 / 3. $N \geq 25$

The field staff should attempt to photograph recovered split spoon samples before removal from the sampler, particularly in cases where the test has crossed a stratum boundary. A photo board - with hole and depth, scale bar and photo patches is to be used.

3.3.5 Split Spoon Samples

Split spoon samples are to be labelled to the required standard and double bagged on site to preserve moisture content, so that liquidity index can be ascertained if required.

3.3.6 Fine Tuning the SPT

Once below the water table and if in loose sands / non-plastic silts, the supervision field staff will use a weighted cloth tape or similar to 'sound' the hole and confirm the depth to be tested, that the bottom of the hole is stable and that loose soil is not 'flowing' into the casing.

The supervising field staff will assure the driller tries to combat the effects of heave in susceptible materials to maintain the accuracy of the SPT. Where heave is encountered the driller shall keep the borehole filled with water to minimise the effects. Wash drilling to return a borehole to depth for SPT testing may loosen the underlying material voiding the test, and is not permitted.

If heave of silts or 'flowing' sands exceeds 300mm the SPT will be cancelled at that centre and the supervising field staff will measure and note on the log the amount of heave or height of sand within the casing. If the supervising field staff believes the base of the borehole to be disturbed they may ask the driller to progress the borehole to the next available centre. The supervising field staff will 'sound' the borehole at the next test centre. In any circumstance where a borehole is progressed from one test centre to another the next test will be a minimum 300.0mm below the previous, i.e. if an SPT ended at 4.00m the borehole must be drilled to a minimum depth of 4.30m before the next test is undertaken.

3.4 Other In-Situ Testing and Sampling

The method for obtaining a 'clean' hole at a known depth described for SPT's shall be followed for all other tests or samples that might be specified, such as:

- thin wall tube;
- piston sampler;
- down hole shear vane.

Specific procedures for other testing and sampling will be provided when they are specified by the Engineer for a particular site.

3.5 Heaving of the Base of Boreholes

When drilling through sand and silt soils, the Contractor shall take all measures necessary to minimise disturbance of the bottom of the borehole from heave or "boiling" of soil. Control of bottom heave may require the use of drilling fluid (i.e., water, drilling mud) and/or modification of drilling method.

In all cases the subcontractor shall measure and record the depth to the bottom of the borehole immediately prior to undertaking every in situ test / sample. If the bottom depth is less than the depth drilled, the subcontractor shall record the difference (heave) in mm and immediately notify the Engineer prior to proceeding with the test/sampling.

Base heave has the potential to become a significant issue if sonic drilling techniques are employed. The drilling technique may liquefy the soil during drilling, resulting in a vacuum effect on withdrawal of the core barrel. This in turn increases the effect of the reduction in the overburden pressure on the susceptible stratum and results in base heave and/or "boiling" at the base of the hole.

3.5.1 Sonic verses Subsonic

Sonic vibrations are measured in cycles per second and are recorded in hertz (Hz). The sonic vibration level generated by Rotary Sonic Drilling Rigs is not consistent between different manufacturers and even between different top drive / drill head units made by the same manufacturer. It is also possible for the operator to vary the sonic level. To be truly 'Sonic' a rig must oscillate the drill string at a frequency of at least 100 Hz. Sub-sonic rigs (<100 Hz) may exacerbate the problem of heave and should be avoided for any hole/geological investigation where accurate borehole depth measurement and SPT data are the priority. For the purposes of the EQC GI Project it is preferable to employ a sonic rig with a head capable of producing at least 100 Hz.

3.6 Groundwater Level Observations

The observation of groundwater level in all types of boreholes shall be made with an electronic dip-meter that permits measurements with 10.00 mm accuracy unless otherwise approved by Engineer. If a borehole is incomplete at the end of a shift and is cased, the casing shall be pulled up by about 300.00 mm and left in such a position overnight. The casing shall be capped overnight by the driller to prevent the entry of surface water or vandalism/contamination from above. The groundwater level shall be recorded each morning before recommencing drilling.

Groundwater level observations should also be made after any stoppage of more than half an hour (e.g. a meal break) or if a change in strata or operating water level suggests a different groundwater level.

The date and time of measurement, depth of borehole, depth of casing and groundwater level relative to the natural ground surface at the site shall be recorded on the preliminary field log.

3.7 Core Records and Presentation

Core is to be boxed. Coreflex 0.6m long boxes are a minimum requirement. Flat plastic sheets will be placed between the lid and the box to preserve core moisture in the medium term.

3.7.1 Labelling

All core box labelling including run depths, core loss and SPT sample/labels will be completed by the field team at the time of drilling. All core box labelling is to be UPPER CASE lettering

3.7.1.1 Minimum labelling requirements:

Field staff will ensure the following core box labelling will be carried out on site:

- Permanent marker pen in legible print;
- T&T job number, BH number, box number on the lid top;
- Left end of lid;
- Core box inside top left corner;
- Job name and or location, and from - to depth on the lid top, and,
- Job number, box number and pod/borehole number on the box itself in case the lid is misplaced or becomes illegible.

Labelling the inside of each core box is essential to prevent issues with misplaced and incorrect lids. Labelling on the outside of the box will be worn off by the overlapping lid. The core run, 'no recovery' and SPT depths are to be checked and corrected as required by the logger before photographing the core.

3.7.1.2 Core Blocks

Core blocks will be pre-cut wooden blocks or made of strips cut from box liners for;

- Start depth of coring (in first box);
- End of each run;
- SPT depth and blows per 75mm increment (6 numbers). Depth of penetration for the final increment if the test has refused e.g. 15 / 5 , 10 / 20 / 20/40mm if the test only penetrated 40mm out of the 75mm for the 5th increment with the final 20 blows;
- Sample depth, length of sample removed, purpose of sample, sample date and initials of sampler, and,
- No Recovery. All "no recovery" blocks should be 1:1 scale up to maximum of 150mm. On each block clearly record "NR" and the assessed range of loss i.e. "NR 10.2-10.5mbgl".

3.7.2 Target depth

For Phase 1a/1e holes; in selecting a target depth for the Sonic / HQT / Mud Rotary drill holes, a balance must be struck between the depth of drilling and the number of locations which can be investigated given the limited investigation timeframe and equipment. The main purpose of these drill holes will be to investigate the upper 15.00 - 20.00 meters of the soil profile, as these soils are of greatest relevance to liquefaction assessment and ground-treatment design.

For Phase 1b/1c/1d boreholes of all drilling techniques, the target depth shall be 10.00 meters below ground level.

To provide general information regarding underlying geology, selected drill holes will be drilled deeper. At these locations the target will be to drill at least 3.00 meters into the underlying Riccarton gravels where practical. This gravel layer is expected at approximately 20.00-25.00 meters depth near the city centre, but may be deeper in the eastern areas of the city. If this gravel layer is not encountered within 30.00 meters of the surface, then the drill hole may be terminated as directed by the Engineer.

3.8 Contractor Invoicing/Daily logs

All contractor invoices will state the drill holes included with Location ID Code (e.g. BH-POD01-BEX-01) as well as an itemised cost for each drill hole. Drill rig breakdown detail also to be provided.

Daily logs, as well as a generalised geological profile, will be submitted for each borehole. Logs will be provided within 24 hours of the day in question or the next working day in the case of weekends or public holidays. If possible the name of the supervising field team member should be included on the driller's daily log.

3.9 Logging of Boreholes

3.9.1 General Core Logging Notes

All logging is to be undertaken in general accordance with the New Zealand Geotechnical Society Guidelines "Field Description of Soil and Rock" dated December 2005, by a suitably qualified Engineering Geologist, Geotechnical Engineer, or a specifically trained Soil-engineering Technician. It is also advised that this be supplemented by the T&T Logging Handbook (issued January 2013) although to preserve continuity across the EQC GI Project the NZGS guidelines will retain precedence as the referenced descriptive document. A copy of the NZGS logging manual can be found in Appendix B.

Logging and preliminary photographing of core shall be carried out as soon as practicable and before the core has dried out. This will be undertaken in the field where possible. Care shall be taken to ensure core is not disturbed by extrusion, handling or transport. Core is to be preserved by placing a plastic bag over the box and sealing it immediately after field logging to preserve moisture.

At the core storage facility all core will be re-photographed using the standardised system, samples selected for laboratory testing (following a general selection methodology developed by experienced earthquake Geotechnical Engineers) and

resealed with the plastic bag to prevent drying out. The remaining core will be stored in the medium-term, so that additional inspection and testing may be undertaken if required as design progresses.

3.9.2 Logging

3.9.2.1 Sonic/HQTT Logging

The preparation of field engineering logs for machine boreholes is a key role of the observing Field Staff. It is important that field logs are:-

- In accordance with the NZGS guidelines for soil description,
- clearly described in accordance with the standards, and,
- Presented in a condition suitable for immediate electronic entry.

The engineering log provides a record of information about the drilling, recovery of samples and test results, as well as a description of the soil materials that make up the samples and core recovered from the borehole. An example of an engineering log from the EQC GI Project is given in Appendix B

The core logging can be divided into 2 major steps, being measurement of the core and description of the soil. Such measurement includes:

- Recording of drilled run lengths;
- Measuring the recovery of core and recording as a percentage of theoretical 100% recovery. Measurement of recovery to the nearest 100mm is suggested. 'No recovery' to be recorded on the field logs;
- Measuring the recovery of sample from the split spoon, record 'no recovery' on the log if less than 200mm of sample is recovered (note any obvious disturbance and record length);
- Placing additional core blocks in the core box to denote 'no recovery' as required;
- Checking and adjusting core blocks and core box annotations if required following discussion and agreement with the driller;
- Recording depths of deformed core or core compression (e.g. From the extrusion process);
- Water levels, and;
- Drilling production (i.e. type, casing, depth vs. time etc.).

Thorough and careful checking and marking of the core will minimise any necessary alterations required prior to photography of the core boxes at the field office. An example of a core box with suitable measurements recorded is presented in Appendix B.

Description of the core is to follow the NZGS guidelines, and be in the same style and format as any example logs which are provided from time to time by the Engineer. It is assumed that all observing Field Staff have some previous experience with engineering descriptions of soils prior to secondment into the EQC GI Project team. The following points relate to specific issues encountered with the description of Christchurch soils:

- Log and describe individual SILT beds approximately 100mm or greater thickness. Less than 100mm SILT within SAND layers, annotate as thin beds or lenses at specific depths;
- When logging silts, provide appropriate notes on the field logs to record observations as to whether the material is obviously dilatant (i.e. liquefiable), or

appears to have some plasticity. If a material displays plastic properties this should be classified in accordance of the recommendations outlined in the NZGS standard;

- Record shell layers (typically 20 to 50mm thick with ½ and ¼ shell fragments) and intervals where broken shell is disseminated in trace proportions through the core;
- SILT varieties (e.g. Sandy, clayey, with some sand) should have both plasticity & dilatancy assessed and recorded (refer to Table 3-1);
- Any description of CLAY in the Christchurch area needs a physical material check (lab-testing) and agreement with the Engineer (soils classifying as clay or clayey are rare);
- Silty SAND & Sandy SILT (non-plastic) should be checked occasionally against the fines content tests to assist in personal 'calibration'. It is difficult to estimate silt content in the fine to medium grained sands due to the narrow grading of the materials and it is not uncommon to overestimate silt content;
- Look out for fining upwards sand to silt layers about 1m thick, especially in the upper alluvial Yaldhurst Formation. In general these can be described as a SAND (typical 100 to 200mm thick) at the base, a Silty SAND in mid-section and a SILT typically 100mm) at the top;
- Gravels. Coarser gravel units are usually GRAVEL/COBBLE, with minor silt and/or sand – there is a tendency to overstate sand/silt percent. Finer gravel units (rounded fine to medium gravel) in the upper Yaldhurst Member can be Sandy GRAVEL to Gravelly SAND;
- Geological Unit. Base the boundaries on materials in the borehole, as well as suburb location and existing information (e.g. CBD investigation), also might consider any CPT Qc signatures in assigning Formation boundaries.
- Description of peat and organic content particularly within possible soil stabilisation zones is important. Samples may be taken for organic content lab tests.
- In general for SILT, plasticity and dilatant descriptors align as follows on page 22.

Table 3-1: Silt Plasticity and Dilatancy Descriptors

Plasticity	Dilatancy	Descriptors
Non plastic	Quick / Dilatant	Tendency to liquefy when shaken - in hand test moisture appears on the surface of the sample when hand is tapped. Undergoes a volume increase when deformed or patted - in hand test moisture disappears from surface when sample is tapped.
Low plasticity	Very slow, slow – quick, Slight Dilatancy	When moulded can be crumbled in the fingers. May roll short threads. May display some dilatancy.
Moderate to high	none	Can be moulded and deformed over a wide range of moisture contents without cracking or displaying a volume change. Can be rolled into 3mm diameter threads without cracking. Becomes 'rock hard' when dry.

For ease of reference a copy of the NZGS logging field specification and logging sheet for soils is contained in Appendix B of this document.

3.9.2.2 Rotary Mud Logging

All logging of Rotary Mud Boreholes must be completed by a specially trained Geologist or Geotechnical Engineer. The drilling process does not generate core recovery and therefore it is necessary to make an assessment of soil type based on a combination of the following:

- Cuttings – using a sieve, towel or settling tank the logging Field Team member will collect and assess cuttings returned to the surface within the drilling fluid.
- Flush colour – assessment of changes of stratum and also (in the case of Christchurch specifically) changes in formation can be made by a suitably skilled and experienced logging engineer.
- Drill progression – it is possible to identify stratum boundaries by changes in progression rates of the drill. Cutting from a low density bed into one of a higher density will generally result in a slower rate of drilling progress.
- Sound – it is often possible to identify coarse soil stratum by the sound emitted during drilling through this material at shallow depth.

Insitu testing in Rotary Mud Boreholes will follow the requirements outlined in section 3.9.2.1 of this document.

An example Rotary Mud Borehole Log is presented in Appendix B.

3.9.2.3 Direct Push/Dynamic Sampling

It is unlikely that direct push drilling methods will function as well as high frequency sonic drilling methods in Christchurch soils. In addition ASTM 1586-11 implies that SPT results are likely to be unreliable if they are undertaken in conjunction with direct push drilling methods. As such no boreholes are currently scheduled to be undertaken on the EQC GI Project using the direct push method. If these methods are trialled at any potentially suitable site, further specification will be provided by the Engineer.

3.10 Sampling Specification for Boreholes

3.10.1 Sample recovery

As a minimum, sample recovery should consist of SPT returns and thin-wall tube samples where applicable. For sonic/HQTT drilling methods, fully cored boreholes are required where practical.

All recovered core is to be boxed, the box placed within a plastic bag and sealed immediately after field logging to prevent loss of moisture.

All recovered SPT and tube samples are to be sealed as appropriate, double bagged in plastic bags and clearly labelled with:

- Location ID Code (e.g. BH -POD01-BEX-01);
- The date, and,
- The depth at the top and bottom of the sample.

3.10.2 Sample Naming

All samples recovered for laboratory testing are to be clearly named with project name, T&T job number, location ID Code, depth range, core box number, and location of borehole (e.g. EQC Geotechnical Investigations, 52003, BH-POD01-BEX-01, 0.0-4.5m, Box01, outside no. 7 Kia Ora St).

3.10.3 Selection of Samples for Laboratory Testing

The Field Team will use the CPTB data and the CPT calculator to generate a list of likely 'zones' within a borehole with a Soil classification index, (I_c , Robertson & Wride, 1998) between 2.0 and 2.8. Material from these zones shall be target sampled for plasticity, fines content / particle size distribution and atterberg limit testing where appropriate. Where a CPTB trace is not available, samples shall be taken from materials visually assessed to be fine soils by the logging Engineer/Geologist.

Core is to be photographed on site then samples taken for laboratory testing and a card inserted stating SAMPLE TAKEN and noting the depth range sampled e.g. 10.25-10.40 m bgl.

Laboratory samples are to be a minimum 500.00 grams weight and representative homogenous material is to be sampled where possible. The material will be double bagged and securely sealed with as little air trapped in with the sample as is possible. The field staff will accurately record the sample information on the field log including notes on assessed sample quality compared to anticipated insitu conditions – i.e. taking account of drilling disturbance, hole collapse, heave etc.

Frequency of sampling is to be discussed and agreed with the Engineer on a suburb by suburb basis prior to undertaking intrusive investigations.

3.10.4 Sample Preservation, Packaging and Transportation

Wherever possible and practical all sample preservation and packaging is to be completed in accordance with ASTM D4220-95.

In addition:

- Core boxes are to be individually bagged and sealed immediately after completion of onsite photography and sampling.
- Subsamples are to be sent to the designated laboratory as soon as is possible. A Chain of Custody system will be employed by the field team and a testing schedule or covering notice included with any samples sent to a laboratory.
- Samples sent for testing will be progress monitored and chased up if results are not returned within a designated period.

No core is to be left on the site at the end of the shift. The supervising field team member will transport the core back to the Project logging facility for safe storage and further processing.

3.11 Standpipe Piezometer Specification for Boreholes

Standpipe piezometer installations will be requested in writing by the Engineer for selected boreholes. The information required from the instrument (ground water levels or falling/rising head testing) will be specified.

3.11.1 Piezometer Installation Specification

Standpipe piezometers are to be installed in selected drill holes to provide an indication of groundwater level, which is particularly important for liquefaction and slope stability analysis. The following specification applies unless otherwise instructed by the Engineer.

3.11.1.1 Below Piezometer

The borehole below the piezometer zone shall be backfilled to ECan standards (see Appendix D) up to 1.50 meters below the base of the screen section. The drill hole will then be sealed with 1.00 meters of bentonite chips which are to be hydrated by the driller by adding potable water if the borehole is dry at this depth range. Above the bentonite seal 0.50 meters of blinding sand is to be installed. Blinding sand grains will be between 0.06 mm and 0.60 mm diameter and well graded.

3.11.1.2 Piezometer casing

The piezometer casing will be 32.00 mm (50.00 mm diameter for falling head tests) internal diameter PVC pipe, installed to a depth of approximately 7.50 meters. Pipe joints are to be of a watertight screw threaded type.

A 3.00 meter long (maximum) machine-slotted screen section will be provided at the bottom of the casing. Slots will be 0.50 mm aperture at 6mm intervals. Screen with an incorporated geotextile filter will have a pore diameter of 240-330 microns. For screen without a geotextile filter a 65.00 mm diameter 'geosock' filter with 240-360 micron pore diameter will be added during installation. The base of the screen section will be sealed with a snug fitting watertight endcap.

3.11.1.3 Material Surrounding Instrument

The slotted screen section of the piezometer (3.00 meters) shall be backfilled with washed, non –calcareous coarse sand to fine gravel aggregate with a grain diameter range between 0.60 and 6.00 mm.

Above the filter screen zone, a 0.50 meter minimum thickness of blinding sand is to be installed to prevent bentonite ingress into the screen section. Blinding sand grains will be between 0.06 mm and 0.60 mm diameter and well graded.

The upper 4.00 meters of the drill hole will be sealed around the plain piezometer casing with bentonite chips which are to be hydrated by the driller using potable water if the borehole is dry at this depth range.

3.11.1.4 Headwork's

The top of the standpipe piezometer pipe is to be sealed with a snug fitting removable end cap to prevent rainwater and debris entering the instrument. The end cap MUST have a breather hole. The finished installation shall not result in an increased risk of 'trip hazard' to the general public.

The flush headwork's is to comprise a lockable metal flush cover set a minimum of 4.00 mm $\pm$ 2.00 mm proud of the ground surface, surrounded by 8.00 MPa site mixed concrete. The concrete dimensions will be 300.00 mm square by 300.00 mm deep minimum. Covers need to be durable metal and of a high standard so as to negate any risk of breakage and/or hazard to the general public. A drainage tube is to be incorporated into the headwork's chamber to allow rainwater to exit the chamber without entering the breather cap hole.

3.11.1.5 Quality Assurance of Standpipe Piezometer Construction

A standard piezometer design is provided in Appendix D. The supervising field team member is responsible for confirming the quality and accuracy of the standpipe piezometer installation and should check and record the actual as-built installation depths of the screen, filter material, sand pack, bentonite seals, backfill and cement around the flush cover, such that an accurate piezometer as built drawing can be produced for each site.

3.11.1.6 Development of Standpipe Piezometers

If standpipes require development the field team will purge three times the volume of water present within the well using a vacuum pump. Further details of piezometer development requirements and procedures can be found in ASTM 4750-87 (currently withdrawn awaiting revision).

3.11.1.7 Readings

Standpipe piezometers shall be read at the following intervals:

- At end of day of the installation;
- One week after installation, and,
- Monthly thereafter for three months minimum unless otherwise directed by the Engineer.

Standpipe readings will be recorded and presented in a format similar to that given below in Table 3-2. All piezometer data shall be provided to the Engineer in .xls format on a monthly basis.

Table 3-2 Example Piezometer Data Sheet

BH ID:	Date of Reading	Time of reading	Ground Surface Elevation (mount pleasant datum)	Depth to Water Surface (mbgl)	Piezometer Base Depth (m bgl) ¹	Groundwater Elevation (mount pleasant datum)	Comments / Observations ²	Measured and Recorded by (name):

¹ In order to monitor silting of standpipe for maintenance purposes.

² Record observations regarding issues such as damage to instrument requiring attention / repair or replacement, complaints from public, H&S issues for dipping

Installation of Divers / Data Loggers will be periodically required. Notification of data logger requirements will be provided in writing by the Engineer.

3.11.2 Installation of Casing for Downhole Seismic Testing

For selected drill holes (typically at least one per suburb), a 50.00 mm diameter PVC casing will be installed to allow down-hole seismic geophysical testing to be undertaken, although other diameters of casing may be specified depending on the equipment being used. This casing will be grouted in place, with headworks and a metal flush-cover installed in accordance with the appropriate requirements outlined in section 3.11.1.4 of this manual. When required this will be requested and the procedure for installation specified in writing by the Engineer. A typical drawing for the downhole seismic testing installation is provided in Appendix D.

3.12 Backfilling and Reinstatement of Boreholes

3.12.1 Backfilling

Where no piezometer or downhole seismic casing is to be installed, the drill hole shall be backfilled. Backfilling of boreholes is to be undertaken in strict compliance with ECan requirements and the details presented in Appendix D.

In summary:

- Holes drilled within the Springston and Christchurch Formations require backfill with cuttings as each casing length is removed. Where sufficient cuttings are unavailable the borehole shall be backfilled with clean, washed, non –calcareous coarse sand to fine gravel aggregate with a grain diameter range between 0.60

and 6.00 mm. A well graded bentonite seal is required for the upper 2.00 meters to prevent surface water entering the upper unconfined aquifer through the borehole. A typical drawing which summarises these requirements is provided in Appendix D

- Holes drilled into the Riccarton Gravel must be backfilled with tremmy pumped cement bentonite grout (ratio of cement to bentonite to be confirmed with the Engineer) to 5.00 meters above the top contact of the gravel, to prevent leakage of the Riccarton Gravel aquifer into the unconfined aquifer above, followed by backfill with cuttings or washed, well graded, non –calcareous coarse sand to fine gravel aggregate with a grain diameter range between 0.60 and 6.00 mm. A 2.00 meter bentonite seal is to be installed at the top of the hole.

The supervising field staff shall liaise closely with the driller in determining depth intervals for backfill. Boreholes subside if not backfilled correctly and the resulting voids may become a hazard to the general public.

3.12.2 Surface Reinstatement

Photographic records must be collected prior to drilling and immediately following surface reinstatement. Additional photos should be taken at the end of each day drilling equipment is present at that location if a site is left unattended overnight whilst awaiting reinstatement. Any damage or incident should also be recorded in both written and photographic form.

Where reinstatement is undertaken by a drill team the quality of that reinstatement is a responsibility of the supervising field staff. The field staff will ensure that a like-for-like approach is adopted i.e. replanting turf, replacing sub-base materials and resurfacing with macadam or concrete as required and appropriate.

All finished reinstatements should be durable and neat. Reinstated boreholes are to pose no injury risk to the general public. All borehole reinstatements are to be checked 2-4 weeks after completion and repairs completed as necessary.

3.12.3 Completion of Boreholes

Practical completion of the works at each Site shall be determined by the Field Staff based on satisfactory recovery of samples and SPT (or other) testing to the target depth, satisfactory installation or backfill and site clean-up.

- As soon as the borehole is complete to the satisfaction of the Field Staff the Contractor shall remove from the Site all machinery, plant, surplus materials, and rubbish of any kind, and leave the Site clean and tidy to the satisfaction of the Field Staff and the landowner

3.13 Core Standards

3.13.1 Core Box Standards

This standard applies to 0.60 meter long 'coreflex' fold up boxes and lids as used by all drilling subcontractors operating in Christchurch on the EQC GI Project.

3.13.2 Measuring Up

Before photography all core is to be measured and checked as follows:

- Measure up all drill runs, check against driller's log (if available) and record runs to scale onto a field borehole log sheet.
- Measure runs for core recovered and record any 'no recovery' as appropriate on the field borehole logs. Consider equivalent core diameter of material in estimating the length recovered, as broken core may be spread out in the core box. . Generally 0.10 meter in the minimum 'no recovery' recorded. Add 'no recovery' core blocks to the core boxes as required.
- Check locations of SPT and other tests/samples. Record test locations and results on field borehole logs. Add or correct core blocks for tests/samples as appropriate.

3.13.3 Length of Core Storage

All core collected during the EQC GI Project will be sealed in plastic after final logging, photography and sampling. The Core boxes will be stored in a warehouse and will be available for review and further sampling if required.

Core will be retained by the field team for six months after completion of a borehole. After five months the stakeholder/owner will be informed of the impending disposal of the core and offered the opportunity to retain the core at an agreed cost per box per month.

3.13.4 Field Photography

All field staff shall check and assure their field cameras are fully charged before the commencement of site works on each day. All photographs shall be taken using a good quality compact camera or tablet. The camera shall be set to 4:3 ratio, 5 megapixels or greater, fine to super fine quality as applicable for the particular camera.

Prior to taking any core photograph the photographer shall clean, scrape or trim the core to remove the surface smear and reveal the 'true' colour and texture. If the recovered core is dry, dampen the surface with a rag or mist bottle but avoid adding water to the material as this may affect its suitability for laboratory testing. Core surface should be moist, so colours are 'dark'.

A standard photo board will be used in all field core photographs. The photo board should have a clear scale bar, measured metric increments, colour and monochrome charts, borehole identification, date and depths. An example photograph board is shown in the example core photograph in Appendix B of this document.

Double check the photo board details before taking the image. Incorrectly labelled core photographs can be difficult to reconcile and may result in inaccurate records and will result in the need to repeat the photography of a borehole.

Take photos in shaded areas but in good light. Avoid flash, or take both forced flash and naturally lit photographs. Stand in front of the box and hold camera out to centre of box and frame so that one box and title fill the frame. Generally this is about waist height. The cameras 3 second self-timer should be used to minimise blur caused by depressing the shutter button, particularly for natural light photographs.

Check the image for glare reflection, contrast, shadow and sunshine across the boxes, framing of box, focus, legibility and brightness of image before moving to the next box.

Take additional photos of specific 'significant' horizons as deemed of value and highlighted on the field log.

3.13.5 Core Shed Photography

Laboratory core photography will be undertaken at the Project Office.

The core photography facility comprises:

- High intensity lighting to maximise the quality and uniformity of photographs;
- A high quality camera in a frame/mounted on a tripod with a timer, remote or cable release to reduce blur, and,
- A photo board – elevated or inclined, grey to minimise glare, with space for recording borehole, box details and core information. Suitable colour and greyscale charts will be shown in all photographs. Refer to the core photograph in Appendix B for an example of an acceptable photo board.

Before photography, field staff will assure the core is clean, check core blocks, labels, sample cards and SPT markers are all clearly visible.

3.13.6 Photograph Archiving

All photographs are to be reviewed by the field team and sorted into folders for ease of location of a specific photograph. The field team will keep separate backup copies of archived photographs as appropriate.

A suitable naming system for photographs is required to accurately identify borehole, box and depths represented by the photograph.

i.e. ARA-POD13-BH02 D 15.50-18.00 meters

3.13.7 Core Photograph Errors

In the course of these investigations, labelling and photoboard errors may occur in core photographs.

A core photograph retake is required if any of the following errors occur:

On the Photoboard:

- Depth from
- Depth to
- Box number
- Address
- Borehole number
- Date

In the Core Box:

- Depths on core block;
- SPT values taken from the field supervisors log;
- Zones of no recovery;
- Lab test information;

- End of borehole labels, and,
- Orientation of box in relation to photoboard.

In the photograph:

- Colour;
- Contrast;
- Box position in frame
- If the core is obscured;
- The scale is not visible;
- The photograph does not contain the whole of the box, and/or,
- The photograph is of generally poor quality.

The orientation of the photograph may be corrected providing no information is lost or altered.

3.14 Auditing

The Engineer and the field staff will independently audit all borehole drilling operations on the EQC GI Project.

A copy of the Engineer's borehole audit checklist is contained in Appendix E. All drillers and field team supervisors shall continuously review the key points outlined in this audit sheet and assure fastidious compliant operation is continuously achieved.

Field staff supervising rigs shall use photocopies of the document contained in Appendix E of this Field Manual for every investigation location. The Engineer shall periodically audit all rigs engaged on the EQC GI Project.

4 Specification for Cone Penetrometer Tests

4.1 Preamble

A primary part of the observing Field Staff's duties are to check that the Subcontractor's procedures are as specified in this document and that the work is carried out in an efficient manner. All observing Field Staff shall be fully familiar with the requirements of ASTM D5778-12 and ensure the Subcontractors method of working complies with these standards.

Before unloading a rig at a CPT sounding location a pre-start meeting (toolbox talk) should be held. This should confirm health and safety (H&S) aspects, including requirements for contaminated land, special requirements relating to the site in question and permit to work. Field team supervisors will also instruct operators on the specification and purpose of each sounding as appropriate.

4.2 Cone Penetration Testing (CPTu)

4.2.1 General Test Requirements

Wherever possible all CPT testing should be undertaken in general accordance with ASTM Standard D5778-12, including measurement and reporting of pre and post-test baselines, calculation of zero shift, pore pressure and push rates. Each new CPT will have a fresh pore pressure filter installed.

The field team will assure before and after photographs are taken at every location. These photographs should contain a photo board with relevant location information and several angles should be captured with particular shots taken of existing cracks or damage. These photographs are important for future dispute resolution, an example can be found in Appendix D

4.2.1.1 Phase 1a/1e CPT's

All CPTu tests will be carried out to the specified minimum target depth for Phase 1a/1e (refer to section 1.2 of this document), to the depth specified in section 4.2.11 if early refusal occurs, or as directed by the Engineer. In some suburbs it is unlikely that predrilling of CPT's will yield a completed investigation as several gravel layers may be encountered within the 20.00 meters depth of investigation resulting in early refusal. In these cases the field staff will ascertain the distance to the nearest existing EQC GI Project borehole and if this falls within 25.00 meters the CPT investigation will be considered complete. If the nearest borehole is greater than 25.00 meters from the CPT location then the procedure for shallow refusals is to be followed and a course of action chosen based on the area of investigation and the depth reached. Further details on shallow refusals can be found in section 4.9.11 of this document. A list of shallow refusal area categories and a flow chart detailing the process for these phases can be found in Appendix C.

4.2.1.2 Phase 1b/1c/1d

All CPTu tests will be carried out to the specified minimum target depth for Phase 1b/1c/1d (refer to section 1.2 of this document), to the depth specified in section 4.2.11 if early refusal occurs, or as directed by the Engineer. In some suburbs it is unlikely that predrilling of CPT's will yield a completed investigation as several gravel layers may be encountered within the 10.00 meters depth of investigation resulting in early refusal. In these cases the Engineer will assess the location and decide on a course of action. CPT's may be replaced with rotary mud boreholes in order to get reliable SPT data for the purpose of liquefaction analysis. If the nearest borehole is greater than 25.0m from the CPT location then the procedure for shallow refusals is to be followed and a course of action chosen based on the area of investigation and the depth reached. Further details on shallow refusals can be found in section 4.2.11 of this document. A list of shallow refusal area categories and a flow chart detailing the process for phase's 1b/1c/1d can be found in Appendix C.

4.2.2 Productivity

We expect that between 4 and 10 CPT tests will be completed per day per rig on average, depending on access and depth. Where practical, the investigation programme will be scheduled so that CPTs are completed adjacent to proposed borehole locations before the holes are drilled, to provide an indication of target layers for sampling and testing.

The Engineer will notify the field team in writing of any special requirements for additional drilling after review of the CPT results.

4.2.3 Field Cone Certificates

Field staff are to check each Subcontractor has a copy of the correct current cone calibration certificate on the testing rig and that this corresponds with the cone being used. Please note that under the rules of the project a cone must be calibrated as a minimum every 12 months or 3000.00 meters of use, whichever occurs first.

4.2.4 Dissipation Testing

The Engineer requires pore pressure dissipation testing to be carried out in a suitable stratum for all CPT soundings. One to two tests per sounding are expected to be completed between 3.00 – 6.00 m bgl and 10.00 -15.00 m bgl for 1a/1e investigations and 3.00 – 6.00 m bgl and 6.00 -10.00 m bgl for 1b/1c/1d investigations.

Field staff should ensure that all Subcontractors are aware that filters must be changed for EACH new sounding, and fully saturated in accordance with ASTM D5778-12 prior to use.

For the purpose of data continuity on the EQC commissioned geotechnical investigations all pore filters are to be submerged within silicone oil or glycerine as a saturation agent. The supervising field team member should satisfy themselves that filters have been properly prepared i.e. stored within the saturation medium for a minimum of 24 hours prior to use (as required by ASTM D5778-12).

The supervising field staff member is to inspect and confirm that each cone is assembled properly whilst fully submerged and is assembled correctly. Assembled cones should be

kept submerged until ready for use and covered with a membrane between removal from liquid and use in a sounding.

Before the first test of the day or after a long break, the cone and testing equipment should be allowed to settle to the ambient ground temperature. A fresh bucket of tap water is to be drawn and the cone submerged within it for a minimum of 15 minutes, in order to thermally homogenise the cone with the ground temperature as much as is practical. It is also suggested that cones are stored in a bucket of freshly drawn water prior to its use to complete a sounding.

4.2.5 Pore Pressure Stabilisation

Pore pressure may vary during the course of a sounding. If pore pressure becomes negative during a sounding the operator will immediately cease pushing the cone and wait whilst pore pressure readings become positive and stabilise. It is anticipated that pore pressure readings will return to positive values within 5 to 30 minutes.

The operator and attending supervisor must record the depth, reason for and duration of any pause in push. If negative pore pressure occurs below the assumed water table (minimum of 2.00 m bgl) and does not return to positive within 60 minutes the Field Team will clearly record this and report to the Engineer prior to continuing with the test.

4.2.6 Reporting Requirements

Field staff shall ensure that all Subcontractors are reporting test results in compliance with the requirements of ASTM D5778-12.

4.2.7 Seismic CPT testing (SCPT)

Full details of all seismic CPT's are to be confirmed by the Engineer prior to commencing fieldwork at that location.

Down-hole seismic CPT tests (SCPT's) will be undertaken at selected locations (upto 20% of the CPT locations) as directed by the Engineer. These tests will supplement the geophysics and down drill hole seismic testing.

This testing method uses seismic CPT probes to measure the travel time of surface generated shear waves (typically generated by hand using a large hammer [to be specified by the Engineer]). The travel time to various depths is calculated, and from this a shear wave velocity profile with depth is calculated. This technique provides a profile of soil shear wave velocity with depth, which is of particular relevance for analysis of liquefaction and seismic site response. Geophysical testing will initially be performed at 2.0m depth intervals; however this interval may be adjusted by the Engineer depending on considerations of testing productivity and interpretation of results.

4.2.8 CPT Predrill.

Where shallow gravels are encountered and the CPT probe refuses at a depth of 12.00 m bgl or less for Phase 1a/1e and 8.00 m bgl or less for Phase 1b/1c/1d, a pre-drill may be required. For this a borehole will need to be undertaken to drill through the obstructing layer and the hole backfilled with builders sand or similar. The need for predrilling is determined by both the area of investigation and also the phase of investigation. Determination of the predrilling requirement will be assisted by the Engineer where necessary. Further guidance regarding shallow refusal requirements are provided in section 4.2.11 of this document.

Where pre-drilling is required to complete CPT testing below a gravel layer, SPT's will be undertaken within the predrill zone as per Section 3 of this document.

4.2.9 CPT Logs and Records

The observing Field Staff shall observe and make sufficient notes to be able to certify the Contractor's Daily Report for each Site. The daily report should, at a minimum, identify the following:

- Rig type and I.D;
- Name of supervisor;
- Site(s) occupied;
- Hours worked, including rig stand-by time and reason(s) for stand-by;
- Refusal depths/target reached;
- Anchor failure during test;
- Consumables used;
- Time travelling between sites, and,
- Any other information relevant for the Engineer's assessment of payments.
- An example EQC GI subcontractors CPT trace is included in Appendix C

All measurements relating to CPT soundings are to be recorded as 'meters below existing ground level' (m bgl). Relative level for CPT soundings will be calculated and reported relative to the Mount Pleasant Datum.

4.2.10 CPTB Investigation Requirements

Each borehole in the verge or roadway has been 'twinned' with a specific CPT to be identified as a CPTB. All boreholes within the EQC geotechnical investigation require a correlating CPT to tie the local suburb CPT's into the observed geology. These correlating CPT's shall be 2 meters from the borehole wherever possible and an absolute maximum of 5.00 meters from the borehole at difficult locations. If this cannot be achieved the Engineer is to be contacted as soon as possible. If a borehole can be moved onto a property where the service strike risk is lowered it may be moved within 5.00 meters of that properties CPT and thus the 'twinned' CPTB will no longer be required and should not be pushed. This process shall be agreed in writing with the Engineer.

CPTBs shall be completed in advance of the boreholes to avoid any potential ground disturbance from the drilling operations.

4.2.11 Shallow Refusals

Reaching the minimum target depth of 20.00 m bgl (12.00 m bgl absolute minimum) set for CPT investigations in phase 1a/1e and 10.00 m bgl (8.00m bgl absolute minimum) for phases 1b/1c/1d undertaken as part of the EQC GI Project is important for effective liquefaction analysis. Occasionally a shallow refusal will be encountered and this minimum target depth will not be met.

A decision will be made between the Engineer and the field staff regarding how to attain the required minimum depth of data based on each scenario. In the first instance, however the field staff shall follow the charts in Appendix C entitled 'EQC Geotechnical

Investigation Program – Shallow CPT Refusal Procedure Phase 1a/1e’ and ‘EQC Geotechnical Investigation Program – Shallow Refusal Procedure Phase 1b/1c/1d’.

4.2.11.1 Shallow Refusal Solutions – Phase 1a/1e

The sequence of attempts and selection of method in the event of a shallow refusal shall be:

1. If a drill hole is located within 25.00 meters of the site the investigation is considered complete;
- 2a. If CPT refusal occurs at a depth of 0.00 to 5.00m bgl, no drill hole is within 25.00 meters and it is in group 3 of the shallow refusal suburbs list contained in Appendix C, the location shall be subjected to the necessary predrilling through the gravel / dense layer with sonic or rotary mud drilling equipment to a maximum depth of 20.00 m bgl;
- 2b. If CPT refusal occurs at a depth of 0.00 to 5.00m bgl, no drill hole is within 25.00 meters and it is in group 2 of the shallow refusal suburbs list contained in Appendix C, the location shall be reviewed by the Engineer and a course of action decided;
- 2c. If CPT refusal occurs at a depth of 0.00 to 5.00 m bgl, no drill hole is within 25.00 meters and it is in group 1 of the shallow refusal suburbs list contained in Appendix C, a rotary sonic and/or mud rotary borehole shall be undertaken at the location. These boreholes are to include SPT's from relative ground level;
4. If CPT refusal occurs between 5.00 and 12.00 m bgl and no drill hole is within 25.00 meters a rotary sonic or mud rotary borehole shall advance the investigation at that location to a maximum depth of 20.00 m bgl provided. These boreholes are to include SPT's from refusal depth;
5. If CPT refusal occurs at a depth greater than 12.00 m bgl the investigation is considered complete.

Please refer to the shallow refusals suburb list and flow diagrams contained in Appendix C of this document for further clarification of the shallow refusals process.

4.2.11.2 Shallow Refusal Solutions – Phase 1b/1c/1d

The sequence of attempts and selection of method in the event of a shallow refusal shall be:

1. If a drill hole is located within 25.00 meters of the site the investigation is considered complete;
- 2a. If CPT refusal occurs at a depth of 0.00 to 8.00 m bgl, no drill hole is located within 25.00 meters and it is in Group 3 of the shallow refusal suburbs list contained in Appendix C, the location shall be subjected to the necessary predrilling through the gravel / dense layer with sonic or rotary mud drilling equipment to a maximum depth of 8.00 m bgl;
- 2b. If CPT refusal occurs at a depth of 0.00 to 8.00 m bgl, no drill hole is located within 25.00 meters and it is in Group 2 of the shallow refusal suburbs list contained in Appendix C, the location shall be reviewed by the Engineer and a course of action decided;

- 2c. If CPT refusal occurs at a depth of 0.00 to 8.00 m bgl, no drill hole is located within 25m and it is in Group 1 of the shallow refusal suburbs list contained in Appendix C, a rotary sonic and/or mud rotary borehole shall be undertaken at the location. These boreholes are to include SPT's from relative ground level;
3. If CPT refusal occurs between 8.00 and 12.00 m bgl the investigation is considered complete.

This section must be read in conjunction with the shallow refusals suburb list and flow diagrams contained in Appendix C of this document.

4.2.11.3 Nomenclature for Multiple CPT's at the Same Location

In the case of multiple phases of CPT investigation at one location the following nomenclature will be adopted:

NNB_POD9_CPT056 – Initial CPT investigation;

NNB_POD9_PDCPT056 – for the predrilled part of the investigation;

NNB_POD9_CPT056-**B** – for the second CPT sounding attempt, etc.

Insert the consecutive letter for each attempt until completion.

NNB_POD9_CPT056-**Z** – Once all parts of the investigation have been presented together in one trace with the predrill zone clearly marked. Note: this stage must be expressly reviewed and approved by the Engineer before issue.

If a CPT is replaced with a borehole (refer to the shallow refusals list and flow diagrams in Appendix C of this document) the new borehole will be given an entirely new designation in keeping with the current EQC GI Project boreholes.

Wherever possible all CPT testing/predrilling at the same location shall be completed using the same machine/cone. All segments of the test location shall be 'spliced' into a single CPT report upon completion of the location.

4.2.12 Quality Control of CPT Data

A high degree of quality control and professional operation is required in order to assure meaningful and realistic CPT data is attained.

All sub-contractor staff and field staff who operate machinery and/or supervise CPT fieldwork shall fully acquaint themselves with the intricacies of CPT testing and the contents of ASTM D5778-12. The Engineer will periodically undertake technical CPT auditing to assess and monitor the performance of CPT subcontractors, however, supervising Field Team members should be sufficiently knowledgeable and experienced in order to make operational assessments of their own and report any areas of concern to the Engineer.

The following are of particular note:

- Field Team staff shall visually inspect the CPT cone and sleeve components for surface wear, deformation/change of shape and confirm o/x ring seals are functioning after each sounding. In cases of obvious disregard for a worn

component, photographs should be taken immediately and provided to the Engineer by the Field Team;

- The operator is to be questioned on at least a daily basis by the supervising Field Team regarding when next cone calibration is needed, be this by date and/or by meterage;
- The Engineer has adopted a maximum of one year or 3000.00 meters of testing between calibrations. It is expected that cone calibration will need to be performed well within these given parameters. This can be checked by viewing the CPT calibration certificate and asking the operator to provide the evidence of total meterage pushed by the cone since last calibration;
- The Field Team should confirm Cone Temperature Homogenisation is undertaken at the start of shift, regardless of whether a cone is temperature stabilised or not. The cone should be placed in a bucket of freshly drawn tap water for 15 minutes prior to use to complete any investigation works;
- Signal loss has occurred with some wireless systems resulting in the need to repush a small percentage of tests. If >300.00mm or two successive instances of signal loss are observed this should be flagged by the Field Team and reported to the Engineer so that a repush can be arranged;

Cone wear is of particular concern in Christchurch ground conditions and will be checked tenaciously by all field staff and investigation sub-contractors. It is recommended that CPT Subcontractors employ a Cone 'template' (shape model) as a quick physical check of cone wear and tip angle.

Field Team members should fully acquaint themselves with ISO 22476-1 (including Technical Corrigendum 1, 2013), particularly in the case of judging cone wear.

A Cone Manufacturing and Operating Tolerances Diagram (taken from ASTM D5778 – 12) is contained in Appendix C.

4.2.13 Subcontractor Invoicing and Daily logs

All sub-contractors invoices will state the CPTs included with Location ID Code (e.g. CPT-POD01-BEX001) as well as a cost breakdown for each CPT. Daily logs and a generalised geological profile, will be submitted by the Subcontractor for each CPT within three working days of the completion of said test.

4.2.14 Reporting requirements

Due to the complex and scientific nature of CPT testing it is imperative for future use of a sounding's data that all required information is captured and reported. Subcontractors are required to report everything required by the testing standard as a bare minimum. This includes baseline calibration measurements and full scale output checks. For those Subcontractors who do not have the ability to provide this information in an acceptable format a template has been designed by the Engineer and will be issued by him for use on the EQC GI Project. The use of this template will ensure all data required by ASTM 5778-12, and any additional items required by the project, are captured. This template is in Microsoft Excel format and will be completed and returned to the Engineer in conjunction with the Subcontractors CPT trace and data files.

It is also important for checking of baselines, calculation of zero shift and quality assurance purposes that all current cone calibration certificates are forwarded to the

Engineer. Certificates will be provided by the Subcontractor for all cones and spare cones carried or in use on the project. Certificates will be forwarded to the Engineer as soon as they become available with a returned, calibrated or new cone. Cone calibration due dates or meterages and total meterage for a cone will be provided to the Engineer within 3 working days of a written request for this information.

4.3 Auditing

Field staff supervising CPT rigs shall complete the CPT checklist contained in Appendix E of this document for every field location which they supervise.

A copy of an Engineer approved CPT checklist is contained in Appendix E. All CPT operators and field team supervisors should review the key points outlined in this document to help assure fastidious compliant operation is achieved at all times.

The Engineer will perform an independent technical audit of all CPT Subcontractors on the EQC GI Project periodically and as deemed necessary. Subcontractors are to be audited as soon as possible after they join the project. If they pass the audit the data they have produced up to that point is accepted into the project. The contractor has 5 working days to respond to and/or satisfactorily address any issues identified by the audit process. If any serious malpractice is identified by the engineer then the contractor is required to correct the issues then repush all tests undertaken prior to the corrections at his own cost. Any further involvement in the project will then be reviewed by the Design and Planning team.

As the EQC GI Project has progressed the quality of CPT data has come under close scrutiny by the wider geotechnical community. The CPT technical auditing process, both in the field and during review of CPT test data has significantly increased the confidence in quality of data obtained under the project and has revealed ways of improving CPT methods for future investigation in New Zealand. All CPT's are to be undertaken to ASTM D5778-12 as a minimum, however, for EQC and T&T investigations additional requirements have been identified based on our experiences, observations, international peer review and in the latter part of the project, by adopting relevant parts of the new ISO 22476-1 (including Technical Corrigendum 1,2013).

5 Additional Geotechnical Methods of Investigation

5.1 Multichannel Analysis of Surface Waves (MASW)

Multichannel Analysis of Surface Waves (MASW) is a geophysical technique which uses a percussive seismic source; the energy from which is expressed as a wave form which travels at a velocity correlatable to the density of the material it moves through and is reflected off of dense geological stratum (such as beds of the Riccarton gravel). The reflections received are captured using an array of geophones with variable spacing depending on the depth/resolution required. This can then be utilised / interpreted by a geophysical specialist and/or the Engineer as appropriate.

If the MASW survey cannot produce sufficient resolution using a surface array in the case of surveying on rough ground, it is usually acceptable to employ buried geophones on this project. The use of these devices is to be agreed with the Engineer prior to commencing works.

MASW surveying technology has provided useful results in previous phases of investigations supervised by T&T and is now being undertaken on selected pods within the scope of the EQC geotechnical investigation.

The Engineer will notify the Field Team of any intended MASW locations and provide maps clearly defining areas to be surveyed. The Field Team will engage an Engineer approved suitably experienced and qualified specialised Subcontractor to complete all MASW surveying and organise traffic management as required.

All MASW results are to be provided to the Engineer in an agreed graphical format in no more than 400m sections. An example of an acceptable output format is provided in Appendix F of this document.

If further MASW or other Geophysical investigation is desired then the Engineer will liaise with the Field Team regarding those requirements.

5.2 Hand operated Dynamic Cone Penetrometer (Scala) Testing

Hand operated Dynamic Cone Penetrometer (Scala) testing it is not likely to form part of the project. The Engineer shall provide further guidance if this method is specified for use on the EQC GI Project.

5.3 Hand Auguring

Hand auguring is a useful tool for both service clearance and for recovering material for description and testing in the upper meters of an investigation where vacuum excavation is necessary due to service proximity. Hand auguring should be performed in accordance with ASTM D1452-09 and logged using Engineer approved borehole terminology (i.e. NZGS guidelines). The Engineer shall provide further guidance on this method as necessary.

5.4 Dynamic Probing Super Heavy-B (DPSH-B)

Dynamic Probe (DP) testing may be employed on the EQC GI Project as part of the Phase 1e investigations. The small, manoeuvrable, percussive rigs lend themselves well to tight access situations and as no anchoring system is needed they can fit into areas where other techniques are ruled out due to service proximity.

DP is similar to SPT in that a known weight is dropped onto a standardised penetrometer anvil, rod and tip arrangement over a known distance and the blows are counted for penetration over a set increment. The main difference is that DP drive increments are 100 mm and the penetrometer is continually driven rather than driven for a fixed number of blows. Refusal blow-counts are also significantly higher which assists DP in penetrating dense and / or coarse grained stratum.

Torque measurements are taken every meter of testing (10 increments) using a torque wrench. It is important to record whether a sacrificial cone tip or a reusable cone tip is used.

There are numerous permutations of DP setup with variations on the drop weight, drop distance, cone type and diameter etcetera. For the purposes of the EQC GI Project the Engineer requires use of the class: Dynamic Probing Super Heavy-B (DPSH-B). This category specifies an approximately 63.50 kilogram weight to be dropped over a 760 mm drop height and blows recorded over 100 mm increments. Rods and cone dimensions are also specified. All DPSH-B testing should be completed in accordance with the recommendations and requirements stipulated in British Standard "BS EN ISO 22476-2:2005".

Dynamic Probe data can be converted to an equivalent SPT N-value which is useful for ground characterisation and geotechnical design. It is also possible to use DP data for liquefaction susceptibility and settlement prediction analysis although the reliability of the method is not well regarded amongst many Engineers and further study is required before this investigative tool can be solely deployed with an appropriate degree of confidence.

5.4.1 Dynamic Probe Hammer Efficiency

It is necessary for all Dynamic Probe rigs employed on the EQC GI Project to provide the Field Team / Engineer with a measured Hammer Efficiency. As there is no published standard specifically for measuring the hammer efficiency of a Dynamic Probe rig the Engineer will use and adapt the ASTM method for SPT hammers where required.

6 Applicability

This field manual has been prepared for the benefit of the Earthquake Commission with respect to the particular project requirements and it may not be relied upon in any other context or for any other purpose without our prior review and agreement.

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Tonkin & Taylor Ltd

Environmental and Engineering
Consultants

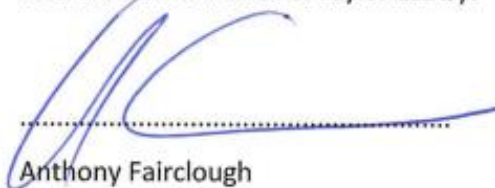
Manual prepared by:

A blue ink signature of Dan Ashfield, consisting of a stylized 'D' and 'A' followed by a horizontal line.

Dan Ashfield

Engineering Geologist

Authorised for Tonkin & Taylor Ltd by:

A blue ink signature of Anthony Fairclough, consisting of a stylized 'A' and 'F' followed by a horizontal line.

Anthony Fairclough

South Island Geotechnical Co-ordinator

APPENDIX A:

INDUCTIONS AND PROFORMA'S

MARKOUT INDUCTION

MARKOUT SHEET'S

SERVICE AVOIDANCE SOP

PERMIT TO DRILL

DAILY RECORD SHEETS

EQC TC3 CPT Markout Induction v 1.4

	(Tick)
1. Purpose	
The primary reason for the markout process is to minimize the risk of damaging services and utilities. Damage to service and utilities can result in <u>serious injury or death</u> , so please take your time to ensure the process is undertaken correctly.	
1. Introduction	
Approximate test locations will be given to you. You will then need to go to these approximate locations and find the best area in which to carry out the test. Marking out a site include the following considerations: rig access, services clearance (underground and overhead) and the necessary reinstatement type. In order to keep the reinstatement cost down and to keep residents happy, we should not damage any pavers, tiles or polished/textured concrete. Please try and limit the testing to surfaces consisting of grass, garden, asphalt or concrete. You should use the <u>field sheet</u> and follow the following steps to carry out a markout.	
2. Check Rig Access	
The dimensions of all rigs will be provided to you. You will measure up the access-way into the site (i.e. how wide is the driveway/path/gap in fence? Will a rig be able to get into the site?). You will also need to measure up the testing/work area (i.e. will the rig have enough room to set up and carry out the test). Remember drillers need an area for their drill rods etc. If access is tight for a CPT hole, we can use either a self-anchoring tracked rig (requires 0.5x3m clear of services) or a man-portable rig (requires 2.5x2.5m clear of services). CPT holes must be minimum 1.5m from a solid object (e.g. wall, fence, tree etc). Measurements must be recorded on the field sheet so that an appropriate rig can be mobilised. CPTs are <u>not</u> to be located in the roadway. Unless being marked out as CPTB. Boreholes may be marked out within 1.5m of the curb <u>if absolutely necessary</u> (i.e. in roadside carpark). Try and keep them off the road when possible. You need to remember to check overhead for trees, power lines etc. 4m from overhead power.	
3. Check Service Plans.	
It is important that you follow the T&T Method Statement for Working Around Services. There are mandatory setbacks from services (i.e. there is to be no work within 15m of high voltage power or gas mains, 4m from overhead power) CPT holes must be kept within the 'Low Risk' category. It is preferable to keep boreholes within the 'Low Risk' category too; however, if this is not possible a hole may be located in 'Medium Risk' with the provision of a 'pre-dig' <u>clearly</u> noted on the field sheet.	

All service plans will be provided to you on an iPad. - Please check that you have all the appropriate plans before you go to site. The 'field maps' index all service plans for each POD.

- a) Use common sense and visually identify services (i.e. access covers/power boxes/signs).
- b) Check location plans for intended location of BH or CPT, the mark out site location must be within 5m from that intended location on the location map.
- c) Marking out a borehole that cannot be placed in private property (refer to diagram). If a borehole cannot be placed on a property and/or within 5 meters of a CPT on a property that borehole will be marked out in the verge or roadway.

In this case a CPTB (borehole CPT) has been assigned for correlation purposes, separate from the main Property CPT list shown on the location maps, a new field sheet will need to be created for this CPT with the new CPTB code from the location maps, the services will remain the same as those for the adjacent BH.

- d) A CPTB must be marked out when a borehole is marked in the verge or roadway, number shown in location maps.

The CPTB needs to be a minimum 2m from the borehole and 2m is also the preferred distance where possible. 5m is the maximum allowed distance between a borehole and a CPTB.

- e) Get GPR (Ground Penetrating Radar) unit to run over the whole area and mark with paint the location of all services visible to the unit.
- f) Use all appropriate service plans to identify every service the GPR has found. All services need to be accounted for and recorded on the diagram of the site
- g) Decide on an area for the test, based on rig access requirements and mandatory setback requirements.
- h) Get the GPR to do a 'double check' over the area and record the radar image. This should be done in two directions. If all clear, mark the test location on the ground.
- i) Place a peg or a road survey pin in the test location. Spray a triangle with a dot in the centre for a CPT | or a circle with a cross through it for a borehole §. Spray the test ID (e.g. NNB-POD02-CPT12) preferably on a solid surface (i.e. kerb or footpath).
- j) Place photoboard next to test location and take photo with iPad. Remember to include something in the background to orientate from and try to avoid glare from the photoboard. It is a good idea to shade the photoboard when taking the photo.
- k) Sign-off field sheet. Include a good description so that anyone can come back and find the location. If necessary, draw a site plan. Record anything on the field sheet that you think other people may need to know.

4. Voids under driveways

Due to liquefaction induced scouring, large voids can be present under concrete and sealed driveways. If large voids are present, our drilling machinery is at risk of falling through the concrete.

It is our responsibility to make sure this doesn't happen.

All concrete and sealed driveways must be checked for voids by GPR. If voids are suspected, be careful not to alarm the residents with the observations. If you have to, tell residents that you have found some anomalies that may make drilling difficult. Avoid giving too much detail to residents as it is possible for our observations to be misinterpreted.

Name		Signed	Date
Inductee:			
Inductor:			

Field Check Sheet							
 GEOTECHNICS							
		CPT					
TEAM							
ID: NNB-POD##-CPT##							
LOCATION DESCRIPTION							
PLANS REQUIRED	SERVICE CLEARANCE	PLANS		CABLE LOCATOR		GPR	
		INITIAL	DATE	INITIAL	DATE	INITIAL	DATE
	ORION (electricity)						
	CHORUS (telecom)						
	CCC (sew/water/gas)						
	TELSTRA CLEAR						
	ROCKGAS (gas)						
	ENABLE (fibre optics)						
	TRANSPower (fibre optics)						
RIG/ACCESS							
MIN WIDTH on Access (m)							
MIN HEIGHT on Access (m)							
Rig Recommended (circle one)		Truck		Clear 0.5x0.5m			
		Tracked		Clear 0.5x3.0m			
		Man portable		Clear 2x2m			
PRIVATE ACCESS CONFIRMED		Y / N					
DATE STARTED	___/___/2012		TIME		:		
DATE COMPLETED	___/___/2012		TIME		:		
SURVEY COMPLETED		Y / N					
TRAFFIC MANAGEMENT REQUIRED (necessary if site is not located on someones property)		Y / N		IF YES DISTANCE FROM INTERSECTION: ___M			
MARKOUT PHOTO TAKEN		Y		PHOTO MUST BE TAKEN REGARDLESS			
REINSTATEMENT REQUIRED		Y / N		IF YES DESCRIBE IN COMMENTS BELOW			
POST REINSTATEMENT PHOTO		Y / N		PHOTO TAKEN IF REINSTATEMENT REQUIRED			
COMMENTS (Reinstatement material needed grass seed, concrete, cold mix etc)							
CONTACTS		ENSLIN VAN SCHALKWYK: 0277048692					
		JETHRO NEESON: 027 512 9545					
		ZEB PATERSON: 027 259 3803					

Field Check Sheet



DRIVE WAY DETAILS & SERVICE PLAN

Driveway Material			
Scan Required	Y / N	Scans are required for slab concrete driveways - including textured concrete	
Scan Results (tick one)	NA	☐	
	No Evidence of voids	☐	
	Possible void	☐	
	Void apparent	☐	
Comments			
Sketch of Services detected and dimensions to show location of test			

Identifying and Working around services method statement



Identifying and Working around Services Method Statement

General

This method statement covers identifying and locating services prior to any investigation, sampling or testing work taking place. "The term 'service(s)' means all underground, above ground and overhead pipes, cables and equipment associated with the electricity, gas, water (including piped sewage) and telecommunications industries. It also includes other pipelines which transport a range of petrochemical and other fluids. It does not include underground structures such as railway tunnels etc"¹

The risk of striking or disturbing a service varies for each investigation and depends on the type and number of services present and proximity to services. This risk must be quantified before any investigation is undertaken using the attached flowchart and table.

It is T&T company policy that the locating of underground services on site, using appropriate location technology (such as an electronic detector), is carried out by an approved specialist company experienced in such work or a T&T employee who has been trained and certified by an approved supplier.

Emergency Response

Should any service be struck or disturbed:

- Cease subsurface investigation works and isolate the area. If it is safe, shut down/switch off all equipment.
- All persons are to be prevented from accessing the isolated area until appropriate remedial action is taken.
- If there has been an injury and it is safe to do so, provide assistance.
- Contact emergency services if necessary and any site health and safety representative.
- Contact the Project Manager, Group Manager and company Health and Safety Officer immediately and establish follow up procedures.
- Should any service be damaged the site owner, and/or Council and relevant service authorities shall be contacted immediately and provided with all relevant information.

Methodology Review Process

This method shall be reviewed initially after three months then annually by the Health & Safety Committee. Changes to the methodology will be highlighted along with any clarifying text.

Review Record

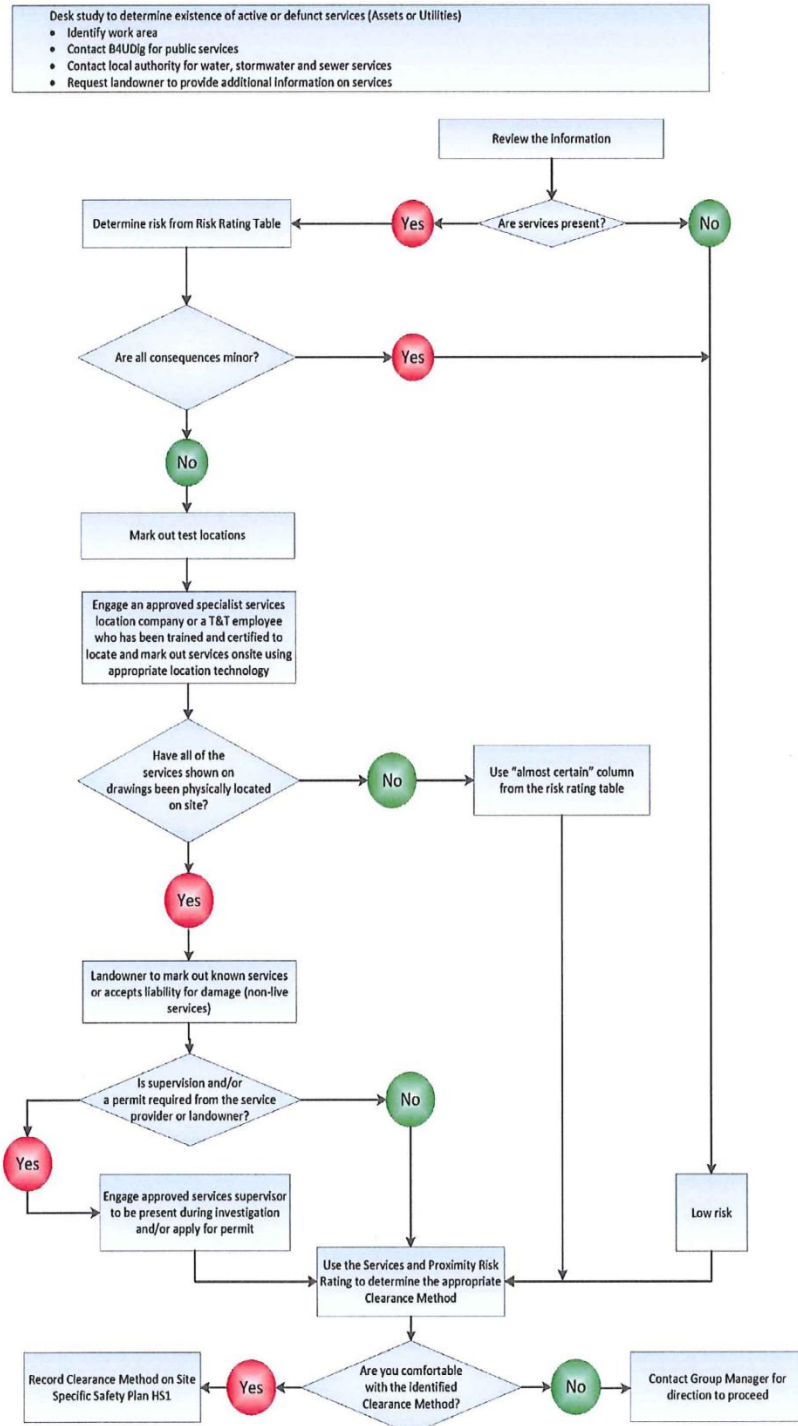
Item	Date	Reviewer	Comments
Launch	8/08/2011	JDJ	
First Review	8/11/2011		

References

1. *Avoiding Danger from Underground Services*, HSG47, Health and Safety Executive (HSE), UK, 2000.
2. *Guide for Safety with Underground Services* (Wellington: Electricity Engineers Association of NZ Inc., 2002) available at <http://www.osh.dol.govt.nz>.
3. *National Code of Practice for Utilities' Access to the Transport Corridors* (Wellington: NZ Utilities Advisory Group, 2009), available for downloading from <http://www.nzuaug.org.nz/national-code/implementation-code.html>;

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Figure 1: Flowchart for identifying and working around services



Identifying and Working around Services Method Statement

Table 1. Services and Proximity Risk Rating

			Likelihood of Striking or Disturbing a Service				
			Almost certain	Likely	Possible	Unlikely	Rare
Rating Description			Distance from services				
		Service	0.0m to 1.0m	1.0m to 2.0m	2.0m to 5.0m	5.0m to 15.0m	>15.0m
Consequence	Minor	Domestic storm water pipe	L	L	L	L	L
	Minor	Domestic water pipe	L	L	L	L	L
	Minor	Domestic telephone cable	L	L	L	L	L
	Minor	Domestic sewer pipe	L	L	L	L	L
	Moderate	Telecommunication cables (excluding Fibre Optic)	M	L	L	L	L
	Moderate	Storm water main pipe	M	M	L	L	L
	Major	Underground power cable	H	M	L	L	L
	Major	Underground gas pipe	H	M	L	L	L
	Major	Sewer main pipe	H	M	L	L	L
	Major	High pressure water main pipe	H	M	L	L	L
	Major	Fibre optic cables	NP	NP	M	L	L
	Catastrophic	Hazardous substances transmission pipe(e.g fuel, chemicals, etc)	NP	NP	M	L	L
	Catastrophic	Overhead power cables	NP	NP	H	M	L
	Catastrophic	Underground High voltage power cable	NP	NP	H	M	L
	Catastrophic	Gas main pipe - all pressures	NP	NP	H	H	L

Table 2. Clearance Method

Risk Rating	Not Permitted (NP)	High Risk (H)	Medium Risk (M)	Low Risk (L)
Note: Clearance method must allow for: Excavation diameter must be greater than the borehole diameter. Excavate to 1.2m or to the invert of the service (where known).	Not permitted without review by the Group Manager, if approved follow High Risk Clearance Method	Must confirm whether supervision and/or permits are required from the services company or landowner to authorise close work to these services. Where work is permitted then vacuum excavation or hand digging or hand auger is mandatory.	Vacuum Excavation or hand digging or hand auger mandatory. Confirmation of safe working distance required for overhead services.	Visual check for services on site



TC3 Permit to Drill

It is mandatory that this sheet is checked and signed by the TC3 Logger/Supervisor, Drilling Operator and Drilling Offsider before any drill hole commences

BH/CPT ID: _____

- | | | | |
|------------------------------------|--|--|--|
| 1. Check address is correct | Yes ☐ No ☐ | 9. GPR signed off | Yes ☐ No ☐ |
| 2. Check BH/CPT ID is correct | Yes ☐ No ☐ | 10. Traffic management required | Yes ☐ No ☐ |
| 3. Check location in markout photo | Yes ☐ No ☐ | 11. Pre-dig required | Yes ☐ No ☐ |
| 4. Orion (power) plans checked | Yes ☐ No ☐ | 12. Toolbox talk (review SS Safety Plan) | Yes ☐ No ☐ |
| 5. Rockgas plans checked | Yes ☐ No ☐ | | |
| 6. Telecom plans checked | Yes ☐ No ☐ | | |
| 7. CCC plans checked | Yes ☐ No ☐ | | |
| 8. Cable locator signed off | Yes ☐ No ☐ | | |

Toolbox talk comments:

All of the boxes above must be checked before signing. Only sign if you are comfortable that all safety precautions have been followed.

	Name	Signed	Date
TC3 Logger/Supervisor			
Drilling Operator			
Drilling Offsider			

APPENDIX B:

BOREHOLES

FIELD DESCRIPTION OF SOILS AND ROCKS- NZGS 2005

FIELD DESCRIPTION OF SOIL FIELD GUIDE SHEET NZGS 2005

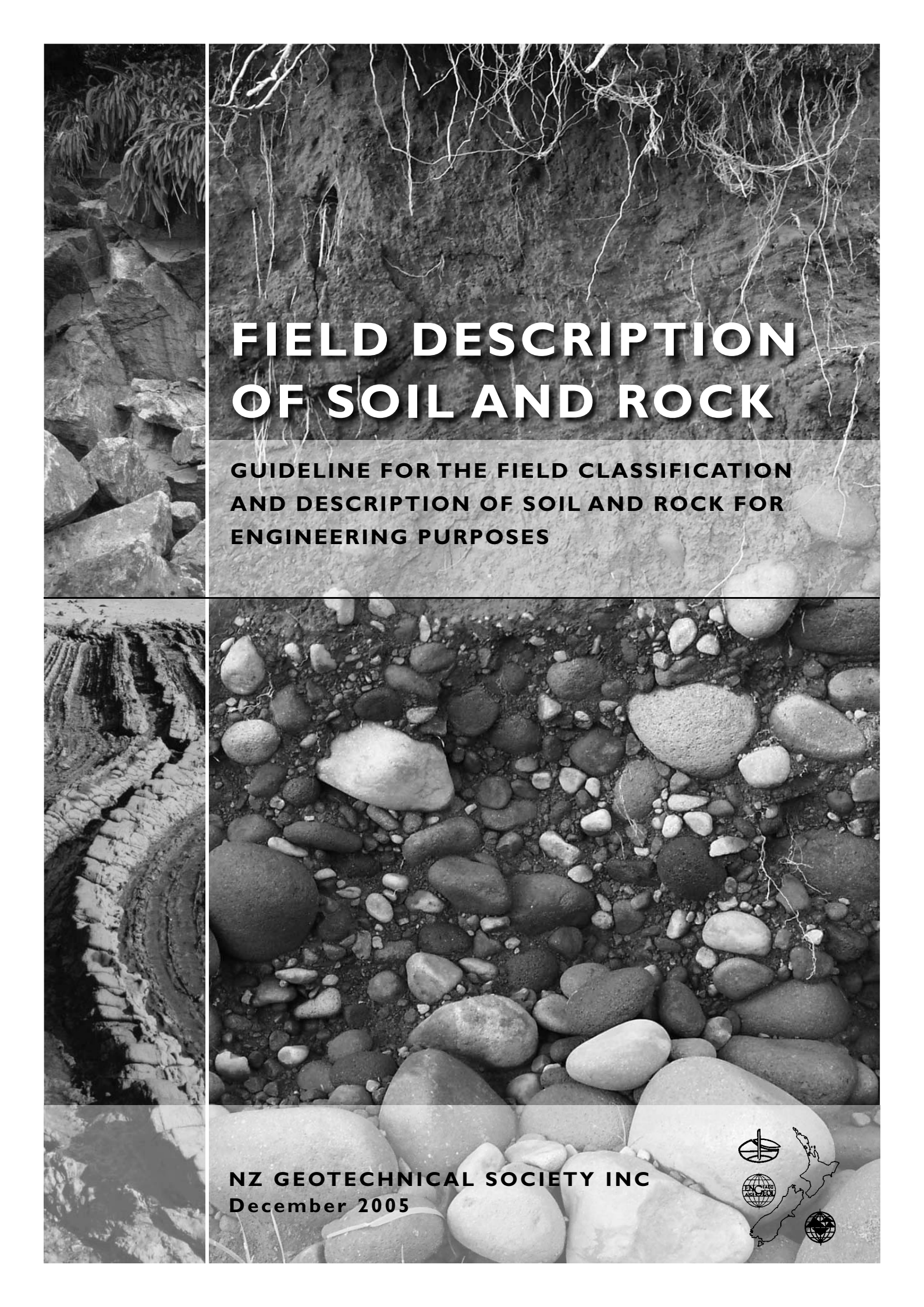
FIELD DESCRIPTION OF ROCK FIELD GUIDE SHEET NZGS 2005

EXAMPLE BOREHOLE FIELD LOG

EXAMPLE ROTARY SONIC BOREHOLE FINAL LOG

EXAMPLE ROTARY MUD BOREHOLE FINAL LOG

EXAMPLE CORE PHOTOGRAPHS

The cover features a collage of four black and white photographs. The top-left image shows a pile of angular rock fragments. The top-right image shows a soil profile with numerous tree roots hanging down. The bottom-left image shows a close-up of layered sedimentary rock. The bottom-right image shows a riverbed or streambed filled with smooth, rounded river stones of various sizes.

FIELD DESCRIPTION OF SOIL AND ROCK

**GUIDELINE FOR THE FIELD CLASSIFICATION
AND DESCRIPTION OF SOIL AND ROCK FOR
ENGINEERING PURPOSES**

NZ GEOTECHNICAL SOCIETY INC
December 2005





NZ GEOTECHNICAL SOCIETY INC

The New Zealand Geotechnical Society (NZGS) is the affiliated organisation in New Zealand of the International Societies representing practitioners in Soil Mechanics, Rock Mechanics and Engineering Geology. NZGS is also an affiliated Society of the Institution of Professional Engineers New Zealand (IPENZ).

The aims of the Society are:

- To advance the study and application of soil mechanics, rock mechanics and engineering geology among engineers and scientists
- To advance the practice and application of these disciplines in engineering
- To implement the statutes of the respective International Societies in so far as they are applicable in New Zealand.

Full members of the NZGS are affiliated to at least one of the following Societies:

- International Society for Rock Mechanics (ISRM)
- International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE)
- International Society for Engineering Geology and the Environment (IAEG).

Members are engineers, scientists, technicians, contractors, students and others interested in the practice and application of soil mechanics, rock mechanics and engineering geology. Membership details are given on the NZGS website www.nzgeotechsoc.org.nz.

COVER PHOTOGRAPHS:

MAIN: Incised bank, Waiwhakaiho River, New Plymouth (courtesy Sian France)

UPPER LEFT: Basalt rock face, Mountain Road, Auckland (courtesy of Wayne Gunn)

LOWER LEFT: Sandstone/ mudstone exposed in shore platform, Auckland (courtesy of GNS Science)

Copy prepared by Karryn Muschamp

EDITORS: David Burns, Geoffrey Farquhar, Mandy Mills, Ann Williams

FIELD DESCRIPTION OF SOIL AND ROCK

**GUIDELINE FOR THE FIELD CLASSIFICATION
AND DESCRIPTION OF SOIL AND ROCK FOR
ENGINEERING PURPOSES**

PREFACE

A draft method of soil description was produced by a working group of the New Zealand Geomechanics Society (now the New Zealand Geotechnical Society) in 1980. Members of the working Group were:

Dr S A L Read	New Zealand Geological Survey (now GNS Science)
Mr P J Millar	Tonkin & Taylor Ltd
Mr N S Luxford	Babbage Consultants Ltd
Mr A J Olsen	Worley Consultants Ltd (now Maunsell Ltd)

The draft was expanded to include a method for the description of rock in 1985, and published in 1988 as “Guidelines for the Field Description of Soils and Rocks in Engineering Use”.

This 2005 revision has been prepared with the objectives of keeping pace with international practice, defining terms used in communicating soil and rock properties in New Zealand and giving emphasis to describing properties that are of engineering significance.

In particular, the soil description part of the Guideline has been revised to emphasize the distinction between classification and description. One notable change from the 1988 Guideline is the omission of Table 2.7 (USBR Unified Soil Classification Chart). This is in keeping with the 3rd edition of the USBR Earth Manual and changes to presentation of the Unified Soil Classification System in ASTM standards.

The rock description part of the Guideline has been simplified, and the section on weathering revised to make it more relevant to the range of rock types normally met in New Zealand. A more complete set of terms is provided to allow description of rock in both core and outcrop.

Contributors to the 2005 revision are:

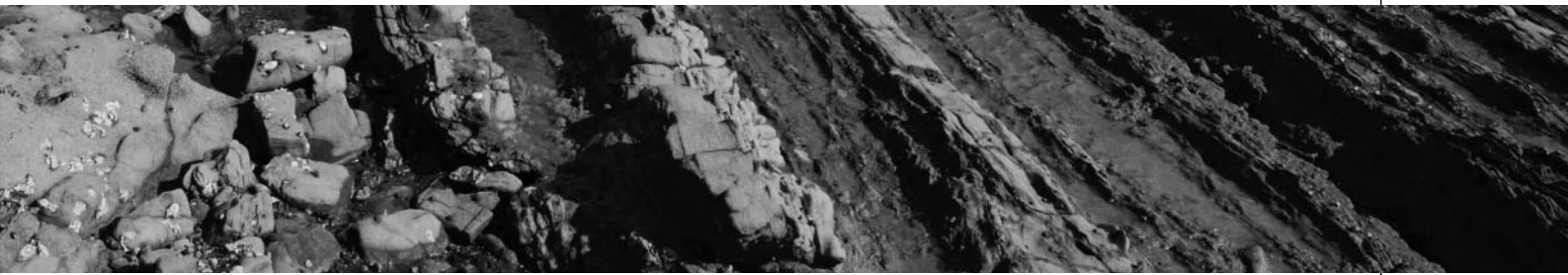
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It is envisaged that in future the Guideline be reviewed and updated on a regular basis. To this end, all submissions on the Guideline should be registered with www.nzgeotechsoc.org.nz.



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1.0 INTRODUCTION

THE OVERALL AIM of a method of soil and rock description is to reduce the subjective nature and variability of descriptions of materials encountered during the investigation, design and construction of an engineering project. As such, the method is designed principally for use in the field where materials are described, and descriptions are recorded on logs. The logging forms and formats used vary according to the investigation method and the materials being investigated. This guideline is not intended to recommend forms for logging but to outline a methodology for the description of materials such that:

- All significant observable properties of soil and rock are described;
- Descriptions of a material consistently use the same terms; and
- Particular properties or groups of properties appear in the same relative position within any description, so that the user may rapidly locate them.

The system is therefore based on a list of applicable terms in a set sequence. The terms used in this document are often based on the results of standard laboratory tests (e.g. Atterberg limits). It should be emphasised however that such laboratory test results are given as a guide to the usage of terminology and that descriptions in the field should not wait for or rely on tests subsequently done in the laboratory. Where laboratory (and/or field) tests are performed, reference to the test or its results should be made on the logging form separate to the description. In compiling the guideline a wide variety of sources have been consulted. Although not referred to individually in the text, most are included in a selected bibliography at the end of this guideline.

There is overlap in the decision for describing a material as a soil or rock and this is largely determined by its geological setting. Soils are materials that can be separated by gentle mechanical means such as agitation in water. Rocks are harder more rigid aggregates of minerals connected by strong bonds. When weathering has reduced the strength of a rock to an unconfined compressive strength of less than 1 MPa (i.e. to that of a soil) and the parent rock fabric is visible, it should still be described as a soil but the rock description may also be given.

SOIL

2.0 SOIL

2.1 OVERVIEW OF CLASSIFICATION AND DESCRIPTION

The terms classification and description have the following meanings in this document:

Classification: the identity of the material itself, i.e. what its composition and intrinsic properties are.

Description: the in-situ properties of the material, i.e. what it is like in its undisturbed state.

Classification systems used in soil mechanics, such as the Casagrande system, refer primarily to the material itself; they make only passing reference to the state in which the material exists in the ground.

Descriptive systems used in logging core, investigation pits etc, enable accurate accounts to be given of the state of the material in-situ. In some situations, for example where borrow sources are being investigated, or when only disturbed samples are available, then classification of the material itself is possible (and relevant), but description of its undisturbed state is not possible (or relevant).

A distinction between these two aspects is therefore made when describing a soil.

2.2 SOIL GROUPS

The framework for the classification and description of soil is provided in the following sections. For engineering purposes soil is grouped as shown in Table 2.1:

Table 2.1 Soil Groups

COARSE SOILS (granular soils or non-cohesive soils)		FINE SOILS (cohesive soils)		OTHER SOIL
Gravel	Sand	Silt	Clay	Organic Soils

The following notes give a brief outline of the engineering meaning attached to the above terms, and the basis on which they are identified or differentiated between.

2.2.1 Gravel and Sand

Gravel and sand comprise rock fragments of various sizes and shapes that may be either rock fragments or single minerals. In some cases there may be only a narrow range of particle sizes present, in which case the material is described as '*uniform*'. In other cases a broad range of particle sizes may be present and the material is described as '*well graded*' (refer Section 2.3.3.4).

2.2.2 Silt

Silt is intermediate between clay and fine sand. Silt is less plastic and more permeable than clay, and displays '*dilatant*' and '*quick*' behaviour. *Quick behaviour* refers to the tendency of silt to liquefy when shaken or vibrated, and *dilatancy* refers to the tendency to undergo volume increase when deformed. A simple test of patting a saturated soil sample in the hand can be undertaken to assess these properties and distinguish silt from clay.

2.2.3 Clay

Clay consists of very small particles and exhibits the properties of '*cohesion*' and '*plasticity*', which are not found in sand or gravel. *Cohesion* refers to the fact that the material sticks together, while *plasticity* is the property that allows the material to be deformed without volume change or rebound, and without cracking or crumbling.

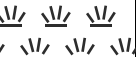
2.2.4 Organic Soil

Organic soil is distinguished in Table 2.1 as a category different from coarse or fine soils, but should only be identified as such if the organic content is high and the material no longer behaves like a silt or clay. Soils containing small to moderate amounts of organic material still retain the properties of silts or clays and should be described within those categories.

2.2.5 Behaviour

Soil behaviour always depends to some extent on grain size and this forms a starting point for the engineering classification of soils. On this basis soils are categorised as in Table 2.2.

Table 2.2 Grain Size Criteria

TYPE	COARSE								FINE		ORGANIC
	Boulders	Cobbles	Gravel			Sand			Silt	Clay	Organic Soil
			coarse	medium	fine	coarse	medium	fine			
Size Range (mm)	200	60	20	6	2	0.6	0.2	0.06	0.002		Refer to Section 2.3.5
Graphic Symbol											

The properties of a coarse soil are closely related to particle size. For this reason, particle size is the sole criterion used in classifying coarse soils.

However, there is no clear relationship between properties and particle size in a fine soil; this is because the properties are influenced by both the *size* and *composition* of particles. For this reason, other methods, including physical manipulation of the soil (for visual description), and Atterberg Limit tests (for laboratory classification) are used to describe and classify them.

In most cases a soil consists of particle sizes spread over more than one category (e.g. sandy gravel). A sandy gravel is mainly gravel sizes but contains some sand.

It is important to understand the difference between the terms “clay” and “clay fraction” or “silt” and “silt fraction”. *Clay* is a descriptive term applied to a fine-grained soil that behaves like a clay (i.e. it has cohesion, plasticity, is not dilatant, and does not contain a noticeable amount of coarse material). *Clay fraction* is the proportion by weight of the particles in the soil finer than 0.002 mm. Similarly *silt* is a descriptive term for a material displaying the properties of a silt and *silt fraction* is the proportion by weight of the material between 0.002 mm and 0.06 mm.

The character of a mixed soil is largely dependent on the smallest constituents. Thus a soil containing 30 % sand, 40 % silt, and 30 % clay material is most likely to behave as a clay and would be termed a clay. Many clays contain less than 30 % clay fraction.

2.3 SYSTEMATIC CLASSIFICATION

2.3.1 Introduction

The basis for systematic classification is the Unified Soil Classification System (USCS), which is described in detail in many soil mechanics textbooks and ASTM D2488-00. It is not intended that the system be “followed to the letter” but that its general principles be adopted. The system provides for the use of group symbols (CH, GW etc), but the use of these is not encouraged in this guideline as this tends to force rather narrow, artificial limits to the classification process.

This guideline departs from the USCS in two areas:

- The basis for division into coarse and fine soils is a 35 % fines content, rather than 50 % as in the USCS (i.e. a Fine Soil has more than 35 % of grains finer than 0.06 mm and a Coarse Soil has less than 35 % of grains finer than 0.06 mm); and
- The division between sand and gravel is 2 mm, not 4.76 mm (the No. 4 sieve) as in the USCS.

The reasons for these differences (which follow British and Australian practice) are that:

- most soils with 35 % in the silt/clay size range are more likely to behave as fine soils rather than coarse soils; and
- 2 mm is more widely recognised as an appropriate boundary for sand/gravel differentiation than is 4.76 mm.

2.3.2 Distinction of Coarse Soils from Fine Soils

The first step in classification is to decide, from Figure 2.1, whether the soil falls into the coarse or fine category. The 0.06 mm size is considered to be the smallest size that can be seen with the naked eye, and it is also the size of the finest sieve used in particle size analysis.

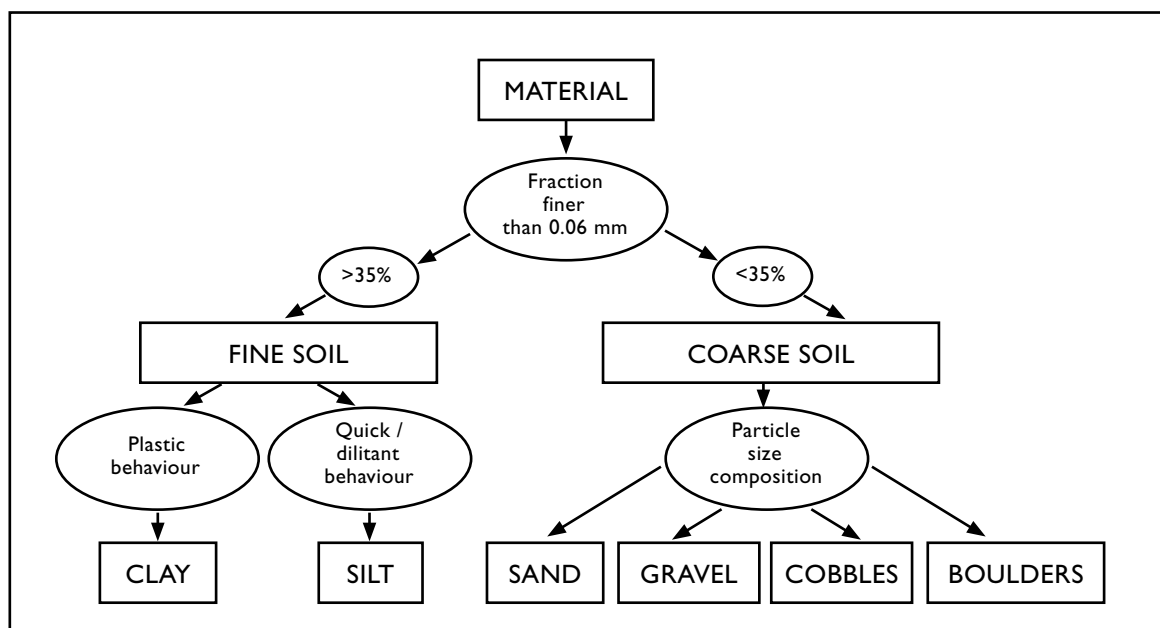


Figure 2.1 Soil Classification

If the material belongs in the fine soil category, it can be classified as silt or clay on the basis of behavioural characteristics – plasticity or quick and dilatant properties. If the material falls into the coarse soil category, it can be further divided into sand, gravel etcetera on the basis of particle size.

2.3.3 COARSE SOILS – classification

2.3.3.1 Introduction

If the soil falls into the coarse group, an estimate is made of the relative proportions of its principal constituents and an appropriate name given (Table 2.3).

In addition to the name given to the soil, further descriptive information should be given:

- Proportions of particle sizes;
- The maximum particle size;
- Grading;
- Particle shape;
- Particle strength/hardness;
- Other material;
- Colour; and
- Geological information.

2.3.3.2 Proportions of Particle Sizes

A material consisting mainly of gravel but containing significant sand would be classified as: *sandy GRAVEL*.

In this case gravel is referred to as the major fraction and sand as the subordinate fraction. Some soils may also contain other material, for example clay. This is indicated by adding descriptive information to the soil name. The full classification might then become: *sandy GRAVEL with some clay*.

With only a very small amount of clay the classification would be: *sandy GRAVEL with a trace of clay or slightly clayey sandy GRAVEL*.

If the clay content is sufficient to influence behaviour, then proceed to Section 2.3.4.

Table 2.3 Proportional Terms Definition (Coarse Soils)

Fraction	Term	% of Soil Mass	Example
Major	(...) [UPPER CASE]	≥ 50 [major constituent]	GRAVEL
Subordinate	(...) _y [lower case]	20–50	Sandy
Minor	with some ... with minor ...	12–20 5–12	with some sand with minor sand
	with trace of (or slightly)...	< 5	with trace of sand (slightly sandy)

Table 2.3 is an attempt to indicate this process, and define the terms some, minor, and trace. However the table will not always be directly applicable. For example, a soil could consist of 40 % gravel, 40 % sand and 20 % clay. This is clearly a coarse soil in terms of Figure 2.1, but does not have a “major” fraction. Its correct description would be either:

*gravelly SAND, some clay, or
sandy GRAVEL, some clay.*

In practice, it may appear as a *clayey GRAVEL* or *clayey SAND*, depending on the fineness of the gravel and sand, and the plasticity of the clay.

An attempt should be made to indicate whether any fines present in a coarse soil are silty or clayey in nature. This is not easy to do either in the field or the laboratory. Fines, which seem plastic and sticky, and cling to the large particles when the material is dried, are clayey. If they are not plastic and sticky, they are silty in nature.

2.3.3.3 Maximum Particle Size

Maximum particle size should be stated as a dimension in mm.

2.3.3.4 Grading

Gravels and sands should be described as *well graded* (a good representation of all particle sizes from largest to smallest), or *poorly graded* (a limited representation of grain sizes). *Poorly graded* materials may be further divided into *uniformly graded* (most particles about the same size), and *gap graded* (absence of one or more intermediate sizes within what otherwise would be a well graded material).

2.3.3.5 Particle Shape

Particle shape can be expressed in terms of *roundness* or *angularity* according to the scale shown in Table 2.4.

Table 2.4 Particle Shapes

Rounded	Subrounded	Subangular	Angular
			

The form of the soil particles may have an important effect on the mechanical properties of the soil mass. Particles can be further described as *equidimensional*, *flat*, *elongated*, *flat and elongated* or *irregular*.

2.3.3.6 Particle Strength/Hardness

Unless otherwise stated, it is assumed that grains of sand or gravel consist of hard, unweathered rock. If this is not the case, then information should be provided indicating the hardness of the grains, and the extent of weathering if this is a factor. Descriptions such as “*easily broken by hand*” or “*can be easily broken by a hammer blow*” are appropriate. The particle strength and weathering of gravel, cobbles and boulders can also be described using the rock descriptive terms given in, Section 3.0.

2.3.3.7 Other Material

Other material such as pieces of coal, shell, or traces of oils should be described. Strong odours should also be noted.

2.3.3.8 Colour

Colour should be described using the terms set out in Table 2.5. Colour may indicate the degree of weathering or the geological origin, and can be used to trace stratigraphic layers. Colour descriptions should focus on the main overall colour, rather than the fine details of colour variability. The choice of a colour from Column 3 in Table 2.5 can be supplemented by a term from Column 1 and/or Column 2 as appropriate.

Table 2.5 Colour Terms

1	2	3
light dark	pinkish reddish yellowish brownish greenish bluish greyish	pink red orange yellow brown green blue white grey black

2.3.3.9 Geological Information

Identify the dominant minerals or parent rock types and the geological unit, if known.

2.3.4 FINE SOILS – classification

2.3.4.1 Silt or Clay

If the soil is fine grained, it is examined to determine whether it is a silt or a clay. As already mentioned, the division into silt or clay is **not** made on the basis of particle size.

To distinguish between silts and clays, the best test to use is the “quick”/dilatancy test. A pat of soft soil (sufficiently wet to be almost sticky) is placed in the open palm of the hand and shaken, or vibrated horizontally. This is most effectively done by tapping the hand holding the soil, with the other hand. With a **silt**, “*quick*” behaviour appears (water will appear on the surface, giving it a shiny appearance), and will then disappear if the sample is squeezed or manipulated. During vibration, the sample tends to collapse and water runs to the surface. When it is manipulated the sample tends to dilate and draw water back into it. With a **clay**, these characteristics are not present. In the laboratory, the division into silt or clay can also be made on the basis of Atterberg Limit tests and use of the Plasticity Chart.

For example, a soil which behaves primarily as a clay, but also contains significant sand is classified as *Sandy CLAY*.

A soil that behaves primarily as a clay, but also displays some tendency towards silt behaviour could be classified as *Silty CLAY*.

The use of this terminology may not be strictly in accordance with the USCS, but it is more sensible to use such terminology than to force the soil into a category to which it does not belong.

In addition to the name given to the soil, the following descriptive information should be given:

- a) Plasticity;
- b) Presence of coarse material;
- c) Colour; and
- d) Geology.

In special circumstances, a field or laboratory classification of the particle size may be required, (e.g. when an estimate of the permeability of the soil is needed). In these cases the classification should be added to the field description of the soil and noted so that it is clear on what basis it has been made.

2.3.4.2 Plasticity

The most important property of a clay or silt is its plasticity. A *highly plastic* soil is one that can be moulded or deformed over a wide moisture content range, without cracking or showing any tendency to volume change. It also shows no trace of “quick” or dilatant behaviour.

To evaluate plasticity in the field it is necessary to remould the soil over a range of moisture contents.

The dry strength of the material is also a good guide to plasticity. *Highly plastic* clays will become ‘rock hard’ when dry, while those of *low plasticity* can be crumbled in the fingers.

2.3.4.3 Presence of Coarse Material (Sand or Gravel)

If the fine soil contains significant amounts of coarse material then this should be described. The guidelines in Table 2.3 for terminology applying to the subordinate or minor fraction can also be used in this case. For example, a soil is a *sandy CLAY* if the proportion of sand lies between 20 and 50 %, and a *CLAY, with trace sand*, if the proportion of sand is less than 5 %. Additional information on the nature of the coarse material should follow the guidelines given in Section 2.3.3.

2.3.4.4 Colour

Refer Section 2.3.3.8.

Unless of significance, the colour given should be the overall colour and not that of individual constituents. If appropriate, the distribution of colour may be described using the terms *mottled*, *banded*, *mixed*, or *speckled*. Where used, such terms should be written after the main colour e.g. brown, mottled yellow.

2.3.4.5 Geological Information

Refer Section 2.3.3.9.

2.3.5 ORGANIC SOILS

A small amount of dispersed organic matter can have a marked effect on plasticity and therefore on engineering properties. It may have a distinctive odour, a dark grey/ black or brown colour and a low density. If organic matter is present, the terms in Tables 2.6 or 2.7 should be used. The relative proportion of organics in a soil should be described as for inorganic soils (Table 2.3).

Table 2.6 Organic Soils

Term	Description
Topsoil	Surficial organic soil layer that may contain living matter. However topsoil may occur at greater depth, having been buried by geological processes or man-made fill, and should then be termed a buried topsoil.
Organic clay, silt or sand	Contains finely divided organic matter; may have distinctive smell; may stain; may oxidise rapidly. Describe as for inorganic soils.
Peat	Consists predominantly of plant remains. Can be further described according to its degree of decomposition and strength. <i>Firm</i> : Fibres already compressed together <i>Spongy</i> : Very compressible and open structure <i>Plastic</i> : Can be moulded in hand and smears in fingers <i>Fibrous</i> : Plant remains recognisable and retain some strength <i>Amorphous</i> : No recognisable plant remains

Table 2.7 Organic Descriptors

Term	Description
Rootlets	Fine, partly decomposed roots, normally found in the upper part of a soil profile or in a redeposited soil (e.g. colluvium or fill).
Carbonaceous	Discrete particles of hardened (carbonised) plant material.

Fine soils with larger amounts of organic matter usually plot below the A-line as organic silt. They have high liquid limits, sometimes up to several hundred percent. The liquid limit, plastic limit and plasticity index show a very marked drop on rewetting or remoulding following air or oven drying.

If a peat forms a horizon of major engineering significance, a fuller description using the scheme of von Post (Smart, 1986) may be appropriate.

2.4 DESCRIPTION OF IN-SITU (UNDISTURBED) CHARACTERISTICS

2.4.1 Introduction

The guidelines outlined above refer only to the material itself; they do not include information on the state in which it exists in the ground. Guidelines for description of the state in which a soil is found in the ground are provided in this section.

2.4.2 COARSE SOILS – description

2.4.2.1 Relative Density

Relative density refers to the “denseness”, or degree of compactness of a coarse soil in the ground, and is expressed as the *density index*. The terms very loose through to very dense are used to describe this property. Table 2.8 provides a guide for relating descriptive terms to Standard Penetration Test (SPT) N-values and Dynamic Cone Penetrometer (Scala) values.

Table 2.8 Density Index (Relative Density) Terms

Descriptive Term	Density Index (R_D)	SPT N-value (blows / 300 mm)	Dynamic Cone (blows / 100 mm)
Very dense	> 85	> 50	> 17
Dense	65 – 85	30 – 50	7 – 17
Medium dense	35 – 65	10 – 30	3 – 7
Loose	15 – 35	4 – 10	1 – 3
Very loose	< 15	< 4	0 – 2
Note: • No correlation is implied between Standard Penetration Test (SPT) and Dynamic Cone Penetrometer Test values. • The SPT “N” values are uncorrected.			

Particular care should be exercised in using the descriptors in coarse gravels. Where the above terms are used without test results, they should be written in inverted commas. Where no test results are available, a simple field assessment can be made using the terms *loosely packed* and *tightly packed*:

Loosely packed: Can be removed from exposures by hand or removed easily by shovel.

Tightly packed: Requires a pick for removal, either as lumps or as disaggregated material.

2.4.3 FINE SOILS – description

2.4.3.1 Soil Strength or “Consistency”

Table 2.9 provides a guide to the terms used to designate soil strength and related properties in fine soils.

Table 2.9 Consistency Terms for Cohesive Soils

Descriptive Term	Undrained Shear Strength (kPa)	Diagnostic Features
Very soft	< 12	Easily exudes between fingers when squeezed
Soft	12 – 25	Easily indented by fingers
Firm	25 – 50	Indented by strong finger pressure and can be indented by thumb pressure
Stiff	50 – 100	Cannot be indented by thumb pressure
Very stiff	100 – 200	Can be indented by thumb nail
Hard	200 – 500	Difficult to indent by thumb nail

The terms and strengths in Table 2.9 match those in AS1726:1993 but not those in BS5930:1999. Undrained shear strength can be determined using either field or laboratory tests. The most common field test in NZ is the hand held shear vane (refer NZGS, 2001).

2.4.3.2 Sensitivity

This is a measure of the loss of strength that occurs when the soil is disturbed or remoulded. Sensitivity is defined as the ratio of the undisturbed strength to the remoulded strength as outlined in Table 2.10.

Table 2.10 Sensitivity of Soil

Descriptive Term	Shear Strength Ratio $\frac{\text{undisturbed}}{\text{remoulded}}$
Insensitive, normal	< 2
Moderately sensitive	2 – 4
Sensitive	4 – 8
Extra sensitive	8 – 16
Quick	> 16

2.4.4 Structure (Applicable to Coarse and Fine Soils)

This refers to the presence or absence of bedding, or any other features such as faults, fissures, fractures, striations and slickensided surfaces as defined in Table 2.11.

Table 2.11 Soil Structure

Term	Description
Homogeneous	The total lack of visible bedding and the same colour and appearance throughout
Bedding	The presence of layers
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Polished	Fracture planes are polished or glossy
Slickensided	Fracture planes are striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensoidal	Discontinuous pockets of a soil within a different soil mass

2.4.5 Moisture Condition

Terms to describe the moisture condition of soil samples are given in Table 2.12.

Table 2.12 Moisture Condition

Condition	Description	Granular Soils	Cohesive Soils
Dry	Looks and feels dry	Run freely through hands	Hard, powdery or friable
Moist	Feels cool, darkened in colour	Tend to cohere	Weakened by moisture, but no free water on hands when remoulding
Wet			Weakened by moisture, free water forms on hands when handling
Saturated	Feels cool, darkened in colour and free water is present on the sample		

2.5 ORDER OF TERMS – SOIL

The descriptive sequence outlined in the preceding sections seeks to place the most important items first and the least important at the end.

Examples are given in Tables 2.13 and 2.14

Table 2.13 Example of Description of a Coarse Soil

Main Paragraph	Example	Item
Subordinate fraction	sandy	Soil name
Major Fraction	fine to coarse GRAVEL	
Minor fraction	with minor silt and clay	
Colour	light greyish brown	Visual characteristics
Structure	bedded	
Qualifying Paragraph		
Strength	loosely packed	Soil mass qualifications
Moisture condition	dry	
Grading	well graded	
Bedding	subhorizontal, thick	
Plasticity		
Sensitivity		
Major fraction	gravel, subangular to subrounded greywacke	Soil fraction qualifications
Weathering of clasts	slightly weathered	
Subordinate fraction	sand, fine to coarse	
Minor fraction	silt and clay, slightly plastic	
Additional structures	few fine sand lenses	Additional information
Additional information	MT JOHN OUTWASH GRAVEL	

The example in Table 2.13 would be written:

Sandy fine to coarse GRAVEL with minor silt and clay; light greyish brown, bedded. Loosely packed; dry; well graded; bedding, subhorizontal, thick; subangular to subrounded, slightly weathered greywacke gravel; sand, fine to coarse; silt and clay, slightly plastic; few fine sand lenses (MT JOHN OUTWASH GRAVEL).

Table 2.14 Example of Description of a Fine Soil

Main Paragraph	Example	Item
Subordinate fraction	clayey	Soil name
Major Fraction	SILT	
Minor fraction	trace peat	
Colour	light grey, mottled black	Visual characteristics
Structure		
Qualifying Paragraph		
Strength	firm	Soil mass qualifications
Moisture condition	moist	
Grading		
Bedding		
Plasticity	low plasticity	
Sensitivity	moderately sensitive	
Major fraction		Soil fraction qualifications
Subordinate fraction		
Minor fraction		
Additional structures		Additional information
Additional information	HINUERA FORMATION	

The example in Table 2.14 would be written:

Clayey SILT, trace of peat; light grey, mottled black. Firm, moist, low plasticity, moderately sensitive, (HINUERA FORMATION).

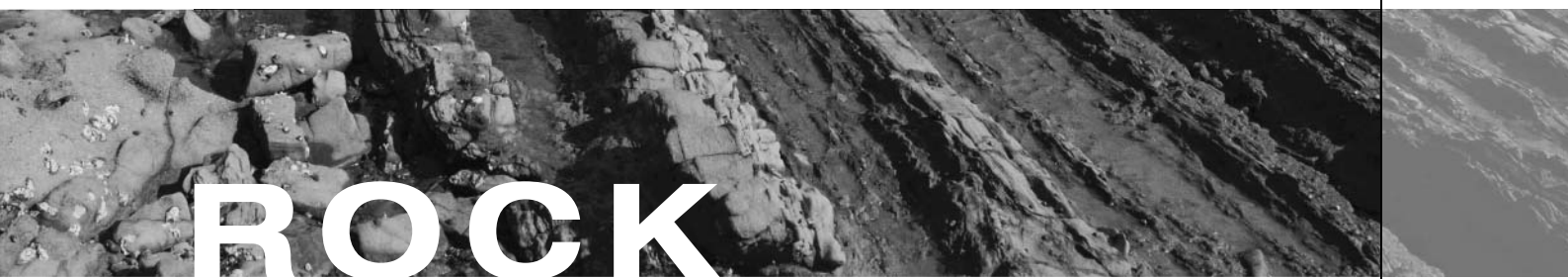
2.6 “DIFFICULT” SOILS

Some New Zealand soils do not fit easily into classification systems, and should not be forced to. Examples are volcanic ash found in various parts of the North Island, containing a high proportion of the clay mineral allophane and wind-deposited loess, found in many parts of the South Island.

Allophane soils normally plot well below the A-line on the Plasticity Chart, but their behaviour is not that of a silt. Allophane soils do not normally display the “quick” or dilatant behaviour associated with silt, but neither do they have the plasticity of a clay. In this case, it is perhaps best to describe the soil as a clayey SILT or a silty CLAY.

Some materials undergo considerable changes when taken from the ground and broken up. In their undisturbed state they may appear as firm or hard materials having little or no plasticity, but disturbance and remoulding changes them to soft, quite plastic materials. In some cases, they may appear to be essentially granular materials before disturbance, but afterwards are closer to silt or clay. This can result from breakdown of “bonds” between particles, or from breakdown of the particles themselves. The undisturbed material may appear to consist of discreet particles of sand or gravel size, but remoulding shows these to be so fragile that they break down into silt and clay material. In this situation the description is difficult, and it is recommended that two descriptions be made: one of the undisturbed sample and one of the disturbed sample.

Example: *sandy GRAVEL, loosely packed, breaks down to a sandy SILT, with some plasticity on remoulding.*



ROCK

3.0 ROCK

3.1 INTRODUCTION

The order of terms used for describing rock is similar to that given for soils, however the description gives greater attention to the presence of discontinuities in the rock mass (fractures or defects) and the effects of weathering, both of these having a significant influence on the mechanical properties and behaviour of a rock mass.

A rock mass is made up of the rock material or rock substance (i.e. parent lithology) and the discontinuities. The presence of discontinuities influences the mechanical behaviour of the rock mass such that it is often different from that of the rock material, which has no discontinuities. This document provides guidelines for the description of a rock mass, not just the intact rock material comprising the rock mass. However it does not extend to mapping of the rock mass defects (e.g. irregularity surveys or stereonet projection), rock mass classification for the design of particular structures (e.g. Q-system of Barton) or the assessment of rock mass for material handling (e.g. correlation with seismic velocity for ripping or blasting).

3.2 COMPONENTS OF ROCK MASS DESCRIPTION

3.2.1 Colour

Colour should be described using the terms set out in Table 2.5. for soil description. Colour may indicate the degree of weathering or the geological origin, and can be used to trace stratigraphic layers. Colour descriptions should focus on the main overall colour, rather than the fine details of colour variability.

3.2.2 Weathering

‘Weathering is the process of alteration and breakdown of rock and soil materials at and near the Earth’s surface by chemical decomposition and physical disintegration’ (Geological Society Engineering Group Working Party Report, 1995).

Of particular note in this definition is that weathering is described as a **process**. It is not a **method** for describing the engineering properties of a rock mass. As such, describing the state of weathering must never be a substitute for an adequate description of the intrinsic physical/mechanical properties of a rock mass using the standard descriptors set out in this guideline (e.g. strength, defects, fabric, rock type). If the degree of weathering cannot be determined, for example because the unweathered version of a particular rock type has not been seen, it is best left out of the description.

This guideline requires both the description of the effects of weathering, and, as far as possible, classification of the degree of weathering according to a scale.

However, it is recognised that the state of weathering of all rock masses (and ‘soil’ masses such as coarse alluvial and pyroclastic deposits) cannot be accurately described using a common weathering scale, and this should not be attempted if ambiguity results. What is important is to fully describe the effects of weathering.

There are many methods and scales for describing the weathering of rock masses. Many are general and attempt to cover a large range of rock types. They typically describe chemical weathering of jointed rock masses, concentrating on colour changes, strength changes and changes to rock fabric and texture. Few specifically include physical weathering effects. Others have been devised for specific rock types (e.g. Chandler and Apted, 1988). Some systems (e.g. BS5930:1999) include the state of weathering of the rock material (often referred to as rock condition) and the rock mass. The reader is referred to ‘The Quarterly Journal of Engineering Geology’, vol 28/3, August 1995 for a more complete discussion of weathering and some difficulties with existing descriptive methods.

Because this document is aimed at the overall description of a rock mass, a description of weathering which addresses both changes in the rock material and in the discontinuities is preferred. If there remains a significant difference in weathering of the defects as compared to the weathering category for the overall rock mass, then this should be pointed out as part of the description (e.g. 200 mm thick soil seam within a slightly weathered rock mass).

The effects of weathering are to be described using the standard soil and rock description terminology in terms of:

- colour and colour changes;
- strength and reduction of strength;
- condition of discontinuities and their infill; and
- weathering products.

While primarily applicable to rock masses it is intended that the effects of weathering on other geological materials such as alluvial and volcanic deposits also be routinely included in descriptions.

Based on the descriptions of weathering effects and products, the rock mass can be classified according to a general weathering scale (Table 3.1). Other scales may be used to aid classification and communication, particularly if the weathering environment is uncommon (e.g. desert/alpine). Any scale used must be clearly referenced. The general scale in Table 3.1 primarily recognises loss of strength, effect on defects and clasts, and weathering products.

In very general terms the boundary between a rock mass being more ‘rock like’ than ‘soil like’ is the boundary between moderately weathered and highly weathered.

Table 3.1 Scale of Rock Mass Weathering

Term	Grade	Abbreviation	Description
Unweathered (fresh)	I	UW	Rock mass shows no loss of strength, discolouration or other effects due to weathering. There may be slight discolouration on major rock mass defect surfaces or on clasts.
Slightly Weathered	II	SW	The rock mass is not significantly weaker than when unweathered. Rock may be discoloured along defects, some of which may have been opened slightly.
Moderately Weathered	III	MW	The rock mass is significantly weaker than the fresh rock and part of the rock mass may have been changed to a soil. Rock material may be discoloured, and defect and clast surfaces will have a greater discolouration, which also penetrates slightly into the rock material. Increase in density of defects due to physical disintegration process such as slaking, stress relief, thermal expansion/contraction and freeze/thaw.
Highly Weathered	IV	HW	Most of the original rock mass strength is lost. Material is discoloured and more than half the mass is changed to a soil by chemical decomposition or disintegration (increase in density of defects/fractures). Decomposition adjacent to defects and at the surface of clasts penetrates deeply into the rock material. Lithorelicts or corestones of unweathered or slightly weathered rock may be present.
Completely Weathered	V	CW	Original rock strength is lost and the rock mass changed to a soil either by chemical decomposition (with some rock fabric preserved) or by physical disintegration.
Residual Soil	VI	RS	Rock is completely changed to a soil with the original fabric destroyed.

3.2.3 Fabric

Fabric refers to the arrangement of minerals and particles in the rock. The arrangement may be of similar mineral/particle sizes, composition or arrangement including showing a preferred orientation. For sedimentary rocks it is preferable to use the descriptors given in Table 3.4; in metamorphic rocks it refers to the development of foliation. General fabric terms are set out in Table 3.2.

Table 3.2 Description of Rock Mass Fabric

Term	Description
Fine fabric	< 25 mm
Coarse fabric	25 – 100 mm
Massive	No fabric observed

3.2.4 Bedding

The term bedded indicates the presence of layers. The latter can be qualified with terms to describe how visible the bedding is, such as indistinctly bedded, or distinctly bedded. Bedding inclination and bedding thickness should be included using terms defined in Tables 3.3 and 3.4.

Table 3.3 Bedding Inclination Terms

Term	Inclination (degrees from the horizontal)
Sub-horizontal	0 – 5
Gently inclined	6 – 15
Moderately inclined	16 – 30
Steeply inclined	31 – 60
Very steeply inclined	61 – 80
Sub-vertical	81 – 90

Table 3.4 Bedding Thickness Terms

Term	Bed Thickness
Thinly laminated	< 2 mm
Laminated	2 mm – 6 mm
Very thin	6 mm – 20 mm
Thin	20 mm – 60 mm
Moderately thin	60 mm – 200 mm
Moderately thick	0.2 m – 0.6 m
Thick	0.6 m – 2 m
Very thick	> 2 m

3.2.5 Strength

The strength term is based on a range of the uniaxial compressive strength (q_u) of the intact rock material comprising the rock mass. The means by which the strength term is selected in the field is given in Table 3.5, together with values of q_u and $I_s(50)$ (from the point load index strength test). The description of rock material strength using the terms strong and weak is preferred to the use of the terms high strength and low strength. The latter terms are considered as more appropriate to the description of rock mass strength.

Table 3.5 Rock Strength Terms

Term	Field Identification of Specimen	Unconfined uniax- ial compressive strength q_u (MPa)	Point load strength $I_{s(50)}$ (MPa)
Extremely strong	Can only be chipped with geological hammer	> 250	>10
Very strong	Requires many blows of geological hammer to break it	100 – 250	5 – 10
Strong	Requires more than one blow of geological hammer to fracture it	50 – 100	2 – 5
Moderately strong	Cannot be scraped or peeled with a pocket knife. Can be fractured with single firm blow of geological hammer	20 – 50	1 – 2
Weak	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow with point of geological hammer	5 – 20	<1
Very weak	Crumbles under firm blows with point of geological hammer. Can be peeled by a pocket knife	1 – 5	
Extremely weak (also needs additional description in soil terminology)	Indented by thumb nail or other lesser strength terms used for soils	<1	
Note: No correlation is implied between q_u and $I_{s(50)}$			

Commonly, rocks with q_u values in excess of 50 MPa are informally referred to as ‘*hard*’ rocks and those less than 20 MPa (especially < 10 MPa) as ‘*soft*’ rocks.

Although the boundary between soil and rock is commonly recognised as being between very weak and extremely weak (i.e. 1 MPa), rock descriptions may include materials with a strength of less than 1 MPa (e.g. Tertiary sandstone) and in such cases a soil description should also be included.

3.2.6 Discontinuities (or Defects)

The range of geological features that form discontinuities (or defects) in rock masses are summarised in Table 3.6.

Discontinuities such as joints, bedding and cleavage should be described where applicable in terms of their spacing, persistence, orientation, separation, tightness and roughness, as well as noting the presence of any coatings or infillings and the nature of these (eg slickensided or polished).

Larger discontinuities such as sheared or crushed zones should be described in terms of their orientation, continuity, aperture, spacing of any internal defects, condition of their walls, and the presence and nature of infillings, coatings and planes of preferential movement.

The full description of discontinuities requires attention to the following:

- Orientation
- Spacing
- Persistence
- Roughness
- Wall Strength
- Aperture
- Infill
- Seepage
- Sets
- Block size and shape.

3.2.6.1 Orientation

Attitude of the discontinuity in space. Described by the dip direction (azimuth) and dip of the line of steepest declination in the plane of the discontinuity.

Example: *dip direction/amount of dip (015°/35°) or strike and dip (105°/35°N).*

3.2.6.2 Spacing

Perpendicular distance between adjacent discontinuities. Spacing refers to the mean or modal spacing of a set of joints as defined in Table 3.7.

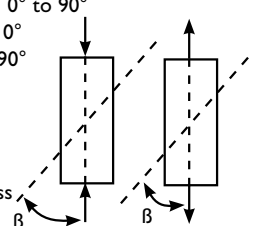
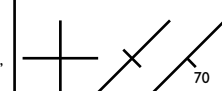
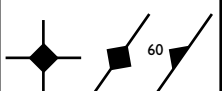
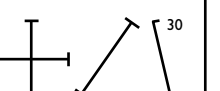
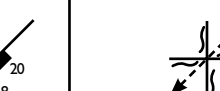
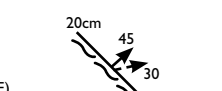
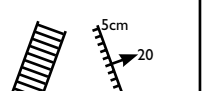
Table 3.7 Spacing of Defects or Discontinuities

Term	Spacing
Very widely spaced	>2 m
Widely spaced	600 mm – 2 m
Moderately widely spaced	200 mm – 600 mm
Closely spaced	60 mm – 200 mm
Very closely spaced	20 mm – 60 mm
Extremely closely spaced	<20 mm

3.2.6.3 Persistence

Discontinuity trace length to its termination in solid rock or against other discontinuities, as observed in an exposure. A crude measure of the areal extent or penetration of a discontinuity may be given. For major discontinuities, the plane may extend beyond the limits of the exposure and then the maximum trace length or area should be recorded.

Table 3.6 Range of Geological Features that Form Discontinuities (or defects) in Rock Masses

TERM ¹	GENERAL		LAYERING (LAYER) ²		FRACTURES AND FRACTURED ZONES		WEAK SEAMS OR ZONES				
	SPECIFIC	BEDDING	FOLIATION	CLEAVAGE	JOINT	SHEARED ZONE		CRUSHED SEAM/ZONE	DECOMPOSED SEAM/ZONE	INFILLED SEAM/ZONE	
PHYSICAL DESCRIPTION		Arrangement in layers, of mineral grains of similar sizes or composition, and/or arrangement of elongated or tabular minerals, near parallel to one another, and/or to the layers.			A discontinuity or crack: planar curved or irregular across which the rock has little tensile strength. The joint may be open (filled with air or water) or filled by soil substances or by rock substance which acts as a cement. Joint surfaces may be rough, smooth or slickensided.	Zone, with roughly parallel planar boundaries, of rock material intersected by closely spaced (generally <50mm) joints and/or microscopic fracture (cleavage) planes. The joints are at small angles to the zone boundaries; they are slightly curved and divide the mass into unit blocks of lenticular or wedge shape. Their surfaces are smooth or slickensided. Type R ranging to Type S →		Zone with roughly parallel planar boundaries, composed of disoriented, usually angular fragments of the host rock substance. The fragments may be of clay, silt, sand or gravel sizes or mixtures of any of these. Some minerals may be altered or decomposed but this is not necessarily so. Boundaries commonly slickensided.	Zone of any shape, but commonly with roughly parallel planar boundaries in which the rock material is discoloured and usually weakened. The boundaries with fresh rock are usually gradational. Geological structures in the fresh rock are usually preserved in the decomposed rock. “Weathered” and “altered” are more specific terms.	Zone, of any shape, but commonly with roughly parallel planar boundaries composed of soil substance. May show layering roughly parallel to the zone boundaries. Geological structures in the adjacent rock do not continue into the infill substance.	
ENGINEERING PROPERTIES ^{3,4}		• Where uniformly developed in a rock substance any of these types of structure render that rock substance anisotropic in its behaviour under stress • Comprehensive strengths and initial shear usually min when β = 30° to 45° max when β = 0° to 90° • Tensile strength usually max when β = 0° min when β = 90° Deformation Modulus usually higher for β = 0° than for β = 90° When <u>not</u> uniformly developed, these structures represent defects in the rock mass i.e. as individual layers or layered zones. 			• Tensile strength low/zero • Sliding resistance depends upon properties of coatings or cement and/or condition of surfaces PARAMETERS c Cohesion of coating/cement/ wall-rock Ø Friction angle of coating/ cement/ wall-rock l Angle of roughness of surface k_n Normal stiffness k_s Tangential stiffness	• Rock properties, very fissile rock mass • When excavated forms GRAVEL • Both types show extreme planar anisotropy. Lowest shear strength in direction of slickensides, in plane parallel to boundaries.	• SOIL properties, GRAVEL	• SOIL properties either cohesive or non-cohesive • Usually shows planar anisotropy; lowest shear strength in direction of slickensides in plane parallel to boundaries	• Extremely decomposed seam has SOIL properties usually cohesive but may be non-cohesive • Mostly very compact except when soluble minerals removed • Slightly to highly decomposed substances. ROCK properties but usually lower strengths than the fresh rock substance.	• SOIL properties, usually cohesive but may be non-cohesive.	
					Engineering properties commonly different from place to place especially where the defect passes through several different rock substance types.						
EXTENT		Usually governed by the thickness and lateral extent of the rock substance or mass containing the defect.			From 10mm to 50m or more, depends on origin.	Generally large (50m to many km)		Weathered zones related to present or past land surface limited extent. Altered zones occur at any depth.	Usually small, limited to mechanically weathered zone. Can be great in rocks subject to solution.		
ORIGIN (USUALLY CONTROLS EXTENT)	Deposition in layers	• Viscous flow		• Shearing during folding or faulting	• Shearing, extension or torsion failure, arising from faulting, folding relief of pressure, shrinkage due to cooling or loss of fluid	FAULTING		• Failure by large movement within narrow zone	• Decomposition of minerals, removal or rupture of cement, due to circulation of mineralized waters usually along joints, sheared zones or crushed zones	• Cohesive soil carried into open joint or cavity as a suspension in water	
		• Crystal grown at high pressures and temperatures				• Shear failure by small displacements along a large number of near-parallel intersecting planes	• Generally formed at shallow depth (<3000m)				• Non-cohesive soil falls or washes in
DESCRIPTION REQUIRED	Bed thickness, grain types and sizes	Fabric description and spacing and extent of microfractures			Shape, aperture, surface condition, coating, filling, extent	Zone width, shape and extent					
	Ease of splitting and nature of fracture faces			Pattern of joints or micro-fractures and resulting shape and size of unit blocks. Standard description of joints.			Degree of Decomposition				
ASSOCIATED DESCRIPTION ETC	Graded – , discord – , and slump-bedding; other primary structures: facing, attitudes and lineations	Attitude of planes and of any linear structure extent			Spacing, attitude of joint and/of slickensides	Attitude of zone. Direction of slickensides and amount, direction, and sense of displacement. Type of fault. History of past movements. Any modern activity. Likelihood of future movements. The terms “major” and “minor” fault are defined whenever used. The definitions are made on the basis of a) width and nature of the fault materials b) significance to the project.		Attitude of zone. Classify as weathered or altered if possible and determine origin, and defect or defects influencing decomposition.		Attitude of zone. Type of defect which is infilled, origin of infill substance.	
		Allocate to set determine origin type									
MAP SYMBOLS (TO RIGHT SYMBOLS IN SEQUENCE HORIZONTAL, VERTICAL, DIPPING)											

NOTES

1. The actual defect is described, not the process which formed or may have formed it e.g. "sheared zone" not "zone of shearing", the latter suggests a currently active process.

2. The terms "layering", "bedding" etc are used as the main headings on this portion of the table instead of "layer", "bed" etc. This is for convenience in descriptions and other notes, allowing them to refer to both rock substances and masses.

3. These notes refer to the engineering properties of the defect type, not those of the rock mass containing the defect.

4. In general each rock defect is more permeable than the substance in which it occurs, and the defect strength becomes lower with increase in water content/pressure.

Adapted from Stapledon (1973).

3.2.6.4 Roughness

A discontinuity surface may be planar, undulating or stepped. Descriptive terms given in Table 3.8 occur at both small scale (tens of millimetres) and large scale (several metres). Both roughness and waviness contribute to the shear strength. Large scale waviness may also alter the dip locally.

Table 3.8 Roughness and Aperture

I	rough	STEPPED
II	smooth	
III	slickensided	
IV	rough	UNDULATING
V	smooth	
VI	slickensided	
VII	rough	PLANAR
VIII	smooth	
IX	slickensided	

3.2.6.5 Wall Strength

Wall strength is the equivalent compressive strength of the adjacent rock walls of a discontinuity, and may be lower than the rock material strength due to the weathering or alteration of the walls. The shear strength of a discontinuity may be significantly affected by the condition or strength of the rock forming the walls of the discontinuity, particularly where infill is limited or the rock walls are in contact. An estimate of unconfined compressive strength can be obtained by using the Schmidt Hammer value (Deere & Miller 1966).

3.2.6.6 Aperture

The mean perpendicular distance between adjacent rock walls of a discontinuity, in which the intervening space is filled with air or water, as described in Table 3.9.

Table 3.9 Aperture of Discontinuity Surfaces

Term	Aperture (mm)	Description
Tight	Nil	Closed
Very Narrow	> 0 – 2	
Narrow	2 – 6	
Moderately Narrow	6 – 20	Gapped
Moderately Wide	20 – 60	Open
Wide	60 – 200	
Very Wide	> 200	

3.2.6.7 Infill

Material that separates the adjacent rock walls of a discontinuity and that is usually weaker than the parent rock. The infill may be soil introduced to the opening, minerals such as calcite or quartz, or clay gouge or breccia in a fault.

The width of an infilled discontinuity may, together with the roughness, be important in determining the resistance to shear along the discontinuity.

The infill material should be identified and described, and the strength of the infill assessed.

3.2.6.8 Seepage

Water flow and free moisture visible in individual discontinuities or in the rock mass as a whole should be described and if appropriate, the rate of flow estimated.

3.2.6.9 Number of Sets

Systematic discontinuity sets are parallel or sub-parallel sets of discontinuities that tend to be persistent. The number, orientation and spacing of sets will influence block size and shape. Discontinuities that are irregular or have limited persistence, without arrangement into distinct sets are called non-systematic.

3.2.6.10 Block Size and Shape

The size of blocks bound by discontinuities can be described using the terms in Table 3.10.

Table 3.10 Description of Block Size in the Rock Mass

Term	Average Dimension
Very Small	< 60 mm
Small	60 – 200 mm
Medium	200 – 600 mm
Large	600 mm – 2 m
Very Large	> 2 m

The shape of blocks is dependent on the spacing of discontinuities and the relative persistence of the different discontinuity sets. On weathering, block shape alters by rounding of block edges. Terms given in Table 3.11 can be used to describe rock block shape.

Table 3.11 Rock Mass Block Shape

Block Shape	Discontinuity Arrangement
Polyhedral	Irregular discontinuities without arrangement into distinct sets, and of small persistence
Tabular	One dominant set of parallel discontinuities (eg bedding planes), with other non-continuous discontinuities; block length and width $\gg$ thickness
Prismatic	Two dominant sets of discontinuities orthogonal and parallel, with a third irregular set; block length and width $\gg$ thickness
Equidimensional	Three dominant orthogonal sets of discontinuities, with some irregular discontinuities
Rhomboidal	Three or more dominant, mutually oblique sets of discontinuities; oblique shaped equidimensional blocks
Columnar	Several (usually more than three) sets of continuous, parallel discontinuities crossed by irregular discontinuities; length $\gg$ other dimensions

3.2.6.11 Rock Name

The most common rock names are given in Table 3.12 although more common usage is limited to the names in uppercase. The table follows general geological practice, and the inclusion is intended as a guide only as geological training is required for satisfactory identification. It must be remembered that engineering properties cannot be inferred from rock names.

3.2.6.12 Additional Features and Geological Information

This includes all additional relevant information such as the name of the geological unit. Additional information may be particularly important when describing weathered rocks that have the properties of soils (e.g. residual soils). In such cases a description of the material as a soil (Section 2.0) should also be given.

3.3 ORDER OF TERMS – ROCKS

The rock description method given in this document is in one paragraph, using the sequence of terms given in Table 3.13. The whole sequence is written in the lower case except for the rock name. Terms in the sequence are separated by commas.

Table 3.13: Sequence of Terms

Weathering
Colour
Fabric
ROCK NAME
Strength
Discontinuities
[Additional features and geological information]

Examples are given in Tables 3.14 to 3.16.

Table 3.14: Example of Rock Description

Main Paragraph	Example	Item
Weathering	Unweathered	Visual characteristics
Colour	Grey	
Fabric	Foliated	
Rock Name	SCHIST	Rock name
Qualifying Paragraph		
Strength	Strong	Rock mass qualifications
Discontinuities	Foliation dips 20-25°, well-developed; several thin sheared zones along foliation. Steep joints moderately widely spaced.	
Geological Information	HAAST SCHIST Textural Zone 4	Additional information

The example in Table 3.14 should be written:

Unweathered, foliated, grey SCHIST; strong; foliation dips 20-25°, well developed, with several thin sheared zones along foliation. Joints steep and moderately widely spaced [HAAST SCHIST Textural Zone 4].

Table 3.15: Example of Rock Description

Main Paragraph	Example	Item
Weathering	Highly weathered	Visual characteristics
Colour	Light yellow-brown	
Fabric	Homogeneous	
Rock Name	SANDSTONE	Rock name
Qualifying Paragraph		
Strength	Very weak	Rock mass qualifications
Discontinuities	Joints closely spaced; very narrow to tight	
Geological Information	TORLESSE SUPERGROUP greywacke	Additional information

The example in Table 3.15 should be written:

Highly weathered, light yellow-brown, homogeneous SANDSTONE. Very weak; closely spaced joints very narrow to tight [TORLESSE SUPERGROUP greywacke].

Table 3.16: Example of Rock Description

Main Paragraph	Example	Item
Weathering	Slightly weathered	Visual characteristics
Colour	Blue-grey	
Fabric	Indistinctly bedded	
Rock Name	SILTSTONE	Rock name
Qualifying Paragraph		
Strength	Extremely weak	Rock mass qualifications
Discontinuities		
Geological Information	MANGAWEKA MUDSTONE	Additional information

The example in Table 3.16 should be written:

Slightly weathered, blue-grey, indistinctly bedded SILTSTONE; extremely weak [MANGAWEKA MUDSTONE].

4.0 REFERENCES

The following documents have been consulted in preparation of the guideline.

AS 1726 – 1993: *Geotechnical Site Investigations*, Standards Australia.

ASTM D2487-00: *Standard Classification of Soils for Engineering Purposes* (Unified Soil Classification System).

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The Secretary
NZ Geotechnical Society Inc.
The Institution of Professional Engineers New Zealand (Inc)
P.O. Box 12-241, WELLINGTON

NEW ZEALAND GEOTECHNICAL SOCIETY INC. APPLICATION FOR MEMBERSHIP

(A Technical Group of the Institution of Professional Engineers New Zealand (Inc))

FULL NAME (Underline Family Name):

POSTAL ADDRESS:

Phone No: () Fax No: () E-MAIL:

DATE OF BIRTH

ACADEMIC QUALIFICATIONS:

PROFESSIONAL MEMBERSHIPS: Year Elected.....

PRESENT EMPLOYER:

OCCUPATION:

EXPERIENCE IN GEOMECHANICS:

STUDENT MEMBERS:

TERTIARY INSTITUTION: SUPERVISOR:

SUPERVISORS SIGNATURE:

Note that the Society's Rules require that in the case of student members "the application must also be countersigned by the student's Supervisor of Studies who thereby certifies that the applicant is indeed a bona-fide full time student of that Tertiary Institution". . . ; Applications will not be considered without this information).

Affiliation to International Societies: (All full members are required to be affiliated to at least one society, and student members are encouraged to affiliate to at least one Society. Applicants are to indicate below the Society/ies to which they wish to affiliate).

I wish to affiliate to:

International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE)	Yes/No
International Society for Rock Mechanics (ISRM)	Yes/No
International Association for Engineering Geology and the Environment (IAEG)	Yes/No
IAEG with Bulletin	Yes/No

DECLARATION: If admitted to membership, I agree to abide by the rules of the New Zealand Geotechnical Society

Signed Date/...../.....

ANNUAL SUBSCRIPTION: Due on notification of acceptance for membership, thereafter on 1st of October. Please do not send subscriptions with this application form. You will be notified and invoiced on acceptance into the Society

PRIVACY CONDITIONS: Under the provisions of the Privacy Act 1993, an applicant's authorisation is required for use of their personal information for Society administrative purposes and membership lists. I agree to the above use of this information:

Signed Date/...../.....

(for office use only)

Received by the Society

Recommended by the Management Committee of the Society

NEW ZEALAND GEOTECHNICAL SOCIETY INC. PUBLICATIONS 2005

PUBLICATION NAME	List Price Members	List Price Non-Members
New Zealand Geomechanics Society Conferences:		
Proceedings of Technical Groups, Vol 22, Issue 1G <i>Geotechnical Issues in Land Development</i> Hamilton 1996	\$20	\$35
Proceedings of the New Zealand Geotechnical Society Symposium – <i>Roading Geotechnics 98</i> Auckland 1998	\$40	\$70
Proceedings of the New Zealand Geotechnical Society Symposium – <i>Engineering and Development in Hazardous Terrain</i> Christchurch 2001	\$50	\$70
Proceedings of the New Zealand Geotechnical Society Symposium – <i>Geotechnics on the Volcanic Edge</i> Tauranga 2003	\$50	\$70
Australia – New Zealand Conferences on Geomechanics:		
<i>Proceedings of the 3rd Australia – NZ Conference on Geomechanics</i> Wellington, May 1980 (Vols 1, 2 & 3 per set)	\$10	\$30
<i>Proceedings of the 2nd Australia – NZ Young Geotechnical Professionals Conference</i> , Auckland, December 1995	\$25	\$40
<i>Proceedings of the 5th Australia – NZ Young Geotechnical Professionals Conference</i> , Rotorua, March 2002 (spiral bound reprint)	\$75	\$85
<i>Proceedings of the 6th Australia – NZ Conference on Geomechanics</i> Christchurch, February 1992	\$50	\$100
<i>Proceedings of the 9th Australia – NZ Conference on Geomechanics</i> Auckland, February 2004 – Vol 1	\$120	\$150
– Vol 2	\$120	\$150
Other Publications:		
<i>NZ Geomechanics News</i> Collection 1970–2003 Volumes 1–66 (CDRom)	\$25	\$40
<i>Guideline for Handheld Shear Vane Test</i>	\$15	\$20
<i>Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes</i>	\$25	\$50
<i>Stability of House Sites and Foundations – Advice to Prospective House and Section Owners</i>	\$5	\$5
Back Issues of <i>NZ Geomechanics News</i>	\$5	\$5

Prices do not include GST or postage & handling

Orders to:

www.nzgeotechsoc.org.nz or Email: nzgs@paradise.net.nz.



This guideline for the field classification and description of soil and rock for engineering purposes is prepared by members of the New Zealand Geotechnical Society for use by geo-practitioners in New Zealand. The document draws from methods and standards published internationally and brings them together in a manner directly applicable to New Zealand conditions. The principal aim of the guideline is to reduce the variability of descriptions of materials encountered in investigation and construction of an engineering project by providing a range of defined terms from which an appropriate selection can be made. The guideline should be used in the field to check that as full a description as possible is given.



NZ GEOTECHNICAL SOCIETY INC

ROCK > field guide sheet



FIELD DESCRIPTION OF ROCK

SEQUENCE OF TERMS – weathering – colour – fabric – rock name – strength – discontinuities – additional

SCALE OF ROCK MASS WEATHERING

Term	Grade	Abbreviation	Description
Unweathered (fresh rock)	I	UW	Rock mass shows no loss of strength, discolouration or other effects due to weathering. There may be slight discolouration on major rock mass defect surfaces or on clasts.
Slightly Weathered	II	SW	The rock mass is not significantly weaker than when fresh. Rock may be discoloured along defects, some of which may have been opened slightly.
Moderately Weathered	III	MW	The rock mass is significantly weaker than the fresh rock and part of the rock mass may have been changed to a soil. Rock material may be discoloured and defect and clast surfaces will have a greater discolouration, which also penetrates slightly into the rock material. Increase in density of defects due to physical disintegration.
Highly Weathered	IV	HW	Most of the original rock mass strength is lost. Material is discoloured and more than half the mass is changed to a soil by chemical decomposition or disintegration (increase in density of defects/fractures). Decomposition adjacent to defects and at the surface of clasts penetrates deeply into the rock material. Lithorelicts or corestones of unweathered or slightly weathered rock may be present.
Completely Weathered	V	CW	Original rock strength is lost and the rock mass changed to a soil either by decomposition (with some rock fabric preserved) or by physical disintegration.
Residual Soil	VI	RS	Rock is completely changed to a soil with the original fabric destroyed (pedological soil).

ROCK STRENGTH TERMS

Term	Field Identification of Specimen	Unconfined uniaxial compressive strength q_u (MPa)	Point load strength $I_{S(50)}$ (MPa)
Extremely strong	Can only be chipped with geological hammer	> 250	>10
Very strong	Requires many blows of geological hammer to break it	100 – 250	5 – 10
Strong	Requires more than one blow of geological hammer to fracture it	50 – 100	2 – 5
Moderately strong	Cannot be scraped or peeled with a pocket knife. Can be fractured with single firm blow of geological hammer	20 – 50	1 – 2
Weak	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow with point of geological hammer	5 – 20	<1
Very weak	Crumbles under firm blows with point of geological hammer. Can be peeled by a pocket knife	1 – 5	
Extremely weak (soil description required)	Indented by thumb nail or other lesser strength terms used for soils	<1	

Note: • No correlation is implied between q_u and $I_{S(50)}$

SPACING OF DEFECTS/ DISCONTINUITIES

Term	Spacing
Very widely spaced	>2 m
Widely spaced	600 mm – 2 m
Moderately widely spaced	200 mm – 600 mm
Closely spaced	60 mm – 200 mm
Very closely spaced	20 mm – 60 mm
Extremely closely spaced	<20 mm

APERTURE OF DISCONTINUITY SURFACES

Term	Aperture (mm)	Description
Tight	Nil	Closed
Very Narrow	> 0 – 2	
Narrow	2 – 6	
Moderately Narrow	6 – 20	Gapped
Moderately Wide	20 – 60	
Wide	60 – 200	
Very Wide	> 200	Open

BEDDING THICKNESS TERMS

Term	Bed Thickness
Thinly laminated	< 2 mm
Laminated	2 mm - 6 mm
Very thin	6 mm - 20 mm
Thin	20 mm - 60 mm
Moderately thin	60 mm - 200 mm
Moderately thick	0.2 m - 0.6 m
Thick	0.6 m - 2 m
Very thick	> 2 m

BEDDING INCLINATION TERMS

Term	Inclination (from horizontal)
Sub-horizontal	0° – 5°
Gently inclined	6° – 15°
Moderately inclined	16° – 30°
Steeply inclined	31° – 60°
Very steeply inclined	61° – 80°
Sub-vertical	81° – 90°

ROUGHNESS AND APERTURE

I	rough	STEPPED
II	smooth	
III	slickensided	
IV	rough	UNDULATING
V	smooth	
VI	slickensided	
VII	rough	PLANAR
VIII	smooth	
IX	slickensided	





SOIL

> field guide sheet

FIELD DESCRIPTION OF SOIL

SEQUENCE OF TERMS – fraction – colour – structure – strength – moisture – bedding – plasticity – sensitivity – additional

GRAIN SIZE CRITERIA

TYPE	COARSE								FINE		ORGANIC
	Boulders	Cobbles	Gravel			Sand			Silt	Clay	Organic Soil
Size Range (mm)	200	60	20	6	2	0.6	0.2	0.06	0.002		
Graphic Symbol											

PROPORTIONAL TERMS DEFINITION (COARSE SOILS)

Fraction	Term	% of Soil Mass	Example
Major	(...) [UPPER CASE]	≥ 50 [major constituent]	GRAVEL
Subordinate	(...) y [lower case]	20 – 50	Sandy
Minor	with some ... with minor ...	12 – 20 5 – 12	with some sand with minor sand
	with trace of (or slightly)...	< 5	with trace of sand (slightly sandy)

DENSITY INDEX (RELATIVE DENSITY) TERMS

Descriptive Term	Density Index (I _D)	SPT "N" value (blows / 300 mm)	Dynamic Cone (blows / 100 mm)
Very dense	> 85	> 50	> 17
Dense	65 – 85	30 – 50	7 – 17
Medium dense	35 – 65	10 – 30	3 – 7
Loose	15 – 35	4 – 10	1 – 3
Very loose	< 15	< 4	0 – 2

Note: • No correlation is implied between Standard Penetration Test (SPT) and Dynamic Cone Test values.
• SPT "N" values are uncorrected. • Dynamic Cone Penetrometer (Scala)

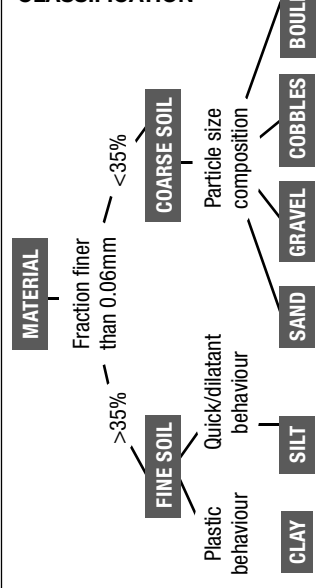
ORGANIC SOILS/ DESCRIPTORS

Term	Description
Topsoil	Surficial organic soil layer that may contain living matter. However topsoil may occur at greater depth, having been buried by geological processes or man-made fill, and should then be termed a buried topsoil.
Organic clay, silt or sand	Contains finely divided organic matter; may have distinctive smell; may stain; may oxidise rapidly. Describe as for inorganic soils.
Peat	Consists predominantly of plant remains. Firm: Fibres already compressed together Spongy: Very compressible and open structure Plastic: Can be moulded in hand and smears in fingers Fibrous: Plant remains recognisable and retain some strength Amorphous: No recognisable plant remains
Roolets	Fine, partly decomposed roots, normally found in the upper part of a soil profile or in a redeposited soil (e.g. colluvium or fill)
Carbonaceous	Discrete particles of hardened (carbonised) plant material.

PLASTICITY (CLAYS & SILTS)

Term	Description
High plasticity	Can be moulded or deformed over a wide range of moisture contents without cracking or showing any tendency to volume change
Low plasticity	When moulded can be crumbled in the fingers; may show quick or dilatant behaviour

SOIL CLASSIFICATION



CONSISTENCY TERMS FOR COHESIVE SOILS

Descriptive Term	Undrained Shear Strength (kPa)	Diagnostic Features
Very soft	< 12	Easily exudes between fingers when squeezed
Soft	12 – 25	Easily indented by fingers
Firm	25 – 50	Indented by strong finger pressure and can be indented by thumb pressure
Stiff	50 – 100	Cannot be indented by thumb pressure
Very stiff	100 – 200	Can be indented by thumb nail
Hard	200 – 500	Difficult to indent by thumb nail

MOISTURE CONDITION

Condition	Description	Granular Soils	Cohesive Soils
Dry	Looks and feels dry	Run freely through hands	Hard, powdery or friable
Moist	Feels cool, darkened in colour	Tend to cohere	Weakened by moisture, but no free water on hands when remoulding
Wet			Weakened by moisture, free water forms on hands when handling
Saturated	Feels cool, darkened in colour and free water is present on the sample		

GRADING (GRAVELS & SANDS)

Term	Description
Well graded	Good representation of all particle sizes from largest to smallest
Poorly graded	Limited representation of grain sizes - further divided into:
	Uniformly graded Most particles about the same size
	Gap graded Absence of one or more intermediate sizes

NZ GEOTECHNICAL SOCIETY INC

This field sheet has been taken from and should be used and read with reference to the document FIELD DESCRIPTION OF SOIL AND ROCK. Guideline For the Field Classification and Description of Soil and Rock for Engineering Purposes. NZ Geotechnical Society Inc, December 2005. www.nzgeotechsoc.org.nz

EXAMPLE BOREHOLE FIELD LOG



GEOTECHNICS LTD

BOREHOLE LOG

BOREHOLE No: BH02

Hole Location:

84 Pegasus St.

SHEET 1 OF 1

PROJECT: TC3 NNB - P022-BH02				LOCATION: 84 Pegusus Street, NNB, JOB No: 52003			
CO-ORDINATES mN mE				DRILL TYPE: ROTARY SONIC HOLE STARTED: 26/3/12			
R.L. m				DRILL METHOD: HQ/Standard 8PT. HOLE FINISHED: 26/3/12			
DATUM				DRILL FLUID: Mud LOGGED BY: J.B. Jongs CHECKED:			
GEOLOGICAL				ENGINEERING DESCRIPTION			
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.				SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.			
FLUID LOSS WATER CORE RECOVERY (%) METHOD CASING TESTS SAMPLES R.L. (m) DEPTH (m) GRAPHIC LOG CLASSIFICATION SYMBOL MOISTURE / WEATHERING CONDITION STRENGTH/DENSITY CLASSIFICATION SHEAR STRENGTH (kPa) COMPRESSIVE STRENGTH (MPa) DEFECT SPACING (mm)				MACADAM ROAD CONSTRUCTION. E-M GRAVEL. Silt. Fine to medium SAND with some gravel, light brown. Medium dense, moist well graded. Gravel is fine to coarse subrounded. 1.0m - trace gravel 1.75m - Saturated 2.0-2.45m no recovery. 2.45m - with some gravel. Fine to medium SAND with minor silt, light grey. Medium dense, saturated, poorly graded. 4.0m - with trace silt. SILT with some sand, bluish grey. Stiff, wet, low plasticity. Sand is fine to medium. Contains broken shells. 5.0m - becoming sandy silt. Silt, fine to medium SAND, bluish grey. Medium dense, wet, poorly graded. 6.0m - Saturated Fine to medium SAND with minor silt, bluish grey. Medium dense, wet, poorly graded. 6.5m - dense 6.95m - with thin silt layers 7.6m contains trace broken shells. 7.8m - Sand becoming fine to coarse. 9.1m - Sand becoming fine to medium. END OF BOREHOLE 10.00m TARGET DEPTH			

EXAMPLE ROTARY SONIC BOREHOLE LOG



TONKIN & TAYLOR LTD BOREHOLE LOG

BOREHOLE No: BH-01
Hole Location: NNB-POD6-BH01
(79 Rookwood Avenue)
SHEET 1 OF 3

PROJECT: TC3 GROUND INVESTIGATIONS- POD06				LOCATION: NORTH NEW BRIGHTON				JOB No: 52003.000																		
CO-ORDINATES		5745747.02 mN 2486661.03 mE		DRILL TYPE: Rotary				HOLE STARTED: 8/5/12																		
R.L.		4.13 m		DRILL METHOD: HQTT/Std SPT				HOLE FINISHED: 9/5/12																		
DATUM		NZMG		DRILL FLUID: LP2000				DRILLED BY: Pro-Drill		LOGGED BY: SKM-DB		CHECKED: BMCd														
GEOLOGICAL				ENGINEERING DESCRIPTION																						
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION:				FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSION STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION					
																					Soil type, minor components, plasticity or particle size, colour.					
																					ROCK DESCRIPTION					
																					Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.					
TOPSOIL												4		SP	M							Fine to medium SAND with some organics and minor silt, dark brown, moist, poorly graded.				
CHRISTCHURCH FORMATION (MARINE/ESTUARINE)						87	Open Barrel							SP			L					Fine to medium SAND with trace silt, greyish brown, loose, moist, poorly graded. 0.63m- with some silt. 0.70m- with trace silt, greyish brown with orange mottling. 1.3 to 1.5m- no recovery. 1.5m- grey, saturated.				
						100	SPT		1/0/1/1/2/3 N=7									S								
						52	HQTT																		2.8 to 3.5m- no recovery.	
						100	SPT		4/2/2/2/4/5 N=13											MD					3.5m- medium dense.	
						100	HQTT																			
						100	SPT		*FC4.8	B							SP								Silty SAND, grey, medium dense, saturated, poorly graded. Sand is fine to medium. 5.0m- contains wood pieces.	
						100	SPT		5/4/4/3/3/3 N=13																5.45m- minor silt.	
						100	HQTT		*PSD6.0	B							ML	W							Sandy SILT, grey, firm, wet, low plasticity. Sand is fine.	
						100	SPT		4/5/6/4/5/6 N=21								SP	S							6.4m- saturated.	
		100	HQTT		*FC7.0	B															Fine to medium SAND with minor silt, grey, medium dense, saturated, poorly graded.					
		100	SPT		4/6/7 7/10/8 N=32 FC8.5	B									W		D				7.85m- wet. 8.0m- dense.					
		100	HQTT												S						8.45m- saturated.					
		100	SPT		7/10/7 10/9/9 N=35																9.95m- silt.					

T-T DATATEMPLATE.GDT.rch

Log Scale 1:50

BORELOG 720016 NNB POD6.GPJ 17/7/12



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-01
Hole Location: NNB-POD6-BH01
(79 Rookwood Avenue)
SHEET 2 OF 3

PROJECT: TC3 GROUND INVESTIGATIONS- POD06						LOCATION: NORTH NEW BRIGHTON						JOB No: 52003.000																											
CO-ORDINATES 5745747.02 mN 2486661.03 mE						DRILL TYPE: Rotary						HOLE STARTED: 8/5/12																											
R.L. 4.13 m						DRILL METHOD: HQTT/Std SPT						HOLE FINISHED: 9/5/12																											
DATUM NZMG						DRILL FLUID: LP2000						LOGGED BY: SKM-DB CHECKED: BMcD																											
GEOLOGICAL						ENGINEERING DESCRIPTION																																	
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.						FLUID LOSS		WATER		CORE RECOVERY (%)		METHOD		CASING		TESTS		SAMPLES		R.L. (m)		DEPTH (m)		GRAPHIC LOG		CLASSIFICATION SYMBOL		MOISTURE / WEATHERING CONDITION		STRENGTH/DENSITY CLASSIFICATION		SHEAR STRENGTH (kPa)		COMPRESSIVE STRENGTH (MPa)		DEFECT SPACING (mm)		SOIL DESCRIPTION	
																																						ROCK DESCRIPTION	
CHRISTCHURCH FORMATION (MARINE/ESTUARINE)										81		HQTT																								Soil type, minor components, plasticity or particle size, colour.			
																																				ROCK DESCRIPTION			
																																				Substance: Rock type, particle size, colour, minor components.			
																																				Defects: Type, inclination, thickness, roughness, filling.			

T-T DATATEMPLATE GDT reb

Log Scale 1:50

BORELOG 720016 NNB POD6.GPJ 17/7/12



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-01
Hole Location: NNB-POD6-BH01
(79 Rookwood Avenue)
SHEET 3 OF 3

PROJECT: TC3 GROUND INVESTIGATIONS- POD06				LOCATION: NORTH NEW BRIGHTON				JOB No: 52003.000							
CO-ORDINATES 5745747.02 mN 2486661.03 mE				DRILL TYPE: Rotary				HOLE STARTED: 8/5/12							
R.L. 4.13 m				DRILL METHOD: HQT/Std SPT				HOLE FINISHED: 9/5/12							
DATUM NZMG				DRILL FLUID: LP2000				LOGGED BY: SKM-DB CHECKED: BMcD							
GEOLOGICAL				ENGINEERING DESCRIPTION											
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.				SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.											
FLUID LOSS				WATER											
CORE RECOVERY (%)				100											
METHOD				SPT											
CASING															
TESTS				6/13//13 15/18/4 for 25mm N>50											
SAMPLES				-16											
R.L. (m)				-17											
DEPTH (m)				-18											
GRAPHIC LOG				-19											
CLASSIFICATION SYMBOL				SP S VD											
MOISTURE CONDITION															
WEATHERING															
STRENGTH/DENSITY															
CLASSIFICATION															
SHEAR STRENGTH (kPa)															
COMPRESSION STRENGTH (kPa)															
DEFECT SPACING (mm)															
CHRISTCHURCH FORMATION (MARINE/ESTUARINE)				Fine to medium SAND with trace silt, grey, very dense, saturated, poorly graded. Contains some broken shells. End of hole at 20.4mbgl (target depth)											

T-T DATA TEMPLATE GDT.rch

Log Scale 1:50

BORELOG 720016 NNB POD6.GPJ 17/7/12

EXAMPLE ROTARY MUD BOREHOLE LOG



TONKIN & TAYLOR LTD
BOREHOLE LOG

BH No: RCL-POD03-BHCPT001
Hole Location: 123 Main Road

SHEET 1 OF 2

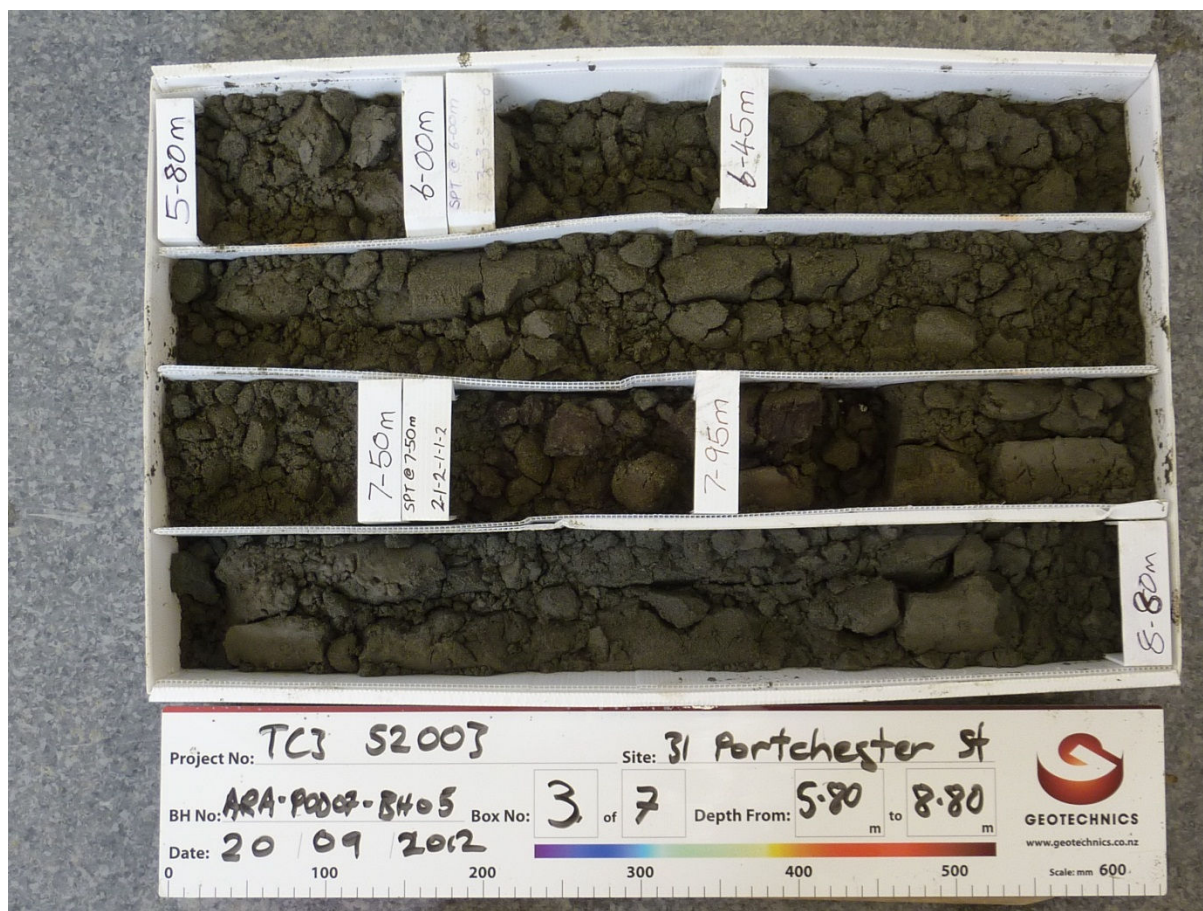
PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS				LOCATION: REDCLIFFS				JOB No: 52003.000										
CO-ORDINATES: 5738242.17 mN 2489033.06 mE				DRILL TYPE: Rotary				HOLE STARTED: 31/1/13										
R.L.: 1.74 m				DRILL METHOD: Rotary mud/Std SPT				HOLE FINISHED: 31/1/13										
DATUM: NZMG, MSL (CCC 20/01/12 Datum -9.043m)				DRILL FLUID: LP2000				DRILLED BY: Pro-Drill										
								LOGGED BY: T&T-JM										
								CHECKED: BMcD										
GEOLOGICAL				ENGINEERING DESCRIPTION														
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSION STRENGTH (kPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL																		
CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)			50	HQTT		0/0/0/0/0 N=0		1	1		SP	M						Fine to medium SAND with some silt and minor organics and trace rootlets, greyish brown, moist, poorly graded.
			18	HQTT				0	0		ML	W	VS					Fine to medium SAND with some silt and trace gravel, yellowish brown, moist, poorly graded. Gravel is fine to medium, subrounded. 0.5 to 1.0m- no recovery.
			78	SPT		*FC@2.0m 1/2/2/1/1/2/ N=6		2	2		SM		L					1.0m- very loose.
			0	RM				-1	-1									SILT, grey, very soft, wet, low plasticity
			100	SPT		*FC@3.0m 0/0/0/0/2/3 N=5		3	3		ML		F					1.45m- some fine to medium sand, trace fine to coarse gravel, subrounded.
			0	RM				-2	-2		SM		L					1.55 to 2.0m- no recovery.
			100	SPT		1/1/2/2/5/6 N=15		4	4		SP		MD					Silty fine to medium SAND with trace gravel, yellowish brown, loose, wet, poorly graded. Gravel is fine to coarse, subrounded. 2.25m- trace broken shells, grey.
			0	RM				-3	-3									2.35 to 2.45m- no recovery.
			78	SPT		4/5/6/7/7/9 N=29		5	5									Sandy SILT with trace broken shells and trace organics, grey, firm, wet, non plastic, slow dilatancy. Sand is fine to medium. Organics are amorphous.
			0	RM				-4	-4									Silty fine to medium SAND with trace broken shells, grey, loose, wet, well graded.
LYTTLETON VOLCANIC GROUP			100	SPT		5/6/7/9/7/9 N=32		6	6				D					4.0m- medium dense.
			0	RM				-5	-5									Fine to medium SAND with trace broken shells and trace silt, grey, medium dense, wet, poorly graded.
			100	SPT		4/6/5/4/4/6 N=19		7	7				MD					5.0 to 5.05m- amorphous organics and silt layer.
			0	RM				-6	-6									5.35 to 5.45m- no recovery.
			100	SPT		4/4/4/6/6/7 N=23		8	8									6.0m- minor silt, dense.
			18	HQTT				-7	-7		GP	SW	VS					7.0m- medium dense.
			100	HQTT				-8	-8			UW	ES					8.0m- brownish grey.
			100	HQTT				-9	-9			SW						8.45 to 8.9m- no recovery.
			100	HQTT				-10	-10									Slightly weathered, fine fabric BASALT, grey, very strong, fractured with vesicular sections and closely spaced rough undulating discontinuities.
																		9.0m- unweathered, extremely strong.
																		9.5m- slightly weathered.

T-T DATATEMPLATE-SPT.GDT.cob

Log Scale 1:50

BORELOG-TC3 720016 RCL-POD03.GPJ 9-Apr-2013

EXAMPLE FIELD CORE PHOTOGRAPHY



APPENDIX C:

CPTS

EXAMPLE CPT TRACE

RIG DATASHEETS

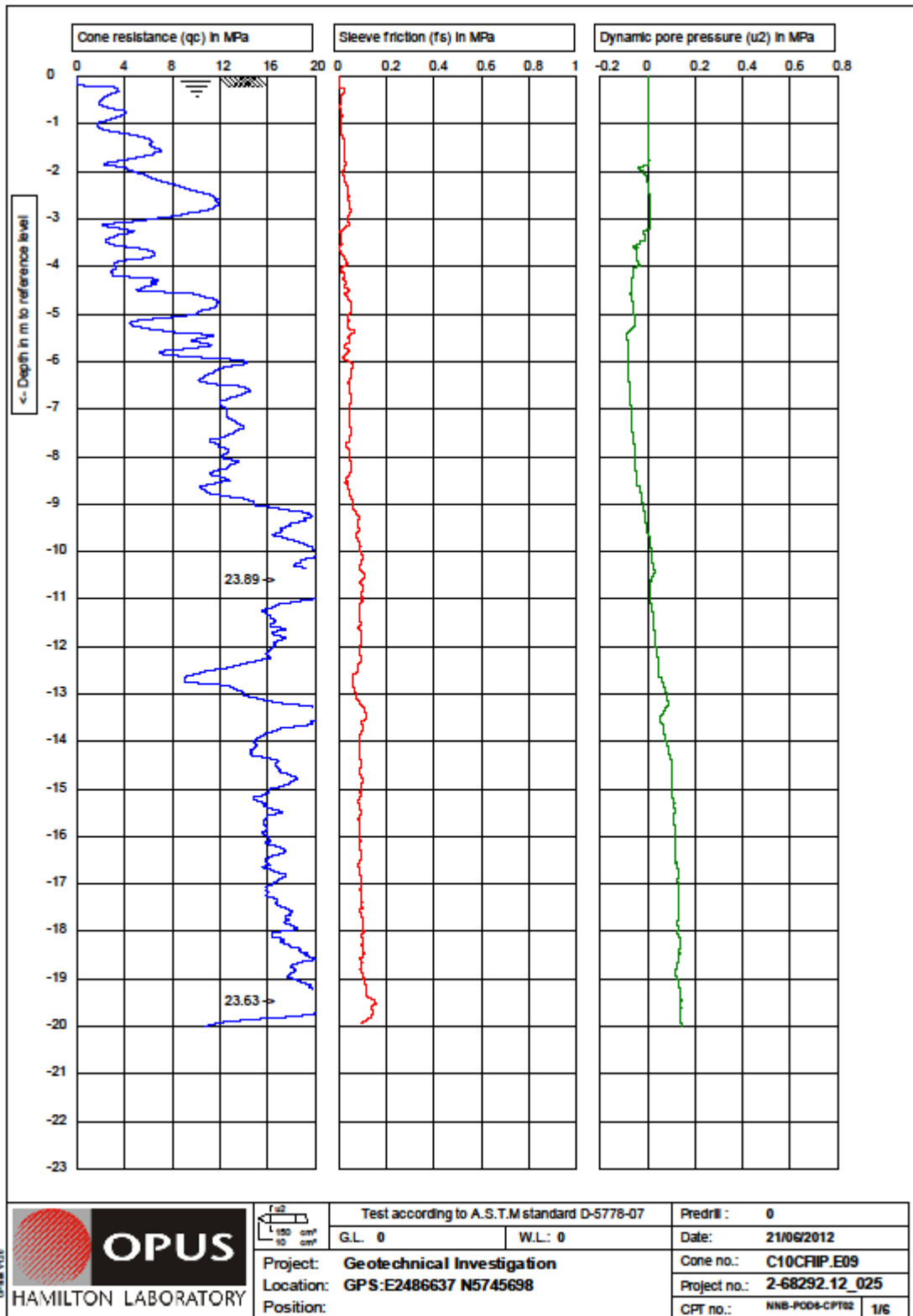
CPT SHALLOW REFUSALS DIAGRAM PHASE 1A/1E

CPT SHALLOW REFUSALS DIAGRAM PHASE 1B/1C/1E

CONE MANUFACTURING AND OPERATING TOLERANCES DIAGRAM (taken from ASTM D5778 – 12)

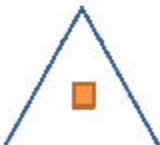
CPTB DIAGRAM

EXAMPLE CPT TRACE



TRUCK CPT RIG DATA SHEET



TRUCK		
Access requirements		
Width	2.65m	
Height	2.9m	
Length	9.0m	
Operating Requirements		
Width	2.65m	
Height	3.65m	
Length	9.0m	
Clearance Requirements		
Area	0.5x0.5m	
Mark out:		
		

TRACKED CPT RIG DATA SHEET



Access requirements

Width	1.8m	
Height	2.0m	
Length	2.7m	

Operating Requirements

Width	1.8m	
Height	3.0m	
Length	2.7m	

Clearance Requirements

Area	3.0x0.5m
------	----------

Mark out:

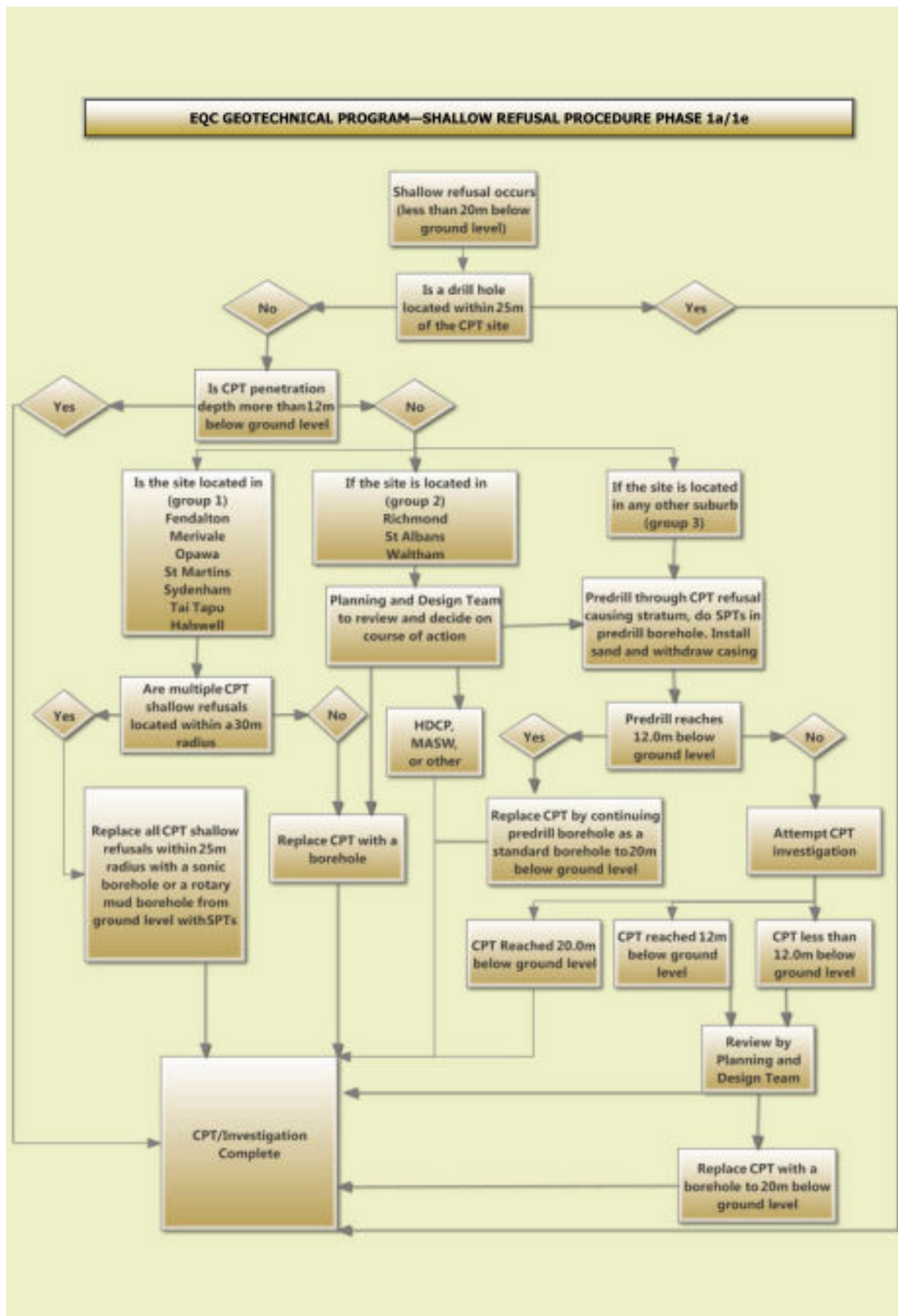


MAN PORTABLE CPT RIG DATA SHEET

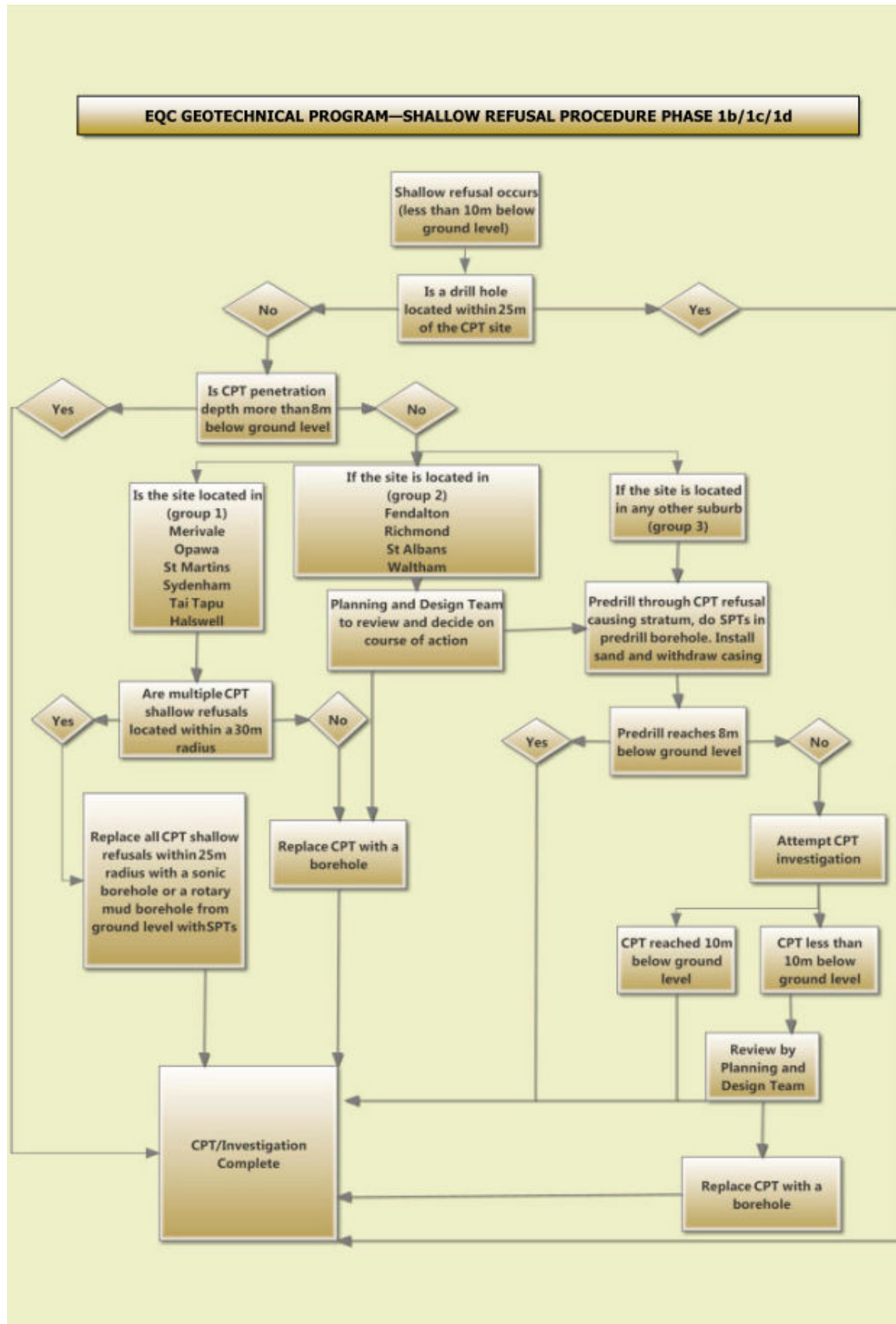


Man Portable		
Access requirements		
Width	0.8m	
Height	1.5m	
Length	N/A	
Operating Requirements		
Width	2.0m	
Height	1.8m	
Length	2.0m	
Clearance Requirements		
Area	2.0x2.0m	
Mark out:		
		

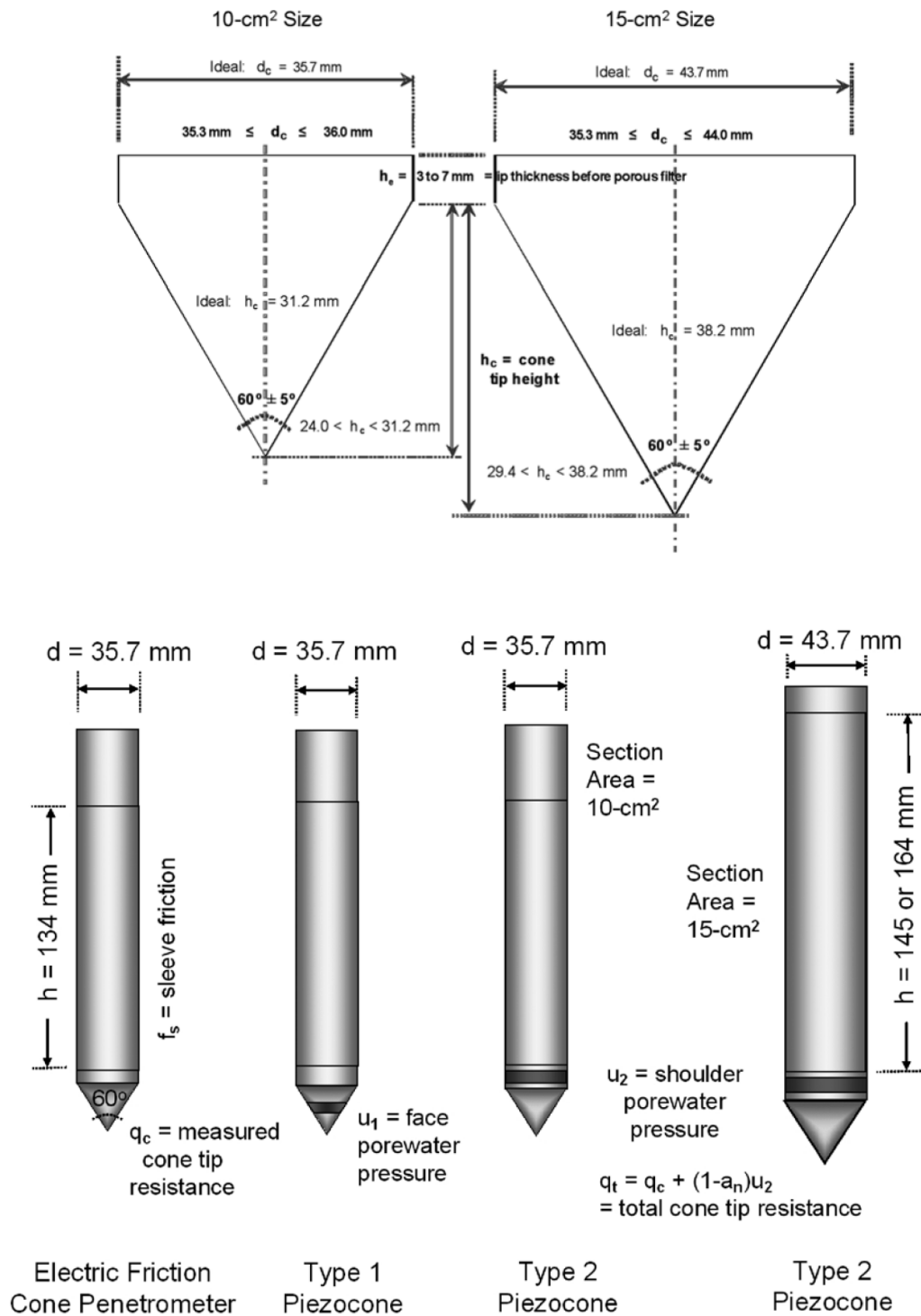
CPT Shallow Refusal Flow Diagram (Phase 1a/1e)



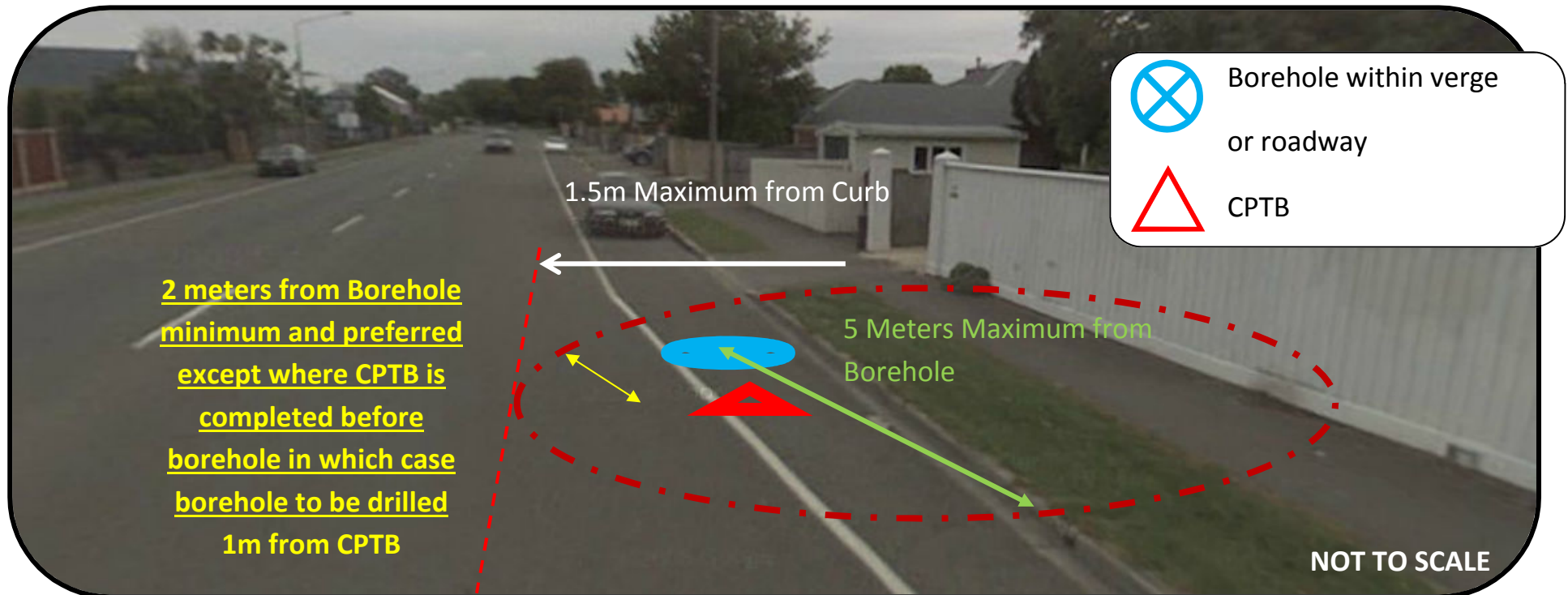
CPT Shallow Refusal Flow Diagram (Phase 1b/1c/1d)



Cone Manufacturing and Operating Tolerances Diagram (taken from ASTM D5778 – 12)



Twinned Borehole/CPTB Investigation Requirements, Rev A - 20/07/2012



- 1) If a borehole cannot be placed on a property and/or within 5 meters of a CPT on a property that borehole will be marked out in the verge or roadway. In this case a CPTB (borehole CPT) has been assigned for correlation purposes, separate from the main Property CPT list
- 2) A CPTB must be marked out when a borehole is marked in the verge or roadway. The CPTB needs to be a minimum 2m from the borehole and 2m is also the preferred distance where possible. 5m is the maximum allowed distance between a borehole and a CPTB. If a CPTB cannot be placed near to a borehole seek guidance from Geotechnics.
- 3) Where possible the CPTB should be pushed before the borehole is drilled allowing vacuum extraction service clearance to be completed within one visit for both investigations. In cases where the borehole is drilled after the CPTB the borehole will be sited 1 meter from the CPTB, location permitting.

APPENDIX D:

BOREHOLE BACKFILLING AND INSTRUMENTATION

STANDPIPE PIEZOMETER DRAWING

BACKFILLING OF BOREHOLES IN THE SPRINGSTON AND CHRISTCHURCH FORMATIONS DRAWING

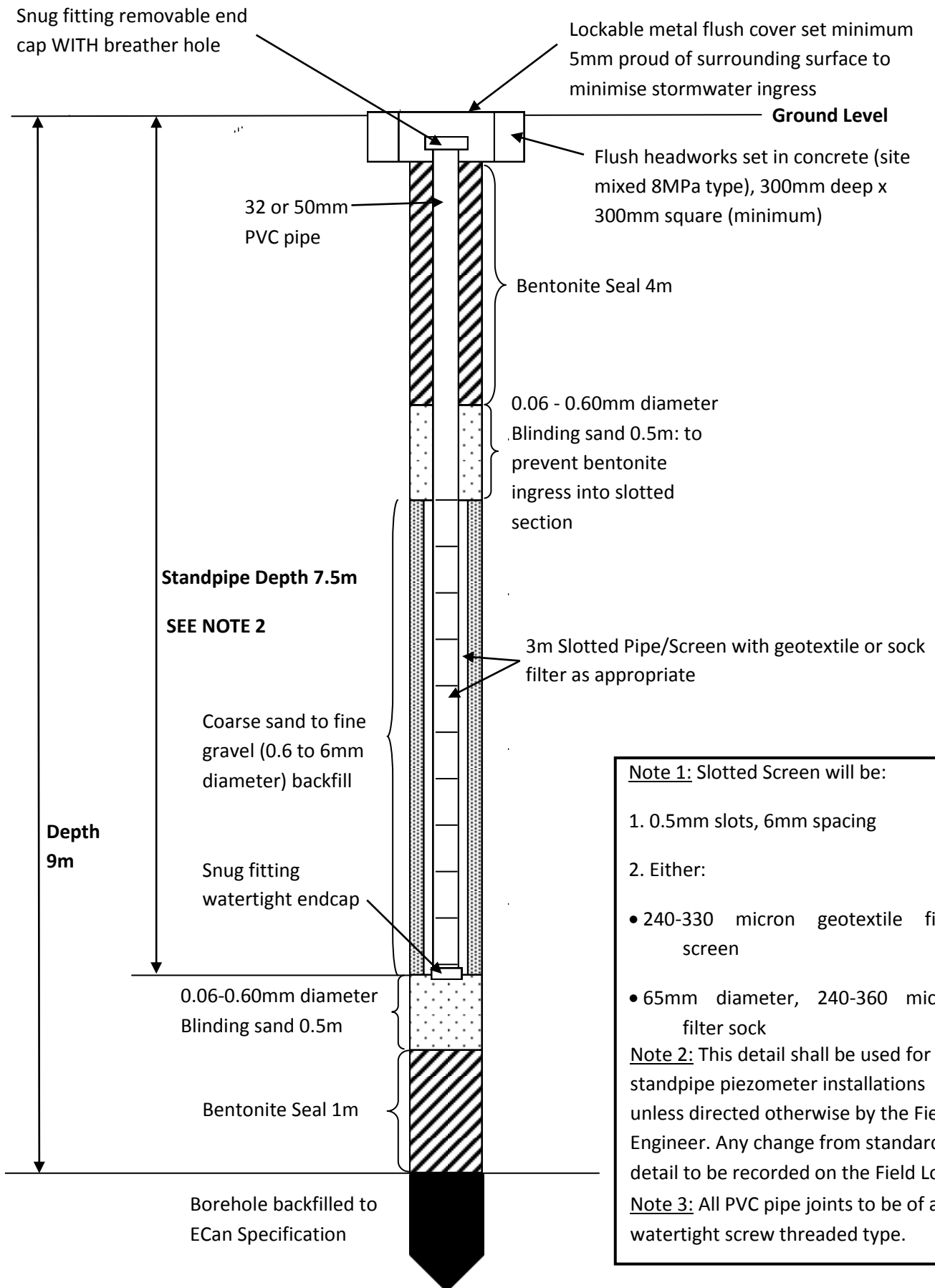
BACKFILLING OF BOREHOLES PENETRATING THE RICCARTON GRAVEL FORMATION DRAWING

DOWNHOLE SEISMIC CASING DRAWING

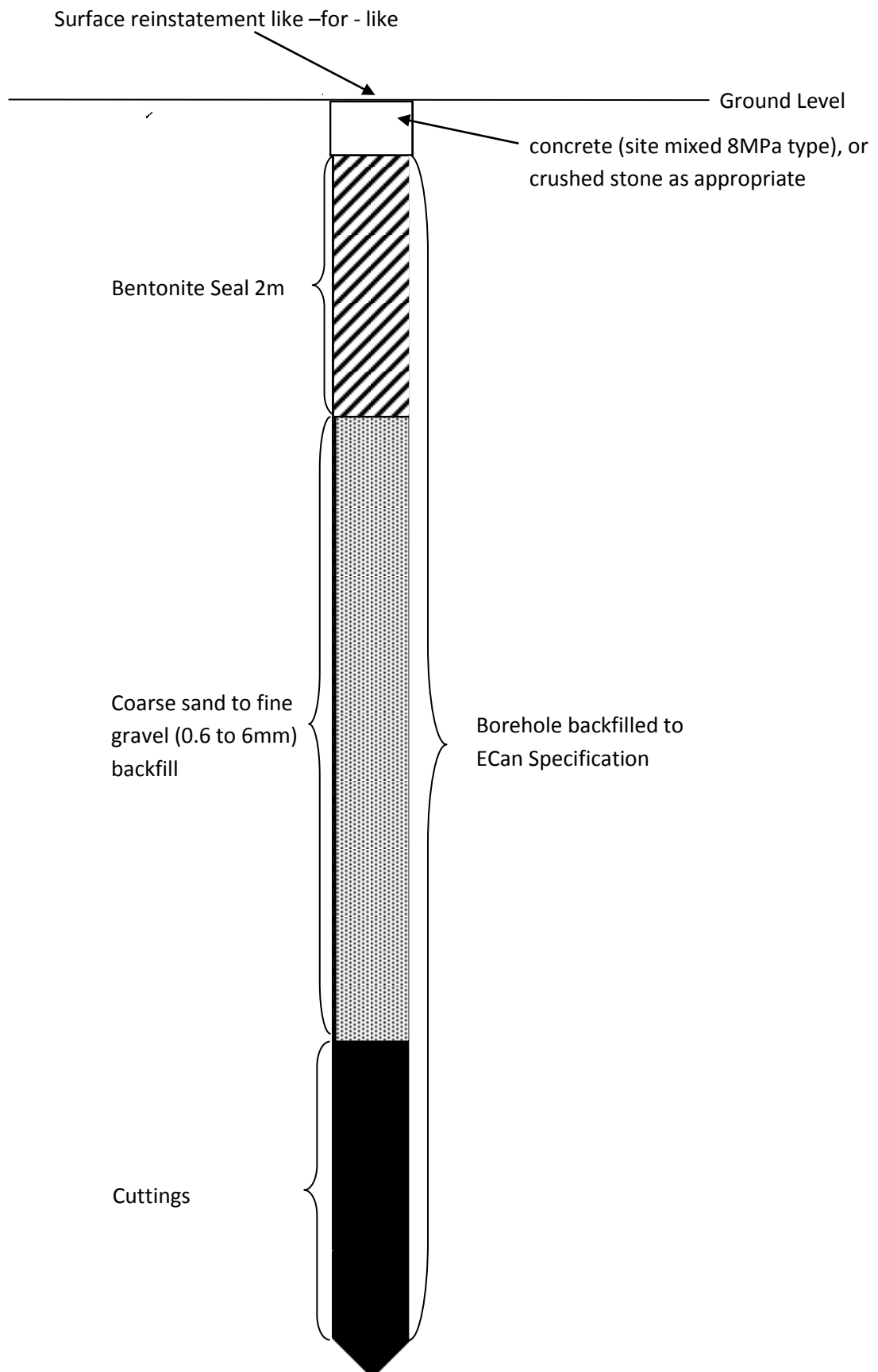
ECAN REGUALTIONS

EXAMPLE BEFORE AND AFTER PHOTOGRAPHS

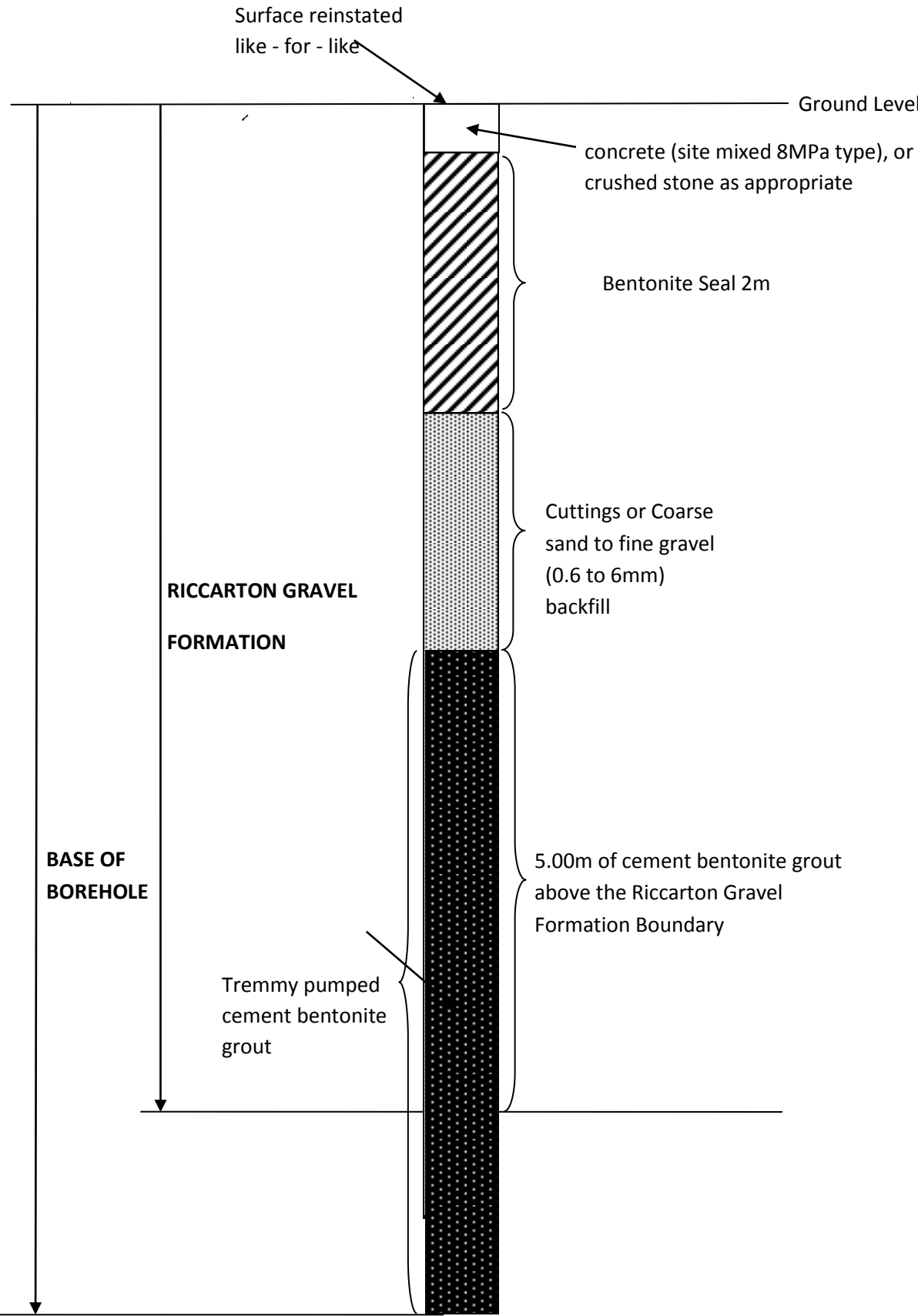
Standpipe Piezometer Installations (Revision B, 30rd July 2012): Standard Detail for Boreholes – Technical
Category 3 Area Wide Investigations



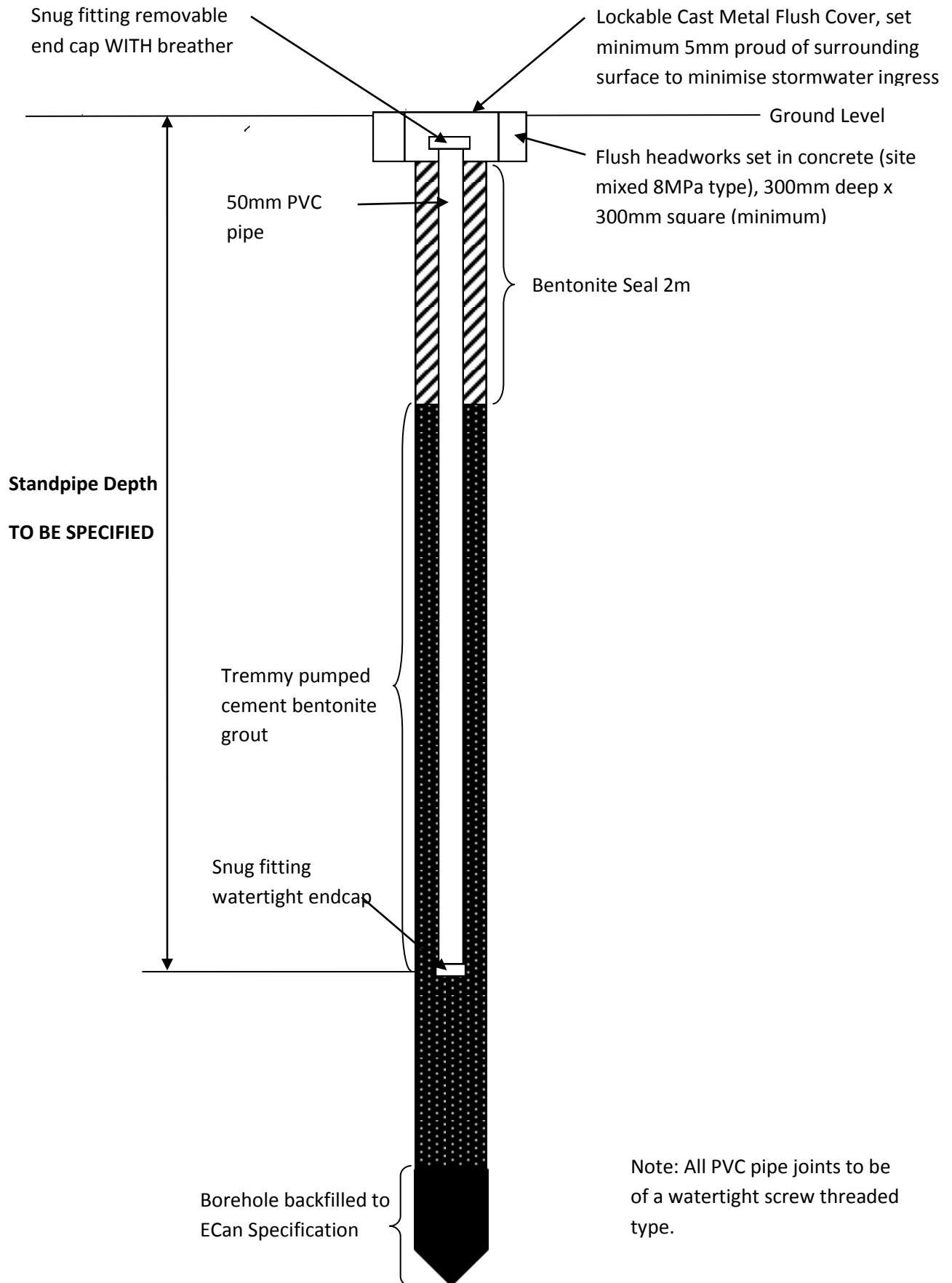
BACKFILLING OF BOREHOLES IN THE SPRINGSTON AND CHRISTCHURCH FORMATIONS DRAWING



BACKFILLING OF BOREHOLES PENETRATING THE RICCARTON GRAVEL FORMATION DRAWING



Downhole seismic testing detail



Backfilling to ECan controlled standard

Outlined below is the methodology of how to backfill boreholes and CPT in the Canterbury Region controlled by ECan.

1.0 Upper/unconfined aquifer requirements -Boreholes

If the upper unconfined aquifer (i.e. above the Riccarton gravels) is punctured during site investigations, the hole is required to be backfilled with:

- Drill cuttings, or
- Grout materials that comply with *WQL4 Standards Terms for the construction of bores and water infiltration*, or
- Clean sand, coarse gravel.

The **top 2 meters** of any hole **must be backfilled using bentonite** or similar which complies with the section 2.4 of WQL4. This is to stop surface transmission of contaminants.

2.0 Puncturing and connecting aquifers- Boreholes

Generally this is where you would have punctured the Riccarton gravels, have an artesian source, or any other aquitard/aquiclude. The following back filling procedure is required:

- A high pressure cement or bentonite/cement grout pumped to the base of the hole (tremmy pump) through the drill rods, in appropriate lifts to ensure that the bearing layers are sealed. The grout seal should be extended beyond the source layer by at least 5m (i.e. 5m above the Riccarton gravel).
- “DO NOT” allow the driller to just pull back the rods and let the hole seal itself, or drop bentonite pellets down the hole. The flows that have been experienced in the Riccarton Aquifer can be quite high and may blow the pellets back out and ultimately not seal the hole. If aquifers are connected additional equipment will be required to seal the hole to the appropriate standard.

This process should prevent movement of water between the aquifers and prevent water transmission between layers.

3.0 Installation of a standpipe

If a standpipe is required for water monitoring on site, install the standpipe to the desired depth and design but still keep within the requirements of section 1, (i.e. 2 metres of bentonite or similar capping)

Where installation of a standpipe is required and you have connected aquifers then we are still required to follow the process in section 2.0. However there are two options for installations of standpipes. These are:

- Install the standpipe above the grouted sealed section of the hole,

However this may not be possible due to the depth of grout sealant required, if this is the case,

- Complete the hole as per section 2, move a few feet and drill a new hole to required depth and install the standpipe. Please note in this case you should have an area that can be drilled free from services. Where a CPT hole is nearby a standpipe can be installed into this hole.

3.0 Puncturing and connecting aquifers- CPT.

The same process as in Section 2.0 is required for a CPT probe that punctures and connects an aquifer.

- Generally the probe is extracted, a sacrificial end cap is placed on to the end of the rods (with the probe and cables removed), the rod are then pushed down to the same end depth, a high pressure cement or bentonite/cement grout is pumped through the rods to the base of the hole (the sacrificial end cap is pushed off in this process) in appropriate lifts to ensure that the bearing layers are sealed. The seal should be extended beyond the source layer by at least 5m.

Additional equipment, from what is typically carried, is required by the CPT operator to undertake this work. For projects where you know that aquifers maybe connected make arrangements with the CPT operator to have equipment available or ultimately reconsider your testing arrangements.

General back filling procedure:

- The hole must be filled from the bottom to the top.
- Recapping of surface to original state, (i.e a cap of concrete/asphalt/regrassing).

**EXAMPLE BEFORE AND
AFTER PHOTOGRAPHS**

MARKOUT PHOTOGRAPH: Showing clear service and location markout. These photographs should also document private property features and any existing damage to the area. It is also a good idea to take general area, wide angle photographs.



POST INVESTIGATION PHOTOGRAPH: Showing any sign of the investigation, any damage caused and the state of installations if applicable. It is also a good idea to take general area, wide angle photographs.



POST REINSTATMENT PHOTOGRAPH: Showing the completed reinstatement and the condition we have left the location in. It is also a good idea to take general area, wide angle photographs.



APPENDIX E:

FIELD STAFF CHECKLISTS

CPT FIELD STAFF CHECKLIST

BOREHOLE FIELD STAFF CHECKLIST

CPT Field Staff Checklist

All Field Staff supervising CPT rigs should carry out the following checks while supervising CPT rigs

SITE

- Ensure required service check is carried out and that the permit to drill signed before breaking the ground
- Ensure a sufficient access route is available for the CPT rig to access the required site
- Ensure all staff are wearing correct Personal Protective Equipment
- Ensure Traffic Management is put in place where required
- Carry out a morning/site by site toolbox meeting to make rig operators aware of hazards at each site
- Ensure site safety is satisfactory at all times while on-site
- Ensure rig operators have access to a fire extinguisher, first aid kit and spill kit on-site and ensure an emergency stop button is available on the CPT rig

CONE / INSTRUMENT

- Check that the cone calibration certificate is available and ensure that the cone is in calibration.
- Photographs should be taken of the cone tip and friction sleeve to be used during each test
- Ensure that a new pore filter is fitted for every test and that the pore filter is assembled beneath glycerine using a funnel apparatus.
- Check that the cone is wrapped in plastic / latex during the time interval between when the cone is removed from the glycerine and prior to testing.

RODS and CABLE / SENSORS / COMPUTING

- Ensure GPS coordinates are logged
- If a friction reducer is fitted ensure that it is >500mm from the cone tip
- Ensure that the CPT computer software operates without error messages
- If a sensor system is used record any loss of signal which may occur
- If a cable system is used ensure cables are in good repair
- Ensure all rods are in good repair prior to testing

SOUNDING

- Ensure that the cone is immersed in a bucket of water at room temperature for 15minutes each morning prior to testing to allow temperature homogenisation to occur
- Ensure all equipment is checked pre and post sounding

- Ensure baseline checks are carried out pre and post sounding.
- Check that zero shifts are within 2% of full scale output (FSO)
- Ensure CPT push rate remains consistent between 15mm/second and 25mm/second.
- Check that no bending of rods takes place during testing
- Ensure site is left in appropriate condition and that any reinstatement requirements are recorded

BH Field Staff Checklist

All Field Staff supervising borehole rigs should carry out the following checks while supervising borehole rigs

SITE

- Ensure required service check is carried out and that the permit to drill is signed before breaking the ground
- Ensure a route providing sufficient access is available for the borehole rig to access the required site
- Ensure all staff are wearing correct Personal Protective Equipment
- Ensure Traffic Management is put in place where required
- Ensure that the site is photographed prior to work commencing to allow site conditions after completion of the ground investigation works to be compared.
- Carry out a morning/site by site toolbox meeting to make rig operators aware of hazards at each site
- Ensure site safety is satisfactory at all times while on-site (Check contaminated land requirements if applicable/ presence of overhead cables etc.)
- Ensure rig operators have access to a fire extinguisher, first aid kit and spill kit on-site and ensure an emergency stop button is available on the CPT rig
- Check that the rig certificate / lifting certificates are available.

DRILLING RIG AND METHOD

- Ensure flush / cuttings are not discharging into watercourses or drainage
- Ensure groundwater levels are measured with depth

LOGGING

- Make sure core is transferred to the core box carefully without any loss of core
- Ensure soil descriptions are carried out in accordance with NZGS guidelines
- Use water to perform a plasticity / silt assessment classification
- Ensure each core run is measured and marked on the core box
- Make sure depths are recorded and labelled in mbgl.
- SPT results should be recorded on the relevant core block
- Make sure that the location of any core loss is inferred and marked on the box
- Ensure to label the core box lid correctly recording:
 - Project name
 - Location
 - Borehole name

- Date drilled
- Core boxes should be photographed with photoboard recording:
 - Borehole ID
 - Depths
 - Box number
 - Date
- Ensure box is sealed in plastic wrap after logging and photography

SPT Sampling

- SPT samples recovered must be logged, measured, photographed and the percentage recovery should be noted
- Samples must be sealed in double bags and labelled
- Note must be taken of the type of SPT hammer used, its energy ratio and the SPT hammer should be checked that it's in calibration
- Prior to an SPT, the depth of the drill bit should be recorded
- The hole should be cleared and sounded prior to the test
- The depth of the sampler prior to testing should be recorded. The purpose of this is to identify heave.
- If heave is >150mm, the SPT should be cancelled and re-attempted a minimum of 300mm lower.
- The water level in the borehole rods should be checked prior to the test
- Ensure to record the number of SPT blows and ensure the number recorded agrees with the number of blows recorded by the drillers
- In locations where SPTs are undertaken in gravels, the number of blows per 25mm should be recorded

Completion

- If a piezometer is required ensure that it is installed in accordance with TC3 specification and in accordance with ECan requirements
- Ensure that the borehole is backfilled in stages as the casing is withdrawn
- Ensure that the site is left clean and tidy and that any additional reinstatement requirements are noted

APPENDIX F:

MASW

EXAMPLE MASW OUTPUT

EXAMPLE MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW) PROCESSED OUTPUT

