## Appendix 4.3 – Soil Consistency Grades & Relative Density of Sands and Silts

### SOIL CONSISTENCY GRADES

| Consistency | Field Identification |
|---|---|
| Very soft | Easily penetrated several inches with fist. |
| Soft | Easily penetrated several inches with thumb |
| Firm | Penetrated by thumb with moderate effort |
| Stiff | Indented but not penetrated by thumb |
| Very stiff | Easily indented with thumb nail |
| Hard | Only grooved with thumb nail |

### RELATIVE DENSITY OF SANDS & SILTS

| Relative Density | Standard Penetration Test (Blows per 0.3 metre) |
|---|---|
| Very loose | 0-4 |
| Loose | 4-10 |
| Medium (compact) | 10-30 |
| Dense | 30-50 |
| Very dense | Over 50 |

## Appendix 5.1 – Soil Classification Test Result Sheets

SOIL CLASSIFICATION TESTS RESULTS FOR:

- particle size distribution
- liquid limit
- plastic limit
- plasticity index
- in-situ moisture content

This appendix is included only in the coy of the report held by the Geological Survey Library.

### Appendix 5.2 – X-Ray Diffraction Analyses

| Bore No/ Depth (m) | Landslide No. | Stratigraphy | Clay Mineral Constituents | | | | |
|---|---|---|---|---|---|---|---|
| | | | Dominant or Co-dominant | Sub-dominant (>20%) | Accessory (5-20%) | Trace (<5%) | Other Major and (Minor) Mineral Constituents |
| 2/3.10 | 15 | Childers Formation | Kaolinite with halloysite admixed | | | Mica/illite | Quartz (goethite) (hematite?) |
| 2/5.80 | 15 | Lower Cretaceous | Montmorillonite* | | Kaolinite | Mica/illite | Quartz (Na feldspar) (alunite?) |
| 4/5.90 | 10 | Tertiary Older Volcanics | Kaolinite with halloysite admixed | Hydrated halloysite | | | (goethite) (hematite?) |
| 5/6.00 | 10 | Tertiary Older Volcanics | Kaolinite with halloysite admixed | Hydrated halloysite montmorillonite | | | (goethite) |
| 14/3.00 | 9 | Tertiary Older Volcanics | Halloysite (dehydrated-metahalloysite) montmorillonite* | | | | (K feldspar) |
| 14/5.00 | 9 | Childers Formation | Kaolinite | Illite-montmorillonite (regularly mixed layers) | | | Quartz |
| 15/4.50 | 10 | Childers Formation | Kaolinite | Mica/illite | Illite-montmorillonite (randomly mixed layers) | | Quartz |
| 16/5.00 | 10 | Tertiary Older Volcanics | Kaolinite with halloysite admixed | Hydrated halloysite | Randomly layered mixed clays | | (goethite) |
| 17/6.40 | 9 | Tertiary Older Volcanics | Kaolinite with halloysite admixed | Randomly layered mixed clays | | | (goethite) (quartz) (hematite?) |

| Bore No/ Depth (m) | Landslide No. | Stratigraphy | Clay Mineral Constituents | | | | |
|---|---|---|---|---|---|---|---|
| | | | Dominant or Co-dominant | Sub-dominant (>20%) | Accessory (5-20%) | Trace (<5%) | Other Major and (Minor) Mineral Constituents |
| 18/2.00 | 17 | Childers Formation | Kaolinite with halloysite admixed | Randomly layered mixed clays | | | (goethite)<br>(hematite?)<br>(quartz)<br>(K feldspar)<br>(dolomite?)<br>(anatase?) |
| 20/1.90 | Klevans | Lower Cretaceous | Montmorillonite* | | Kaolinite | Mica/illite | Quartz<br>(Na feldspar) |
| 21/5.33 | 20 | Childers Formation | Kaolinite<br>Randomly layered mixed clays | Mica/illite | | | Quartz |
| 22/4.30 | 20 | Childers Formation | Layered montmorillonite-vermiculite-illite? | Kaolinite | Illite-montmorillonite* (randomly mixed layers)<br>Mica/illite | Mica/illite | Quartz<br>(alunite?)<br>(anatase?) |
| 27/5.62 | 7 | Lower Cretaceous | Montmorillonite* | | Mica/illite | Kaolinite<br>Chlorite | Quartz<br>Na feldspar<br>(alunite?) |

* Inhibited montmorillonite: Inert interlayered material such as gibbsite or brucite present

## MINERALOGY OF 15 SOIL SAMPLES

## 1. Introduction

A batch of fifteen samples received from the Victorian Department of Minerals & Energy (Mr J Brumley) were soils from various depths (up to 6.4 m) from thirteen boreholes. They were to be examined by X-ray diffraction methods to determine their clay and non-clay mineralogies, according to AMDEL Code MC2. This consists of a diffractometric examination of the bulk sample, plus the separation of a -2µ 'clay' fraction and the examination of samples prepared from this fraction.

### 2. Procedure

The samples, which were damp, were removed from their plastic bags and air-dried at rom temperature. Sub-samples were taken, ground finely by hand, and used to prepare X-ray diffractometer traces which were interpreted by standard procedures.

Further weighed sub-samples were taken and dispersed in water with the aid of deflocculants and an electric blender, and allowed sediment to produce -2µm esd 'clay fraction' material by the pipette method. The resulting dispersions were examined in a plummet balance to determine their solids contents, and were then used to produced oriented clay preparations on ceramic plates. Two plates were prepared per sample, both being saturated with $Mg^{++}$ ions and one in addition being treated with glycerol. When air-dry, these were examined in the diffractometer. Various additional diagnostic examinations were carried out as required, including examination of the glycerol-free hot (130$^{o}$C) and after heating for 1 hour at 550$^{o}$C.

### 3. Results

The results are given in Table 1, which lists the following:

(a) The mineralogy of the total sample, as derived from XRD scan of the bulk material, with supporting evidence as available. The minerals found are listed in approximate order of decreasing abundance, using the semi-quantitative abbreviations given. Coverage of clay minerals may be incomplete, and for the full clay mineralogy the section on the clay fraction (c) should always be consulted. This section (a) should be used for information on non-clay minerals, and to give a general idea of the proportions and make-up.

(b) The proportion of the sample found to separate into the -2µm size fraction, as determined by plummet balance. The figure obtained may be variable according to the pre-treatment and dispersion conditions used.

(c) The mineralogy of the -2µm fraction, given in the same way as (a).

### 4. Remarks

In general, the minerals are typical of those in soils in that they are poorly crystalline and poorly defined, and the interpretation is consequently sometimes difficult.

Goethite and hematite are invariably very poorly crystalline and give XRD patterns difficult to identify. In general, the reported presence of these minerals corresponds well with those samples identifiable as iron-bearing from their colour.

Kaolinite and halloysite. The two closely-related minerals are widely present. It is difficult to identify moderate amounts of metahalloysite in the presence of kaolinite; hence they are often reported together as K/H in the table where there are indications of the presence of halloysite. If halloysite identification is of great importance in these or other instances the use of electron microscopy is recommended. In some cases hydrated halloysite, which has a 10Å rather than a 7Å basal spacing, has been definitely detected and is reported separately.

Montmorillonite (smectite). In some cases this has been reported as 'inhibited'. This refers to the presence of inert interlayer material, probably gibbsitic or brucitic, which inhibits the collapse of the clay layers when the Mg-saturated clay is heated to low temperatures (e.g. 110-150$^{o}$C). The inhibited montmorillonites reported here collapse to about 13.5Å (from 15Å) at such temperatures, instead of to a more usual spacing of about 12-12.5Å. Heating to 550$^{o}$ promoted a fully collapse to about 10Å. This is unlikely to be of practical importance, but is reported for completeness.

Interstratified materials. Various types of interstratified or 'mixed-layer' clays are reported, as listed in the mineral key. The material found in BH22 4.30 m appears to be very unusual, and may consist of a 3-component interstratification. It is tentatively identified as a montmorillonite-vermiculite-illite.

**Mineral Key**

| | |
|---|---|
| AL | Alunite |
| An | Anatase |
| C | Chlorite |
| Dol | Dolomite |
| F | Na feldspar |
| F' | K feldspar |
| G | Goethite, very poorly crystalline |
| H | Halloysite, dehydrated (metahalloysite) |
| HH | Hydrated halloysite |
| Hm | Hematite, very poorly crystalline |
| K | Kaolinite |
| K/H | Kaolinite with probable or definite admixed halloysite |
| M | Mica/illite |
| $(M\text{-}Mo)_{ran}$ | Illite-montmorillonite mixed-layer clay, more or less randomly interstratified |
| $(M\text{-}Mo)_{reg}$ | Illite-montmorillonite mixed-layer clay, more or less regularly interstratified |
| ML | (Sample BH22) – mixed-layer clay of complicated type, possibly montmorillonite-vermiculite-illite |
| Mo | Montmorillonite (smectite) |
| Mo' | 'Inhibited' montmorillonite – see text |
| Q | Quartz |
| RI | Randomly-interstratified clay material of indeterminate type. Likely to contain montmorillonite. |

**Semi-quantitative abbreviations**

These are defined as follows:

D = Dominant. Used for the component apparently most abundant, regardless of its probable percentage level.

CD = Co-dominant. Used for two (or more) predominating components, both or all of which are judged to be present in roughly equal amounts.

SD = Sub-dominant. The next most abundant component(s) providing its percentage level is judged above about 20.

A = Accessory. Components judged to be present between the levels of roughly 5 and 20%.

Tr = Trace. Components judged to be below about 5%.

**Table 1 – Bulk and -2µm mineralogies of 15 soils**

| Sample | BH2 3.10m | | BH2 5.80m | | BH4 5.90m | | BH5 6.0m | | BH14 3.0m | | BH14 5.00m | | BH15 4.50m | | BH16 5.0m | | BH17 6.40m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulk Mineralogy | K/H | D | Mo | D | K/H | D | K/H | D | H | D | Q | D | Q | D | K/H | D | K/H | D |
| | Q | SD | Q | A-SD | G | A | HH | SD | Mo | SD | K | SD | K | SD | HH | SD | G | A |
| | G | A | F | A | Hm? | A | G | A | F' | Tr | M | A | M | SD | G | A | Hm? | A |
| | Hm? | A | K | A | | | Mo | A | | | Mo? | A | | | | | Q | A |
| | M | Tr | M | Tr | | | | | | | | | | | | | | |
| | | | Al? | Tr | | | | | | | | | | | | | | |
| -2 µm fract. % of total | 62 | | 20 | | 50 | | 20 | | 24 | | 36 | | 28 | | 19 | | 73 | |
| Mineralogy | K/H | D | Mo' | D | K/H | D | K/H | D | H | CD | K | D | K | D | K/H | D | K/H | D |
| | G | A | K | Tr-A | HH | SD | HH | SD | Mo' | CD | (M-Mo)reg | SD | M | A-SD | HH | SD | RI | SD |
| | M | Tr | Q | Tr-A | G | A | Mo | SD | | | Mo | A | (M-Mo)ran | A | RI | A | G | A |
| | Q | Tr | M | Tr | | | G | A | | | M | A | Q | Tr | | | | |
| | | | | | | | | | | | Q | Tr | | | | | | |

| Sample | BH18 2.0m | | BH20 1.90m | | BH21 5.33m | | BH22 4.30m | | BH24 3.00m | | BH27 5.62m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulk Mineralogy | K/H | D | Mo | D | K | D | K | CD | Q | D | Mo | CD |
| | Q | SD | Q | SD | Q | SD | ML | CD | K | SD | Q | CD |
| | Hm? | A | F | A | M | A | Q | A-SD | M | A | F | A-SD |
| | F' | Tr | M | Tr | | | M | Tr | C? | Tr | M | Tr-A |
| | Dol? | Tr | K | Tr | | | Al? | Tr | F | Tr | C | Tr |
| | Ana? | Tr | | | | | Ana? | Tr | | | Al? | Tr |
| -2 µm fract. % of total | 37 | | 30 | | 75 | | 67 | | 45 | | 18 | |
| Mineralogy | K/H | D | Mo' | D | K | CD | ML | D | K | D | Mo' | D |
| | RI | SD | Q | A-SD | RI | CD | K | SD | (M-Mo)ran | A | M | A |
| | G | A | K | A | M | A-SD | M | Tr | M | A | Q | Tr |
| | Q | Tr | M | Tr-A | Q | A | Q | Tr | Q | Tr-A | K | Tr |
| | | | F | Tr | | | | | | | C | Tr |
| | | | | | | | | | | | F | Tr |

Mineral Key (see separate page)

## Appendix 7.1 – Recommended Laboratory Soil Testing

TELEPHONE
345 1844

TELEGRAMS
UNIMELB PARKVILLE

**University of Melbourne**

DEPARTMENT OF CIVIL ENGINEERING

*Parkville, Victoria 3052*

7th June, 1978

Mr John Neilson,
Department of Minerals and Energy,
Mines Department,
151 Flinders Street,
MELBOURNE.

Dear John,

I would like to submit a quotation for specialized testing of samples of clay soil from the Narracan land slip material.

We have allowed for careful sample preparation, reconsolidation to an isotropic mean insitu stress condition, undrained triaxial testing with pore pressure measurement at extremely slow strain rates to establish the peak failure strength and to investigate whether there is any substantial reduction in strength in the post peak behaviour. Automatic recording equipment will be used to continuously monitor the sample performances.

Specialized testing for residual strength such as ringshear-torsion or repeated direct shear to large strains has not been allowed for in this quotation but may be required if a substantial variation between peak and residual strengths is indicated.

For each consolidated undrained test to large strains - $460-00 each.

Yours sincerely,

P.J. Hoadley
Senior Lecturer in Civil Engineering