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Record 1972/73

GEOLOGICAL, SEISMIC AND SOILS EVALUATION OF THE ROUTE PROPOSED FOR THE TUGGERANONG FREEWAY, STAGE II, A.C.T.

by

P.H. VandenBroek and J.R. Kellett

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CONTENTS

SUMMARY

Stage 2 of the proposed Tuggeranong Freeway runs at an elevation of 610 - 645 m above mean sea level (M.S.L.) along the western side of Mount Taylor on a pediment formed between the Canberra-Yass Tableland surface and the Yarralumla Landsurface. Pediments are noted for rapid soil and soil thickness changes along and downslope.

The area is drained by surface and subsurface water flow. Surface drainage by Weston and Village Creeks has incised gullies in the side of Mount Taylor and stripped soil* cover from the upper slopes. Groundwater and soil water commonly create problems, particularly in an area such as Canberra where ground moisture conditions can change markedly with the seasons.

Two rock types, a purple spherulitic rhyodacite** and a blue-grey rhyodacite were mapped. No sediments crop out and it is considered unlikely that they occur concealed below soil cover. The blue-grey rhyodacite does not appear to be as susceptible to weathering as the purple spherulitic rhyodacite. Thin sections of both rhyodacites show potassium fledspar altered in part to sericite and kaolinite, and biotite mica altered in part to chlorite and epidote.

Air-photos indicate that there is a joint system, comprising three joint sets striking at 045°, 095° and 150°, present in the two rhyodacites. No folding of the volcanic rocks has been observed but they appear to have been tilted to the southwest.

Volcanic rocks along the freeway tend to weather irregularly; completely weathered rock may be difficult to excavate where large boulders of slightly weathered rock are present as 'floaters' in appreciable numbers. Highly weathered rock is expected to need light blasting before it can be excavated. The lower part of each cut is to be made in moderately or highly weathered volcanic rock; moderately weathered volcanic rock will need to be extensively blasted before it can be removed.

Eleven seismic spreads were surveyed along and across the freeway where five major cuts are to be made; the highest velocity layer encountered above the freeway level was 1500 - 1600 m/s for the two southern cuts and 2100 - 2400 m/s for the three northern cuts.

Sixteen soil units were distinguished on the basis of undisturbed auger sampling, field classification, and laboratory testing. The unified soil classification system was used for the investigation. Soils which test results indicate may be suitable for use as gravel pavement and base-course gravel were located. Fat heavy clays were detected close to the proposed finished surface level of the freeway in a number of places; they will have to be stabilized or removed. Old soil slip surfaces may be concealed in some soil units.

* The term "soil" is used in an engineering sense in this report. Soil is a natural aggregate of mineral grains that can be separated by such gentle mechanical means as agitation in water (Terzaghi and Peck, 1967).

** Definitions of selected geological and weathering terms are given in Appendices 1 and 2.

The present drainage system for surface water run-off will require some redesigning. Seepage of water through alluvium could cause springs to develop on the upstream side of the freeway and possible piping under the freeway; careful drainage so as not to induce recharge or subsidence should be considered. It is not expected that seepage will tend to undercut the sides of excavations; a few initial deep jack hammer holes in the areas where cuts are to be made would enable the Bureau to take piezometer readings and complete the assessment of possible groundwater problems.

All results of laboratory testing are included as appendices* and Plate 1 shows seismic, soil, and CBR sections along Stage 2 of the freeway.

* The Bureau commenced conversion to the metric system of units in 1970. Metric units are used in this report except in the presentation of definitions and testing results in Appendices 1, 4, 5 and 6.

1. INTRODUCTION

1.1 Scope

In August 1971 the National Capital Development Commission (NCDC) requested the Bureau of Mineral Resources (BMR) to undertake an engineering geological, seismic, and soils survey along the route of Stage 2 of the proposed Tuggeranong Freeway.

1.2 Location

The proposed Tuggeranong Freeway extends from Scrivener Dam to the proposed urban development area of Tuggeranong. Stage 2 of the freeway is the section between Hindmarsh Drive and the proposed Village Creek arterial road (Fig. 1).

1.3 Geological Mapping

The geology of the area along and adjacent to the freeway route was mapped in detail (Fig. 2). Rock exposures were classified as (1) solid outcrop, (2) scattered outcrop, or (3) scattered boulders. 'Solid outcrop' is hard rock normally too difficult to rip. 'Scattered outcrop' includes areas of solid outcrop but is mostly rippable near the surface.

1.4 Seismic Survey

A separate geophysical report (Hill & Pettifer, in prep.) is being compiled in the BMR Geophysical Branch's Engineering Geophysics Group; essential geophysical data made available by Hill & Pettifer is included in Section 5. A 24-channel SIE seismograph was used in conjunction with 20Hz TIC geophones. A geophone interval of 3 m was used giving a spread of 66 m. Eleven spreads totalling 726 m were laid along adjoining and intersecting traverses.

1.5 Soil Investigations

Undisturbed soil samples were taken using a Proline auger, equipped with coring barrel, mounted at the rear of a Landrover utility. Forty auger holes, shown on Figure 8 and totalling 105 m, were sunk in July, August, and November 1971. Soil cores taken were tested in the BMR laboratory; they gave a clear picture of soil layering and types; detailed diagrammatic and written logs of cores are included as Appendix 3.

Undisturbed samples for compaction and CBR testing in the laboratory were taken from six test pits (Fig. 8) dug in areas where representative soil units occur.

1.6 Maps

The base map for the investigation (1:5 000) was adapted from two contoured ACT Detail Series maps (1:2 400): Sheets H9A and H9C drawn by the Department of the Interior. A plan of the proposed freeway alignment was supplied by the NCDC. The base map for text figures 2, 3, 8, and 10 is adapted from T.P. 150/67 (NCDC).

1.7 Air Photos

Colour air photos at 1:22 500 scale, taken in October 1968 (CAC/C14, Run 11, 9583, 9584) were used for preliminary air-photo interpretation and planning of the investigation.

2. PHYSIOGRAPHY

2.1 Topography

The proposed Tuggeranong Freeway skirts the western side of a north-trending ridge that separates the urban areas of Woden and Weston Creek. The ridge includes Mount Taylor in the south as its highest point, 850 m above mean sea level (M.S.L.), and Oakey Hill, 690 m above M.S.L., in the north (Fig. 1).

The steeper slopes of the ridge generally break to rolling terrain below 660 m above M.S.L., and this changes to undulating terrain below 600 m above M.S.L.

Stage 2 of the proposed freeway runs at an elevation of 610 - 645 m above M.S.L. along the western side of Mount Taylor.

2.2 Drainage

Drainage of the area traversed by Stage 2 of the proposed freeway is partly by surface run-off and partly by subsurface soil water and grounwater movement.

2.21 Surface drainage to the north is by the tributaries of Weston Creek and south by tributaries of Village Creek; both creeks have dendritic drainage patterns, which are partly controlled by the jointing in the under-lying volcanic rocks. Creeks contain little or no water except after heavy rain. Water in Weston Creek flows to the Molonglo River, a tributary of the Murrumbidgee River; Village Creek runs directly to the Murrumbidgee River.

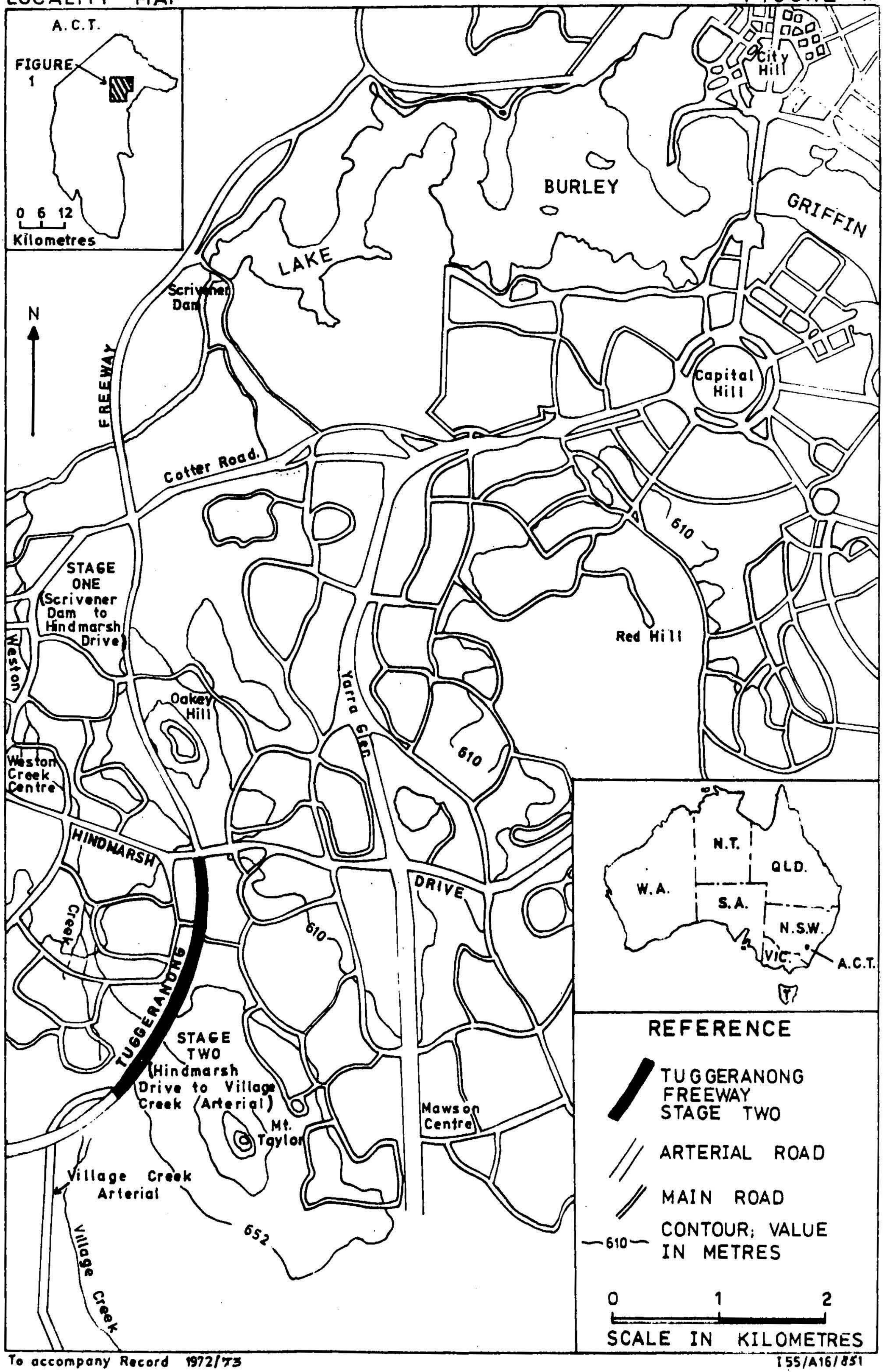
2.22 Sub-surface drainage by soil water and groundwater movement is through confined and unconfined aquifers.

2.3 Erosion

Clearing of trees from Mount Taylor has contributed to the rapid erosion of soil cover. The lower slopes have been deeply gullied; gullies 2-3 m deep have cut into indurated slope wash. The middle slopes have gullies 1-2 m deep incised down to solid rock; progressively more rock has been exposed and soil cover becomes thinner as relief increases. The upper slopes are covered with solid rock, boulders, cobbles, and thin skeletal soil; the skeletal soil is generally less than 0.5 m thick. Formation of new scours by erosion during heavy storms is very rapid on Mount Taylor and is partly the result of high local rainfall on the steep upper slopes. Prominent high physiographic features in the Canberra area are subject on occasions to appreciably higher precepitation than the surrounding plains (Hounam, 1957).

LOCALITY MAP

FIGURE 1



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3. GEOMORPHOLOGY

3.1 General

The geomorphology of the region has been developed to two different degress of intensity: major erosional processes developed landsurfaces* at different elevations; minor processes developed superficial groundsurfaces (van Dijk, 1959).

3.2 Major Landscape Development

Continental uplifts since late Palaeozoic or early Mesozoic time (Craft, 1933b) have developed landsurfaces at different topographic elevations mainly by pediplanation. Pediplanation is an erosional process whereby destruction of older topographic features and landsurfaces is by scarp retreat levelling to a new base. When incomplete, older landsurfaces that have stable local base levels persist in elevated positions.

Four landsurfaces have been recognized by Craft in the Canberra region (Table 1).

Table 1

Landsurfaces of the Canberra Region

Name	Elevation (m)
Monaro Landsurface	920
Molonglo Landsurface	760 - 790
Yass-Canberra Tablelands	670
Yarralumla Landsurface	565 - 580

The Molonglo Landsurface is preserved near the summit of Mount Taylor at 820 m; a scarp separates it from the Yass-Canberra Tableland surface, preserved as a change in slope at 700 - 720 m; a pediment separates it from the Yarralumla Landsurface at 600 m.

3.3 Minor Landscape Development

Superimposed on each landsurface are complex groundsurfaces; several groundsurfaces each representing the materials, soils, and surfaces

* See Appendix 8 for definitions and explanations of selected, underlined, geomorphological terms.

relating to one K cycle may be preserved on any particular land surface. A K cycle, the time interval covering the formation of a groundsurface, spans a phase of erosional stability and instability, (Butler, 1959).

During the unstable phase older groundsurfaces are either destroyed, buried, or partly destroyed and partly buried. During the stable phase a soil profile, often developing pedological A and B horizons, forms on the new groundsurface soil layer. Six K cycles have been recognised in the Canberra region (Table 2).

Table 2

K cycles of the Canberra Region

Cycle	Name	Soil developed
K_0	Kambah	Recent alluvium
K_1	Tharwa	Minimal prairie soil
K_2	Kurrumbene	Red earths, minimal podzolics
K_3	Pialligo	Red and yellow podzolics
K_4	Gundaroo	Thick, strongly differentiated podzolics
K_5 (?)	Mugga	Remnants of stable clays only

The area traversed by the freeway forms a pediment between the Yass - Canberra Tableland surface and the Yarralumla Landsurface. It lies in an intermediate position between the pediplain basin, where dominantly depositional processes operate, and the scarp, where dominantly erosional processes operate. The area of the freeway has therefore been subjected to erosion as well as deposition during unstable phases; a complex zone of soils has resulted (the 'alternating zone' of Butler). Consequently old soils are commonly truncated prior to burial in the pediment.

Along the section of the freeway are two distinct soil mantles which are distinguished by their soils and the weathered condition of the underlying rock type. The boundary between the two, referred to in this report as the northern and southern soil mantles, is creek C (Fig. 10).

The southern soil mantle, which at one time may have been drained by Village Creek, has undergone more severe phases of instability than the northern soil mantle. A comparison between the two is shown in Table 3.

Table 3

Comparison of the two soil mantles along the freeway

Soil and rock types	Northern soil mantle	Southern soil mantle
Moderately weathered volcanic rock	Below soil cover	Not detected
Highly weathered volcanic rock	Not present	Below soil cover
Completely weathered volcanic rock	Forms a mantle at the base of the ground-surface	Found only at lower elevations
Indurated slopewash	Overlies completely weathered volcanic rock in places. Clayey in places	Occurs over nearly whole area above highly weathered volcanic rock, clayey at lower elevations
K_4 soils	Remnants of strongly differentiated pod-zolic B1 and B2 horizons found over most of the area	A and B horizons, buried in slopewash, found at lower elevations. B horizon occurs in other places
K_3 soils	Truncated B_1, B_2, and C horizons extend over most of the ground-surface. B horizon often mottled plastic or heavy clay	Remnants of B horizon occur in places
K_2 soils	A and B horizons occur as buck-shot ironstone silty gravels and iron-stone clayey gravels.	Not detected

4. GEOLOGY

4.1 General

The area traversed by Stage 2 of the proposed Tuggeranong Freeway is underlain by Siluro-Devonian acid volcanic rocks.

The detailed geological map of Canberra (1:50 000) shows the rocks as part of the Deakin Volcanics (Sud.). The Deakin Volcanics include rhyolite*

* See Appendix 2 for definitions and explanations of selected, underlined, geological terms.

rhyodacite, dacite, and toscanite welded tuff and lava as well as interbedded sandstone, shale, and limestone bands (Henderson & Strusz, 1971).

4.2 Detailed Mapping

The geology south of the area covered by this report has been mapped at 1:9 600 scale (Sheet P52, A.C.T. Planning Series) by Rossiter (1971) and Gardner (1968). Part of the area along and adjacent to Stage 2 of the freeway has been mapped by Gardner (1968) at 1:2 400 scale (Sheet H9C, A.C.T. Detailed Planning Series.). Figure 2 shows rock exposure along and adjacent to the freeway alignment.

4.3 Rock Types

Two rock types have been distinguished in the area; a blue-grey rhyodacite welded tuff, and a purple spherulitic rhyodacite welded tuff (Fig. 2). Sediments do not crop out in the area mapped. It is considered unlikely they would occur in this area concealed below soil cover.

The geological boundary between the two rhyodacites is obscured by soil cover but it is a continuation of that mapped by Rossiter to the south. Blue-grey rhyodacite does not appear to be as susceptible to weathering as the purple rhyodacite. This could be because the purple rhyodacite is spherulitic and contains more volcanic glass.

4.31 Blue-grey rhyodacite

In hand specimen this rock is porphyritic and comprises phenocrysts of transparent quartz (up to 5 mm across), white to pale green feldspar (up to 3 mm across) and dark brown to black biotite (up to 2 mm across) set in a dense blue-grey aphanitic matrix of devitrified volcanic glass.

A thin section cut from this rock type, collected by Rossiter immediately south of the area mapped, was examined. The section shows the rock is composed of phenocrysts of quartz, orthoclase and plagioclase feldspar, and biotite, set in a cryptocrystalline ground-mass of alkalic feldspar and quartz. The rock has undergone some alteration, the feldspar to sericite and kaolinite; biotite to epidote, chlorite, and iron oxide.

4.32 Purple spherulitic rhyodacite

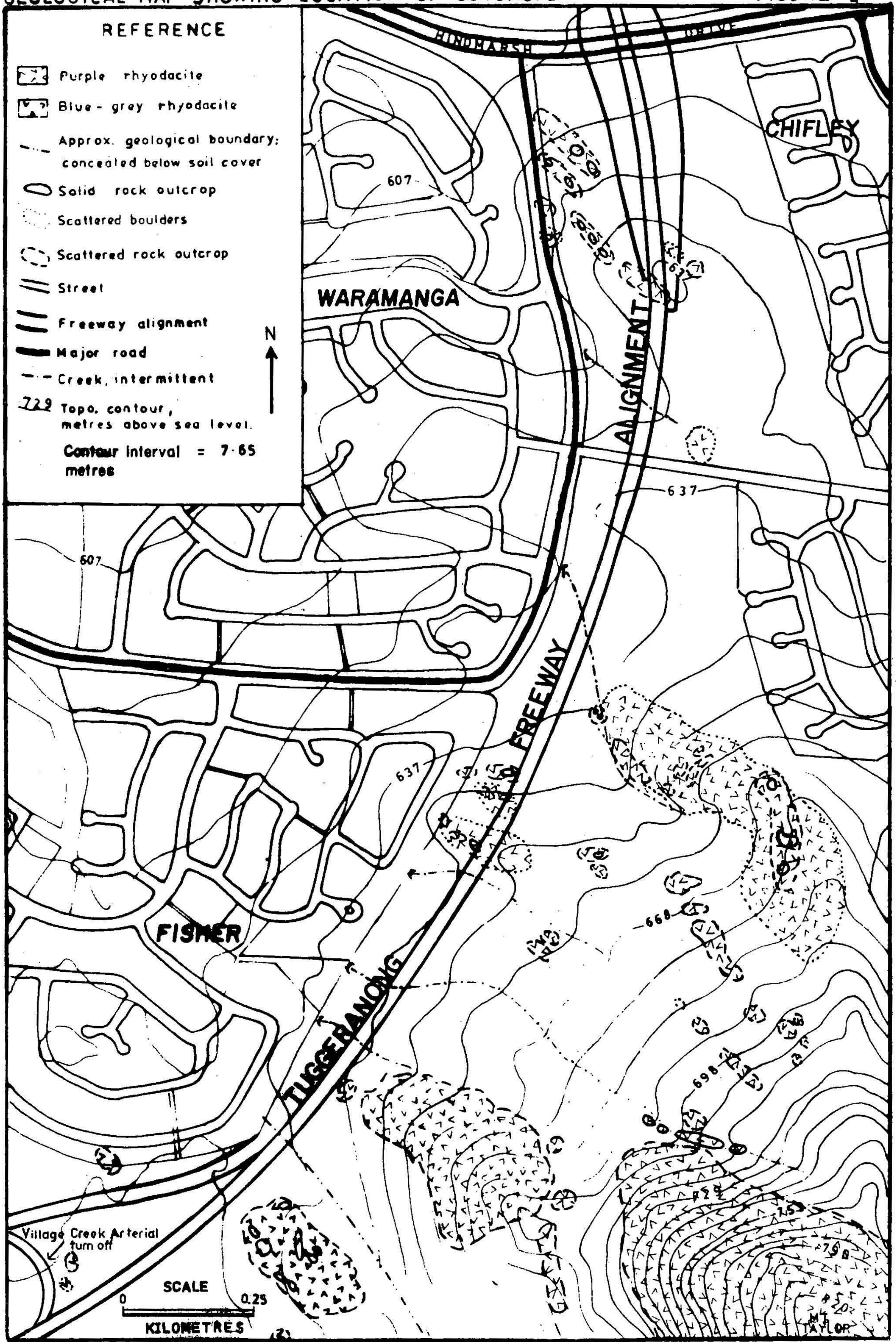
In hand specimen this rocks is also porphyritic and comprises phenocrysts of transparent quartz (up to 3mm across) and white, pale pink, and pale green feldspar (up to 5 mm across) set in a dense purple-grey to green-grey aphanitic matrix of devitrified volcanic glass. The overall colour of the rock depends partly on the degree of chemical weathering and partly on trace chemical constituents.

Thin sections of the rock collected by Gardner, and to the south by Rossiter, were examined. The sections show the rock is composed of phenocrysts of quartz, orthoclase and plagioclase feldspar, and biotite set in a cryptocrystalline groundmass of alkalic feldspar and quartz; spherules composed of

TUGGERANONG FREEWAY II

GEOLOGICAL MAP SHOWING LOCATION OF OUTCROPS

FIGURE 2



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alkalic feldspar and quartz, and devitrified glass shards, occur throughout both sections. The rock has undergone extensive alteration, feldspar to sericite and kaolinite; biotite to epidote.

4.4 Rock Structure

Inspection of air-photo lineations indicates a strong joint system is present in the volcanics. The joint system comprises three joint sets which strike at about 045°, 095° and 150° grid north. Joint measurements were not taken in the field because all outcrops comprised boulders.

No folding of the volcanic rocks in this area has been observed but they may have been tilted as interbedded and underlying sediments outside the freeway area dip at 35° - 45° to the southwest (Wilson and Newstead, 1967).

4.5 Rock Weathering

Welded tuff when unweathered is very hard and strong and can only be excavated by heavy drilling and blasting. Volcanic rock along the freeway tends to weather somewhat irregularly to considerable depths; moderate weathering (defined in Appendix 1) has proceeded to a maximum depth of 30 m, complete weathering has progressed down to 10 m (seismic results). Moderately weathered volcanic rock can generally be drilled at a medium rate and requires moderate charges of explosives to shatter it sufficiently for removal. Highly weathered volcanic rock needs light drilling and blasting or may be removed by using heavy equipment, in places. Completely weathered volcanic rock has the properties of a soil and is treated as such in this report.

Under conditions of elevated topography, widely spaced* rock jointing, and rapid grounwater drainage, weathering of volcanic rock along joint surfaces leaves large boulders of intervening rock as cores surrounded by completely weathered volcanic rock. The resultant weathering profile is irregular and difficult to predict.

In low-lying poorly drained areas, volcanic rock weathering also begins along joint surfaces but the intervening blocks of rock are commonly more quickly decomposed than the rock in elevated localities.

5. SEISMIC REFRACTION SURVEY

5.1 Results

Eleven seismic spreads (Figure 3) along nine intersecting and adjoining traverses were surveyed along and across the freeway alignment where major road-cuts will be made. The results of these spreads are shown as seismic sections in Figures 4-7. Each section has three or four seismic velocity layers; the top layer in each case yielded a velocity of 310 m/s. The maximum seismic velocity recorded was 5100 m/s (E-F, G-H, Figs 4 and 5).

* 1-2 m apart.

Seismic sections A-B and C-D (Fig. 4) suggest there is seismic anisotropy in the underlying rocks; that is, the rock has a faster seismic velocity east-west than north-south. This might suggest the rock is more strongly jointed east-west than north-south; some other seismic sections do not confirm this anisotropy. 4.4 indicates the rocks should show some anisotropy.

5.2 Interpretation

Correlation of seismic velocity layer with particular soil or rock type, indicated by augering, is given in Table 4 and shown diagrammatically on Plate 1. Auger holes were sunk during the same field moisture conditions, at about the same time as the seismic traverses were surveyed.

Table 4

Correlation of seismic velocity layer with soil or rock type

Seismic velocity layer (m/s)	Soil or rock type
310	Topsoil, subsoil, clay
950 - 1100	Completely weathered volcanic rock
1150 - 1200	Indurated slopewash
1500 - 1600	Indurated slopewash underlain by highly weathered volcanic rock
2100 - 3000	Moderately weathered volcanic rock
3000 - 3900	Slightly weathered volcanic rock
4000 - 5100	Unweathered volcanic rock

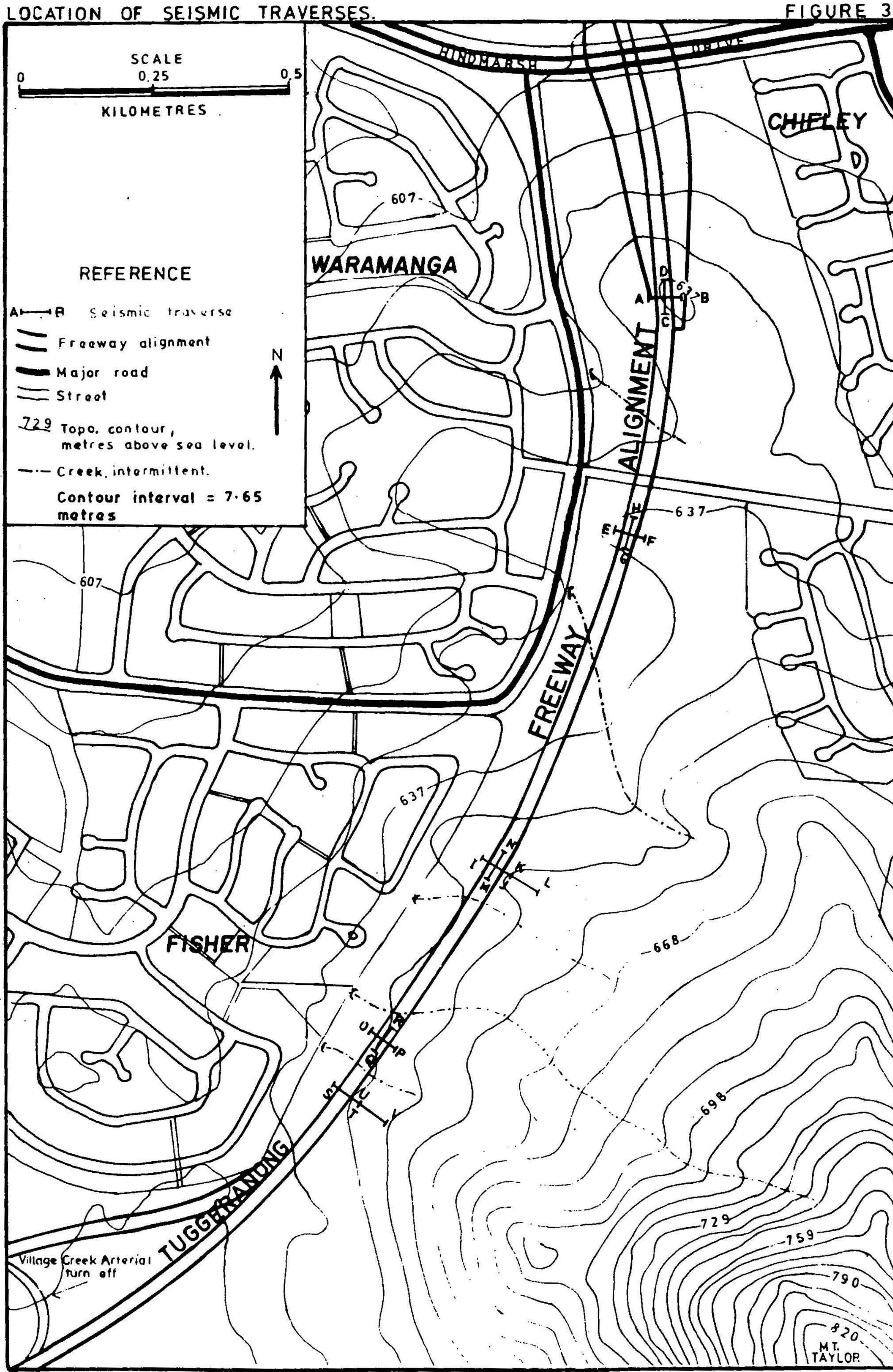
5.3 Application of Results

Seismic results taken in conjunction with rock type and structure, usually reliably indicate the excavatability of a particular soil or rock type. Material with a seismic velocity of up to 900 m/s can be moved by tractor-mounted scraper, blade, or shovel; velocity layers up to 1500 m/s can usually be ripped by D7 and D8 tractors or similar, fitted with hydraulic rippers (Bartlett, 1971).

Hard slightly weathered boulders less than 3 m across are not detected by seismic work (Hill, 1970). Numerous large boulders make mechanical excavation difficult, and as they can be expected to occur in cuts along the

TUGGERANONG FREEWAY, II.

LOCATION OF SEISMIC TRAVERSES. FIGURE 3



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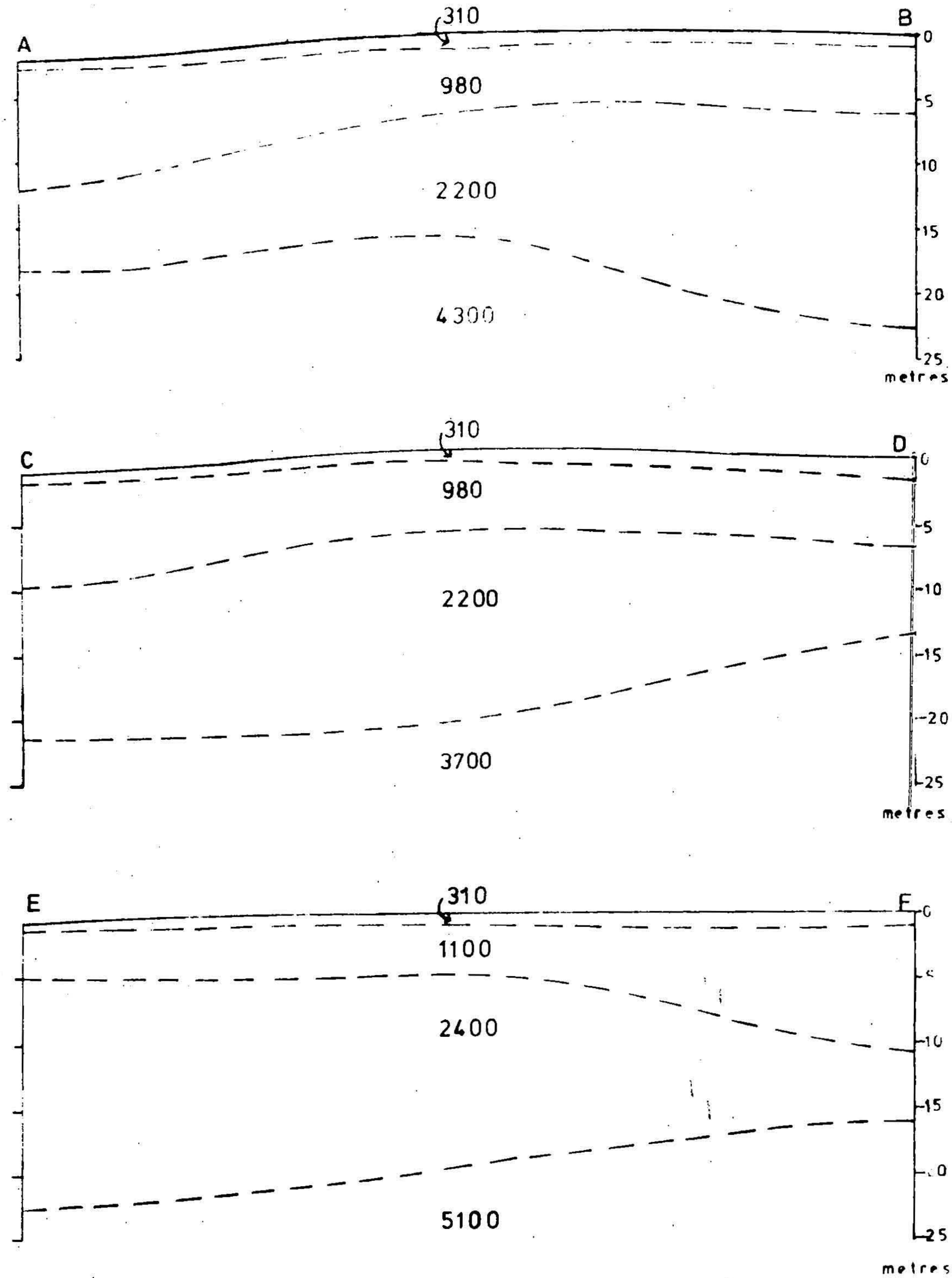
SEISMIC CROSS-SECTIONS A-B, C-D, AND E-F. FIGURE 4

VERTICAL AND HORIZONTAL SCALE 1 centimetre = 5 metres

FOR REFERENCE SEE FIGURE 7



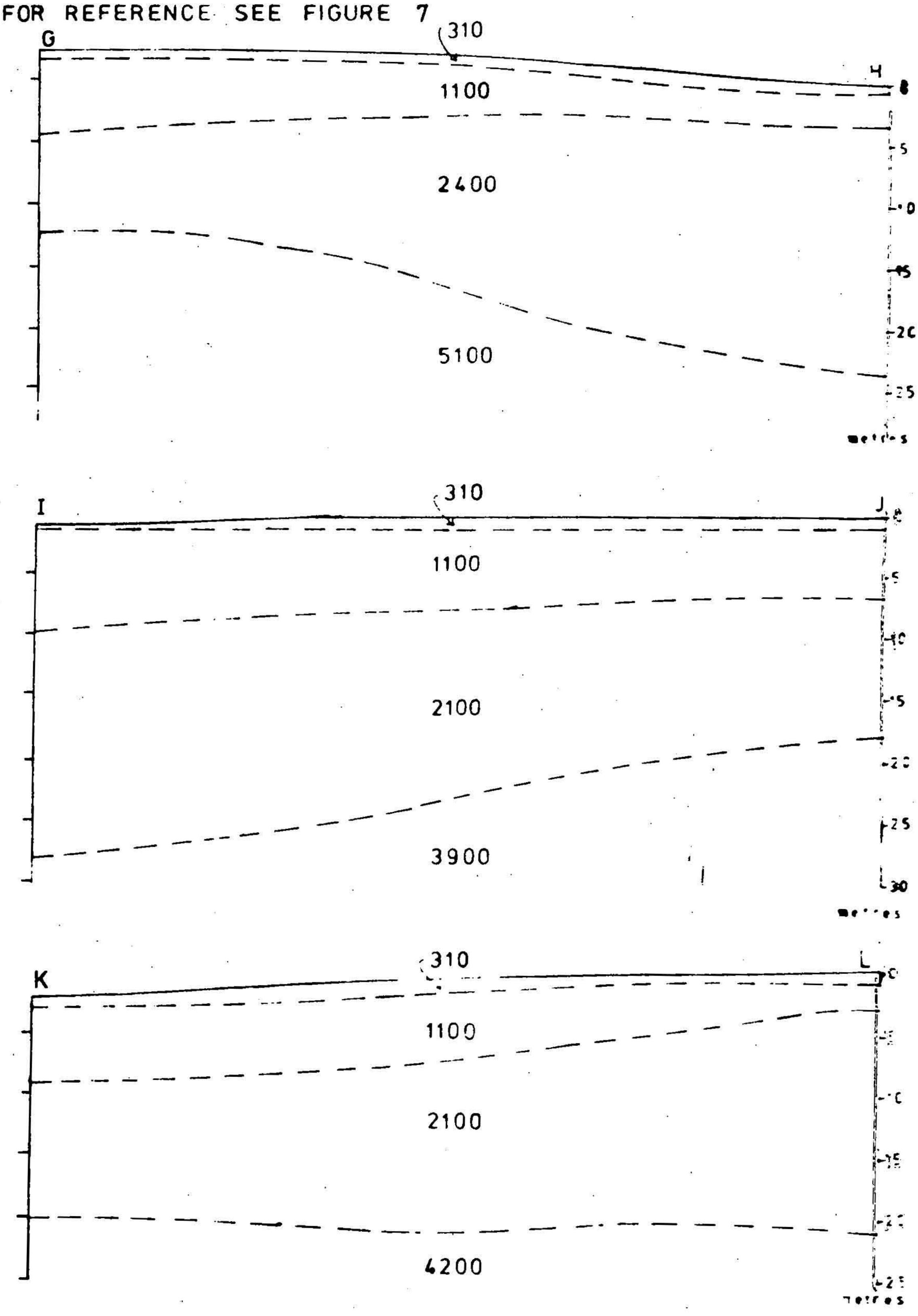
See Figure 3 for locations of traverses surveyed

To accompany Record 1972/73 After survey by Hill & Pettifer. I55/A16/854

SEISMIC CROSS SECTIONS G-H, I-J, AND K-L   FIGURE 5

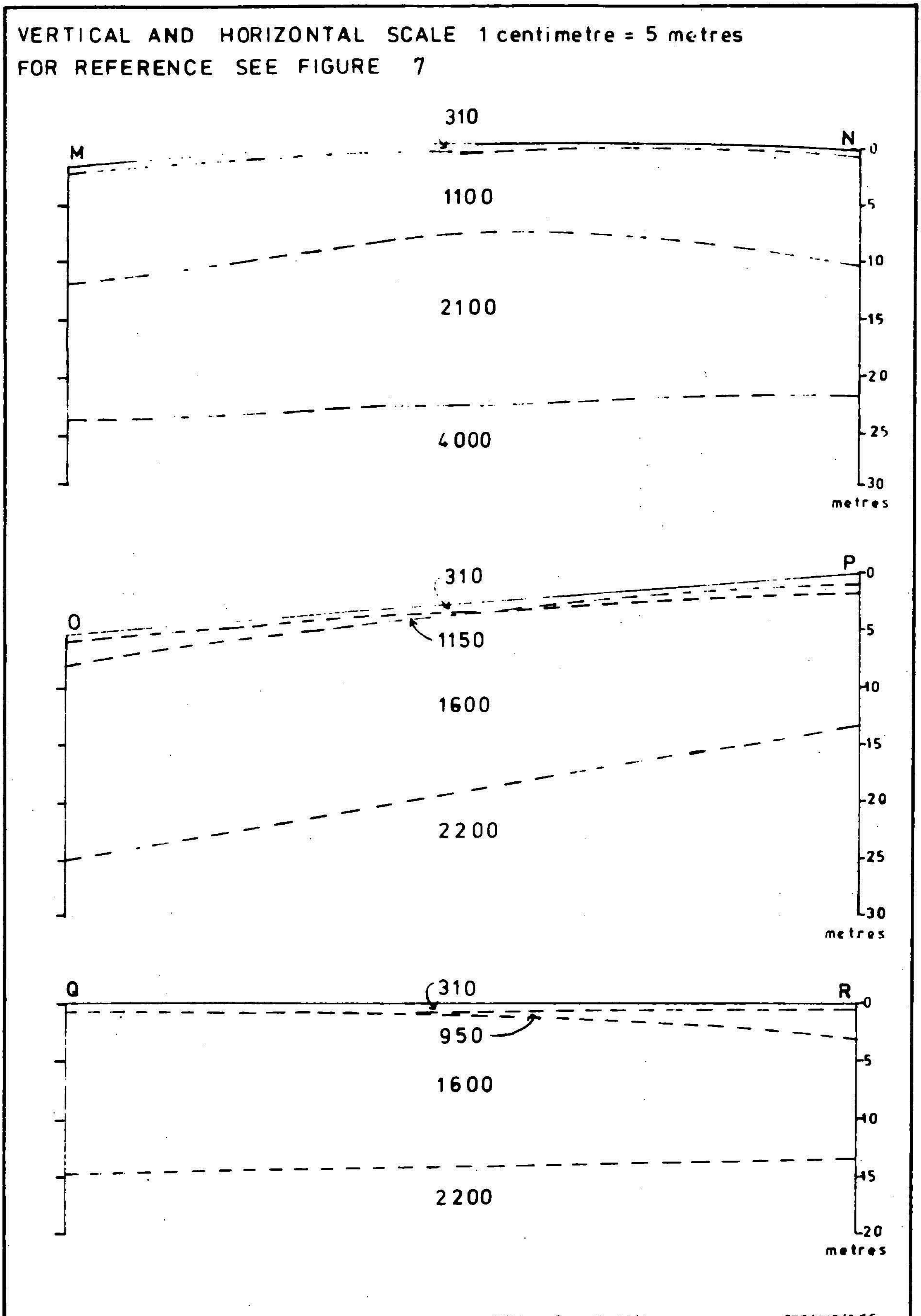
VERTICAL AND HORIZONTAL SCALE 1 centimetre = 5 metres

FOR REFERENCE SEE FIGURE 7



To accompany Record 1972/73   After survey by Hill & Pettifer.   E5/A16/855

SEISMIC CROSS SECTIONS M-N, O-P, AND Q-R. FIGURE 6



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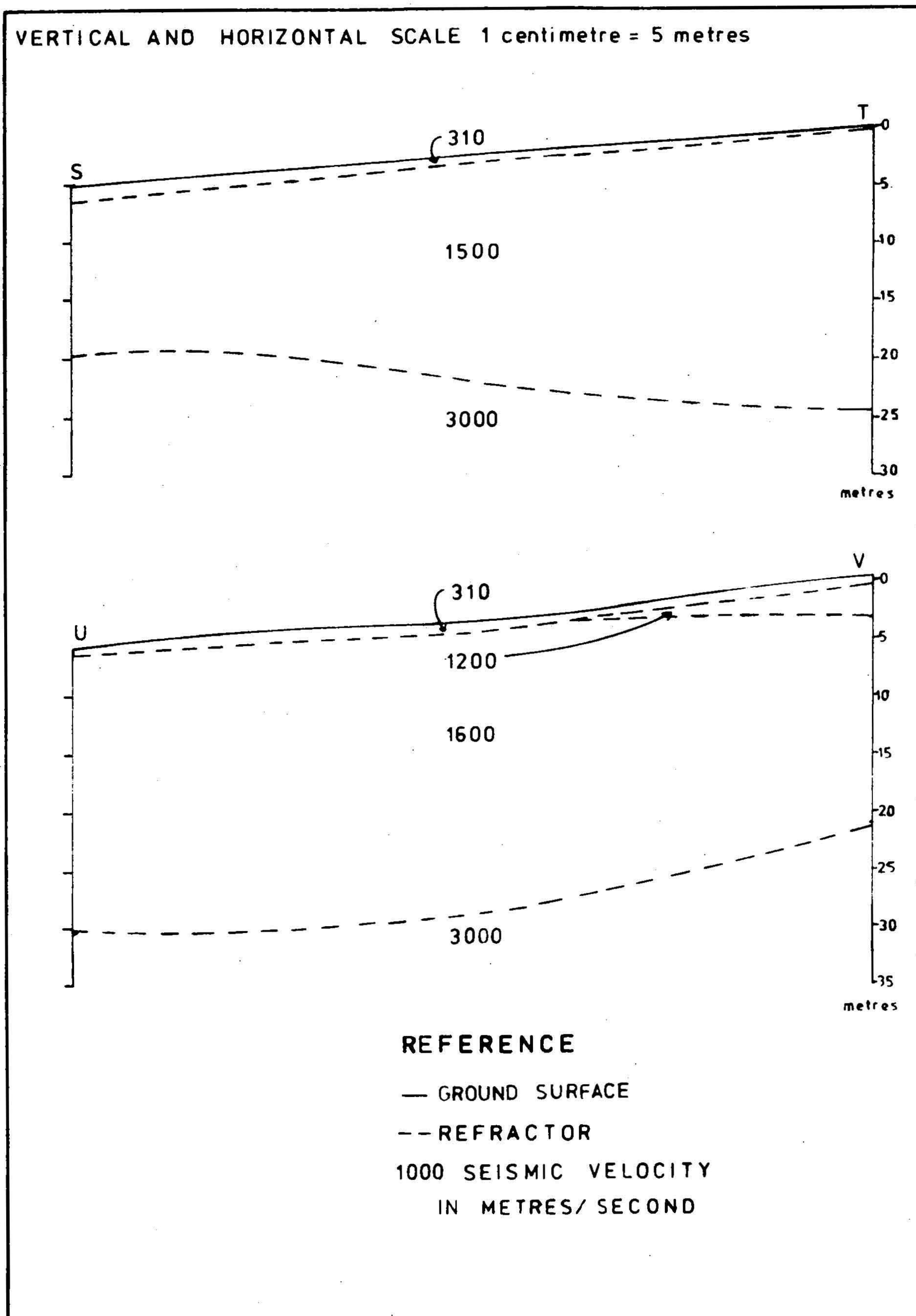
SEISMIC CROSS SECTIONS S-T AND U-V

FIGURE 7



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freeway 1400 m/s is probably the ripping limit where they occur (Bartlett, 1971).

6. SOILS

6.1 General

The area traversed by Stage 2 of the proposed Tuggeranong Freeway is underlain by a large number of different soil layers. The upper layers of most profiles consist of an organic topsoil underlain by a leached sand-silt subsoil. Beneath these soils one or more clay layers may occur. Clay layers are usually thicker on gentle (2 - 3°) slopes and thinner or absent on moderate (3 - 6°) slopes.

Other soils that occur are creek-deposited alluvium, residual ironstone gravels, slopewash off Mount Taylor, and residual completely weathered volcanic rhyodacite.

6.2 Detailed Mapping

No previous soil mapping has been undertaken by BMR in this area, and no other detailed soil mapping is known to the authors. Wilson investigated the soils on the eastern slopes of Mount Taylor (Wilson, 1963).

Soils were given a provisional unified soil classification (Fig. 9) in the field. Colour was assigned to each soil in its moist state according to the Munsell notation. Where soils were mottled the dominant colour was recorded. Field samples were sealed, transported to the laboratory, and a field moisture content* determination was performed on each sample.

6.3 Soil Testing, Results, and Classification

When field work was completed all samples were grouped; samples representative of each group were tested for particle size analysis and plasticity in accordance with Australian Standard A89-1966. Assessed California Bearing Ratio (CBR) of each sample was calculated from particle size, plasticity, and linear shrinkage data by using three equations included in Appendix 7(a).

Modified compaction and experimental CBR tests were performed on untreated field test pit samples (location shown in Fig. 8). Where the durability of mineral grains was in doubt and breaking up of grains under compaction was evident in a sample, particle-size analyses and plasticity determinations were performed on the compacted sample. Compacted samples were recycled until the particle-size distribution and plasticity became constant. Assessed CBR's on these samples fell on compaction.

Detailed results of mechanical gradings, plasticities, and assessed CBR's on samples tested are given in Appendix 4. Experimental CBR and modified compaction results of samples tested are given in Appendix 5.

* Note: Winter of 1971 had well below average rainfall.

Grading and plasticity results of samples that broke down on compaction are given in Appendix 6, which shows how the grading curves for each sample change in relation to its ideal grading curve. Ideal grading curves for all samples were calculated using the Talbot equation, details of which are given in Appendix 7(b).

Auger drilling and excavation of test pits (Fig. 8), classification, and selected testing of samples defined 16 distinct soil units.

6.4 Soil Units

The 16 soil units that occur along this section of the freeway are listed in Table 5.

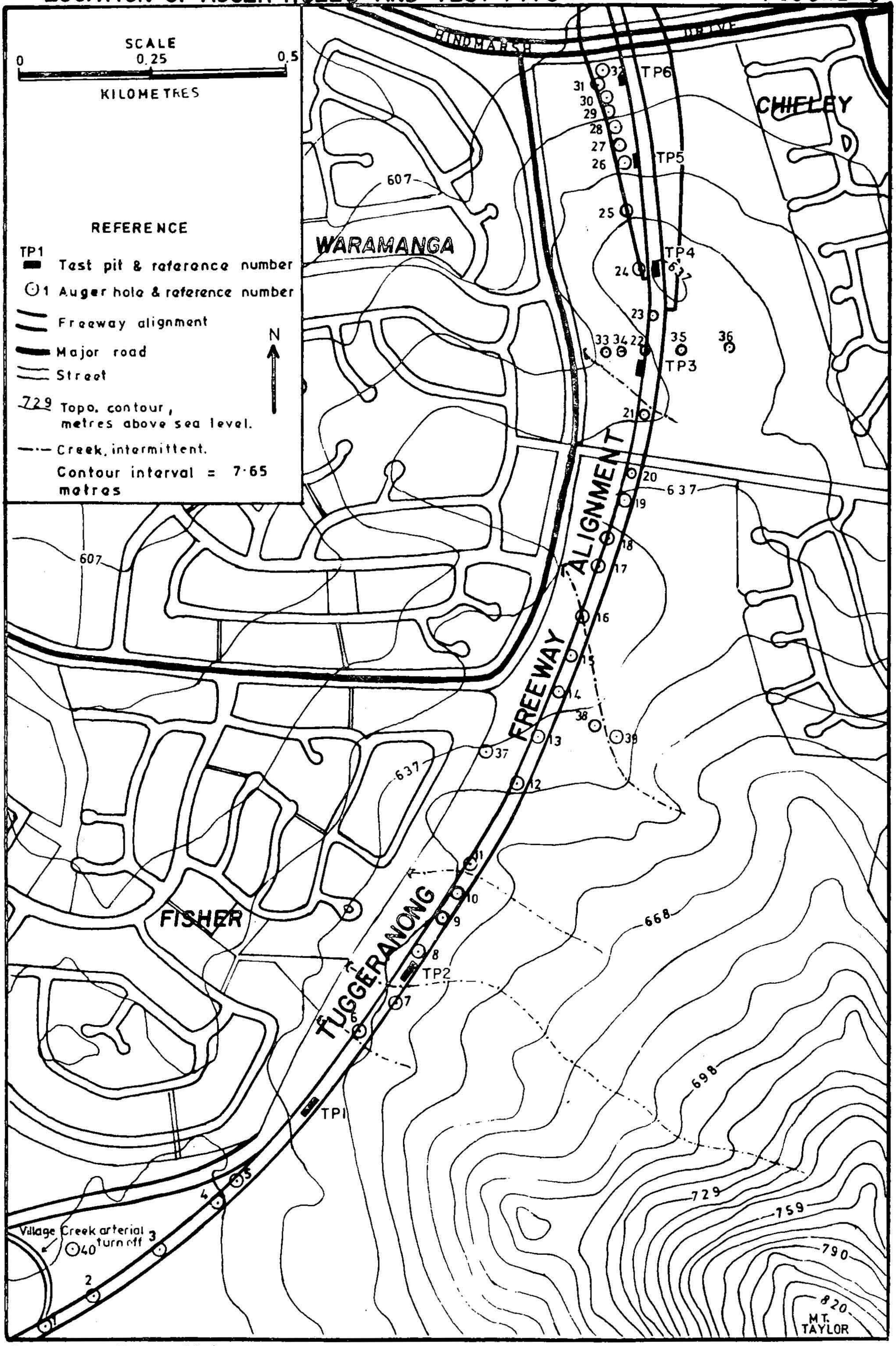
Table 5

Soil Units along the Freeway

Number	Soil description
Unit 1	Sands and silts containing various amounts of organic matter.
Unit 2	Pinkish grey to brown sandy and fine gravelly silts, clayey silts and sands of low plasticity.
Unit 3	Pinkish grey to brown silty ironstone gravels.
Unit 4	Yellowish brown clayey ironstone gravels.
Unit 5	Pinkish grey indurated slopewash of low plasticity.
Unit 6	Brown clayey indurated slopewash.
Unit 7	Interstratified sand and silt.
Unit 8	Completely weathered volcanic rock.
Unit 9	Grey clayey sand.
Unit 10	Red clayey sand.
Unit 11	Red friable sandy clay.
Unit 12	Red heavy sandy clay.
Unit 13	Red to mottled red and yellow silty and lean clays.
Unit 14	Mottled grey and yellowish red clays of high plasticity.
Unit 15	Mottled red, grey, and yellow heavy clay.
Unit 16	Massive olive fat clay.

The distribution of soil units beneath the freeway is shown on Plate 1. Units are numbered 1 to 16 and each is described as follows:

LOCATION OF AUGER HOLES AND TEST PITS FIGURE 8



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UNIFIED SOIL CLASSIFICATION SYSTEM

FIGURE 9

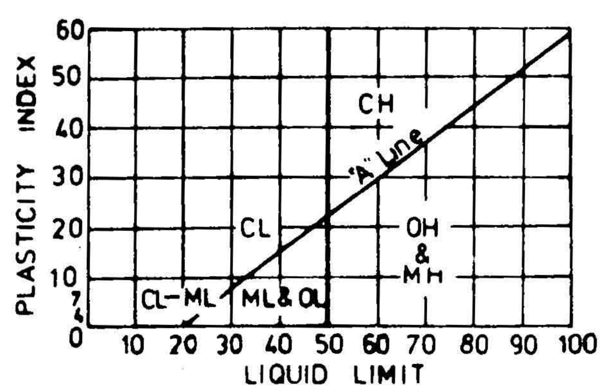
MAJOR DIVISIONS		SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS (More than 1/2 of soil > No 200 sieve size)	GRAVELS. (More than 1/2 of coarse fraction > no.4 U.S. sieve size)	GW	Well graded gravels or gravel-sand mixtures, little or no fines*
		GP	Poorly graded gravels or gravel sand mixtures, little or no fines
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (More than 1/2 of coarse fraction < no. 4 U.S. sieve size)	SW	Well graded sands or gravelly sands, little or no fines
		SP	Poorly graded sands or gravelly sand, little or no fines
		SM	Silty sands, sand silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS (More than 1/2 of soil < No 200 sieve size)	SILTS & CLAYS Liquid Limit < 50	ML	Inorganic silt and very fine sands, rock flour, silty or clayey fine sands or clayey silts with low plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
	SILTS & CLAYS Liquid Limit > 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silty clays, organic silts
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils

CLASSIFICATION CHART
(Unified Soil Classification System)

* fines - portion of a soil finer than a no. 200 sieve

CLASSIFICATION	RANGE OF GRAIN SIZES	
	U S Standard Sieve Size	Grain Size in millimeters
BOULDERS	Above 12"	Above 305
COBBLES	12" to 3"	305 to 76·2
GRAVEL	3" to No. 4	76·2 to 4·76
coarse	3" to 3/4"	76·2 to 19·1
fine	3/4" to No. 4	19·1 to 4·76
SAND	No 4 to No 200	4·76 to 0·074
coarse	No 4 to No 10	4·76 to 2·00
medium	No 10 to No 40	2·00 to 0·420
fine	No 40 to No 200	0·420 to 0·074
SILT & CLAY	Below No 200	Below 0·074

GRAIN SIZE CHART



PLASTICITY CHART
(adapted from various sources)

UNIT 1: Sands and silts containing various amounts of organic matter (topsoil).

Unified classification: Organic silts (OL)

Occurrence: The uppermost soil layer along the entire length of the alignment except where removed by erosion between chainages 15 510 to 15 970 m. It is normally 0.1 - 0.2 m thick.

Comments: Unsuitable for use as fill material but could be used for landscape topdressing.

UNIT 2: Pinkish grey to brown sandy and fine gravelly silts; clayey silts and fine sands of low plasticity.

Unified classification: Inorganic silt of low plasticity (ML)

Occurrence:**

Chainage	Thickness (m)	Depth below ground surface (m)
13 590 - 14 500	0.1 - 0.5	0.1 - 0.2
14 640 - 15 210	0.2 - 0.5	0.1 - 0.2
15 300 - 15 510	0.1 - 0.5	0.1 - 0.2
16 050 - 16 310	0.1 - 0.6	1.8 - 1.9

Field characteristics: Close to the surface this soil is hard except where disturbed. Where more deeply buried (between chainages 16 050 - 16 310) it is soft and wet or very moist.

Comments: This soil represents a strongly leached zone in the soil profile.

UNIT 3: Pinkish grey to brown ironstone gravels.

Unified classification: Silty gravel (GM)

Occurrence:

Chainage	Thickness (m)	Depth below ground surface (m)
14 500 - 14 640	0.2 - 0.3	0.1 - 0.2
14 820 - 14 950	0.1 - 0.5	0.4 - 0.7
15 140 - 15 300	0.1 - 0.6	0.1 - 0.6

Field characteristics: Very hard in situ especially when dry; consists of ferruginous concretions up to .02 m diameter embedded in a matrix of fine sand

** Note: the data given in the tables under Occurrence are interpretive and based on the limited augering: they should be treated with due caution.

and silt. Shows a significant loss of strength once its structure is disturbed.

Parameters:

Lower liquid limit	25%
Plasticity index	9%
Linear shrinkage	5%
Assessed CBR	22%

Comments: This soil is poorly graded as it contains low percentage of medium and coarse sand fractions (Appendix 4). The high silt fraction is responsible for a rapid strength decrease once the optimum moisture content is exceeded. Close moisture control will be necessary when these ironstone gravels are being compacted.

UNIT 4: Yellowish brown clayey ironstone gravel.

Unified classification: Clayey gravel (GC)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
14 190 (Cross-section I - J)	0.1 - 0.6	0.3 - 0.7
14 870 (Cross-section E - F)	0.4 - 0.5	0.3 - 0.5

Field characteristics: The soil consists of concretionary ironstone nodules up to .02 m diameter embedded in a silt and clay matrix. It is not well graded as there is a lack of sand size fractions.

Comments: Soil west of chainage 14 190 may have formed from alluvium whereas that west of 14 870 probably had a colluvial origin.

UNIT 5: Pinkish grey indurated slopewash of low plasticity.

Unified classification: Silty sand (SM)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
14 620 - 15 130	0.2 - 1.6	0.3 - 1.5
15 250 - 16 080	0.3 - 4.2	0 - 1.0
16 050 - 16 200	0.1 - 1.0	1.8 - 3.0
16 200 - 16 330	0.2 - 0.8	0.8 - 1.6

Field characteristics: The soil is hard, porous, and permeable in situ and consists of cemented quartz and feldspar sand and silt size grains. Slopewash between 15 550 and 16 000 contains weathered boulders, and cobbles up to 0.5 m in diameter; this material could be not penetrated with the auger.

Parameters:		
	Lower liquid limit	19 - 28%
	Plasticity index	5 - 12%
	Linear shrinkage	2 - 6%
	Assessed CBR	20 - 25%
	Experimental CBR	43 - 173%

Comments: When disturbed the slopewash breaks down to small porous aggregates which are unstable in water; on compaction slopewash forms a tight interlocking mass which is very elastic. There is a small increase in the silt-size fraction on remoulding; this rapidly decreases the strength of the slopewash once the optimum moisture content is exceeded. Close supervision of field moisture content is necessary to achieve good compaction.

UNIT 6: Brown clayey indurated slopewash.

Unified classification: Clayey sands (SC)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 640 - 13 700	0.1 - 0.7	0.3 - 0.7
13 680 - 13 810	0.1 - 1.3	1.0 - 2.3
14 050 - 14 180	0.1 - 0.7	0.7 - 1.2
14 190 - 14 290	0.3 - 0.5	0.3 - 0.6
14 580 - 14 780	0.2 - 1.2	2.5 - 2.8
14 770 - 14 860	0.1 - 0.3	2.3 - 2.5
15 920 - 16 290	0.1 - 2.4	0.3 - 0.7

Field characteristics: This slopewash is relatively hard and porous in situ. It consists of quartz and feldspar sand and silt-size particles cemented by silica and clay. Feldspar has undergone extensive weathering to clay which lowers the strength of this slopewash considerably.

Parameters:		
	Lower liquid limit	30 - 36%
	Plasticity index	13 - 19%
	Linear shrinkage	6 - 10%
	Assessed CBR	14 - 15%

Comments: Should be rippable and will compact well.

UNIT 7: Interstratified sand and silt (alluvium).

Unified classification: Inorganic silt and fine sands of low plasticity (ML)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
14 730 - 14 860	0.1 - 0.3	1.6 - 2.7

Field characteristics: Alluvium consists of alternate sand and silt layers each about 0.02 m thick. They are very soft; when examined in the field sand layers were wet and silt layers moist.

Comments: The alluvium is a good aquifer and drains groundwater from upslope.

UNIT 8: Completely weathered rhyodacite.

Unified classification: clayey sands (SC)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
11 590 - 15 240	1.3 - 4.9	0.8 - 3.1
16 070 - 16 340	0.1 - 5.5	1.2 - 3.3

Field characteristics: Completely weathered rhyodacite is capped by an indurated ferruginous crust up to 0.10 m thick; underlying material is normally soft and shows an increase in grain size and a decrease in plasticity with increasing depth. Three sub-units of the completely weathered rhyodacite can be distinguished on the basis of colour and other field properties; they are:

Sub-unit 8A : Purple completely weathered rhyodacite.
Sub-unit 8B : Reddish, yellowish, and greyish brown completely weathered rhyodacite.
Sub-unit 8C : Greenish yellow completely weathered rhyodacite.

Parameters:

Lower liquid limit	28 - 36%
Plasticity index	10 - 18%
Linear shrinkage	6 - 10%
Assessed CBR	20 - 23%
Experimental CBR	23 - 30%

Comments: Sub-unit 8A has a higher strength than sub-unit 8B which is stronger than Sub-unit 8C. Residual strength is derived from quartz, feldspar, and mica; however, only quartz does not break down easily under pressure. The change of index properties for each sub-unit after compaction is shown in Appendix 6. The approximate percentage breakdown of sand-sized mineral grains to silt and clay-size fractions is estimated to be:

Sub-unit 8A	30%
Sub-unit 8B	50%
Sub-unit 8C	100%

UNIT 9: Grey clayey sand.

Unified classification: Clayey sands (SC)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
14 280 - 14 500	01 - 0.3	1.0 - 1.9

Field characteristics: This grey clayey sand is quite permeable in situ and has formed in place from completely weathered rhyodacite. Colour is due to the reduction of ferric ions in the clay.

Parameters:

Lower liquid limit	46 - 53%
Plasticity index	26 - 35%
Linear shrinkage	10 - 12%
Assessed CBR	12 - 14%

UNIT 10: Red clayey sand.

Unified classification: Clayey sand (SC)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 760 - 13 870	0.1 - 0.7	0.2 - 0.3
14 030 - 14 140	0.1 - 0.5	0.3 - 0.4

Field characteristics: This clayey sand is made up of sand-size quartz and weathered rock grains in a lean clay binder.

Parameters:

Lower liquid limit	29%
Plasticity index	13%
Linear shrinkage	6%
Assessed CBR	19%
Experiment CBR	17%

Comments: Compaction of this soil will break down the weathered rock grains to silt and clay-size particles (Appendix 6) but good compaction should be achieved especially if the field moisture content is slightly above the optimum.

UNIT 11: Red friable sandy clay.

Unified classification: Clayey sand (SC)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 850 - 13 970	0.1 - 0.6	0.3 - 0.4

Field characteristics: This soil consists of sand-size quartz and weathered rock grains in a stiff red clay binder.

Parameters:

Lower liquid limit	44%
Plasticity index	25%
Linear shrinkage	11%
Assessed CBR	15%

Comments: Compaction of this soil breaks down the weathered rock grains to silt and clay-size particles (Appendix 6) but good compaction can be achieved over a large range of field moisture contents.

UNIT 12: Red heavy sandy clay.

Unified classification: Clayey sand (SC)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 930 - 14 050	0.1 - 0.6	0.3 - 1.0

Field characteristics: This soil consists of sand-size quartz and weathered rock grains in a heavy red clay binder.

Parameters:

Lower liquid limit	54%
Plasticity index	34%
Linear shrinkage	12%
Assessed CBR	10%
Experimental CBR	10%

Comments: Compaction of this soil will break down the weathered rock grains to clay and silt-size particles (Appendix 6) but good compaction can be achieved provided the optimum moisture content is not greatly exceeded. The workability and strength of this soil can be improved by stabilization.

UNIT 13: Red to mottled red and yellow, silty and lean clays.

Unified classification: Inorganic clays of low to medium plasticity (CL)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 710 - 13 770	0.1 - 0.3	0.2 - 0.3
14 440 - 14 500	0.1 - 0.3	0.1 - 0.2
14 530 - 14 850	0.1 - 0.7	0.5 - 1.0
14 940 - 15 000	0.1 - 0.2	1.6 - 2.1
16 090 - 16 340	0.1 - 0.5	0.2 - 0.3

Field characteristics: Soft and friable over a wide range of moisture contents.

Parameters:

Lower liquid limit	40 - 50%
Plasticity index	25 - 30%
Linear shrinkage	11 - 13%
Assessed CBR	7 - 10%

UNIT 14: Mottled grey and yellowish red clays of high plasticity.

Unified classification: Inorganic clay of high plasticity, (CH)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 640 - 13 800	0.1 - 0.3	0.4 - 1.7
14 140 - 14 220	0.1 - 0.3	0.2 - 0.3
14 280 - 14 410	0.1 - 0.3	0.2 - 0.4
14 480 - 14 690	0.1 - 0.3	0.3 - 0.4
14 940 - 15 000	0.1 - 0.2	0.7 - 1.0
16 280 - 16 340	0.1 - 0.2	0.1

Field characteristics: This soil consists of soft, crumbly red ironstone nodules up to 0.01 m in diameter set in a matrix of yellowish-brown clay. It has a friable consistency in dry and moist conditions but tends to pug when the moisture content exceeds the lower plastic limit.

Parameters:

Lower liquid limit	55 - 70%
Plasticity index	35 - 45%
Linear shrinkage	13 - 17%
Assessed CBR	5, 6, and 7%

Comments: Compaction of this soil breaks down the sand-size ironstone grains to silt-size particles. Maximum compaction will be obtained below the optimum field moisture. This highly plastic clay can be stabilised to improve its strength.

UNIT 15: Mottled red, grey, and yellow heavy clay.

Unified classification: Inorganic clays at high plasticity (CH)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 580 - 13 670	0.1 - 0.7	0.2 - 1.5
14 270 - 14 500	0.30 - 0.46	0.46

Field characteristics: This heavy clay has a massive structure and a high water absorbtive capacity; it is very hard when dry and very puggy when the field moisture content exceeds the lower plastic limit.

Parameters:

Lower liquid limit	65 - 75%
Plasticity index	40 - 50%
Linear shrinkage	15 - 18%
Assessed CBR	3 and 4%
Experimental CBR	4%

Comments: The potential swell and compressibility of this clay is high; the bearing strength is low; it is not suitable for use as subgrade material immediately below the freeway though it could probably be used in some fills. This clay should be stabilized or removed.

UNIT 16: Massive olive fat clay.

Unified classification: Fat clay (CH)

Occurrence:

Chainage (m)	Thickness (m)	Depth below ground surface (m)
13 580 - 13 680	0.1 - 1.3	1.1 - 2.1
14 120 - 14 450	0.1 - 1.0	0.5 - 0.7
14 500 - 15 030	0.1 - 1.5	0.8 - 2.8
14 700 - 14 790	0.1 - 0.7	0.2 - 1.0
14 930 - 15 030	0.1 - 0.6	0.3 - 1.0

Occurrence:
(Cont'd)

Chainage (m)	Thickness (m)	Depth below ground surface (m)
15 370 - 15 530	0.1 - 0.3	0.4 - 0.8
15 430 - 15 500	0.1 - 0.2	1.1 - 1.5
15 550 - 15 810	0.1 - 0.2	0.5 - 0.8
15 550 - 15 810	0.1 - 0.2	1.0 - 1.5
16 100 - 16 270	0.1 - 0.2	1.2 - 1.3
16 100 - 16 270	0.1 - 0.3	2.1 - 2.2

Field characteristics: The colour of this clay varies from light olive grey to light olive brown; it has a high capacity to absorb water, is very hard when dry, and is very puggy when the field moisture content exceeds the lower plastic limit.

Parameters:

Lower liquid limit	70 - 90%
Plasticity index	50 - 65%
Linear shrinkage	15 - 20%
Assessed CBR	2 and 3%
Experimental CBR	5%

Comments: The potential swell and compressibility of this clay is high and the bearing strength low; therefore it would not be suitable for use as subgrade immediately below the freeway. It should be stabilized or removed.

7. ENGINEERING ASPECTS

7.1 Water

7.11 Surface water run-off from the area was originally by five tributaries of Weston Creek, designated A, B, C, D, and E on Figure 10. At present a stormwater drainage channel, excavated above the suburb of Fisher, diverts the flow of water from creeks D and E southwards into the Village Creek catchment. This presumably prevents large volumes of fast-flowing water, carried by the creeks after heavy rain on the western slopes of Mount Taylor, from spilling onto residential areas.

The stormwater drain that diverts creeks D and E southwards increases the recharge onto this part of the Village Creek catchment. Natural drainage after heavy rain is inadequate to remove the recharge and has resulted in large areas of boggy ground developing below the stormwater discharge point (see Fig. 10). The boggy ground and stormwater channel both lie in the path of the freeway; therefore the stromwater channel will have to be moved and redesigned before freeway construction begins.

Surface water should not present any problems in cuts along the freeway if normal drainage provisions are made.

The road cut down to the level of creek C through moderately weathered volcanic rock will require the underpassing or diversion of the creek. The existing stormwater drainage intake for this creek appears to be inadequate so it may be more practical to divert this creek into the stormwater channel that will drain creeks D and E.

7.12 Groundwater seepage occurs through alluvium beneath the freeway alignment adjacent to creek B (Figure 10). The flow of water in the alluvium is maintained after heavy rain by creek B, which is fed for most of the year by groundwater flowing through the zone of near-surface weathered rock. The groundwater seeps into the creek through a major linear structure that is oriented parallel to the creek. Construction of the freeway over, and the subsequent loading of, the alluvium will impede groundwater flow and could result in springs appearing on the upstream side of the freeway. Drains upstream of the alluvium (Fig. 10) would prevent groundwater problems from occurring. As surface water, soil water, and groundwater are all inter-related a change of one will necessarily bring about a change of the others.

It is not expected that seepage will present difficulties where cuts are to be made. The sides of excavations should not be undercut by seepage as the lower part of each cut is in moderately weathered or highly weathered rhyodacite. A few initial drill holes in areas where cuts are to be made would enable the Bureau to assess possible water flow.

7.2 <u>Excavation</u>

7.21 The upper part of the completely weathered volcanic rock (generally about 0.1 m thick) has been cemented and is in most places hard. It may be difficult to rip this upper part but, once removed, the remaining completely weathered rock is generally softer.

7.22 Completely weathered volcanic rock is difficult to excavate in cuts where large boulders of fresh or slightly weathered rock are present in appreciable numbers.

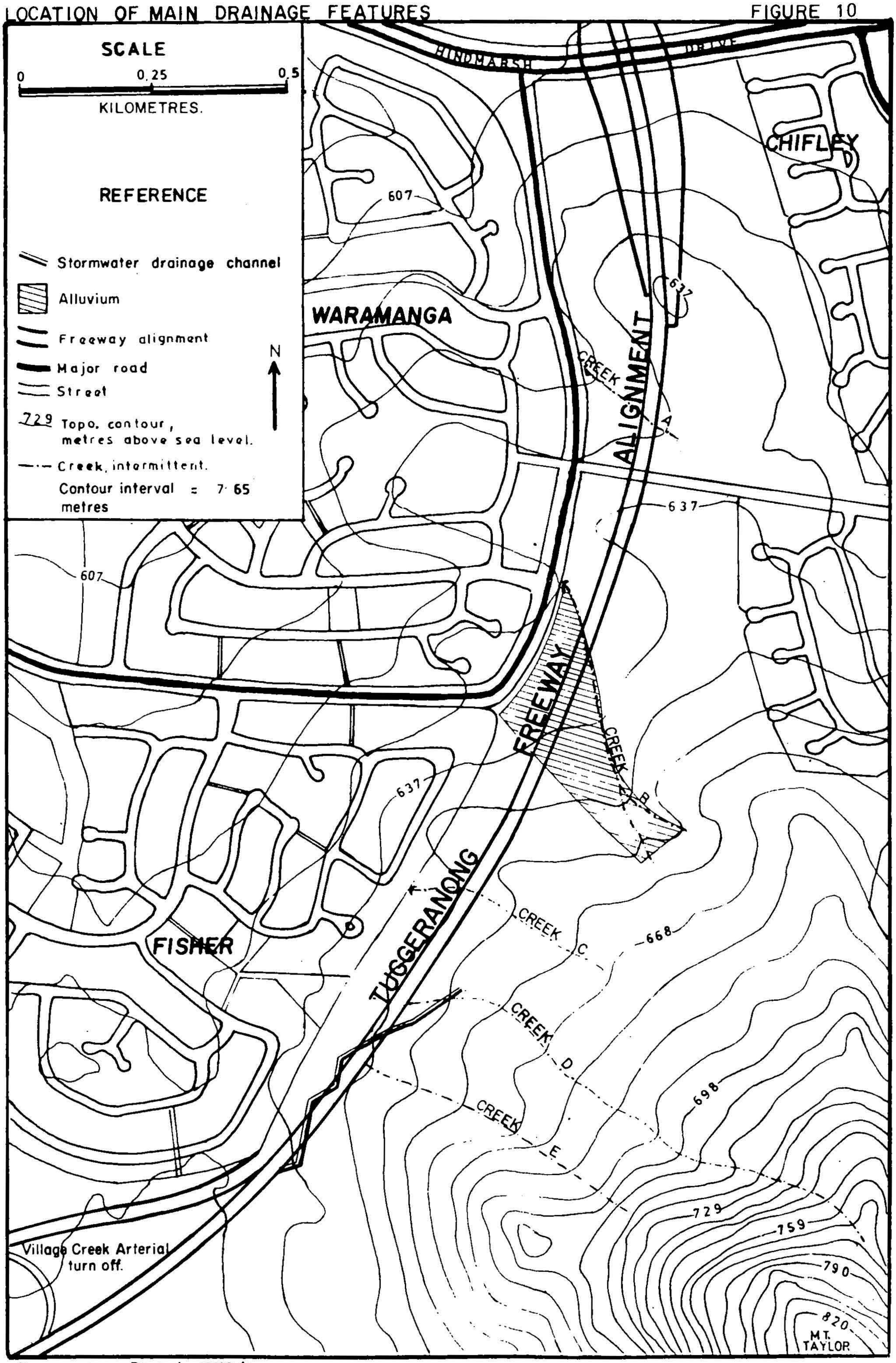
7.23 Indurated slopewash could be ripped by heavy ripping equipment such as a D8/D9 or tractor fitted with hydraulic rippers. The thickness of indurated slopewash is variable and the boundary between it and highly weathered volcanic rock is irregular. Highly weathered volcanic rock normally needs light blasting before it can be moved.

7.24 Stability of weathered rhyodacite in cuts depends primarily on joint orientation; once excavation of cuts beings, rock jointing could be examined by Bureau geologists and a stability assessment made.

TUGGERANONG FREEWAY, II.

LOCATION OF MAIN DRAINAGE FEATURES

FIGURE 10



To accompany Record 1972/73

Drawing No 155/A16/882

8. CONCLUSIONS

1. Two distinct soil mantles occur along the route of the proposed freeway.

2. The area traversed forms a pediment of diverse soils between the Canberra-Yass and Yarralumla landsurfaces.

3. Two rhyodacites were mapped; purple spherulitic rhyodacite appears to be more susceptible to weathering than blue-grey rhyodacite.

4. Rock joint orientations determine cut stability; air-photographs indicate three joint sets at about 045°, 095° and 150°; a visit by Bureau officers to examine stability should be made soon after excavation begins.

5. Excavation in completely weathered volcanic rock will be difficult where appreciable numbers of slightly weathered boulders occur as floaters.

6. Seismic refraction surveys indicate that most cuts will be through soil and underlying moderately or highly weathered rhyodacite.

7. Tests carried out by BMR indicate that the 16 soil units mapped are nearly all usable for fill or subgrade; heavy fat clays close to the finished surface level of the freeway will have to be removed or stabilized.

8. Drainage of creeks, C, D, and E (Fig. 10) will need to be redesigned; the present stormwater drain will need to be relocated.

9. Seepage into and undermining of cuts should not be a problem; several initial drill holes where cuts are to be made would enable BMR geologists to assess possible water flow.

10. Seepage through alluvium adjacent to Creek B (Fig. 10) should decrease if the flow of water from the creek is drained off above the aquifer.

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APPENDIX 1

WEATHERING - DEFINITION OF TERMS

FRESH	Rock shows no discolouration or loss of strength.
SLIGHTLY WEATHERED:	Rock is slightly discoloured but not noticeably weakened; a two-inch diameter drill core cannot usually be broken by hand across the rock fabric.
MODERATELY WEATHERED:	Rock is discoloured and noticeably weakened, but a two inch drill core cannot usually be broken by hand across the rock fabric; ripping by bulldozer not possible.
HIGHLY WEATHERED:	Rock is usually discoloured and weakened to such an extent that a two-inch drill core can be broken by hand across the rock fabric. Wet strength generally lower than dry strength; ripping with bulldozer may be possible along joint planes.
COMPLETELY WEATHERED:	Rock is discoloured and entirely broken down to an aggregate of particles that has the mechanical property of a soil; the original fabric of the rock is mostly preserved. The properties of the soil depend on the composition of the parent rock; easily ripped by a bulldozer.

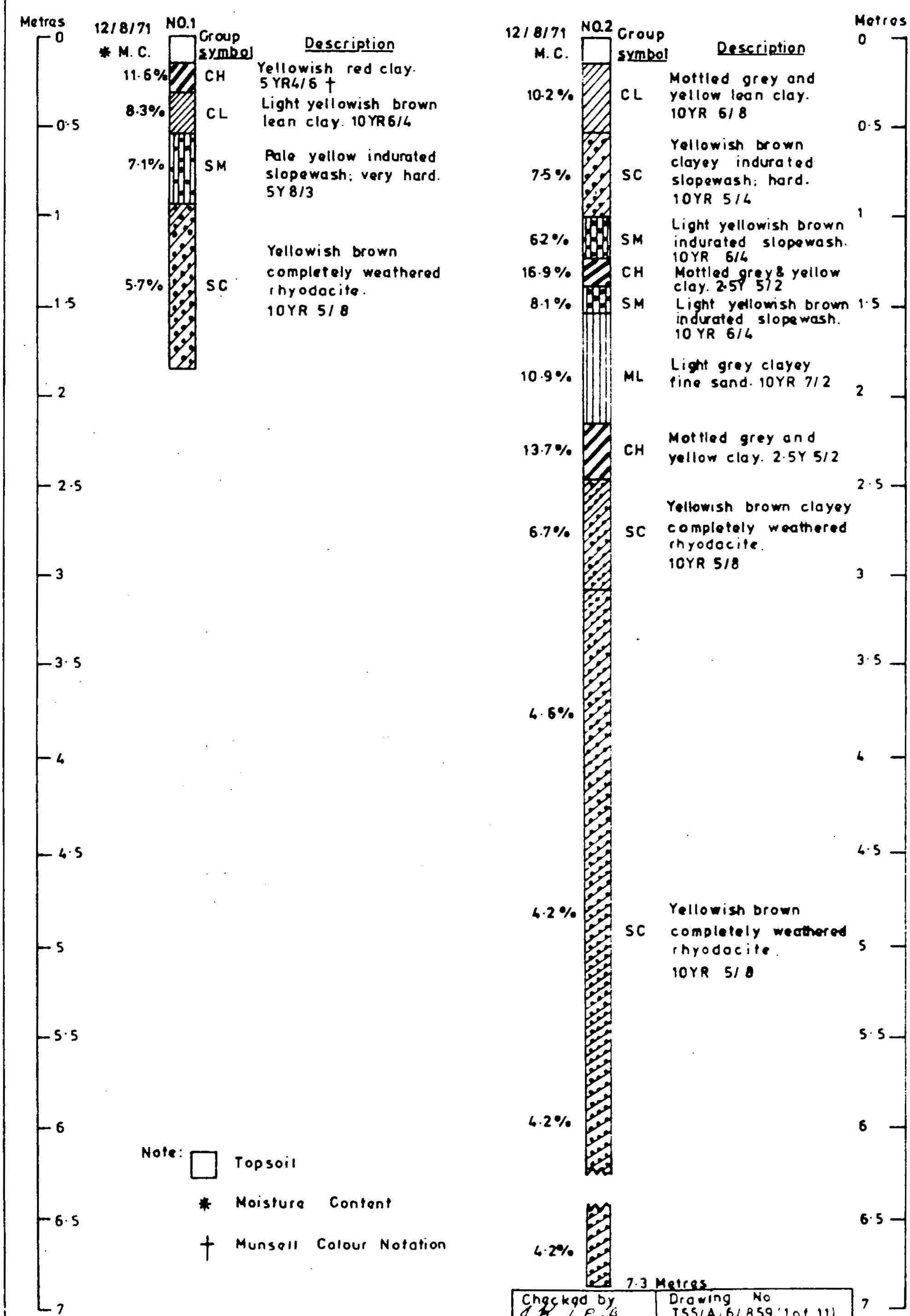
APPENDIX 2

GLOSSARY OF SELECTED GEOLOGICAL TERMS

ACICULAR:	Needle-shaped.
ALKALIC:	Containing ions of one or more alkali metals.
APHANITIC:	A crystalline texture too finely grained to be distinguished by the unaided eye.
CRYPTOCRYSTALLINE:	Crystalline, but so finely grained that individual component crystals cannot be resolved under a microscope.
DACITE:	The aphanitic or glassy equivalent of a granodiorite; that is, a rock consisting essentially of plagioclase, quartz, pyroxene or hornblende or both.
GROUNDMASS:	Material between phenocrysts in a porphyritic igneous rock.
MATRIX:	The groundmass of a porphyritic irngeous rock.
PHENOCRYST:	Large conspicuous crystal of earliest generation in a porphyritic igneous rock.
PORPHYRITIC:	Large crystals set in a finer groundmass which may be crystalline or glassy, or both.
RHYODACITE:	The aphanitic or glassy equivalent of an adamellite; that is, a rock consisting essentially of plagioclase, orthoclase, quartz, and biotite. The proportion of orthoclase to plagioclase feldspar is greater than 1:1.
RHYOLITE:	The aphanitic or glassy equivalent of a granite; that is, a rock consisting essentially of alkalic feldspar and quartz.
SPHERULE:	Radial aggregate of acicular crystals.
SPHERULITIC:	Containing spherules (which see).
TOSCANITE:	A rock of rhyodacitic composition in which the plagioclase feldspar is labradorite.
TUFF:	A rock made of compacted volcanic fragments.
WELDED TUFF:	A tuff indurated by residual heat.

APPENDIX 3

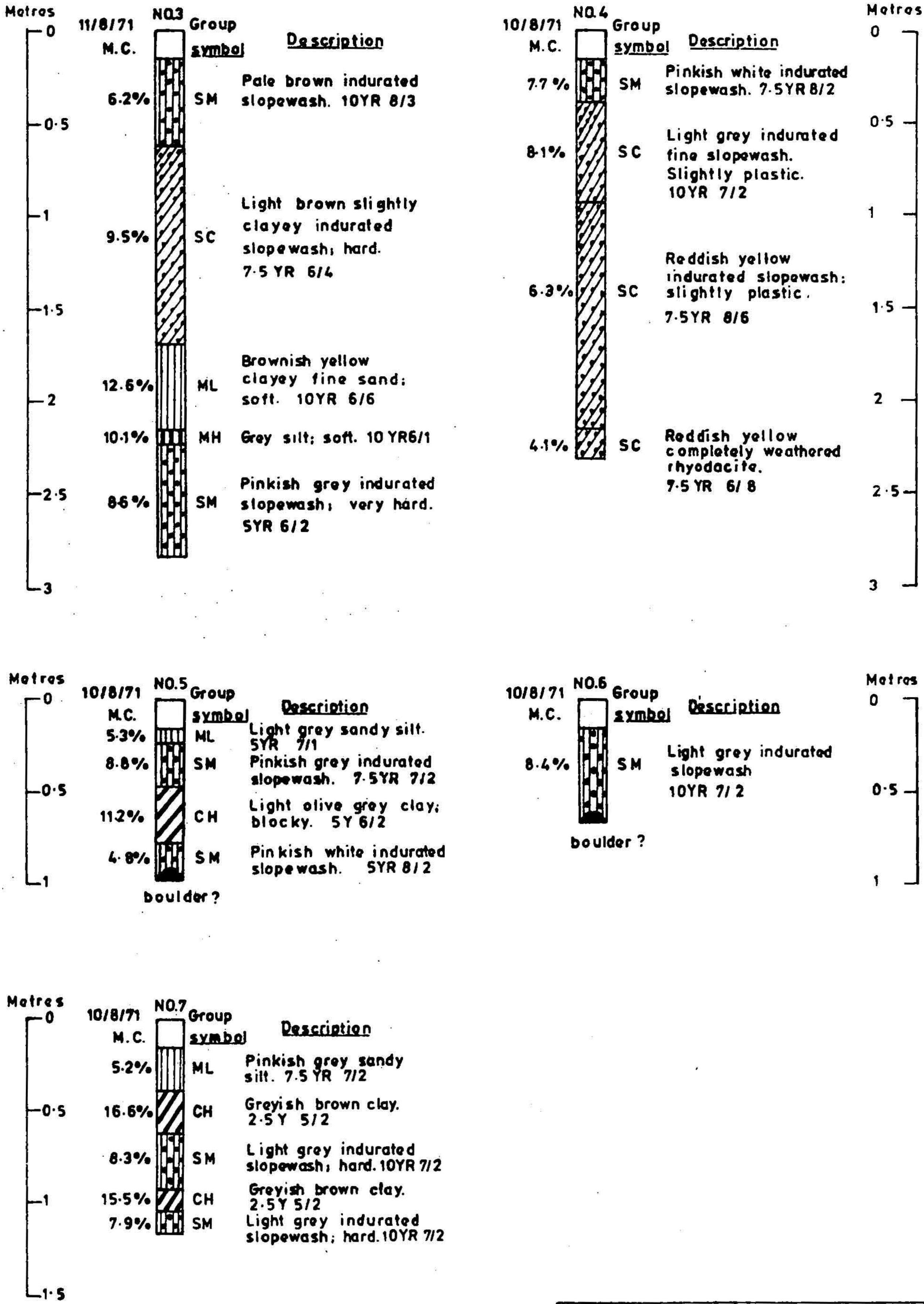
VERTICAL SECTION OF AUGER HOLES 1 AND 2



To accompany Record 1972/73

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 3,4,5,6 AND 7



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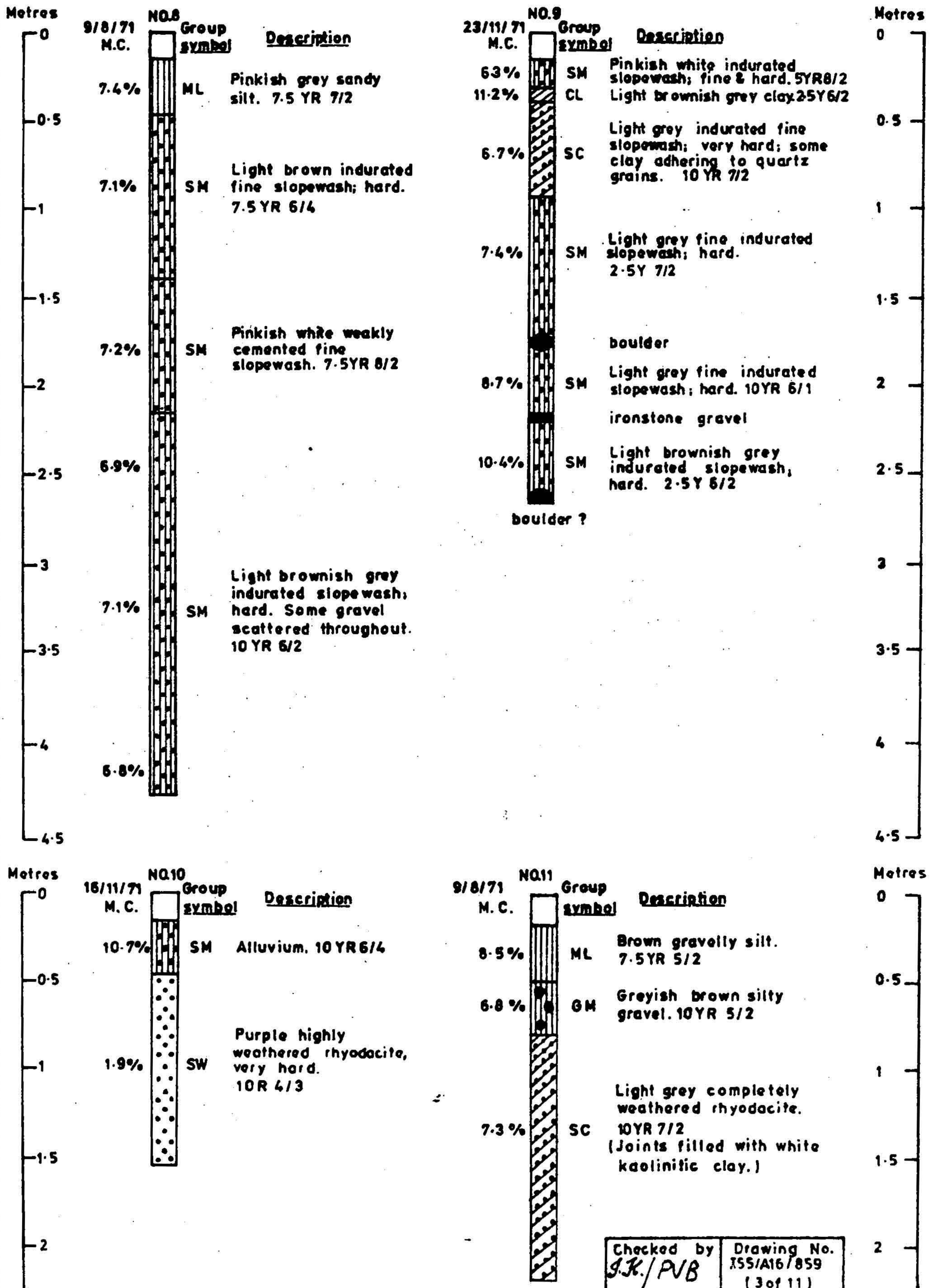
To accompany Record 1972/73

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 8, 9, 10 AND 11



To accompany Record 1972/73

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 12, 13 AND 14

NO.12 (9/8/71)

Metres: 0 – 2

M. C.	Group symbol	Description
7·4%	ML	Pinkish grey sandy silt. 7·5 YR 6/2
	CL	Red clay
8·6%	SM	Pinkish grey weakly cemented slopewash. 5YR 6/2
9·9%	SC	Yellowish red clayey completely weathered rhyodacite. 5YR 5/8
18·9%	CH	Olive clay. 2·5Y 5/4
8·1%	SC	Reddish yellow completely weathered rhyodacite. 7·5 YR 6/8

NO.13 (23/7/71)

Metres: 0 – 2

M. C.	Group symbol	Description
7·1%	ML	Pinkish grey sandy silt. 7·5 YR 6/2
28·0%	CH	Pale olive massive clay with yellow and red mottles. 5Y6/4
18·0%	CH	Mottled yellowish red and grey clay 5YR 4/8
7·7%	SM	Pinkish grey indurated slopewash. 7·5 YR 7/2 ironstone gravel.
11·1%	CL	Mottled grey & reddish yellow lean clay. 10YR 6/2
17·2%	CH	Light olive brown massive clay with red & yellow mottles. 2·5Y5/4

NO.14 (21/7/71)

Metres: 0 – 4·5

M.C	Group symbol	Description
6·7%	ML	Brown sandy silt. 7·5 YR 5/4
6·6%	ML	Reddish brown clayey silt. 5 YR 5/4
6·6%	GM	Light reddish brown indurated slopewash containing 50% ironstone concretions up to 2 cm; hard. 5YR 6/4
9·5%	SM	Pinkish grey indurated slopewash; very hard. 7·5YR 7/2
		ironstone gravel.
9·5%	SM	Pinkish grey indurated slopewash ; very hard. 7·5YR 7/2
6·4%	SM	Light browish grey indurated slopewash; fine grained and hard. 10YR 6/2
16·4%	CH	Light olive brown massive clay with disseminated carbonate & feldspar. 2·5Y 5/4
6·9%	SC	Light brownish grey completely weathered rhyodacite. 10YR 6/2
10.4%	CL	Chloritic clay. 5Y68
8·0%	SC	Greenish yellow completely weathered rhyodacite with bands of kaolinitic and chloritic clay; very soft. 5Y 6/8

NO.14 (cont.)

Metres: 4·5 – 7

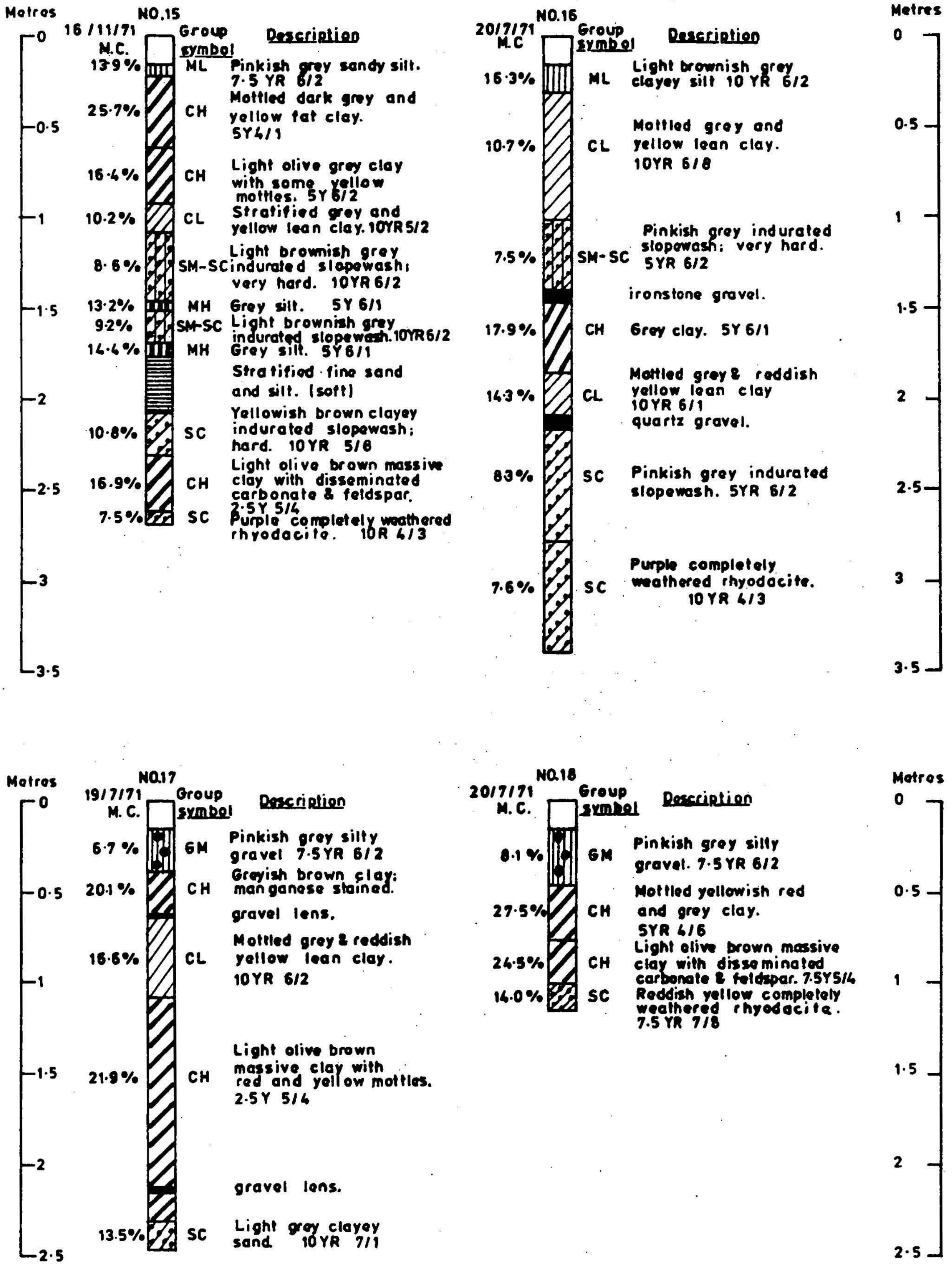
M. C	Group symbol	Description
5·8%, 4·2%	SC	Purple completely weathered rhyodacite; soft. 10R 4/3
2·8%	SC	Purple coarser grained completely weathered rhyodacite; hard. 10R 4/3

Checked by J.K./PVB | Drawing No. I55/A16/859 (4 of 11)

To accompany Record 1972/73

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 15, 16, 17 AND 18



Checked by	Drawing No.
J.K./PVB	I55/A16/859 (5 of 11)

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 19, 20, 21, 22 AND 23

NO.19 (19/7/71) — Metres 0–2·5

M.C.	Group symbol	Description
5·4%	ML	Pinkish grey sandy silt. 5YR 6/2
11·7%	CL	Yellowish red lean clay. 5YR 4/6
17·8%	CH	Mottled red, grey & yellow heavy clay. 10YR 5/4
12·5%	SC	Light olive grey clayey sand. 5Y 6/2
5·6%	SC	Purple completely weathered rhyodacite. 10YR 4/3

NO.20 (20/7/71) — Metres 0–2·5

M.C.	Group symbol	Description
22·3%	CH	Mottled yellowish red and grey clay. 5YR 4/8
23·1%	CH	Mottled red, grey and yellow heavy clay. 10 YR 5/4
23·0%	CH	Light olive grey massive clay with red mottles. 5 Y 6/2
21·5%	CH	Light olive grey massive clay with disseminated carbonate & feldspar. 5Y6/2
22·3%	CH	Olive grey massive clay. 5Y 5/2
19·4%	SC	Light grey clayey sand. 5Y 7/2

NO.21 (16/7/71) — Metres 0–2

M.C.	Group symbol	Description
5·8%	SM	Alluvium.
12·6%	SC	Yellowish brown clayey indurated slopewash. 10YR 5/6
22·6%	CH	Light olive brown massive clay with red mottles. 2·5Y 5/6
15·4%	CH	Mottled yellowish brown & grey clay. 10YR 6/8

NO.22 (20/7/71) — Metres 0–2

M.C.	Group symbol	Description
5·8%	ML	Pinkish grey sandy silt. 7·5YR 6/2
16·7%	CH	Dark greyish brown fat clay. 10YR 3/2
19·2%	CH	Light olive brown massive clay with disseminated carbonate and feldspar. 2·5Y 5/4
	SC	Completely weathered rhyodacite.

NO.23 (8/7/71) — Metres 0–1·5

M.C.	Group symbol	Description
6·5%	ML	Light brown sandy silt. 7·5YR 6/4
8·4%	SC	Yellowish red clayey sand. 5YR 5/8
12·1%	SC	Brown indurated slopewash; hard. 7·5YR 5/4
16·1%	SC	Yellowish brown clayey indurated slopewash. 10YR 5/8
	SC	Completely weathered rhyodacite.

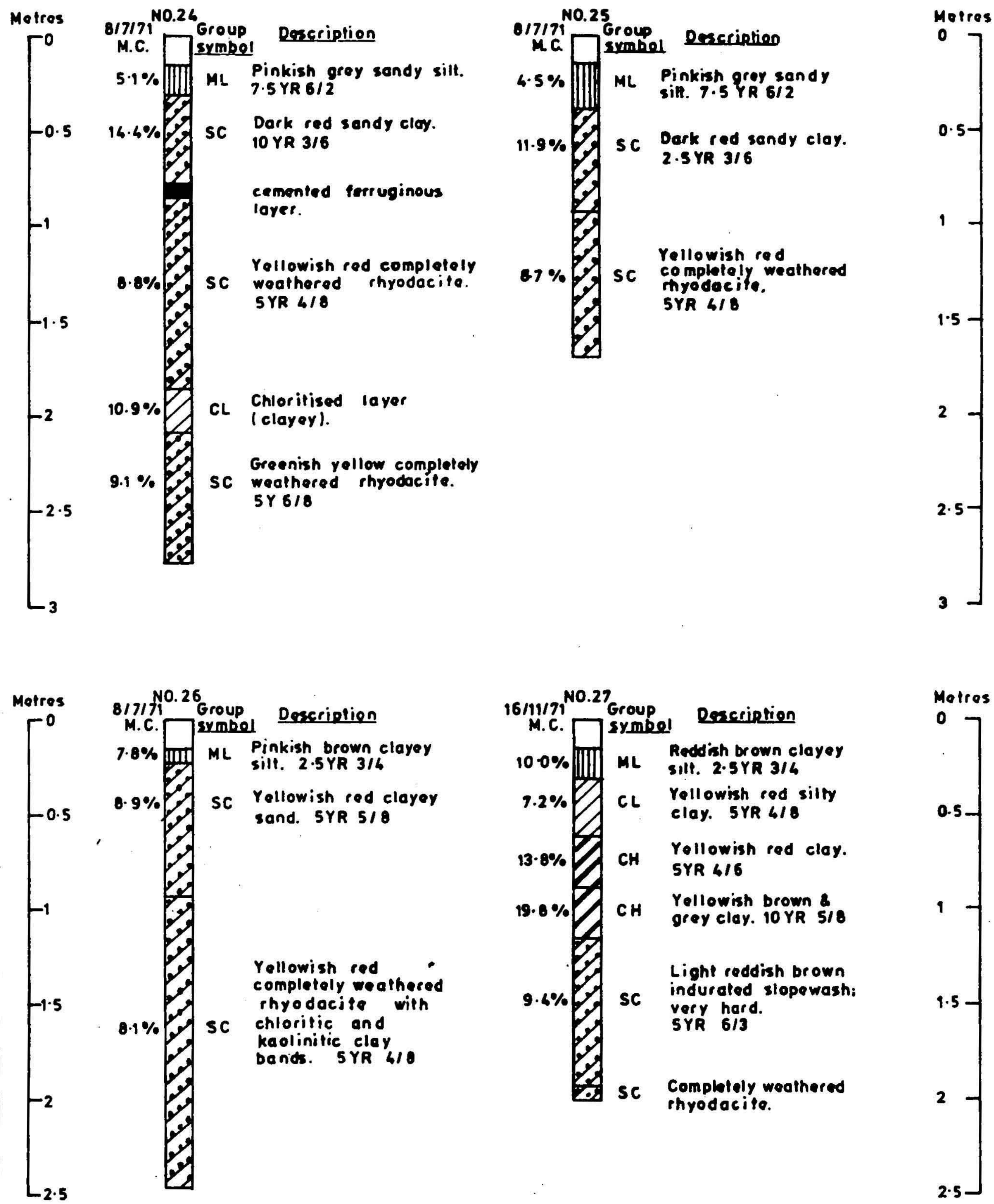
Checked by J.K./PVB

Drawing No. I55/A16/859 (6of 11)

To accompany Record 1972/73

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 24, 25, 26 AND 27



Checked by	Drawing No.
J.K. / PVB	I55/A16/859 (7 of 11)

To accompany Record 1972/73

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 28, 29, 30 AND 31

NO.28 — 8/7/71 (Metres 0–3)

M.C.	Group symbol	Description
6·0%	ML	Light brownish grey sandy silt. 2·5Y 6/2
15·0%	CL	Yellowish red silty clay. 5YR 4/6
18·5%	CH	Mottled yellowish red and grey clay. 5YR 4/8
11·5%	SC	Yellowish red clayey indurated slopewash 5YR 5/8

NO.29 — 15/11/71 (Metres 0–3)

M.C.	Group symbol	Description
10·5%	ML	Reddish grey sandy silt. 5YR 5/2
9·2%	SC	Yellowish red clayey indurated slopewash. 5YR 5/6
17·0%	CH	Mottled yellowish red & grey clay. 5YR4/8
10·0%	SC	Yellowish red weakly cemented clayey slopewash 5YR 4/8
10·6%	SC	Hard indurated clayey slopewash. 5YR 4/8
		cemented ferruginous layer.
11·7%	SC	As above with silt lenses 5YR 4/8
11·2 %	SC	Light brownish grey hard indurated clayey slopewash. 2·5Y 6/2
8·7%	SC	Yellowish red compelety weathered rhyodacite. (bands of kaolinitic clay.) 5YR 5/8
6·0%		cemented ferruginous layer.
7·6%	SC	Light brownish grey completely weathered rhyodacite. 10YR 6/2

NO·30 — 11/11/71 (Metres 0–3·5)

M.C.	Group symbol	Description
9·3%	ML	Pinkish grey sandy silt. 7·5YR 6/2
10·3%	SM	Yellowish red gravelly silt. 5YR 5/6
7·8%	ML	Pinkish grey sandy silt. 5YR 7/2
9·0 %	SC	Yellowish red clayey indurated slopewash. 5YR 5/6
21·1 %	CH	Yellowish brown massive clay with disseminated carbonate. 10YR 5/8
16·9%	CH	Mottled yellowish red & grey clay. 5YR 4/8
16·2%	CH	Light olive brown massive clay with disseminated carbonate & feldspar. 2·5Y 5/6
7·9%	SC	Light brownish grey completely weathered rhyodacite. 10YR 6/2

5·5 Metres

NO.31 — 15/11/71 (Metres 0–3·5)

M.C.	Group symbol	Description
7·5%	ML	Pale brown sandy silt. 10YR 7/3
16·6%	CH	Mottled red, grey and yellow clay. ferruginous. 10YR 5/4
26·0%	CH	Light olive brown massive clay with red mottles 2·5Y 5/4
22·3%	CH	Light olive brown massive clay with red mottles and disseminated carbonate and calcic feldspar. 2·5Y 5/4
15·2 %	CH	Olive clay & completely weathered rhyodacite. 2·5Y 6/4
7·9%	SC	Light brownish grey completely weathered rhyodacite. 10YR 6/2
7·5%		

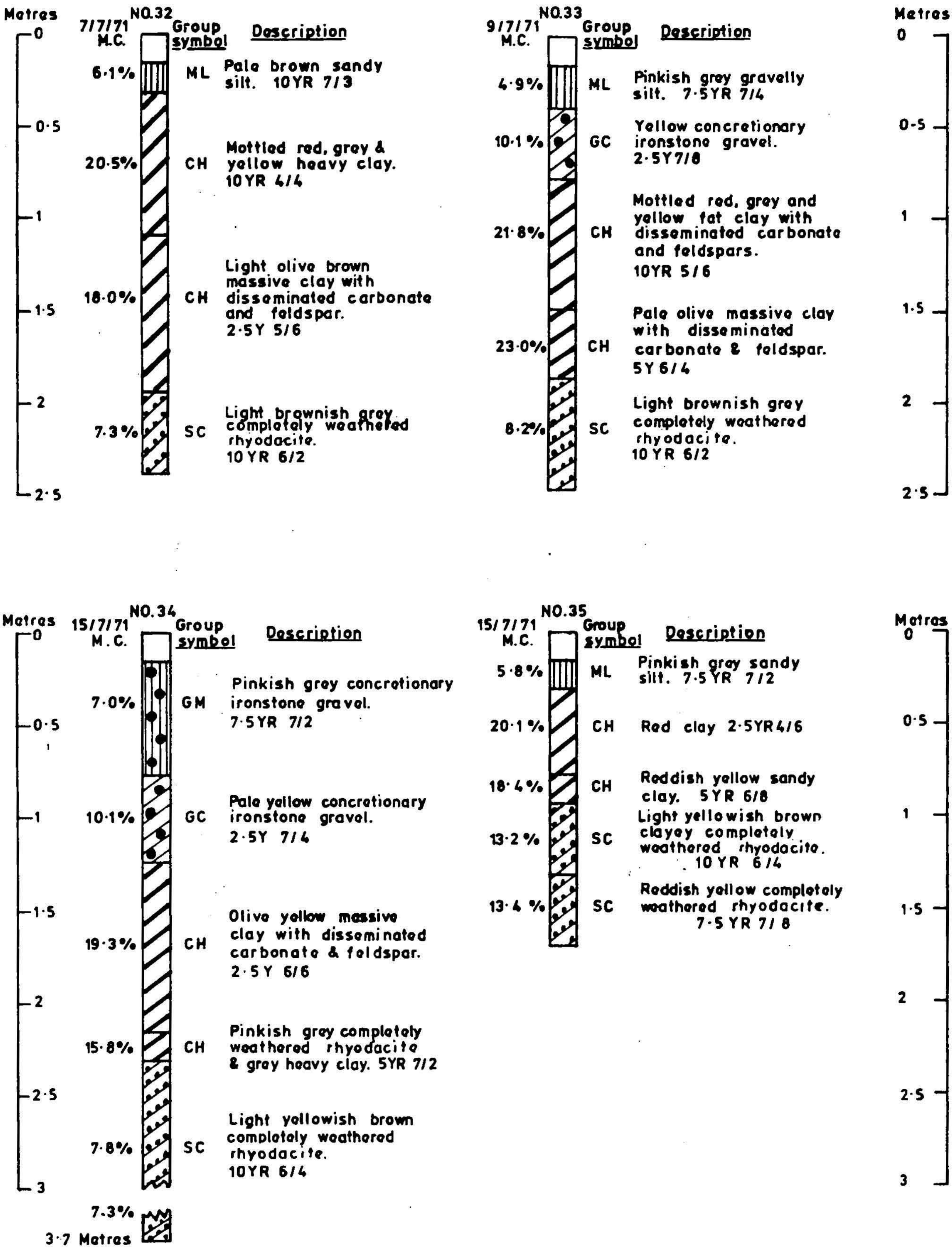
4·9 Metres

Checked by	Drawing No.
G.K./PVB	I55/A16/859 (8 of 11)

To accompany Record 1972/73

APPENDIX 3

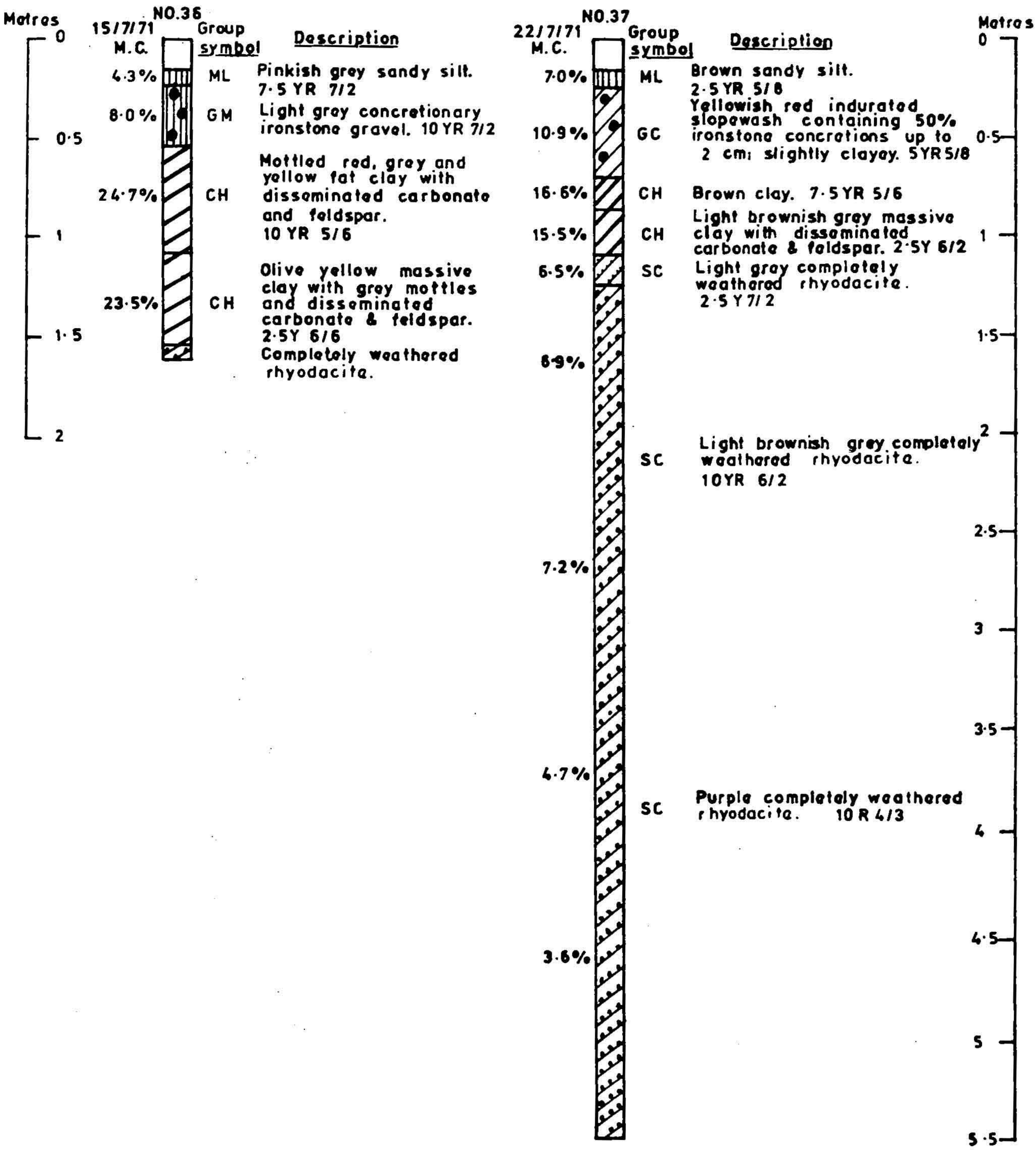
VERTICAL SECTION OF AUGER HOLES 32, 33, 34 AND 35



Checked by	Drawing No.
J.K./PVB	I55/A16/859 (9 of 11)

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 36 AND 37

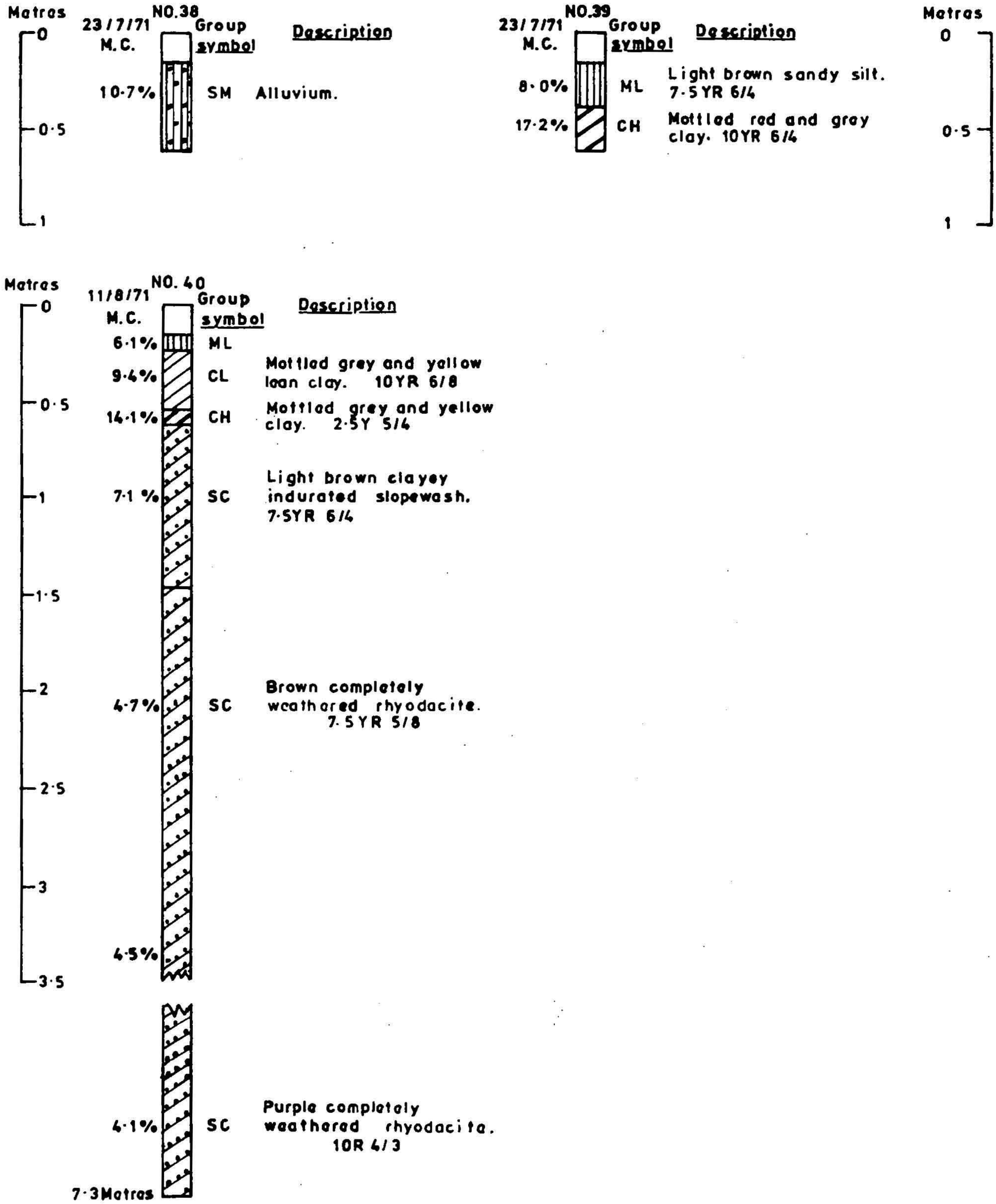


Checked by	Drawing No.
J.K. / PVB	I55/A16/859 (10 of 11)

To accompany Record 1972/73

APPENDIX 3

VERTICAL SECTION OF AUGER HOLES 38, 39 AND 40



Checked by	Drawing No.
J.K./PVB	I55/A16/859 (11 of 11)

To accompany Record 1972/73

APPENDIX 4

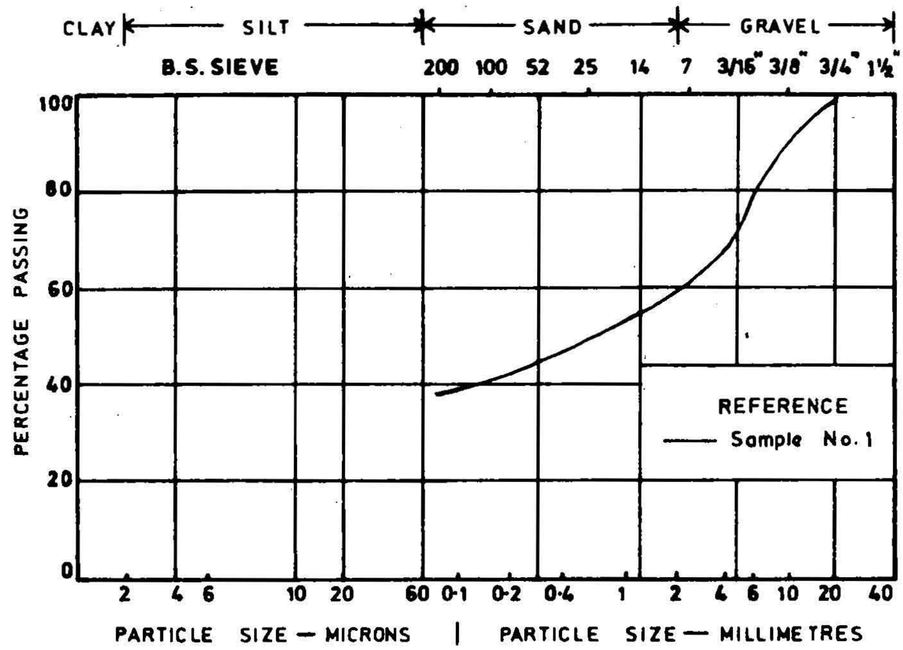
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 3

Unified Soil Classification: GM

Description: Pinkish grey silty concretionary ironstone gravel

PARTICLE SIZE DISTRIBUTION CURVE



LOCATION OF SAMPLES	
Sample No.	Location
1	Auger hole 34 (0·15 - 0·76 m)

OTHER PARAMETERS						
Index	Sample No.					
	1					
Lower Liquid Limit	25					
Lower Plastic Limit	16					
Plasticity Index	9					
Linear Shrinkage	5					
Assessed CBR	22					

Test by J.K. and L.P.	Drawn by M.E.	Project Geologist P. VandenBroek	
Calculations by J.K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. 155/A16/860 (1 of 12)

APPENDIX 4

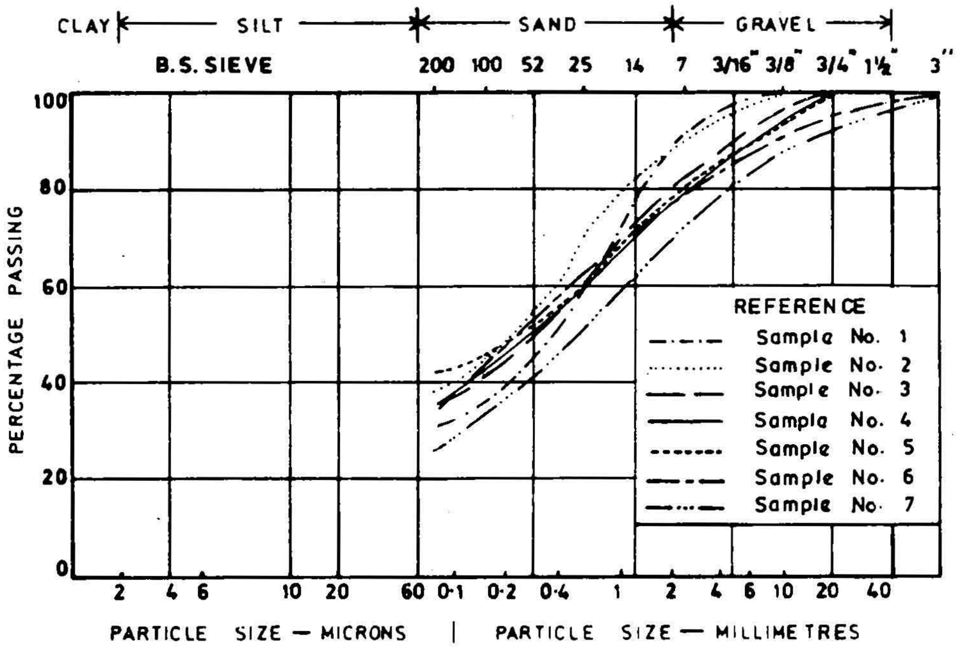
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 5

Unified Soil Classification: SM

Description: Pinkish grey indurated slopewash

PARTICLE SIZE DISTRIBUTION CURVES



LOCATION OF SAMPLES	
Sample No.	Location
1	Test pit 1 (0·46 - 0·76 m)
2	Test pit 1 (1·07 - 1·37 m)
3	Test pit 2 (2·13 - 2·44 m)
4	Test pit 2 (1·52 - 1·83 m)
5	Auger hole 14 (1·83 - 2·76 m)
6	Auger hole 3 (2·21 - 2·84 m)
7	Auger hole 8 (2·13 - 4·28 m)

OTHER PARAMETERS							
Index	Sample No.						
	1	2	3	4	5	6	7
Lower Liquid Limit	18	20	28	25	20	20	19
Lower Plastic Limit	14	14	16	15	13	14	14
Plasticity Index	4	6	12	10	7	6	5
Linear Shrinkage	2	3	6	5	4	4	3
Assessed CBR	23	21	20	20	20	23	25

Test by J.K. and L.P.	Drawn by M.E.	Project Geologist P. Vanden Broek	
Calculations by J.K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. ISS/A16/860 (2 of 12)

APPENDIX 4

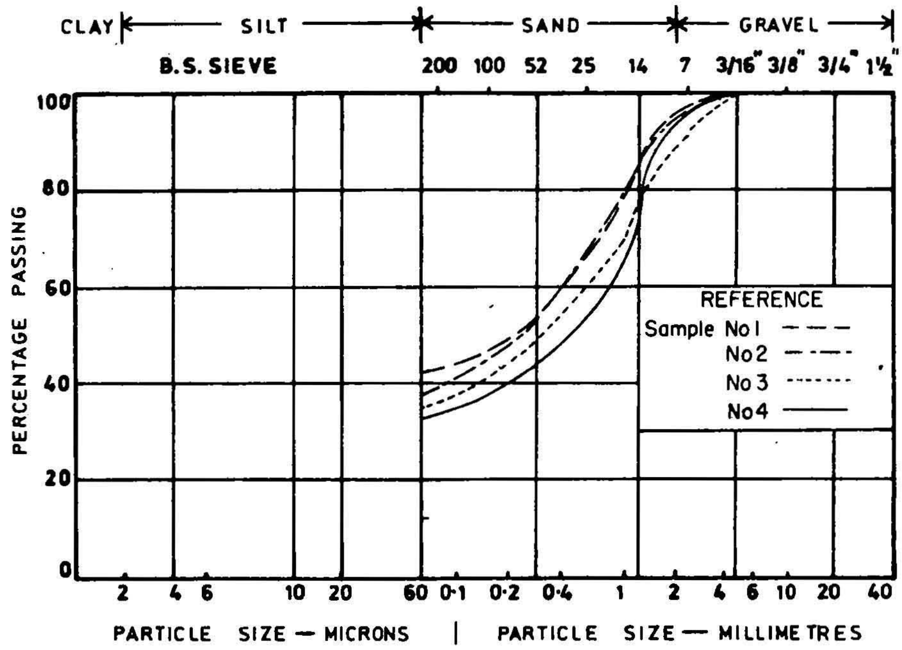
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 6

Unified Soil Classification: SC

Description: Brown clayey indurated slopewash

PARTICLE SIZE DISTRIBUTION CURVES



LOCATION OF SAMPLES	
Sample No.	**Location**
1	Auger hole 16 (2·13 – 2·76m)
2	Auger hole 28 (0·91 – 1·68m)
3	Auger hole 2 (0·53 – 0·99m)
4	Auger hole 23 (0·61 – 0·91m)

OTHER PARAMETERS						
Index	**Sample No.**					
	1	2	3	4		
Lower Liquid Limit	36	36	34	30		
Lower Plastic Limit	17	17	17	17		
Plasticity Index	19	19	17	13		
Linear Shrinkage	11	10	8	6		
Assessed CBR	15	14	16	18		

Test by J. K. and L. P.	Drawn by asg	Project Geologist P. Van den Broek	
Calculations by J. K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. 155/A16/860 (3 of 12)

APPENDIX 4

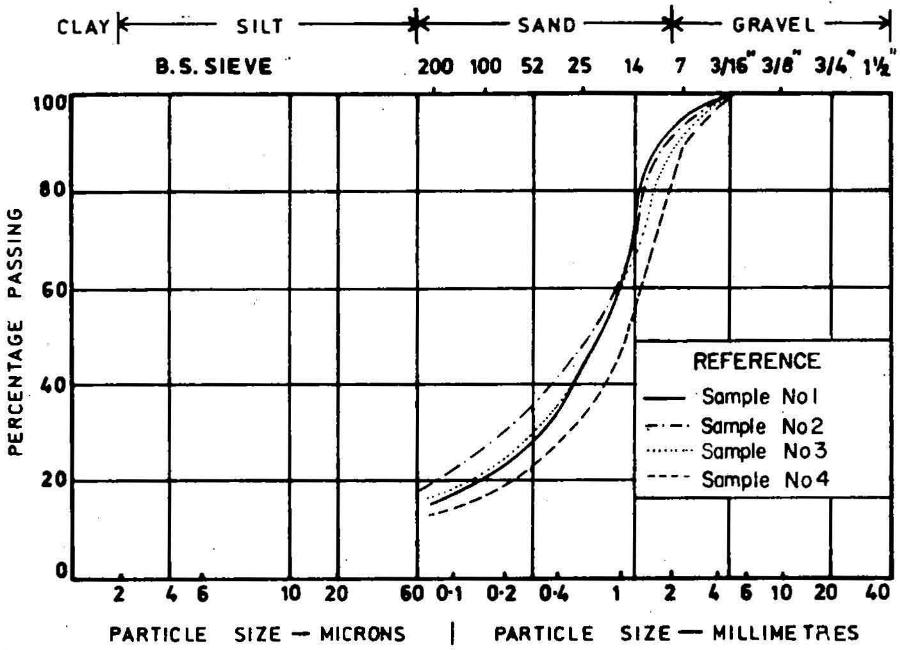
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 8

Unified Soil Classification: SC

Description: Completely weathered rhyodacite

PARTICLE SIZE DISTRIBUTION CURVES



LOCATION OF SAMPLES	
Sample No.	Location
1	Auger hole 2 (3·05 - 7·35m)
2	Auger hole 31(2·36 - 4·91m)
3	Auger hole 24(0 84 - 1·83m)
4	Auger hole 16(2·76 - 3·35m)

OTHER PARAMETERS						
Index	Sample No.					
	1	2	3	4		
Lower Liquid Limit	34	36	33	28		
Lower Plastic Limit	17	18	16	18		
Plasticity Index	17	18	17	10		
Linear Shrinkage	9	10	9	6		
Assessed CBR	22	20	22	23		

Test by J. K. and L.P.	Drawn by asg	Project Geologist P. VandenBroek	
Calculations by J. K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. I55/A16/860 (4 of 12)

APPENDIX 4

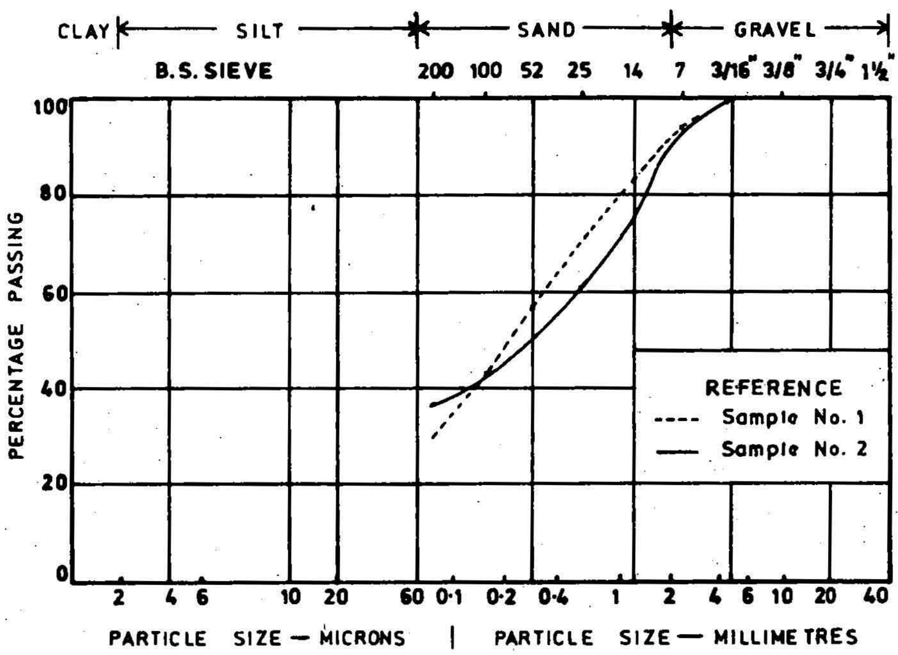
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 9

Unified Soil Classification: SC

Description: Grey clayey sand

PARTICLE SIZE DISTRIBUTION CURVES



LOCATION OF SAMPLES	
Sample No.	Location
1	Auger hole 20 (1·75 - 2·06 m)
2	Auger hole 19 (0·76 - 1·07 m)

OTHER PARAMETERS						
Index	Sample No.					
	1	2				
Lower Liquid Limit	46	53				
Lower Plastic Limit	20	18				
Plasticity Index	26	35				
Linear Shrinkage	10	12				
Assessed CBR	14	12				

Test by J. K. and L. P.	Drawn by M. E.	Project Geologist P. VandenBroek	
Calculations by J. K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. I55/A16/860 (5 of 12)

APPENDIX 4

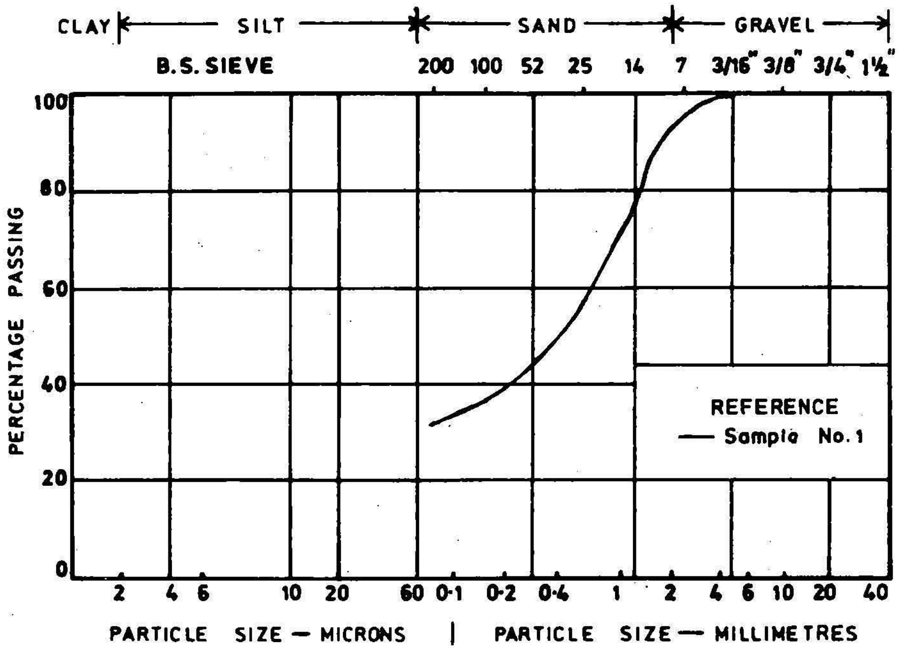
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 10

Unified Soil Classification: SC

Description: Red clayey sand

PARTICLE SIZE DISTRIBUTION CURVE



LOCATION OF SAMPLES	
Sample No.	Location
1	Auger hole 26 (0·23 - 0·91m)

OTHER PARAMETERS						
Index	Sample No.					
	1					
Lower Liquid Limit	29					
Lower Plastic Limit	16					
Plasticity Index	13					
Linear Shrinkage	6					
Assessed CBR	19					

Test by J.K. and L.P.	Drawn by M.E.	Project Geologist P. Vanden Broek	
Calculations by J.K.	Checked by J.K. and P.V.B.	To accompany Record 1972/73	Drawing No. I55/A16/860 (6 of 12)

APPENDIX 4

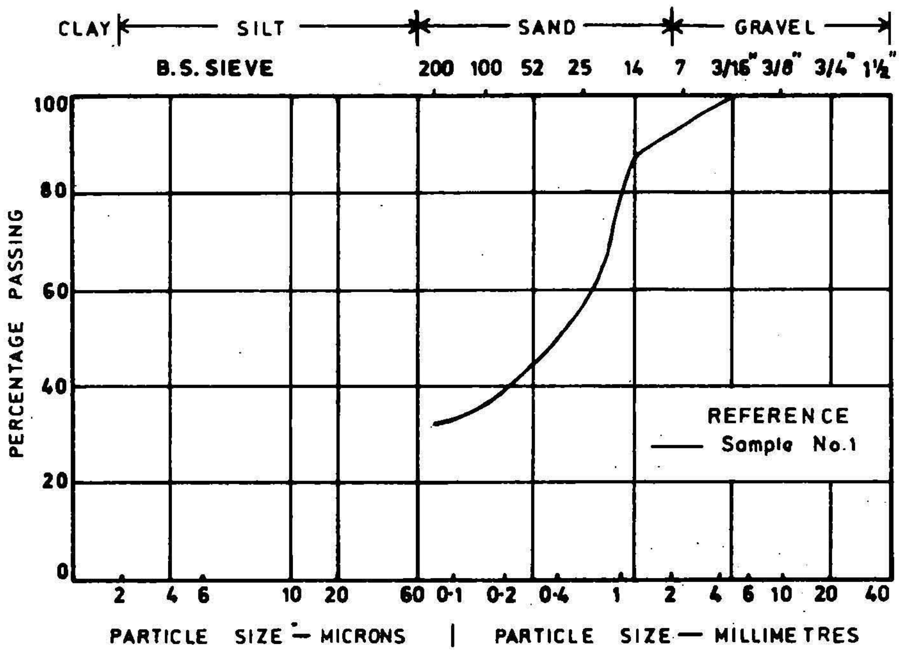
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 11

Unified Soil Classification: SC

Description: Red friable sandy clay

PARTICLE SIZE DISTRIBUTION CURVE



LOCATION OF SAMPLES	
Sample No.	Location
1	Auger hole 25 (0·38 - 0·91m)

OTHER PARAMETERS						
Index	Sample No.					
	1					
Lower Liquid Limit	44					
Lower Plastic Limit	19					
Plasticity Index	25					
Linear Shrinkage	11					
Assessed CBR	15					

Test by J. K. and L. P.	Drawn by M. E.	Project Geologist P. Vandenbroek	
Calculations by J. K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. ISS/A16/860 (7 of 12)

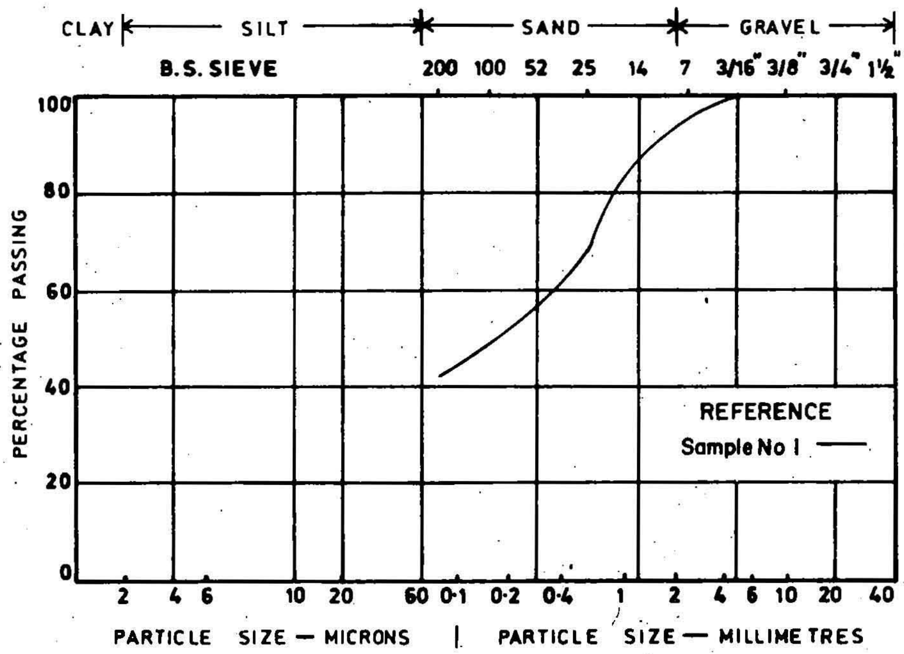
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 12

Unified Soil Classification: SC

Description: Red heavy sandy clay

PARTICLE SIZE DISTRIBUTION CURVE



LOCATION OF SAMPLES	
Sample No.	Location
	Test Pit 4 (0·46 - 0·76m)

OTHER PARAMETERS						
Index	Sample No.					
	1					
Lower Liquid Limit	54					
Lower Plastic Limit	20					
Plasticity Index	34					
Linear Shrinkage	12					
Assessed CBR	10					

Test by J. K. and L. P.	Drawn by asg	Project Geologist P. Vanden Broek	
Calculations by J. K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. I55/A16/860 (8 of 12)

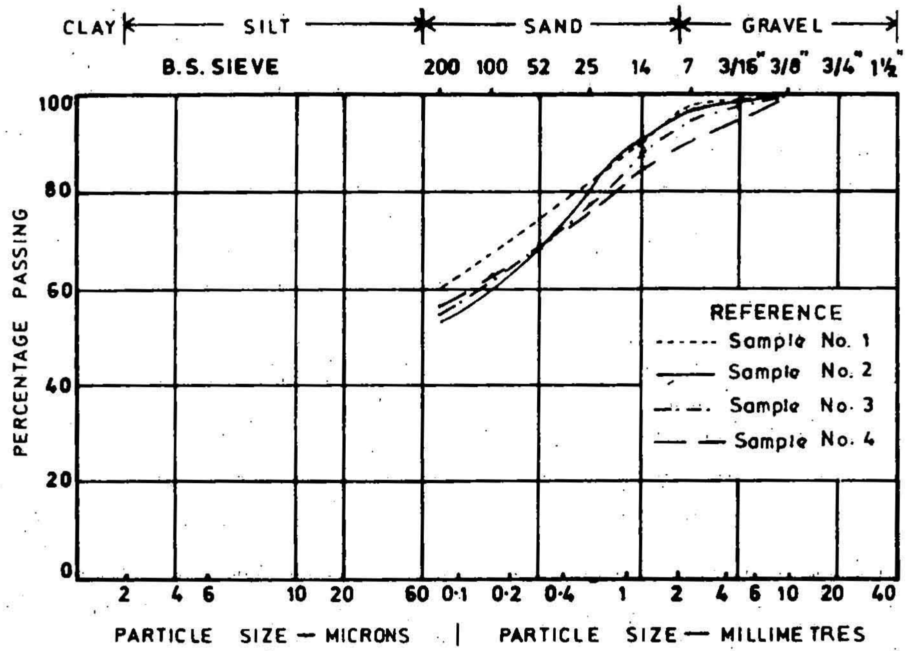
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 13

Unified Soil Classification: CL

Description: Red to mottled red and yellow silty and lean clays

PARTICLE SIZE DISTRIBUTION CURVES



LOCATION OF SAMPLES	
Sample No.	Location
1	Auger hole 19 (0·30 - 0·46m)
2	Auger hole 16 (0·30 - 0·99 m)
3	Auger hole 2 (0·15 - 0·53m)
4	Auger hole 17 (0·69 - 1·07 m)

OTHER PARAMETERS						
Index	Sample No.					
	1	2	3	4		
Lower Liquid Limit	39	42	41	47		
Lower Plastic Limit	14	14	14	15		
Plasticity Index	25	28	27	32		
Linear Shrinkage	11	12	11	13		
Assessed CBR	8	10	10	7		

Test by J. K. and L. P.	Drawn by M. E.	Project Geologist P. Van den Broek	
Calculations by J. K.	Checked by J. K. and P. B.	To accompany Record 1972/73	Drawing No. I55/A16/860 (9 of 12)

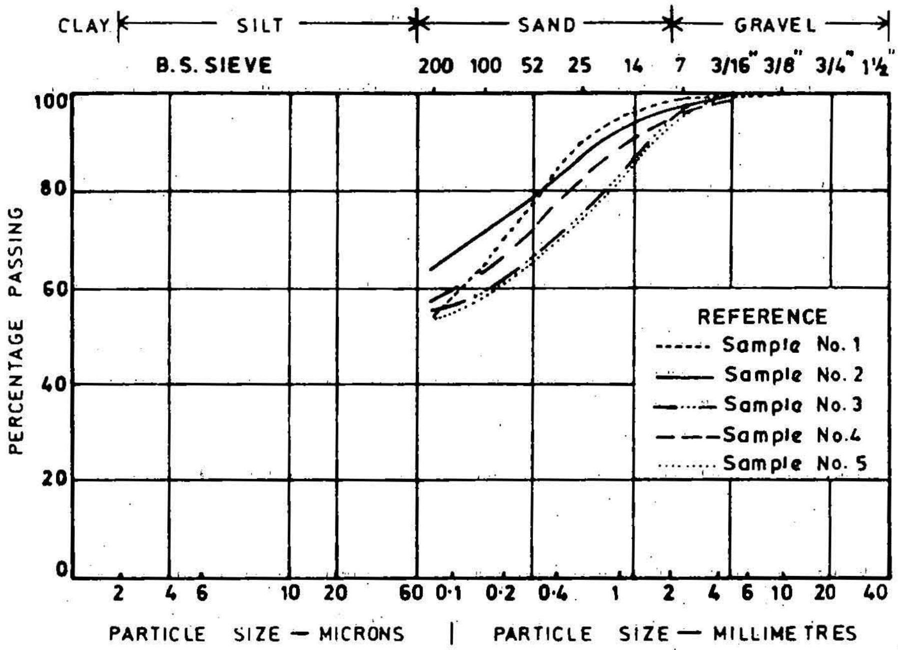
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 14

Unified Soil Classification: CH

Description: Mottled grey and yellow red clay of high plasticity

PARTICLE SIZE DISTRIBUTION CURVES



LOCATION OF SAMPLES	
Sample No.	Location
1	Auger hole 20 (0·15 - 0·46m)
2	Auger hole 17 (0·38 - 0·61m)
3	Auger hole 28 (0·46 - 0·91m)
4	Auger hole 13 (0·84 - 1·07m)
5	Auger hole 18 (0·46 - 0·76m)

OTHER PARAMETERS						
Index	Sample No.					
	1	2	3	4	5	
Lower Liquid Limit	71	55	62	59	60	
Lower Plastic Limit	25	18	23	21	22	
Plasticity Index	46	37	39	38	38	
Linear Shrinkage	17	14	14	13	14	
Assessed CBR	5	6	6	7	6	

Test by J.K. and L.P.	Drawn by M.E.	Project Geologist P. Van den Broek	
Calculations by J.K.	Checked by J.K. and PVB	To accompany Record 1972/73	Drawing No. I55/A16/860 (10 of 12)

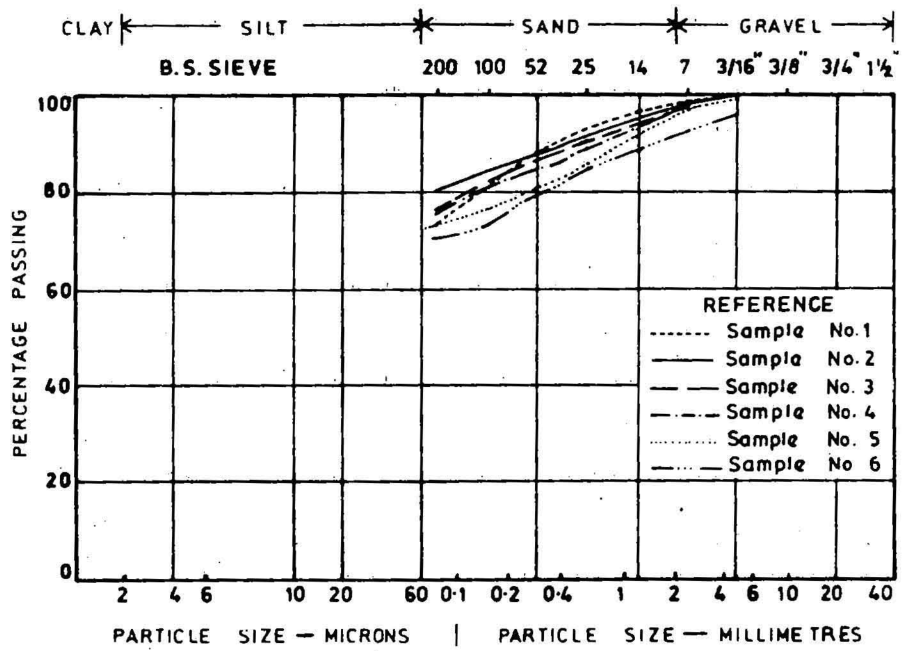
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 15

Unified Soil Classification: CH

Description: Mottled red; grey and yellow heavy clay

PARTICLE SIZE DISTRIBUTION CURVES



LOCATION OF SAMPLES

Sample No.	Location
1	Auger hole 20 (0·46 - 0·91m)
2	Auger hole 36 (0·53 - 1·07 m)
3	Auger hole 32 (0·61 - 1·07 m)
4	Auger hole 19 (0·46 - 0·76 m)
5	Auger hole 32 (0·30 - 0·61 m)
6	Test pit 6 (0·61 - 0·91 m)

OTHER PARAMETERS

Index	Sample No.					
	1	2	3	4	5	6
Lower Liquid Limit	73	67	69	65	69	70
Lower Plastic Limit	26	22	23	22	21	22
Plasticity Index	47	45	46	43	48	48
Linear Shrinkage	18	16	18	15	15	16
Assessed CBR	1	4	3	4	4	6

Test by J.K. and L.P.	Drawn by M.E.	Project Geologist P. VandenBroek	
Calculations by J. K.	Checked by J.K. and P.V.	To accompany Record 1972/73	Drawing No. I55/A16/860 (11 of 12)

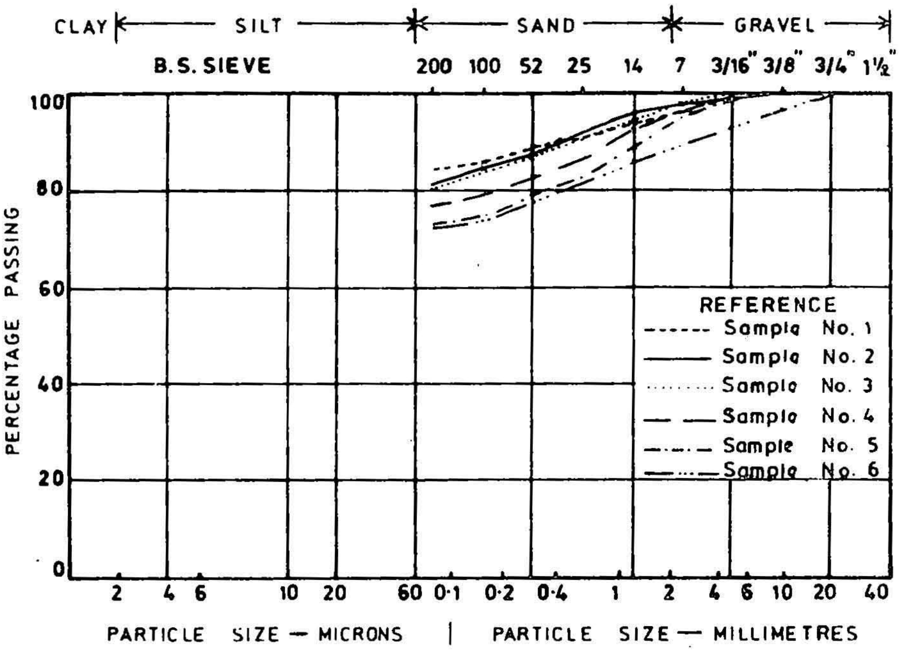
RANGE OF PARTICLE SIZE AND PLASTICITY

SOIL UNIT 16

Unified Soil Classification: CH

Description: Massive olive fat clay

PARTICLE SIZE DISTRIBUTION CURVES

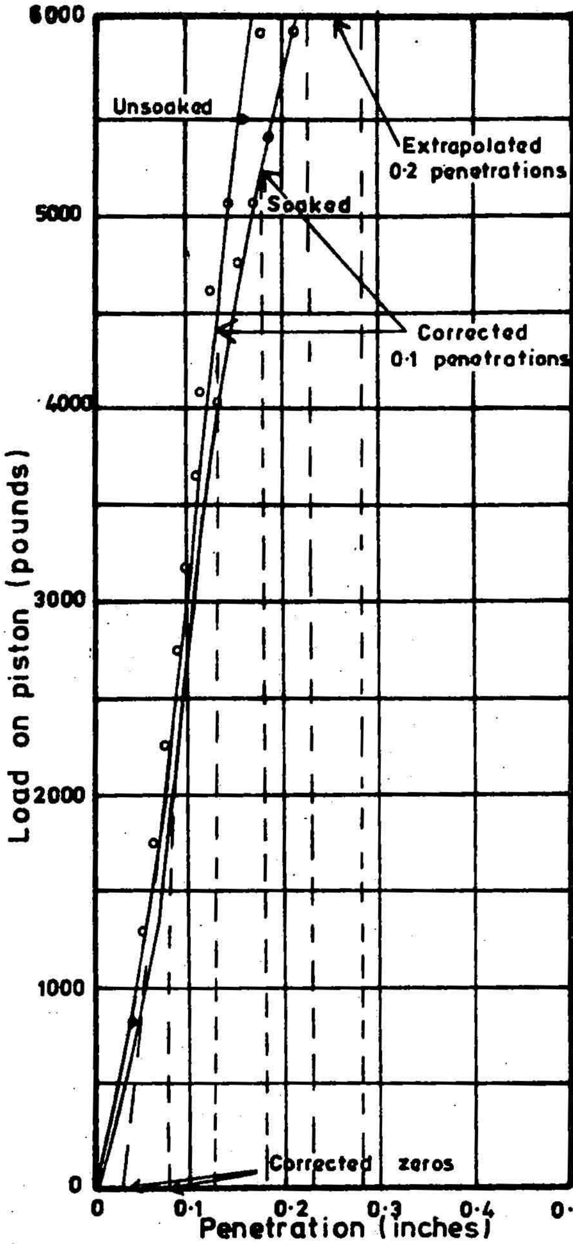


LOCATION OF SAMPLES	
Sample No.	Location
1	Test pit 3 (0·91 - 1·22m)
2	Auger hole 13 (0·23 - 0·84 m)
3	Auger hole 21 (0·69 - 0·99m)
4	Auger hole 22 (0·61 - 1·52 m)
5	Auger hole 32 (1·07 - 1·98m)
6	Auger hole 17 (1·07 - 2·29m)

OTHER PARAMETERS						
Index	Sample No.					
	1	2	3	4	5	6
Lower Liquid Limit	87	77	75	73	84	78
Lower Plastic Limit	24	24	25	23	29	24
Plasticity Index	63	53	50	50	55	54
Linear Shrinkage	18	17	15	18	19	18
Assessed CBR	2	3	3	3	2	3

Test by J. K. and L. P.	Drawn by M. E.	Project Geologist P. Vanden Broek	
Calculations by J. K.	Checked by J. K. and PVB	To accompany Record 1972/73	Drawing No. I55/A16/860 (12 of 12)

APPENDIX 5



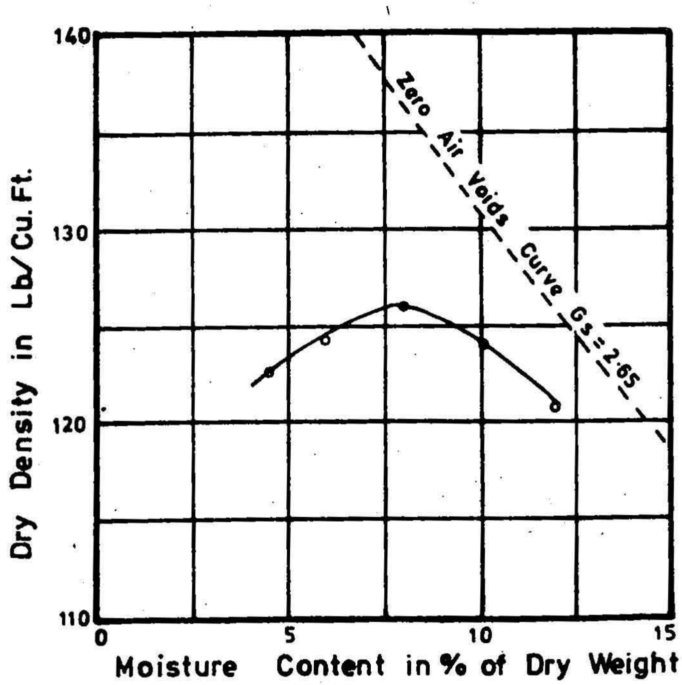
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu.ft)	125	125
Moisture Content before soaking (%)	9	9
Moisture Content after soaking (%)	N.A.	10
Swell (% of initial height)	N.A.	0·1
CBR at 0·100" penetration (%)	140	173
CBR at 0·200" penetration (%)	144	155

Compaction Summary

Maximum Dry Density (lb./cu. ft.)	126
Opt. Moisture Content (%)	8



MODIFIED COMPACTION

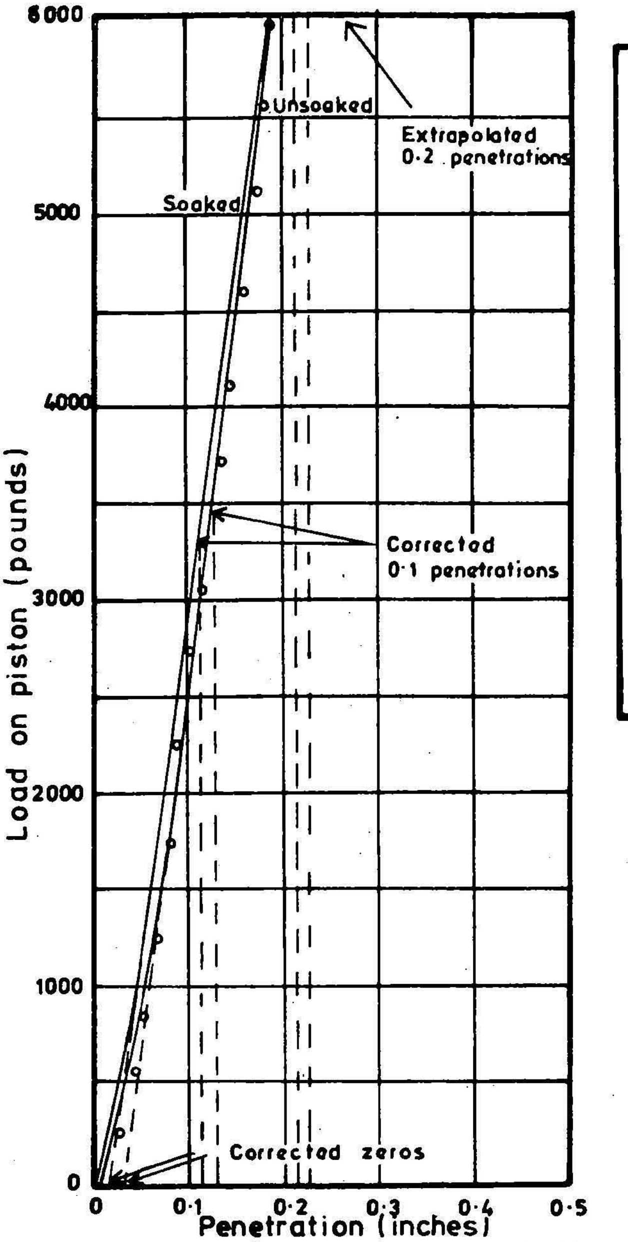
COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES

PROJECT
TUGGERANONG FREEWAY STAGE II

CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS

Soil Unit 5	Location Test Pit 1 (0·46 – 0·76 m)
Description Pinkish grey indurated slopewash	
Tested by J. K. and L.P.	Calculations by J.K.
Drawn by M.E.	Checked by J.K. and PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (1 of 10)

APPENDIX 5



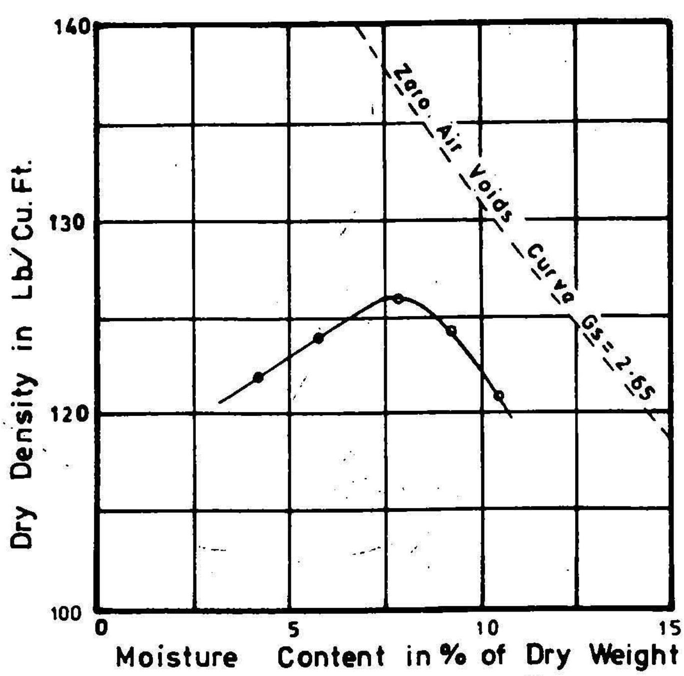
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	126	127
Moisture Content before soaking (%)	8	8
Moisture Content after soaking (%)	N.A.	10
Swell (% of initial height)	N. A.	0·1
CBR at 0·100" penetration (%)	128	122
CBR at 0·200" penetration (%)	150	144

Compaction Summary

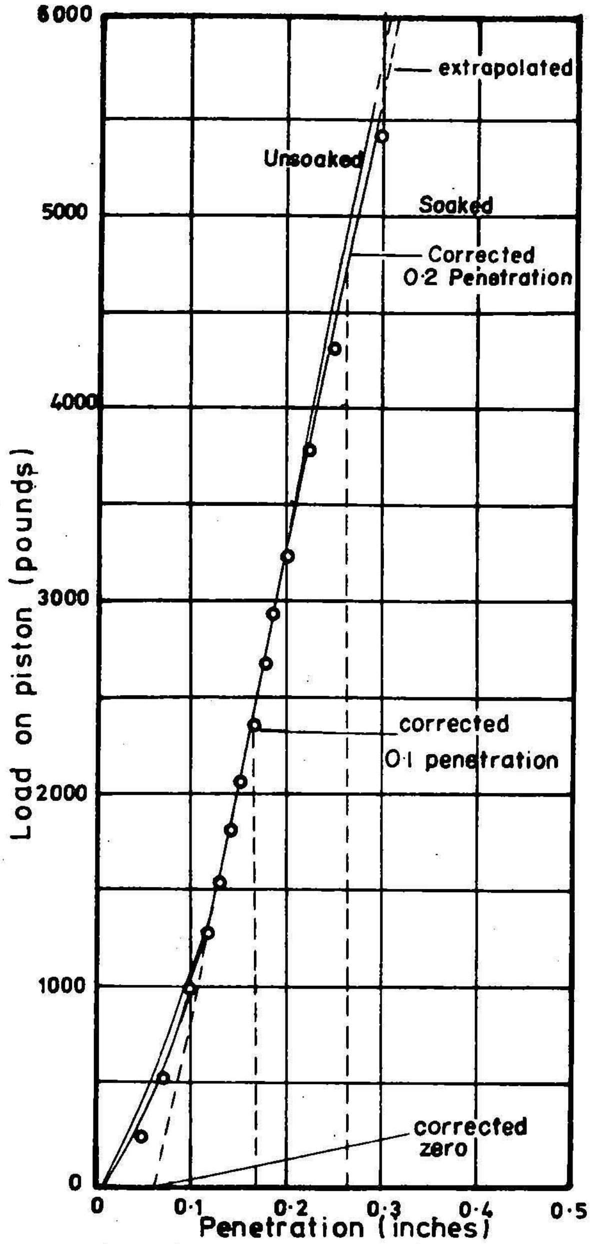
Maximum Dry Density (lb./cu. ft.)	126
Opt. Moisture Content (%)	8



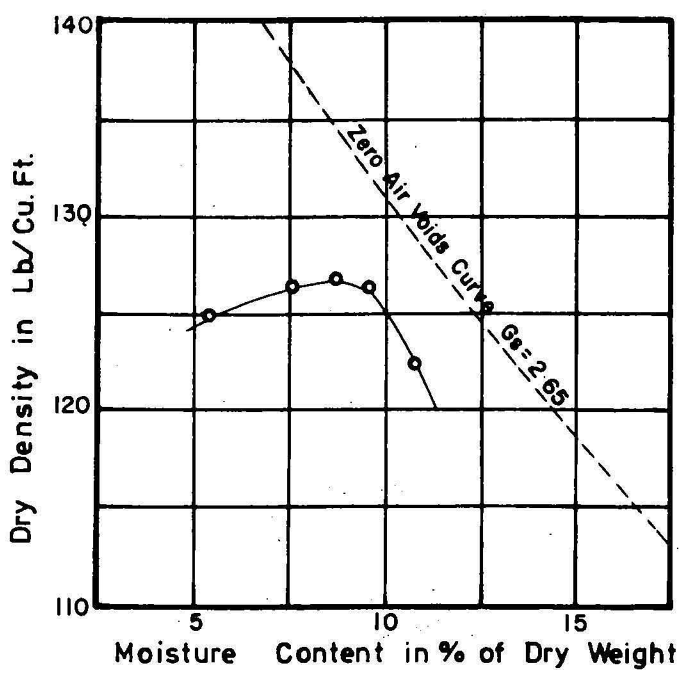
MODIFIED COMPACTION

COMMONWEALTH OF AUSTRALIA BUREAU OF MINERAL RESOURCES	
PROJECT TUGGERANONG FREEWAY STAGE II	
CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS	
Soil Unit 5	Location Test Pit 1 (1·07 - 1·37 m)
Description Pinkish grey indurated slopewash	
Tested by J.K. and L.P.	Calculations by J. K.
Drawn by M.E.	Checked by J.K. and PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (2 of 10)

APPENDIX 5



CALIFORNIA BEARING RATIO



MODIFIED COMPACTION

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	128	128
Moisture Content before soaking (%)	9	9
Moisture Content after soaking (%)	N.A.	9
Swell (% of initial height)	N.A.	Nil
CBR at 0·100" penetration (%)	72	72
CBR at 0·200" penetration (%)	100	100

Compaction Summary

Maximum Dry Density (lb./cu. ft.)	128
Opt. Moisture Content (%)	9

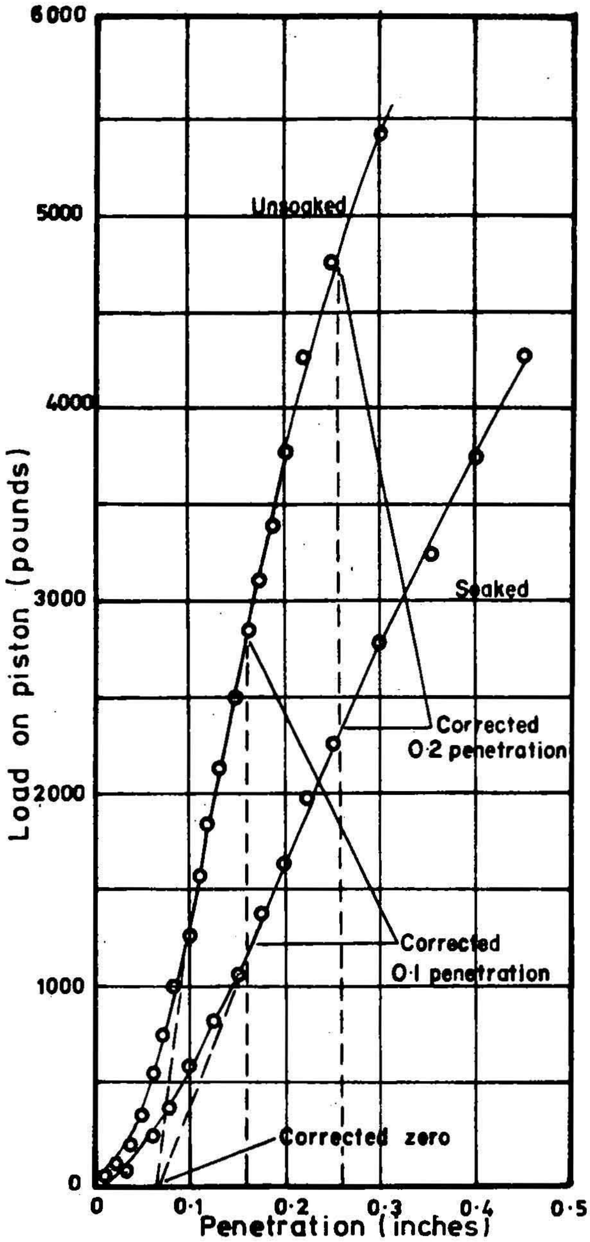
COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES

PROJECT
TUGGERANONG FREEWAY STAGE II

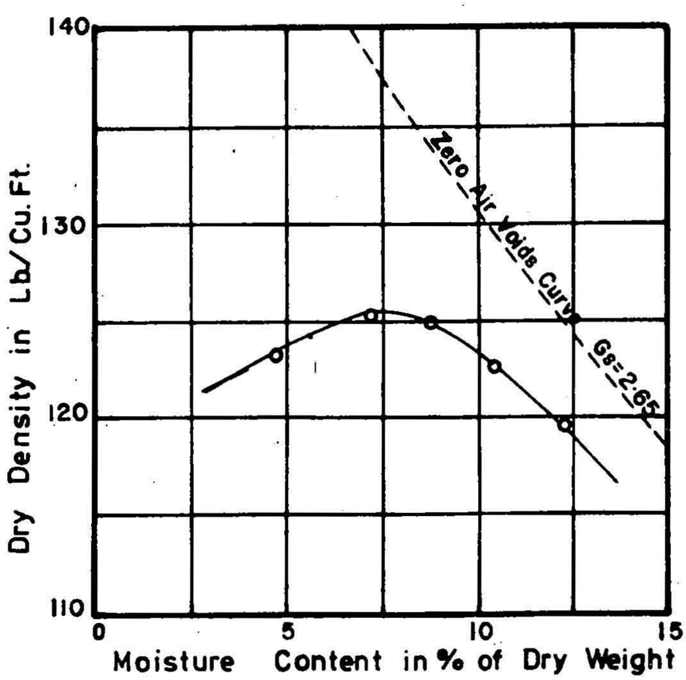
CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS

Soil Unit 5	Location Test Pit 2 (1·52 - 1·83 m)
Description: Pinkish grey indurated slopewash	
Tested by J.K. & L.P.	Calculations by J.K.
Drawn by a.s.g	Checked by J.K. & PVB
Supervising - Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (3of 10)

APPENDIX 5



CALIFORNIA BEARING RATIO



MODIFIED COMPACTION

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	127	127
Moisture Content before soaking (%)	9	9
Moisture Content after soaking (%)	N.A.	9
Swell (% of initial height)	N.A.	Nil
CBR at 0·100" penetration (%)	83	43
CBR at 0·200" penetration (%)	104	56

Compaction Summary

Maximum Dry Density (lb./cu. ft.)	126
Opt. Moisture Content (%)	8

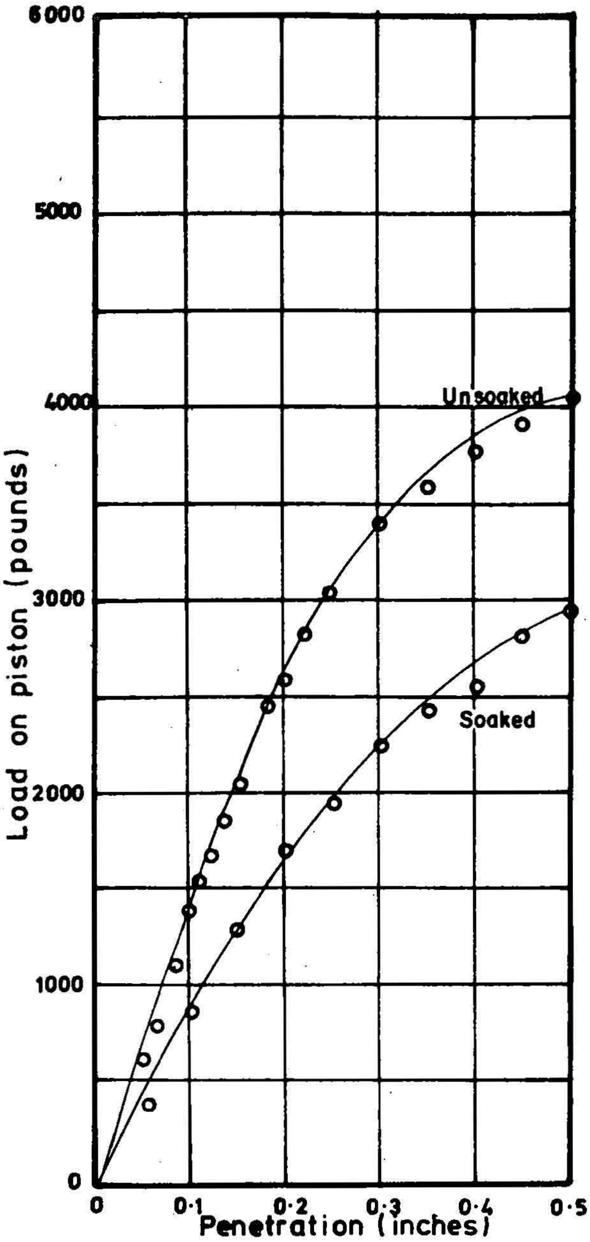
COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES

PROJECT
TUGGERANONG FREEWAY STAGE II

CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS

Soil Unit 5	Location Test Pit 2 (2·13 - 2·44 m)
Description: Pinkish grey indurated slopewash	
Tested by J.K. & L.P.	Calculations by J.K.
Drawn by a.s.g.	Checked by J.K. & PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. 155/A16/861 (4 of 10)

APPENDIX 5



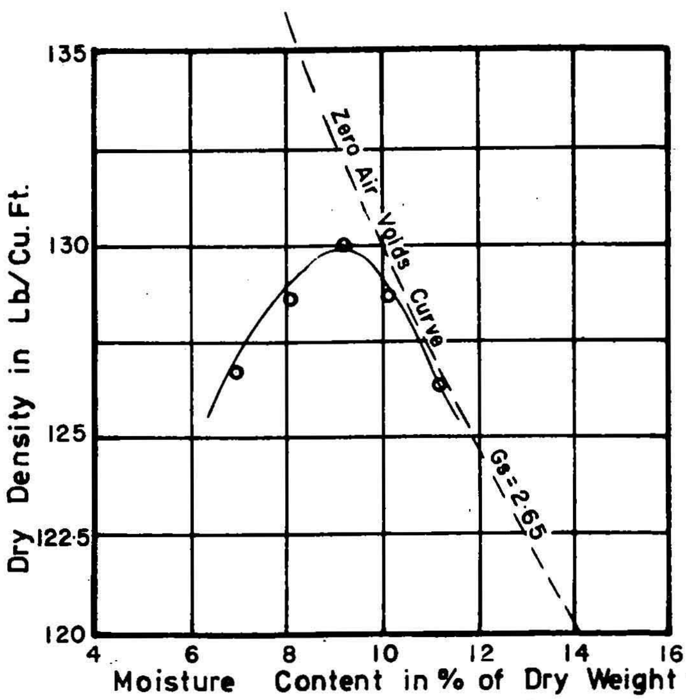
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	128	131
Moisture Content before soaking (%)	9	9
Moisture Content after soaking (%)	N.A.	9
Swell (% of initial height)	N.A.	0·7
CBR at 0·100" penetration (%)	46	30
CBR at 0·200" penetration (%)	57	37

Compaction Summary

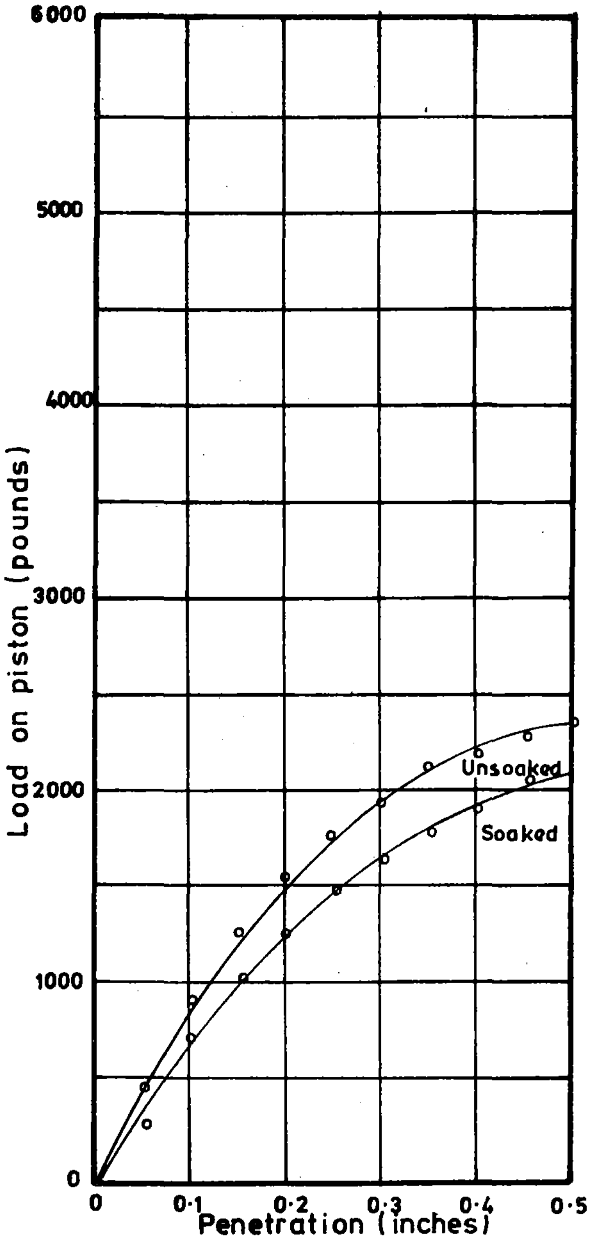
Maximum Dry Density (lb./cu. ft.)	130
Opt. Moisture Content (%)	9



MODIFIED COMPACTION

COMMONWEALTH OF AUSTRALIA BUREAU OF MINERAL RESOURCES	
PROJECT TUGGERANONG FREEWAY STAGE II	
CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS	
Soil Unit 8	Location Test Pit 4 (1·22 - 1·52 m)
Description Yellowish red completely weathered rhyodacite	
Tested by J.K. & L.P.	Calculations by J.K.
Drawn by a.s.g.	Checked by J.K. & PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (5of 10)

APPENDIX 5



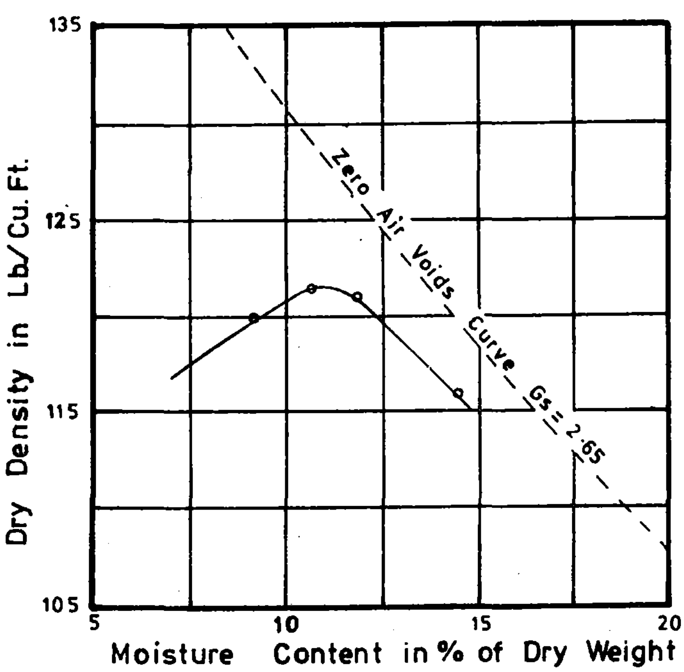
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	123	123
Moisture Content before soaking (%)	11	11
Moisture Content after soaking (%)	N. A.	12
Swell (% of initial height)	N. A.	0·5
CBR at 0·100" penetration (%)	30	23
CBR at 0·200" penetration (%)	34	29

Compaction Summary

Maximum Dry Density (lb./cu. ft.)	122
Opt. Moisture Content (%)	11



MODIFIED COMPACTION

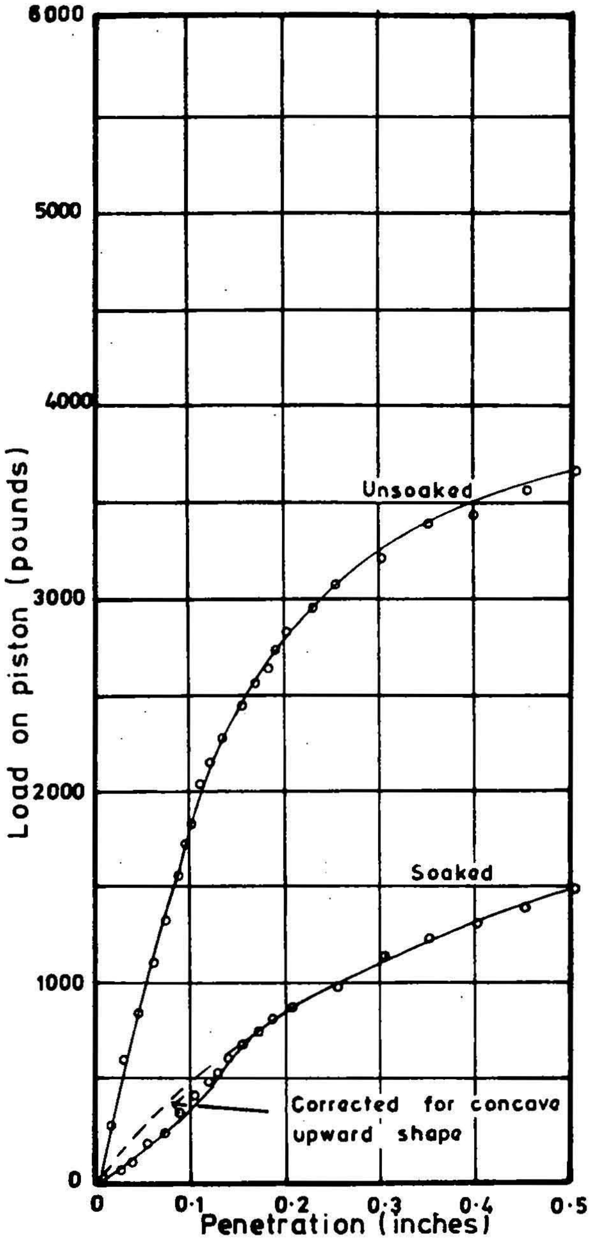
COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES

PROJECT
TUGGERANONG FREEWAY STAGE II

CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS

Soil Unit 8	Location Test Pit 4 (2·29 - 2·59 m)
Description Greenish yellow clayey completely weathered rhyodacite	
Tested by J.K. and L.P.	Calculations by J.K.
Drawn by M.E.	Checked by J.K. and PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. 155/A16/861 (6of10)

APPENDIX 5



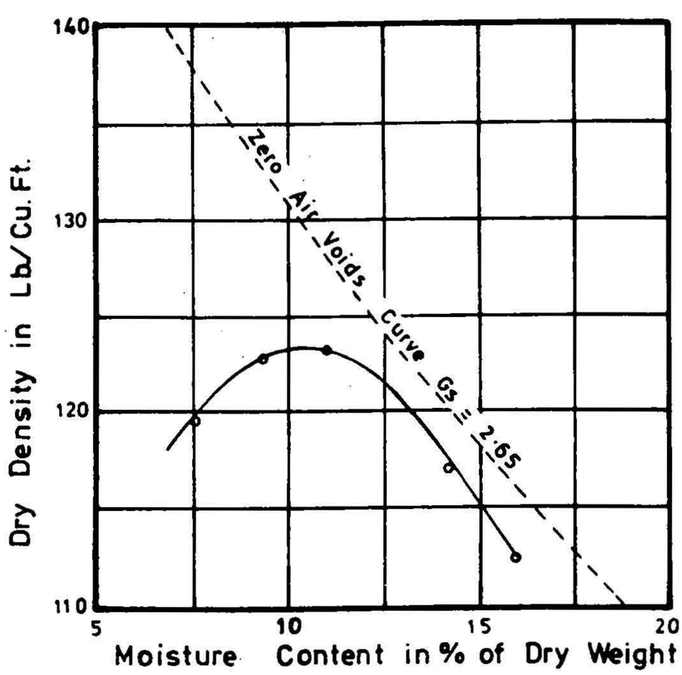
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	125	123
Moisture Content before soaking (%)	11	11
Moisture Content after soaking (%)	N. A.	13
Swell (% of initial height)	N. A.	1·4
CBR at 0·100" penetration (%)	64	17
CBR at 0·200" penetration (%)	63	19

Compaction Summary

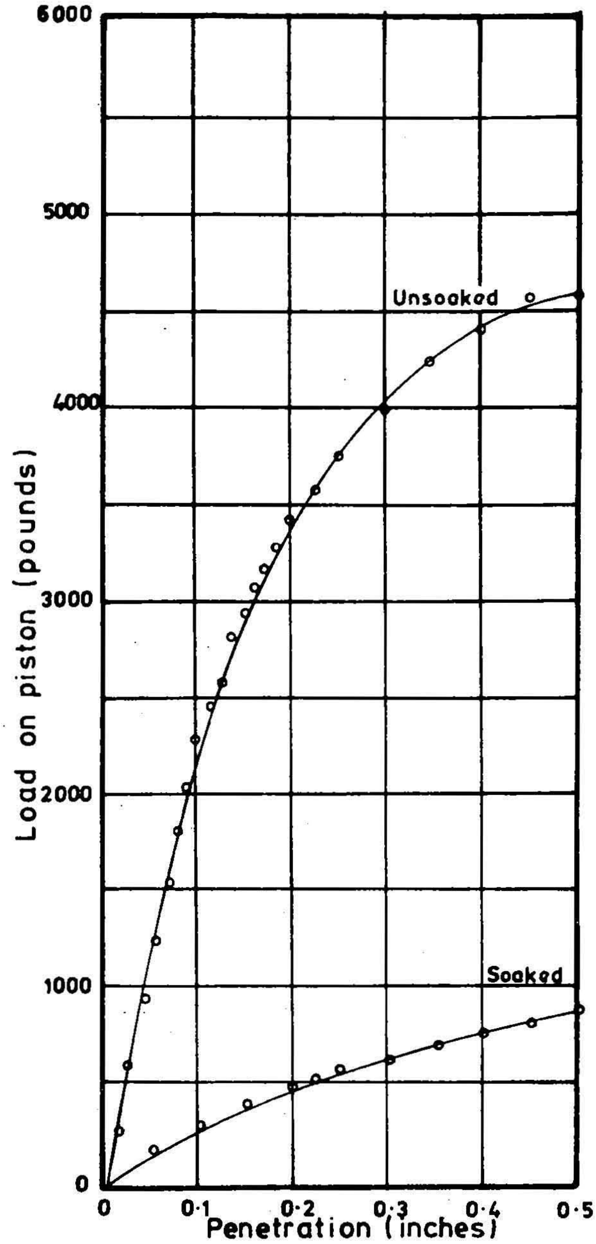
Maximum Dry Density (lb./cu. ft.)	124
Opt. Moisture Content (%)	11



MODIFIED COMPACTION

COMMONWEALTH OF AUSTRALIA BUREAU OF MINERAL RESOURCES	
PROJECT TUGGERANONG FREEWAY STAGE II	
CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS	
Soil Unit 10	Location Test Pit 5 (0·46 – 0·76 m)
Description Red clayey sand	
Tested by J.K. and L.P.	Calculations by J.K.
Drawn by M.E.	Checked by J.K. and PVE
Supervising Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (7 of 10)

APPENDIX 5



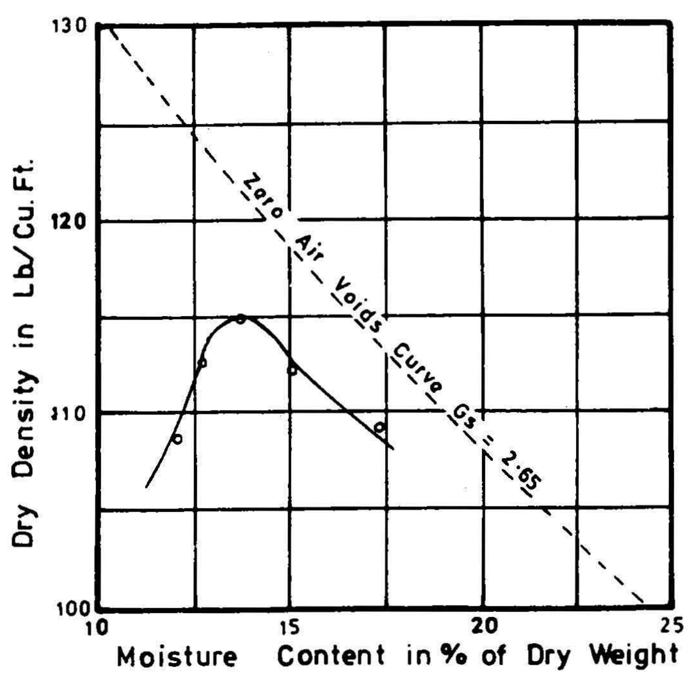
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	113	112
Moisture Content before soaking (%)	15	15
Moisture Content after soaking (%)	N.A.	17
Swell (% of initial height)	N.A.	2·1
CBR at 0·100" penetration (%)	75	10
CBR at 0·200" penetration (%)	76	11

Compaction Summary

Maximum Dry Density (lb./cu. ft.)	115
Opt. Moisture Content (%)	13



MODIFIED COMPACTION

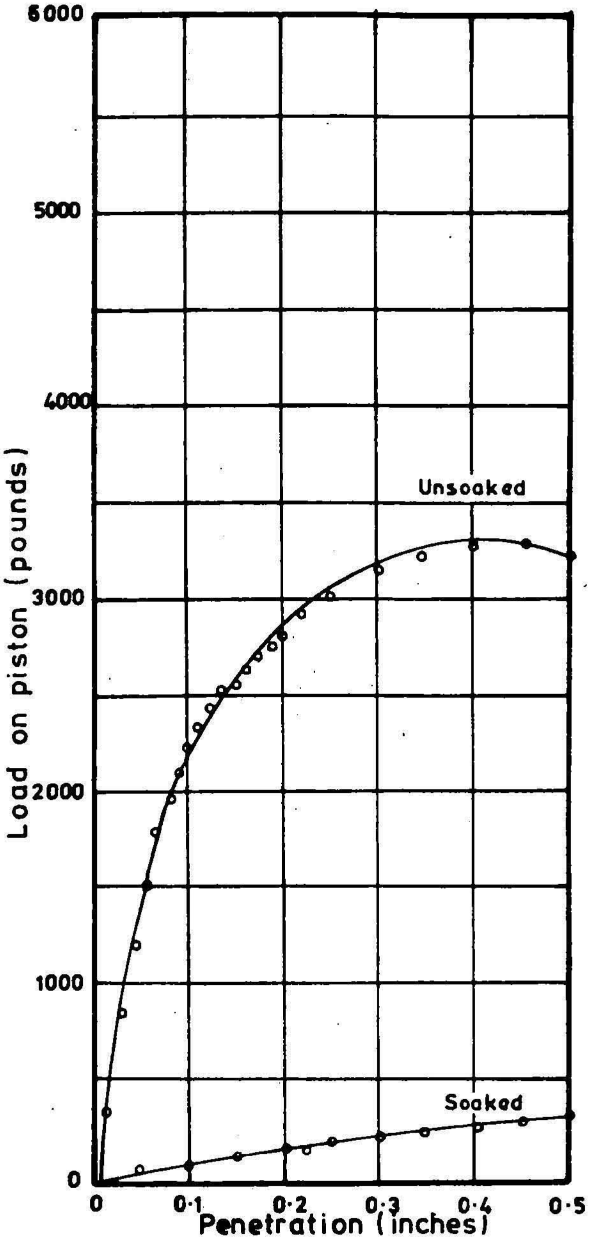
COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES

PROJECT
TUGGERANONG FREEWAY STAGE II

CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS

Soil Unit: 12	Location: Test Pit 4 (0·46 - 0·76 m)
Description: Red heavy sandy clay	
Tested by: J.K. and L.P.	Calculations by: J.K.
Drawn by: M.E.	Checked by: J.K. and PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (8 of 10)

APPENDIX 5



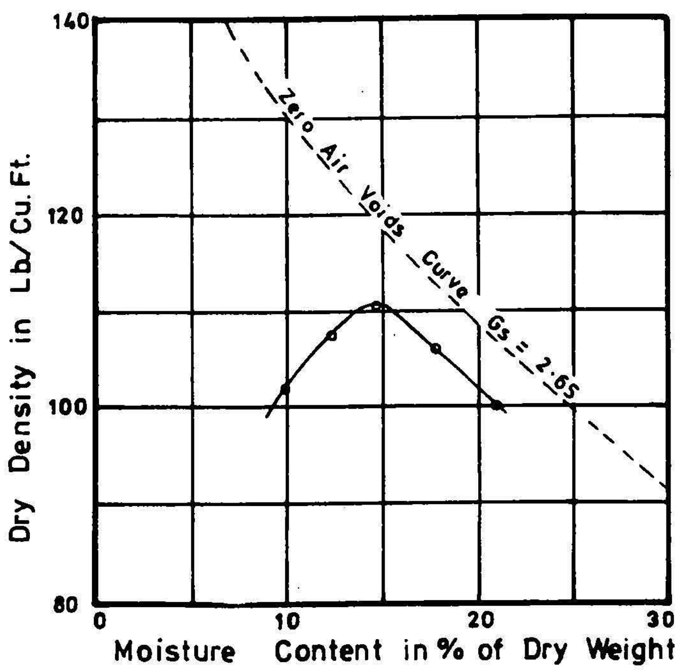
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft. lb./cu. ft.)	56,250	56,250
Dry Density before soaking (lb./cu. ft)	107	109
Moisture Content before soaking (%)	15	15
Moisture Content after soaking (%)	N.A.	19
Swell (% of initial height)	N.A.	3.6
CBR at 0·100" penetration (%)	74	4
CBR at 0·200" penetration (%)	63	4

Compaction Summary

Maximum Dry Density (lb./cu. ft.)	112
Opt. Moisture Content (%)	14



MODIFIED COMPACTION

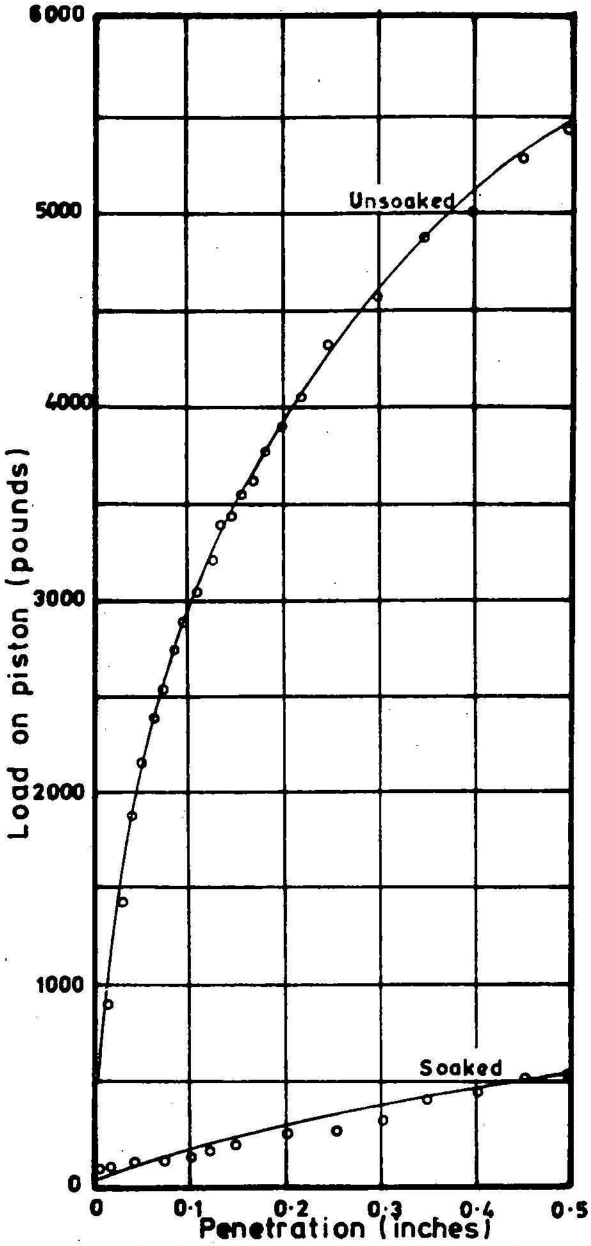
COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES

PROJECT
TUGGERANONG FREEWAY STAGE II

CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS

Soil Unit 15	Location Test Pit 6 (0·61 - 0·91 m)
Description Mottled red, gray and yellow heavy clay	
Tested by J.K. and L.P.	Calculations by J.K.
Drawn by M.E.	Checked by J.K. and PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (9 of 10)

APPENDIX 5



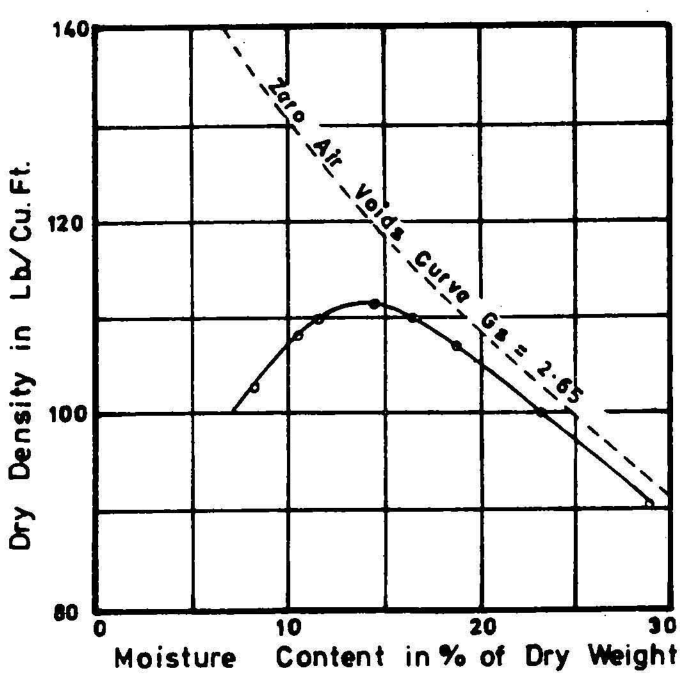
CALIFORNIA BEARING RATIO

CBR. Summary

	Unsoaked	Soaked
Compactive effort (ft.lb./cu.ft.)	56,250	56,250
Dry Density before soaking (lb./cu.ft)	108	109
Moisture Content before soaking (%)	14	14
Moisture Content after soaking (%)	N.A.	15
Swell (% of initial height)	N.A.	4·4
CBR at 0·100" penetration (%)	97	5
CBR at 0·200" penetration (%)	87	6

Compaction Summary

Maximum Dry Density (lb./cu. ft.)	112
Opt. Moisture Content (%)	14



MODIFIED COMPACTION

COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES

PROJECT
TUGGERANONG FREEWAY STAGE II

CALIFORNIA BEARING RATIO AND MODIFIED COMPACTION RESULTS

Soil Unit: 16	Location: Test Pit 3 (0·91 – 1·22 m)
Description: Massive olive fat clay	
Tested by: J.K. and L.P.	Calculations by: J.K.
Drawn by: M.E.	Checked by: J.K. and PVB
Supervising Geologist	
To accompany Record 1972/73	Drawing No. I55/A16/861 (10 of 10)

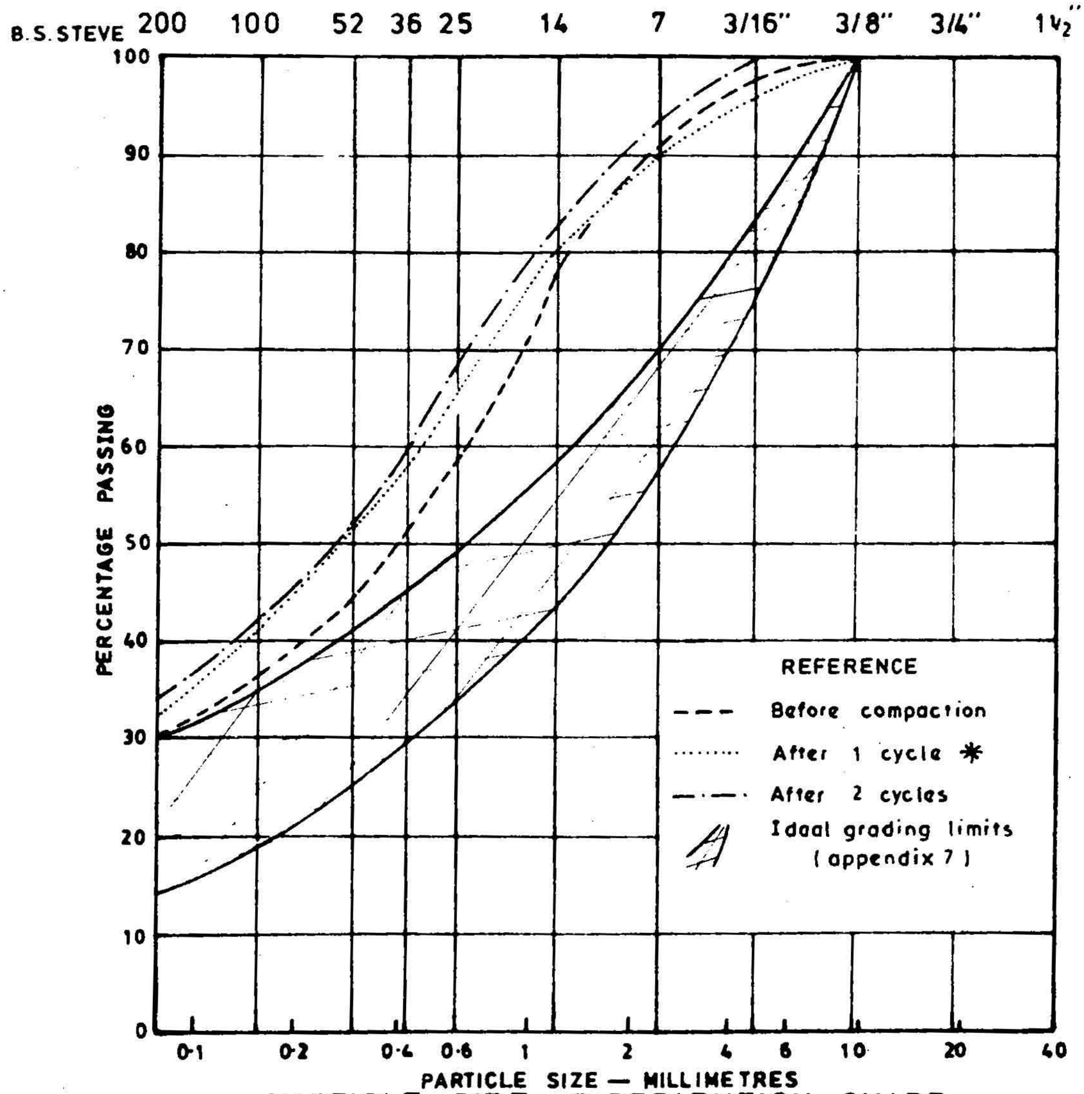
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 5

Description Pinkish grey indurated slopewash

Location Test pit 1 (0·46 – 0·76m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	18	18			
Plasticity Index	4	4			
Assessed CBR	23	23			

✱ 1 cycle is equivalent to a compactive effort of 56,250 ft lbs / cu ft (274,500 Kgs m/m³)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. ISS/A16/862 (1 of 10)

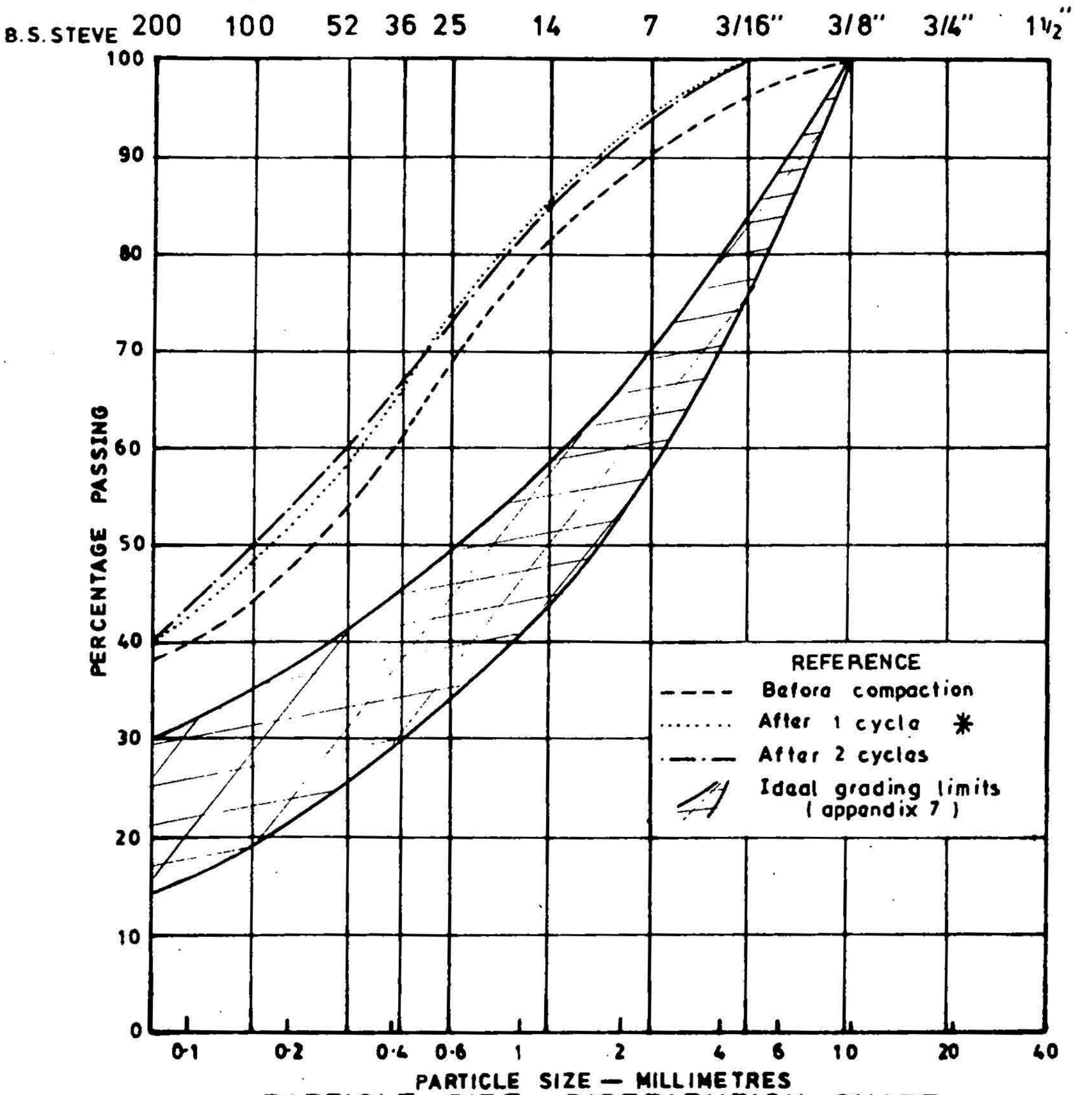
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 5

Description Pinkish grey indurated slopewash

Location Test pit 1 (1·07 – 1·37m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	20	19			
Plasticity Index	6	5			
Assessed CBR	21	21			

✳ 1 cycle is equivalent to a compactive effort of 56,250 ft lbs / cu ft (274,500 Kgs m/m³)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. I55/A16/862 (2 of 10)

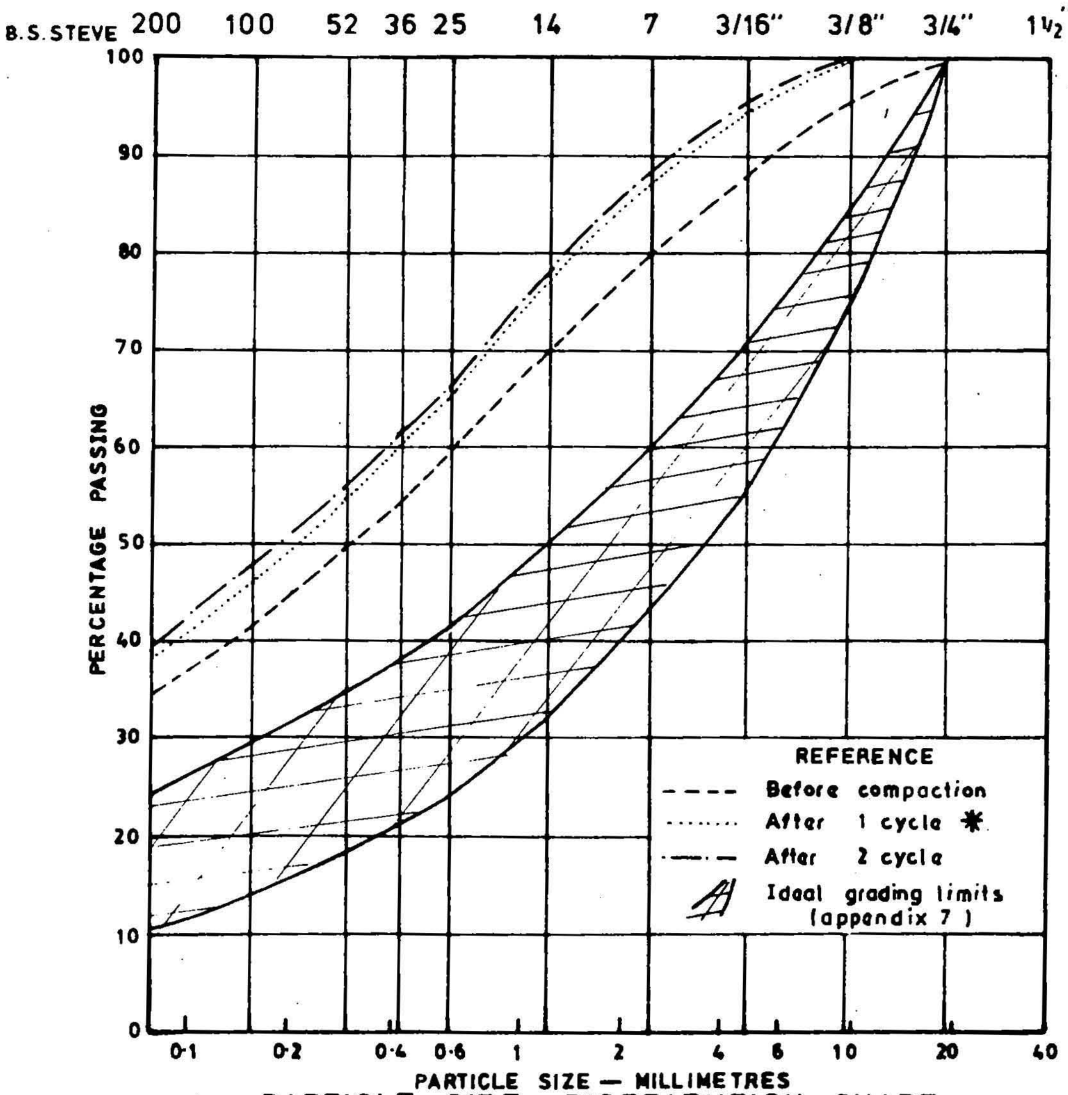
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 5

Description Pinkish grey indurated slopewash

Location Test pit 2 (1·52 – 1·83 m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	25	25			
Plasticity Index	10	10			
Assessed CBR	20	20			

* 1 cycle is equivalent to a compactive effort of 56,250 ft lbs/cu ft (274,500 Kgs m/m³)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. ISS/A16/862 (3 of 10)

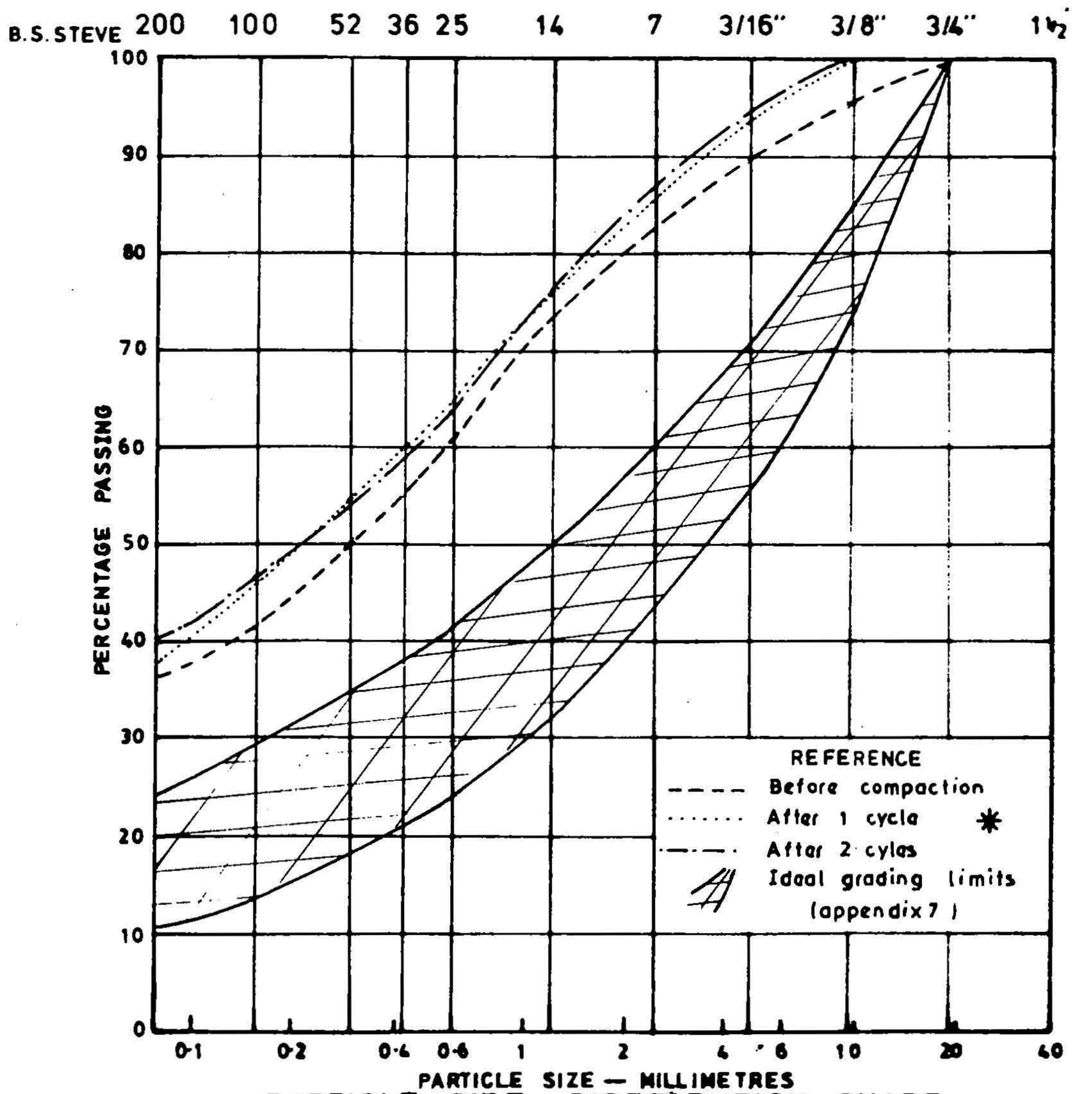
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 5

Description Pinkish grey indurated slopewash

Location Test pit 2 (2·13 - 2·44m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	28	29			
Plasticity Index	12	13			
Assessed CBR	20	20			

✱ 1 cycle is equivalent to a compactive effort of 56,250 ft lbs / cu ft (274,500 Kgs m/m²)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. I55/A16/862 (4 of 10)

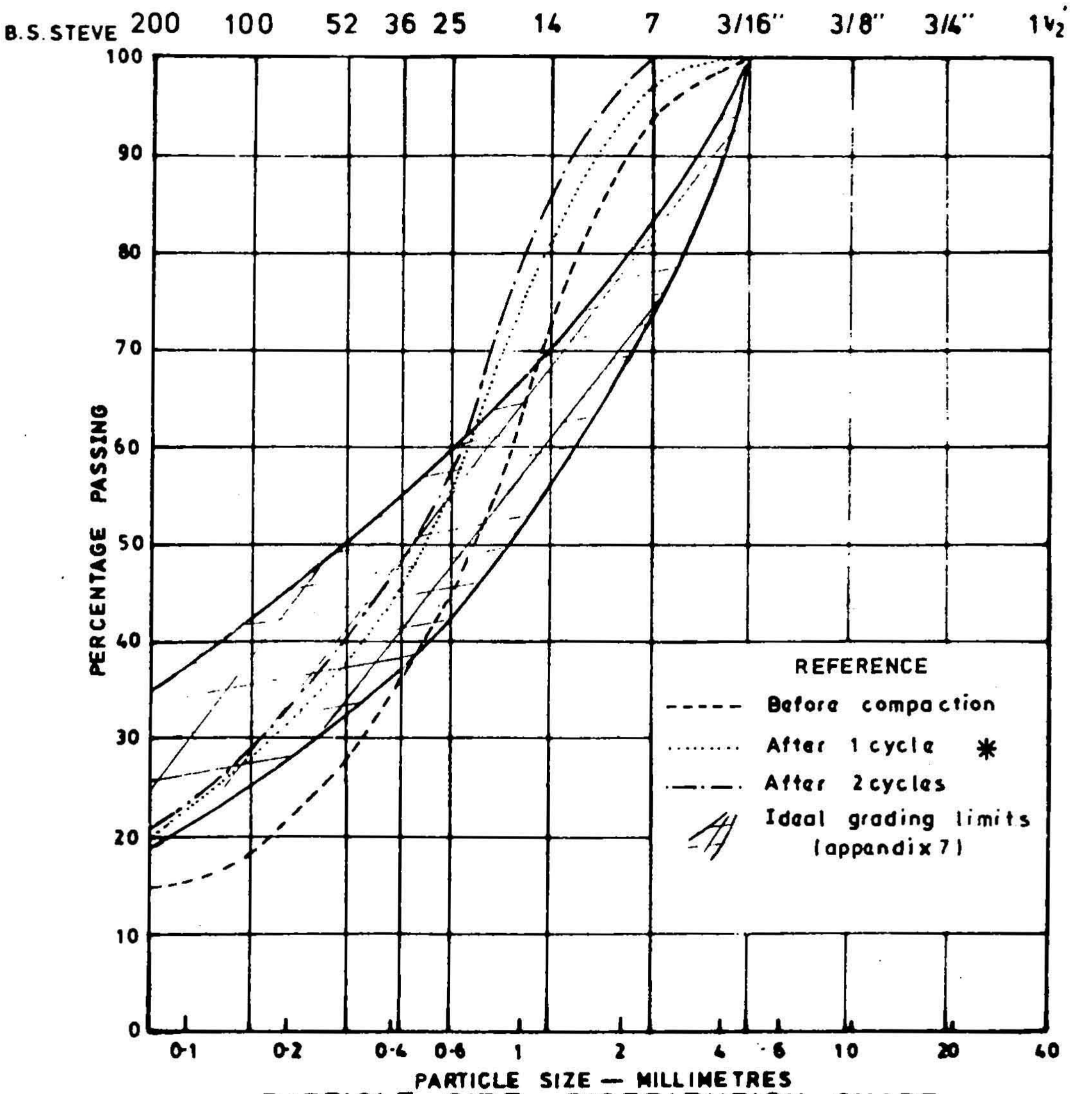
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 8 Sub-unit 8A

Description Purple completely weathered rhyodacite

Location Combined samples from auger hole 14 (4·57–6·40m) & auger hole 16 (2·76–3·35m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	28	29			
Plasticity Index	10	11			
Assessed CBR	15				

* 1 cycle is equivalent to a compactive effort of 56,250 ft lbs/cu ft (274,500 Kgs m/m³)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. I55/A16/862 (5 of 10)

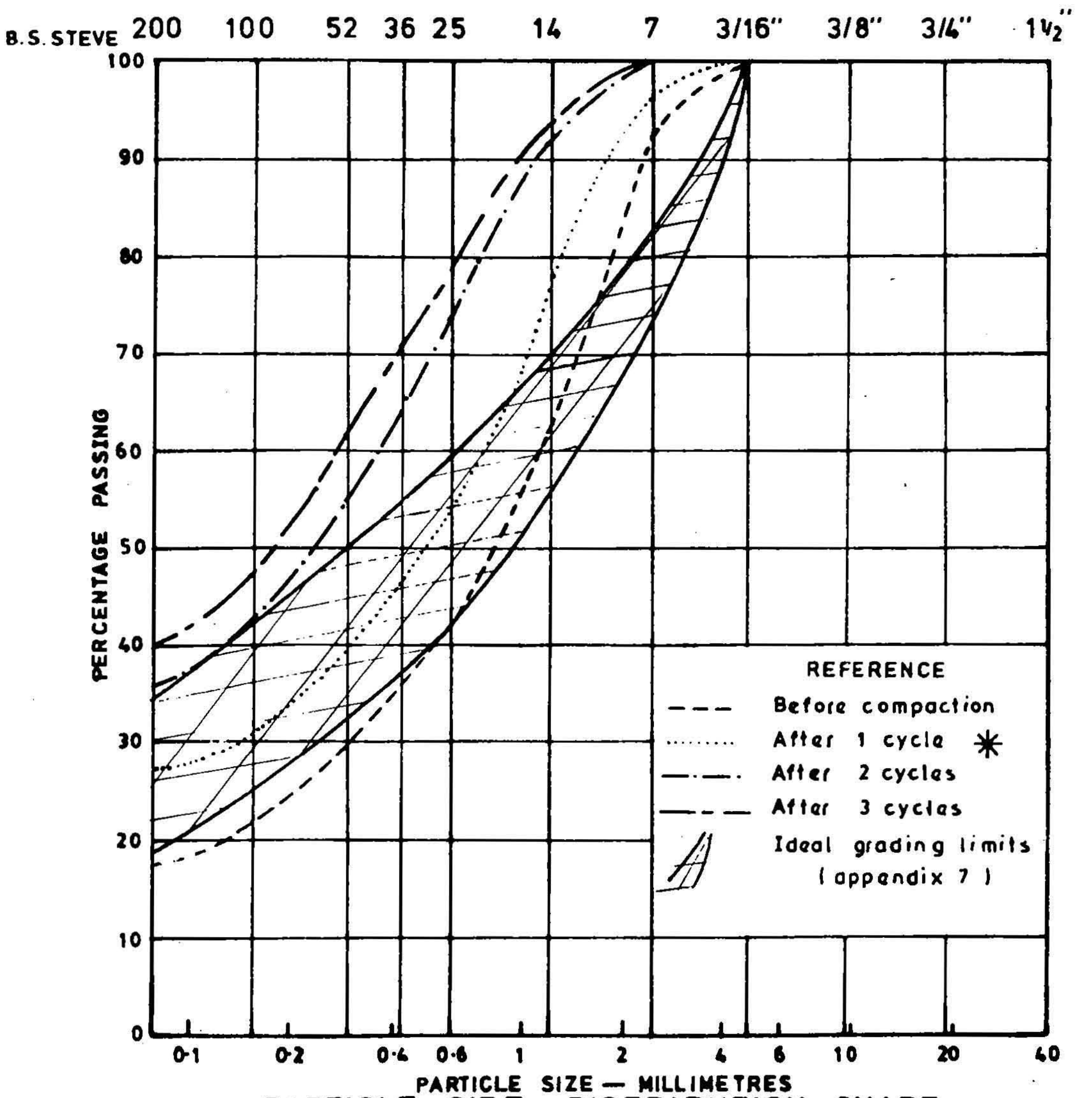
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 8 Sub-unit 8B

Description Yellowish red completely weathered rhyodacite

Location Test pit 4 (1·22 – 1·52 m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	34	37	38	38	
Plasticity Index	17	19	21	20	
Assessed CBR	22	16	13	13	

✳ 1 cycle is equivalent to a compactive effort of 56,250 ft lbs / cu ft (274,500 Kgs m/m³)

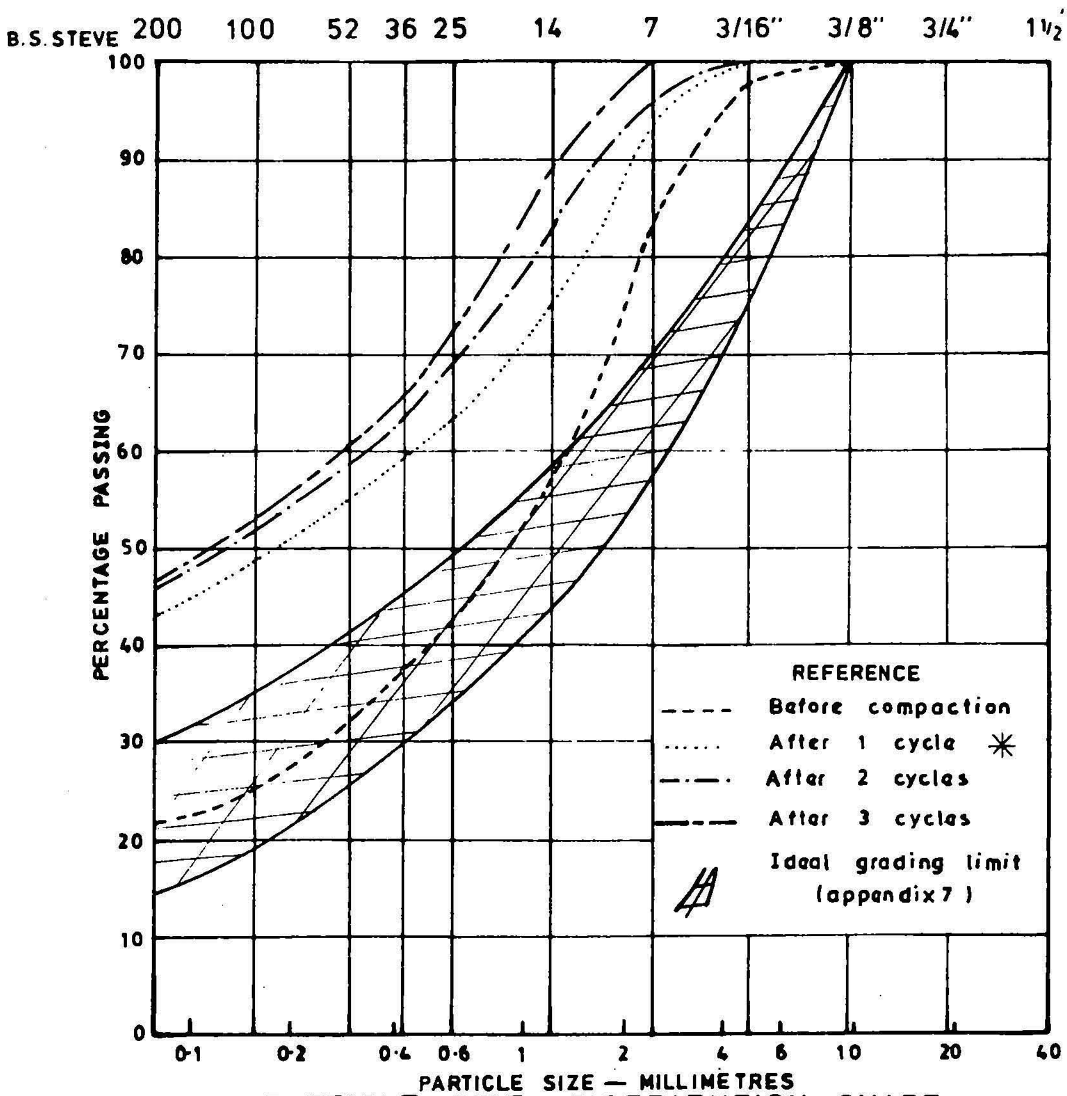
Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. I55/A16/862 (6 of 10)

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 8 Sub-unit 8

Description Greenish yellow completely weathered rhyodacite

Location Test pit 4 (2·29 – 2·59 m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	37	43	44	44	
Plasticity Index	18	25	25	26	
Assessed CBR	18	11	11	10	

✳ 1 cycle is equivalent to a compactive effort of 56,250 ft lbs/cu ft (274,500 Kgs m/m³)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. I55/A16/862/ (7 of 10)

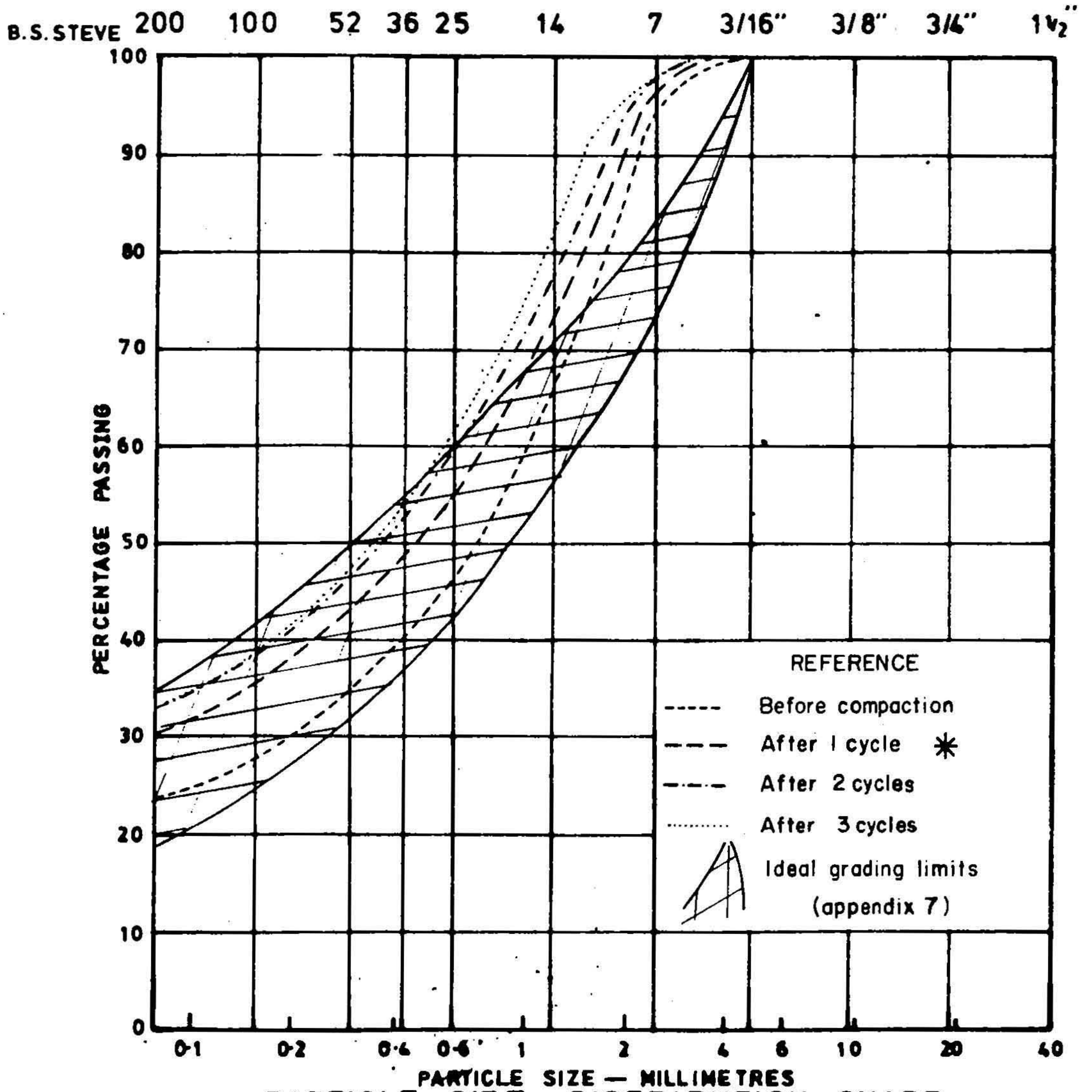
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 10

Description Red clayey sand.

Location Test pit 5 (0·46-0·76m).



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	28	30	29		
Plasticity Index	12	13	13		
Assessed CBR	21	19	19		

* 1 cycle is equivalent to a compactive effort of 56,250 ft lbs / cu ft (274,500 Kgs m/m^3)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. 155/A16/862 (8 of 10)

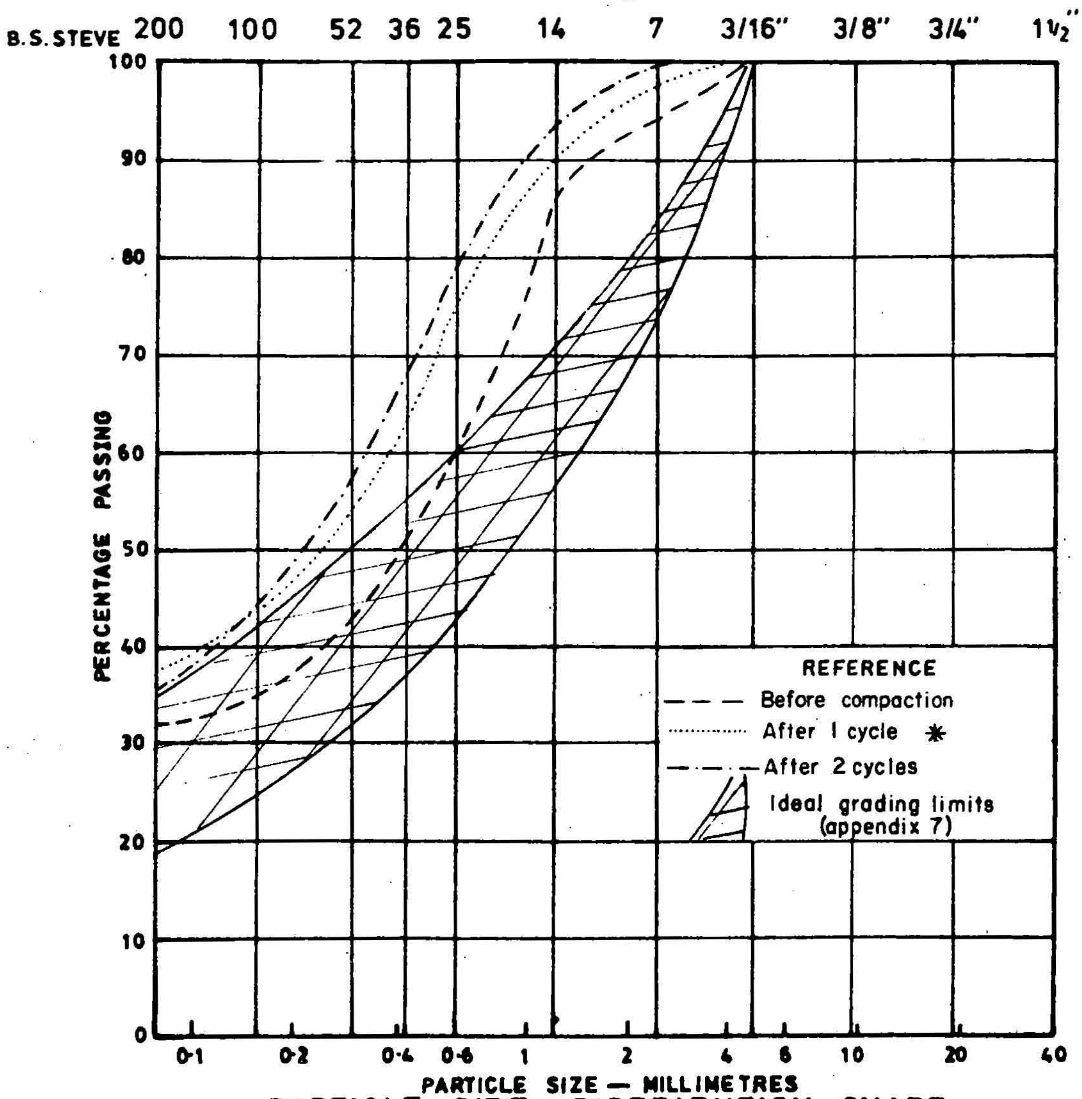
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT II

Description Red friable sandy clay

Location Combined sample from several probes around auger hole 25 (0·38-0·91m).



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	44	45			
Plasticity Index	25	26			
Assessed CBR	15	13			

* 1 cycle is equivalent to a compactive effort of 56,250 ft lbs / cu ft (274,500 Kgs m/m³)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. 155/A16/862 (9 of 10)

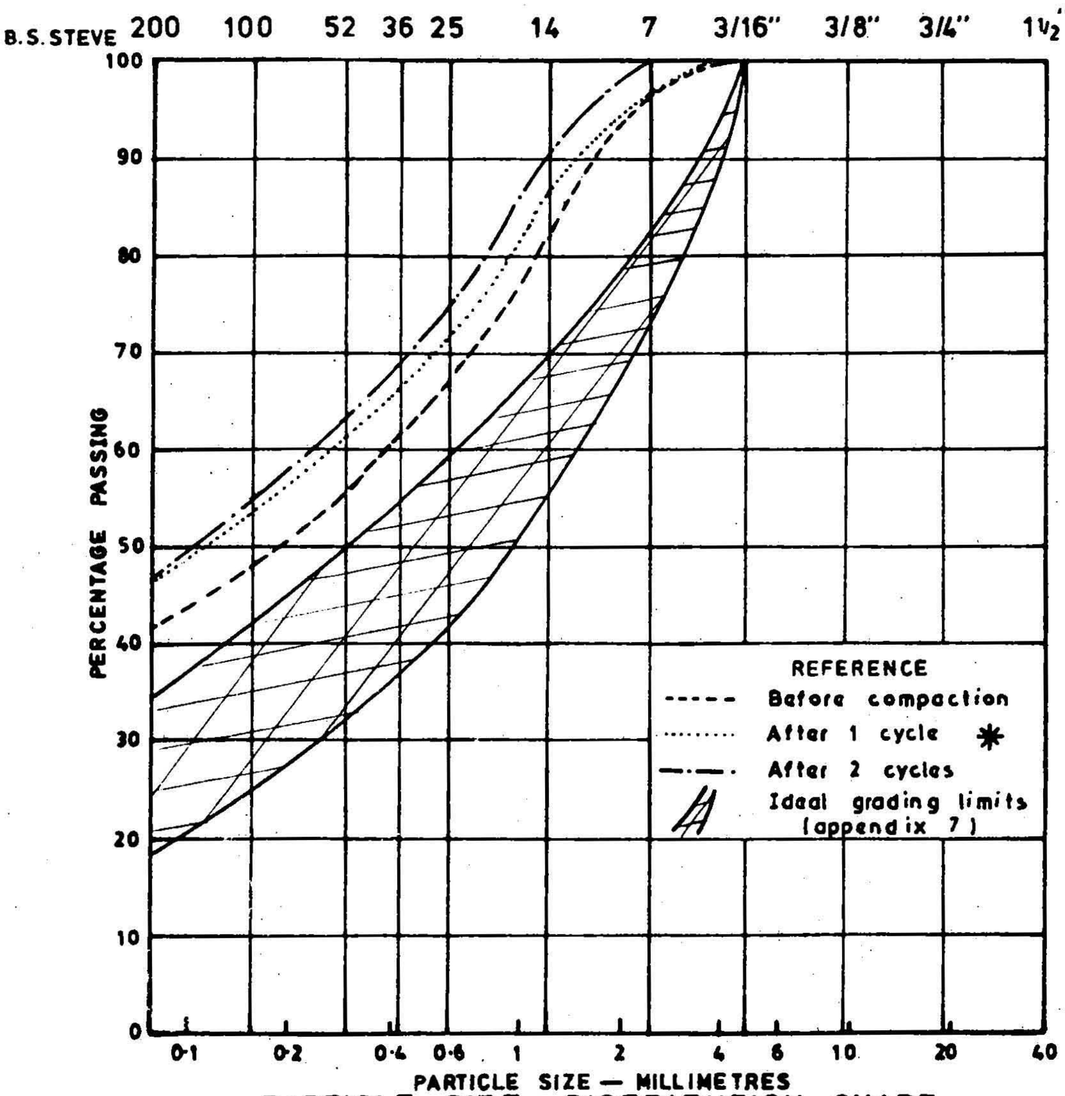
APPENDIX 6

CHANGE OF INDEX PROPERTIES AFTER COMPACTION

SOIL UNIT 12

Description Red heavy sandy clay

Location Test pit 4 (0·46 – 0·76m)



PARTICLE SIZE DISTRIBUTION CHART

OTHER PARAMETERS					
Index	Before compaction	After 1 cycle	After 2cycles	After 3cycles	After 4cycles
Lower Liquid Limit	54	56			
Plasticity Index	34	35			
Assessed CBR	10	8			

✱ 1 cycle is equivalent to a compactive effort of 56,250 ft lbs / cu ft (274,500 Kgs m/m³)

Tested by J.K. and L.P.	Drawn by M.E.	Project Geologist	
Calculations by J.K.	Checked by	To accompany Record 1972/73	Drawing No. I55/A16/862 (10 of 10)

APPENDIX 7

TECHNICAL NOTES

(a) Assessment of the California Bearing Ratio (CBR)

Assessed soil CBR values are used in the A.C.T. to calculate gravel pavement thickness. Values can be calculated from plasticity, particle size, and linear shrinkage parameters; three different equations (1, 2, 3 below) all derived empirically from experimental CBR results, can be used (NCDC & CRBV).

Values calculated for fine-grained plastic soils approximate to true values but for coarser soils there can be large discrepancies. Equation 1 (see below) gives erronously high results for coarse-grained plastic soil so for these Equations 2 and 3 were averaged. For all other soils the average value obtained from the three equations was taken as the assessed CBR.

$$CBR = 4.5 + \frac{(20.0.01bd - a(0.2 + 0.005c))^2}{18} \quad \ldots\ldots\ldots\ldots (1)$$

where a = that portion of the percentage smaller than 75 microns (passing No. 200 sieve) which is greater than 35 but does not exceed 75 expressed as a positive whole number from 1 to 40.

b = that portion of the percentage smaller than 75 microns (passing No. 200 sieve) which is greater than 15 and does not exceed 55 expressed as a positive whole number from 1 to 40.

c = that portion of the numerical lower liquid limit greater than 40 and not exceeding 60 expressed as a whole number from 1 to 20.

d = that portion of the numerical plasticity index greater than 10 and not exceeding 30 expressed as a whole number from 1 to 20.

Equation 2:

$$CBR = 10^x$$

where $x = (1.668 - 0.00506a + 0.00186b - 0.0168c - 0.00385bc)$

and a = percentage <420 microns

b = percentage < 75 microns

c = Linear shrinkage expressed as a percentage.

Equation 3:

$$CBR = 10^y$$

where $y = (1.886 - 0.0143d - 0.0045a + 0.00515\left(\frac{100b}{a}\right) - 0.0000456\left(\frac{100b}{a}\right)^2 - 0.00372)$

and a, b, and c have values as used in Formula 2.

d = plasticity index

e = percentage smaller than 2.40 mm

(b) Ideal Grading Limits

Ideal grading limits in Appendix 6 are drawn through points derived from the Talbot Equation, i.e.

$$p = 100(\frac{d}{D})^x$$

where

p = percentage, by weight, smaller than any particle size d

d = particle size

D = maximum particle size

x = an exponent

The exponent x is a function of the particle shape and its lower and upper limits are usually taken as 0.25 and 0.40 respectively.

If a particular soils' particle size distribution curve is within its grading limits, as determined by the maximum particle size; then it will compact very close to the maximum compaction possible depending on how close the value of x for that soil lies to the value 0.33.

REFERENCES

CRBV, 1969 - The design of flexible pavements. Country Roads Board of Victoria. Tech. Bull. 26.

NCDC - Recommended procedure for the design of flexible pavements in the A.C.T. National Capital Development Commission. Contract specifications.

SPANGLER, M.G., 1960 - Soil Engineering. 2nd Edition. Scranton Penn., International Textbook Co.

APPENDIX 8

GLOSSARY OF SELECTED GEOMORPHOLOGICAL TERMS

A HORIZON:	Zone of eluviation. The uppermost zone in the soil profile from which soluble salts and colloids have been leached and in which organic matter has accumulated.
BASE LEVEL:	The theoretical lower limit to which erosion can proceed.
B HORIZON:	Illuvial horizon. Lower soil zone enriched by deposition or precipitation of material from the overlying A horizon.
GROUNDSURFACE:	The materials, soils and surfaces relating to one K cycle.
K CYCLE:	The interval of time covering the formation, by erosion and/or deposition, of a new groundsurface.
LANDSURFACE:	Erosion surface representing a ground level in a landscape.
PEDIMENT:	Gently inclined planate erosion surfaces carved in rock and/or soil, generally veneered with fluvial and colluvial deposits and occurring between mountain fronts and valley basins.
PEDIPLAIN:	A plain, widely extending, usually alluviated, formed where pediments coalesce (the peneplain of the arid cycle).
PEDOLOGICAL:	The scientific description of soils.
PHASE:	Period of time.
PODZOLIC:	A soil which has a strong differentiated profile with contrasting A and B horizons; light grey-brown sandy silt changes abruptly to red-brown, yellow-brown, or mottled fine sandy clay to heavy clay.
PRAIRIE SOIL:	Uniform soil with weak profile differentiation, strong biological root influence throughout.
RED EARTH:	Soil that shows gradual vertical differentiation from greyish brown sandy silt to reddish brown fine sandy clay or light clay.
SCARP:	A steep slope which is the active zone of erosion along the margin of a landsurface.

SOIL PROFILE: A vertical section through a soil showing the various layers.

TABLELAND: A flat or undulating elevated area.

TRUNCATE: To cut the top from.

TUGGERANONG FREEWAY STAGE 2
INTERPRETATIVE SECTIONS ALONG FREEWAY ALIGNMENT