Guideline

Geotechnical Logging

March 2019

Queensland Government

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1 Introduction

1.1 General

This Guideline provides instructions for the compilation of geotechnical logs (including geotechnical borehole and test pit logs) as undertaken by the Department of Transport and Main Roads' Geotechnical Section geologists and by external geologists engaged by Transport and Main Roads for geotechnical site investigation work. It provides procedural direction for logging in the field and for the finalisation of logs in the office. It specifies the type of information that shall be recorded on the logs, and the order in which this information shall be presented.

In general, all information presented on geotechnical logs (including the description, naming and classification of materials) shall be in accordance with this Guideline, the *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017*, and with Australian Standard AS1726:2017 *Geotechnical site investigations*.

1.2 Methods of geotechnical investigation and sample types

The drilling of boreholes and excavation of test pits are perhaps the most widely used means of invasive subsurface geotechnical investigation. Both these methods provide opportunities to sample and test subsurface materials (soil, rock and groundwater) and to record a representative log of the subsurface profile.

Test pits are useful for near surface investigations, primarily of the soil profile; however, the extent of excavation is limited to the capability of the plant in terms of both depth and strength of material.

The drilling of boreholes provides access to depths greater than is possible by test pit excavation, enabling investigations to be targeted to reach materials of specified engineering qualities, and thus meet the conditions required by the project. Boreholes also provide downhole access for specialised *in situ* testing and for the installation of geotechnical instrumentation.

The samples collected during subsurface geotechnical investigations fall under the following categories:

- disturbed and undisturbed soil samples (obtained from both test pits and boreholes)
- rock core samples (obtained from boreholes)
- groundwater samples (mainly obtained from boreholes, once the groundwater well has been properly developed).

1.3 The purpose of geotechnical logging and scope of this Guideline

Irrespective of how they are accessed, subsurface materials are described, named and classified by the geologist according to their physical characteristics observed in the field, and via assessment of their properties using both *in situ* and laboratory testing methods.

A clear and consistent approach to the description, naming and classification of materials and to the production and presentation of geotechnical logs is essential to the development of a representative geotechnical model that can be used as a basis for the engineering design of infrastructure projects.

This Guideline aims to ensure that geotechnical logging undertaken by or on behalf of the State of Queensland is performed accurately and systematically in accordance with Australian Standard AS1726:2017 *Geotechnical site investigations*.

2 Geotechnical investigation and logging procedures

2.1 Planning and staging

All geotechnical site investigations shall be planned, staged and carried out in accordance with an established purpose, scope of work and evolving geotechnical model in mind.

Prior to the commencement of any subsurface investigations, the following preliminary activities shall be undertaken:

- a desktop review of available literature, including maps, reports and so on
- the establishment of a concept geotechnical model
- consultation with the relevant cultural heritage and environmental authorities
- a preliminary site walk-over, to assess site access cultural heritage and environmental constraints, traffic management requirements, underground / overhead services and other workplace health and safety (WH&S) issues.
- simple *in situ* testing (for example, Dynamic Cone Penetrometer (DCP) testing) may be carried out during the preliminary site-walk-over, as a cost-effective means of better targeting any following, more detailed investigations.

The geotechnical model and requirements for any further site / laboratory investigations shall be reviewed after each stage of the site investigation, including after the preliminary site walk-over. The model should include geological maps, 2D cross-sections and longitudinal sections and a 3D visualisation (generally for more complex sites).

2.2 Site investigation (field work)

2.2.1 Materials and equipment checklist

A checklist of investigation equipment should be used, inclusive of the following items:

- field logging forms (see Section 2.2.2.1 following)
- plastic snap-lock bags (resealable)
- large (strong) plastic bags or plastic 'ergo' containers
- permanent marker pens, retractable pencils, chinagraph pencils, fine tip pens
- bucket of water, plastic sieve and water spray bottle
- Transport and Main Roads standard 750 mm long galvanised core trays
- core tray stickers / labels
- undisturbed 'U50 mm, U75 mm or U100 mm' tubes
- tape measure, ruler, protractor, strip protractor, Douglas protractor
- spatula / knife and grinders for cutting samples
- pocket penetrometer (PP), geologists hammer, compass and hand lens.

This list does not include items of Personal Protective Equipment (PPE) or other items required for field or laboratory work.

2.2.2 Investigation supervision and logging procedures

The geologist shall be in the field at all stages of the geotechnical investigation, in order to take advantage of interactions with the drillers / excavators, and to ensure materials are described and photographed either *in situ* or immediately upon excavation.

Samples should be set out as obtained downhole for visual and tactile assessment and description. Ideally samples from adjacent test locations should be set out to enable simultaneous inspection, to best facilitate the development of a geotechnical model for the site.

The geologist shall also ensure that the soil and rock core samples are recovered, bagged or boxed, and stored in an appropriate manner.

Wherever possible, logging forms should be completed in the field. In circumstances where this is not physically possible, logging should be completed as soon as practical in an area that is well-lit and ventilated, with sufficient bench or work space for the laying out of samples.

If the logging area is fully enclosed, the facility should be equipped with a dust extraction system.

2.2.2.1 Project and test location information

Field logging forms include the following:

- *Transport and Main Roads Borehole Drilling Data Form F:GEOT026*
- *Transport and Main Roads Detailed Core Logging Data Form F:GEOT199*
- *Transport and Main Roads Detailed Defect Log Form F:GEOT533*
- *Transport and Main Roads Geotechnical Borehole Log sheets*
- *Transport and Main Roads Geotechnical Test Pit Log sheets*
- *Transport and Main Roads Dynamic Cone Penetrometer Test Log sheets.*

Prior to or while the drilling rig / excavator is setting up, project and test location information should be recorded on the field logging forms, sample bags and/or core trays.

Project and test location information shall include (as appropriate) the following:

- project name; project number, project location (for example, chainage and offset)
- test ID (for example, borehole or test pit number) and reference number ('H' No. or 'T' No.)
- height datum, for example, AHD
- surface R.L.
- grid datum, for example, MGA94 Zone 56
- Easting and Northing (please note these will be replaced by the 'as-tested', surveyed coordinates of the completed borehole when made available)
- Plunge (90˚ if the borehole is drilled vertically); plunge and bearing (if the borehole angled)
- date started, and date completed
- drilling company, for example, Boring Contractors Pty Ltd
- logged by (initials of geologist).

2.2.2.2 Investigation data

For borehole investigations, the following items shall be recorded on the *Transport and Main Roads Borehole Drilling Data Form F:GEOT026* during the drilling:

- drilling methods / sample types; run length / from depth – to depth)
- core-loss; from depth – to depth; recovery %
- rock quality designation per core-run (RQD (per CR))
- sample ID, labelled alphabetically (A–Z, followed by AA–AZ and so on as required)
- *in situ* test methods and results
- brief material description (*name, colour, moisture, consistency for soils; name colour, grainsize, degree of weathering and field assessed strength* for rocks).

Other items to be recorded on the Borehole Drilling Data Sheet should include an activity time log and summary of quantities for consumables.

For test pits, recording of all general investigation data is accommodated by the geotechnical test pit log sheet, for example:

- plant type and model
- bucket size
- contractor
- sample ID, labelled alphabetically (A–Z, followed by AA–AZ and so on as required)
- sample type, in the 'Samples / tests' column
- *In situ* test methods and results (a separate DCP Log sheet shall be completed).

For both boreholes and test pits, the depth and time at which groundwater is encountered should also be recorded on the field logging forms. Where piezometers are installed, subsequent readings of groundwater level will be shown on the finalised logs, with the date of measurement.

3 Logging of soils

Logging of soil samples includes the description, naming and classification of soils. Interpretation of the origin of stratum is also required, as informed by inherent features and structural evidence.

3.1 Description, naming and classification of soils

Soil description is based on visual and tactile assessment of drill cuttings (spoil) as well as disturbed and undisturbed samples obtained from the drilling or test pit excavation.

To avoid misrepresentation, it is important to cross-check sample information recorded on the draft borehole log and the *Borehole Drilling Data Form* with the labels on the soil samples.

Disturbed (SPT) samples should be examined and described prior to sealing them in labelled plastic containers or bags for storage in a cool place out of the sun.

The ends of undisturbed (U50, U75 or U100) tube samples should be inspected and tested with a pocket penetrometer before sealing. After extrusion and selection of material for laboratory testing, the remainder of the undisturbed sample should be split, examined, described and then stored in a sealed, labelled plastic container.

Preliminary naming of soils can be carried out with the assistance of simple field tests. A preliminary group symbol can be entered (in brackets) in the 'Group symbol / weathering' column. Soils are assigned a group symbol, in accordance with the major divisions shown on the soil classification tables in the *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017*.

Final soil names and group symbol classification are determined according to laboratory test results for particle size distribution and plasticity tests. The Group Symbol is recorded on the finalised borehole log without brackets.

3.1.1 Organisation of soil data on the borehole log

On the Field Geotechnical Borehole log, soil descriptors shall be entered in the 'Material Description' column, ordered in rows as shown in Table 3.1.1(a).

Table 3.1.1(a) – Description and naming of soil on the field geotechnical borehole log

Row	Item	Material description
1	Soil name	secondary component PRIMARY COMPONENT minor component (Origin)
2	Soil condition	colour, moisture, consistency
3	Primary component particle characteristics	estimated (%), grainsize, particle shape, sorting or grading, plasticity
4	Secondary component particle characteristics	estimated (%), grainsize, particle shape, sorting or grading, plasticity
5	Minor component particle characteristics	estimated (%), grainsize, particle shape, sorting or grading, plasticity
6	Soil structure	zoning, defects, cementation

Each row of the material description is detailed as follows:

Row 1 – Soil name and origin

Soils comprising a single fraction shall be named accordingly, for example, SAND; however, in most instances soils are composite, consisting of more than one fraction. Composite soils are named on the borehole log with the 'secondary component' written as the prefix in lower case, followed by the 'PRIMARY COMPONENT' in upper case, and then, if required, followed in lower case by the 'minor component' as the suffix.

Accompanying the soil name is the soil origin (in brackets). If the soil origin is determined to be FILL or TOPSOIL, it shall be written in upper case (in brackets).

Row 2 – Soil colour and soil condition

The soil colour and condition descriptors shall be entered consecutively across the row in lower case according to the following order: Colour, moisture condition, consistency / relative density.

Colour should be described in the moist condition, using black, white, grey, red, brown, orange, yellow, purple, green or blue. Borderline cases can be described as a combination of two colours, with weaker colour followed by stronger colour. Colour can be modified as necessary with pale, dark or mottled (primary colour mottled secondary colour)

Moisture condition is generally described as dry, moist or wet.

Consistency terms are applicable to cohesive soils. Relative density terms are applicable to non-cohesive soils.

Rows 3 to 5 – Primary, secondary and minor soil components

The primary and accessory components shall be described in separate rows. Descriptors shall be entered consecutively across the row in lower case in the following order: Estimated proportion (%), grainsize, particle shape, and grading / sorting (of the coarse-grained fractions), plasticity (of the fine-grained fractions), organic content, carbonate content if applicable.

Row 6 – Soil structure

In the undisturbed state, soil structure description shall include any observed zoning, defects or cementation, using the applicable terms in the *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017*. Thicknesses shall be described in millimetres.

Table 3.1.1(b) provides some examples of material descriptions for soils as entered onto the logs.

Table 3.1.1(b) – Example geotechnical borehole log material descriptions (soil)

Material description
gravelly SAND (Alluvium). pale grey brown, wet, medium dense. 75% fine to coarse grained sand, rounded grains, poorly graded. 25% medium grained gravel, sub-rounded grains. weakly cemented
sandy CLAY, trace organic matter (Holocene–Estuarine) orange mottled brown, moist, firm to stiff. 45% clay, high plasticity. 50% fine grained sand, rounded grains, uniformly graded. 5% fibrous organic matter.

4 Logging of rocks (rock core)

Logging of rock samples (as per soil samples) includes the description, naming and classification of materials based on the characteristics of the intact rock, the integral discontinuities (potential weaknesses) and the mechanical discontinuities (defects inherent in the rock mass).

4.1 Description, naming and classification of rocks

Rock description relies upon visual and tactile assessment of cored rock samples. It is best practice to inspect and describe the core samples as soon as they are sampled and boxed, in natural light and in the 'wet' condition. To achieve this, the geologist must ensure that the core is clean. A spray bottle is useful for keeping the core wet while carrying out inspection and description.

The rock name, shall be assigned in accordance with the tables for naming sedimentary, igneous, metamorphic and duricrusted rocks presented in the *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017*.

Classification of rocks is based on the degrees of material weathering, alteration and strength, and shall also be in accordance with the tables presented in *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017*.

4.1.1 Organisation of rock data on the borehole log

On the field geotechnical borehole log, the descriptive rock data should be entered in the 'Material description' column, ordered in rows as shown in Table 4.1.1(a).

Table 4.1.1(a) – Description and naming of rock on the field geotechnical borehole log

Row	Item	Material description
1	Rock name	NAME (map unit symbol)
2	Classification and primary descriptors	Material weathering or alteration: colour, grainsize, texture, fabric and representative Rock Mass Unit (RMU) strength, where applicable Rock Quality Designation (RQD) (per RMU).
3	Features, inclusions, minor components	vesicles or amygdales, veins, phenocrysts or nodules, cross stratification, clast or matrix support (all with indication of scale in mm)
4	Defects sets	type, angle of incidence, frequency (No./m), roughness, shape (if observable at scale >100 mm), aperture, infill

Each row of the rock material description is detailed as follows:

Row 1 – Rock name

The rock type (name) is recorded first, in upper case, followed in brackets by the abbreviated name for the lithological unit as published on the appropriate geological map.

Row 2 – Degree of weathering or alteration and primary descriptors

The prevalent degree of weathering or alteration (as applicable) for each rock mass unit will appear in upper case followed by a colon, followed across the row by the primary rock descriptors in lower case. Overlapping weathering or alteration terms such as HW / MW or XA / HA are not to be used. Minor zones of weathering or alteration within a layer (of thickness greater than 0.1 m and less than 1.0 m) will be detailed in the weathering / alteration column (refer to Section 4.1.2).

In the case of extremely weathered (XW) or extremely altered (XA) rock where the material is degraded to such an extent that it has 'soil' properties, but the inherent rock structure / fabric / texture is still recognisable, the material description will read 'recovered as', followed by the relevant soil description, ordered as per Table 3.1.1(a) (Section 3.1.1).

For all other degrees of weathering or alteration, through to fresh (FR) rock, the primary descriptors will be ordered across the row in the order: colour, grain size, texture, fabric and rock strength.

Colour should be described as per for soils (refer to Section 3.1.1).

Grain size refers to the average dimension of the mineral or rock fragments comprising the rock. An estimate by eye is generally sufficient.

The texture of the rock refers to the nature of individual grains. Textural terms may include crystalline, cryptocrystalline, porphyritic, amorphous, glassy, granular / clastic.

The fabric of the rock refers to the arrangement (or preferred orientation) of the grains. Rock fabric descriptors may include bedding terms (from thinly laminated through to very thickly bedded) and other terms describing inherent anisotropic fabrics such as liesegang banding, flow banding, foliation, mineral lineation or elongation.

The term 'massive' is used to describe a homogeneous and isotropic rock mass in outcrop and is only applicable to rock core where observed at large scale (length greater than 1 m).

Rock fabric shall be described as either 'indistinct', where the fabric has little effect on the intact rock strength, or as 'distinct', where the rock may break more easily parallel to the fabric.

Preliminary estimates of intact rock strength can be achieved by use of simple field tests. For a guide to field assessment, refer to *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017.*

Field assessed estimates of material strength are to be later confirmed or adjusted according to the results of Point Load Strength Index (PL) tests and Uniaxial Compressive Strength (UCS) tests.

In cases where it is appropriate, Rock Quality Designation (RQD) shall be calculated for the Rock Mass Unit (RQD per RMU) and included at the end of Row 2 of the description.

Row 3 – Features inclusions, minor components

Descriptors are to be entered consecutively across the row in lower case in the following order: Vesicles or amygdales, veins, phenocrysts or nodules, cross stratification, clast or matrix support (all with indication of scale in mm).

Secondary minerals or minor alteration zones, selvages or halos, shall be noted (for example 50 mm vein selvages of silica, albite, pyrite, sericite or clay alteration).

For presentation purposes the additional data / test results column may also be used for features inclusions or minor components.

Row 4 – Defect groups

Defects (mechanical discontinuities) shall be grouped according to 'group range' of angle of incidence to the normal to the core axis (the horizontal plane for vertical boreholes).

Defect groups shall be listed in order of prevalence down the column and described across the row according to the following order: Defect, angle of incidence, frequency (No./m), roughness, shape (if observable across lengths greater than 100 mm), aperture, infill.

Table 4.1.1(b) provides some example material descriptions for rock.

Table 4.1.1(b) – Example geotechnical borehole log material descriptions (rock)

Material description
GRANITE (Rg) XW: Recovered as grey brown, moist, hard, clayey GRAVEL.
GRANITE (Pg) MA: Pale white-red, grey and black, coarse grained, crystalline, weak sub-horizontal mineral lineation (micas), medium strength, RQD ($_{per\ RMU}$) = 90%. Pervasive, week iron-staining. LIN: 05° to 15°, Js: 30° to 45°, (4/m), VRo, TI, Fe Stn Js: 60° to 75°, (2/m), Ro, OP, Cly Vr
METAGREYWACKE (Dcf) SW: Pale brown grey, fine to medium grained, weakly foliated (sub-horizontal), high to very high strength, RQD ($_{per\ RMU}$) = 70%. Strongly silicified throughout, some HW bands <50 mm thick, (3/m). FP: 0° to 15°, (8/m), Sm – Po, TI, Cn DI: 0° to 15°, (3/m), along FP SZ: 45°, (<1/m), Sm, FL, Cly Ct.

Notes relating to defects:

1. Aperture of open defects shall be measured in millimetres
2. Infill greater than 1 mm thick shall be described as a seam or vein in terms of both composition and thickness
3. Drilling-induced defects shall be distinguished from mechanical defects inherent in the rock mass
4. Healed defects and other lineaments or anisotropic fabrics within a solid / unbroken rock mass shall be described as such
5. Note that defect persistence can only be measured in the field.

4.1.2 Detailed weathering and alteration

For intervals of width greater than 100 mm, localised variation within a broader weathering or alteration zone is recorded on the *Transport and Main Roads Detailed Core Logging Data Form F:GEOT199*. This information will populate the 'Group symbol / weathering' column on the geotechnical borehole log.

The *Transport and Main Roads Detailed Core Logging Data Form F:GEOT199* is not appropriate for weathering / alteration zones of width less than 100 mm, as these will not present in a readable fashion in the 'Group symbol / weathering' column.

Significant intervals of less than 100 mm width should be mentioned in the 'Additional data and test results' column.

4.1.3 Detailed intact strength

A detailed downhole histogram representation of intact strength is provided by the 'Intact strength' column. Data entry for this histogram is also facilitated by use of the *Transport and Main Roads Detailed Core Logging Data Form F:GEOT199*. The more detailed presentation provided by the intact strength histogram is designed to highlight the degree of strength variation, within the broader layer context.

The intact strength histogram should be reconciled against (PL) and (UCS) test results, which are entered upon receipt into the 'Additional data and test results' column. Careful consideration of the mode of failure shall be taken.

4.1.4 Detailed defect spacing histogram

The defect spacing histogram provides a visualisation of discontinuity distribution down the hole, considering all discontinuities aside from those defects that are drilling induced. This histogram should be reconcilable against RQD and be reflective of the discontinuity sets listed in the 'Materials description' column.

Data entry for the defect spacing histogram is also facilitated by use of the *Transport and Main Roads Detailed Core Logging Data Form F:GEOT199*. Refer to *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017* for definition of the defect spacing descriptors.

Note that for some projects where kinematic analysis is required, a separate detailed defect log should be completed, using the *Transport and Main Roads Detailed Defect Description Form F:GEOT533*.

4.1.5 Additional data and test results

The 'Additional data and test results' column is populated with *in situ* and laboratory test results and any data obtained from the monitoring of installed instruments.

Other significant features within a layer, for example shear zones, broken zones, clay seams, veins, selvages and distinctive joints should also be described in this column.

4.1.6 Additional remarks

At the bottom of the borehole log sheet, there is a 'Remarks' section, where any footnotes can be entered. These may include definitions of terms or symbols that are not included on the *Transport and Main Roads Geotechnical Terms and Symbols Form F:GEOT017.* Definitions of abbreviated map unit names, and notes on surrounding geomorphological conditions can also be entered here.

5 Log review, revision approval and finalisation

After completion of the initial draft borehole log, an overview should be carried out to ensure that any identified geological boundaries make sense in the context of a developing geological model. This is best achieved by laying out adjacent boreholes for comparison and by drafting geological sections.

The 'PRELIMINARY' borehole logs should then be passed on to a Senior Engineering Geologist for review and comment.

Once all necessary corrections have been made and no laboratory test results are outstanding, the 'FINAL' borehole logs can be approved for release by the reviewer.

Only finalised borehole logs can be included in the finalised geotechnical report, which is appropriately reviewed and approved by the departmental Geotechnical Section.

6 Policy for sample retention and chain of custody

All samples of soil or rock that are obtained by or on behalf of Transport and Main Roads' Geotechnical Section and transported to the 'Core-shed' shall become the property of the department and shall remain so until they are disposed of, or until they are repossessed by the relevant Project Principal.

If they choose to do so, the Project Principal shall contact the Geotechnical Section Office so that they may take possession of the samples, prior to scheduled disposal by the department (as outlined in Sections 6.1 and 6.2).

In general, there are three types of samples obtained by the Transport and Main Roads Geotechnical Section and their geotechnical subconsultants: disturbed soil samples (includes bulk samples from test pits), undisturbed soil samples, and rock cores.

6.1 Soil samples

Disturbed soil samples are typically used for soil classification purposes, though on occasion they may be used for more sophisticated testing. Undisturbed soil samples are primarily used for more sophisticated testing, though they may also be used for evaluation of detailed soil structure.

Undisturbed soil samples typically degrade significantly and are not useful for testing purposes after about three to six months.

Disturbed and undisturbed soil samples that have not been tested by Transport and Main Roads' Geotechnical Section will be retained for a minimum of 90 days after the geotechnical report is completed, after which time they will be disposed of, unless repossessed by the relevant Project Principal.

6.2 Rock core samples

Rock core obtained by Transport and Main Roads' Geotechnical Section or by their subconsultants shall be delivered to the 'Core-shed' as part of the deliverables associated with the Geotechnical Report.

Rock core is generally retained until after the construction project is complete and it is clear that claims related to the rock are not forthcoming. After construction, the core will be disposed of unless it is repossessed by the relevant Project Principal.

Subject to prior approval of the **Director, Transport and Main Roads Geotechnical Section**, rock core may be disposed of prior to project construction if it is determined that the risk of claims related to rock quality issues is sufficiently low, and/or the rock core is degraded and therefore not useful for visual inspection or testing, or possibly other reasons that cause the risk of early core disposal to be low.

In all cases, whether or not early disposal of the core is conducted, all rock core shall be photographed at high resolution and in colour correct light, to provide a permanent record of the core.

The Transport and Main Roads Guideline on Geotechnical Logging, *Transport and Main Roads Geotechnical Terms & Symbols Form F:GEOT017* and other logging forms can be accessed via: https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Geotechnical-Borehole-Logging