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MELBOURNE CABLE TUNNELS

GEOLOGICAL INVESTIGATIONS 1977-78

VOL. I

by

D.C. Purcell and G. Trand

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1. INTRODUCTION

This report describes the geological investigations carried out for the proposed Telecom Cable Tunnels under Queen, Lonsdale, Russell, Exhibition and Rathdowne Streets, Melbourne. The Department of Construction is designing the tunnels for the Australian Telecommunication Commission.

The tunnel locations, together with the location of shafts, chambers, investigation drillholes and surface geology are shown on Plates 1 to 8.

Design of the works including location of tunnel invert, chambers and shafts was not finalised until January 1978. Consequently, some drillholes do not now co-incide with the final location of the engineering structures that they were originally drilled for. Some drillholes were deepened in order to locate better rock conditions below the Quaternary deposits as a deeper tunnel alternative. Recent changes in tunnel location meant that drillhole 29 in Exhibition Street is now not located on the final tunnel alignment. Drillholes 1 and 2A are located on a future tunnel alignment in Queen Street.

Queen, Lonsdale and Russell Street tunnels will be "single" tunnels with a maximum width of 3.1 m and a height of 3.3 m (B-line to B-line). The Exhibition Street tunnel (Lonsdale to Victoria Streets) will have an enlarged profile with a width of 4.4 m and a height of 3.9 m (B-line measurements) (Plate 2). The total length of the tunnel (including chambers) is about 1834 m or 1881 m including the open out section across Latrobe Street.

Depths of cover above tunnel crown will vary from about 8-9 m in Queen Street, 5-8 m in Lonsdale Street, 4.5-5 m in Exhibition Street, 6-7 m in Russell Street, and about 5 m in Rathdowne Street.

The site investigations were carried out between July 1977 and February 1978 by Mr G. Trand (Department of Construction) and Mr D.C. Purcell (Bureau of Mineral Resources). Twenty six diamond-drill holes and two auger holes were drilled by Soilmech Pty. Ltd. for a total depth of 477 m.

2. SUMMARY OF CONCLUSIONS

Following the site and laboratory investigations it can be concluded that:

1. Construction of the tunnels, chambers and other appurtenant works are feasible; from a geological aspect a deeper invert would provide better tunnelling conditions over much of the route.

2. The tunnels will be driven through the following stratigraphic units:

<u>Rock type</u>	<u>Weathering*</u>	<u>Approximate length (m)</u>	<u>Approximate total length in unit (m)</u>
Mudstone	Zones 1 and 1-2	404	
	Zone 2 and 2-3	223	
	Zones 3 and 4	634	1261
Older Volcanics			188
Brighton Group and Werribee Formation			38
Colluvium			193
Elizabeth St. Formation			154
** TOTAL LENGTH OF TUNNELS			1834

* Definitions in Appendix 1

** Including chambers

3. Tunnelling conditions will be extremely variable within individual units and between units. The best conditions will be in zones 3 and 4 mudstone, and the worst in the Colluvium and Zone 1 mudstone.
4. The factor that will determine tunnelling conditions and stability more than any other will be the presence or absence of groundwater. The most sensitive units will be the Colluvium and Zone 1 Mudstone. Units will have a fairly low permeability, except the Colluvium, Werribee Fm and fractured Older Volcanics. No major sustained inflows are expected.
5. Rock loads should not be very high, the largest vertical load being about 290 kPa (Zone 1 Mudstone) and the smallest about 50 kPa (Zone 3 Mudstone). Rock loads in the Colluvium are very close to the strength of the material. Lateral pressures will be about one-third the vertical loads in all rock units, (excepting EW rock and unconsolidated material). Initially the tunnel face in clay (Zone 1 Mudstone or Elizabeth Street Formation) will be stable in all cases, but a decrease in strength associated with dissipation of pore water pressure may reduce long term stability.
6. Some loss of ground can be expected from all units; the loss could be potentially large from the Colluvium if it is water saturated and has not been pre-grouted. Good tunnelling techniques should minimise the ground losses and rock loads, and therefore ground surface settlements should be small, possibly up to about 15 mm in places.

7. The entire length of the tunnels and all appurtenant excavations will require full support during construction. A concrete sub-invert may be required in places. Combinations of steel sets, lagging and shotcrete will be the dominant support system. Shotcreting may not be possible in Zone 1 Mudstone, Colluvium and the Elizabeth Street Formation, particularly if these units are water saturated. Chemical grouting from the surface (if practical) may be necessary where the Colluvium intersects tunnels, chambers or shafts.
8. The most appropriate excavation methods would be as follows:

<u>Method</u>	<u>Approximate length of route (m)</u>	<u>Percent of route</u>
<u>Conventional drill-blast-muck</u>		
Zones 3-4 and 4 Mudstone (92 m)		
Basalt (110 m)	202	(10)
<u>Road Header (or like) machine</u>		
Zones 2 and 3 Mudstone (765 m)		
Basalt (78 m)		
Elizabeth Street Formation, if dry (154 m)	997	(55)
<u>Hand mining or/and overhead mucker</u>		
Zone 1 and 1 to 2 Mudstone (404 m)		
Colluvium (193 m)		
Brighton Gr. & Werribee Fm (38 m)	635	(35)
	<u>TOTAL</u>	<u>1834</u>

9. Chamber excavation conditions will be poor, even where they are located above the groundwater table. The potential for loss of ground during underground excavation is high, and if not carefully excavated and supported, caving to surface level is possible. Settlements will be greater than in the tunnels and traffic loads will need to be added to rock load computations. In open cut excavations it will be easier to control ground movements, and conditions will be good compared to underground operations. Colluvium occurring at or close to chamber locations should be stabilized prior to excavation.
10. Excavation conditions for the shafts will be poor and support in the form of steel rings and full timber lagging will be required.
11. Manholes and ventilation shafts can be easily drilled and cased to prevent caving.
12. The portal in Leichhardt Street will be located mainly in competent Zone 3 Mudstone. It is possible that some instability may occur in

parts of the open cut associated with poorly oriented defects in the Zone 3 Mudstone, and the top 3-4 m of the cut in Zone 1 and 2 Mudstone.

3. SITE INVESTIGATIONS CARRIED OUT

3.1 REVIEW OF EXISTING INFORMATION

The geology of the central business district of Melbourne is described by J.C. Brunley (1974) in "Explanatory notes on the 1:5,000 stratigraphic Map of Melbourne Central Business District" and "An Engineering Geologic Mapping System for the Central Business District of Melbourne, Australia" (1975). Additional information on the geology of the project area has been obtained from rock exposed in nearby building and civil engineering projects. In compiling this report reference has been made to many published papers on the properties of the Melbourne mudstone.

3.2 DRILLING

Twenty eight holes were drilled by Soilmech Pty. Ltd. between July and November 1977; 6 were angled and 22 were vertical. The planned holes were numbered consecutively, but decisions not to drill some holes account for missing numbers in the drillhole logs. The holes were drilled to an average depth of about 17 m. Of the 22 vertical holes two were augered to their full depth. A total of 477 m was drilled. Tube samples were taken in unconsolidated materials and piezometers were installed in appropriate drillholes (see geological logs of drillholes, Appendix 5). Cores were photographed in the core barrel prior to sealing (against moisture loss) and were later photographed in the core boxes prior to selection of samples for mechanical testing (Core photographs, Appendix 4).

3.3 ROCK TESTING

Selected samples of drillcore have been subjected to rock strength tests. Appendix 2 summarises results of these tests. A more detailed report on methods and results has been prepared by the Department of Construction (C.I.R.L. Report No. 78/S102)

3.4 SITE DISCUSSIONS

Discussion on tunnel design, geology and likely ground conditions were held at various times during site investigations with M. Ilbery, Department of Construction, and A.G. Bennet and G. Bailey of John Connell-Mott, Hay and Anderson, Hatch, Jacobs.

4. GENERAL GEOLOGY

Plate 1 shows a plan of the tunnel layout and the interpreted surface geology of the tunnel route.

4.1 PHYSIOGRAPHY AND WEATHERING

Construction fill covers most of the city area; it is usually less than about 1 m thick but is often deeper where it overlies Quaternary sediments. The Silurian Dargile Formation of mudstone or more precisely claystones and clayey siltstones with minor beds of fine sandstone (Nielson, 1970) has been weathered to varying degrees depending on the structure, defects, and proximity to dykes and/or sills, and can be highly weathered to depths in excess of tunnel invert. Weathering and lithologic boundaries will often be extremely irregular. The igneous intrusions are also weathered to varying degrees and are often extremely weathered to a stiff, whitish-grey siliceous kaolinite; some are only slightly weathered.

Five zones of weathering in the mudstones have been recognised by Neilson (1970) and are defined in Appendix 1. These zones have been used in the weathering description of mudstone in this report, but the weathering of other lithologies e.g. sandstone, basalt, is described in accord with the 'Degrees of Rock Weathering' also set out in Appendix 1.

4.2 ROCK TYPES AND STRATIGRAPHY

Silurian mudstones and sandstones crop out over about half of the city area and elsewhere they underlie Cainozoic sediments and basaltic lavas.

SILURIAN

Dargile Formation - The formation is composed of interbedded mudstone (claystones and clayey siltstones) and fine-grained sandstone and is intruded by acid igneous dykes and sills. Where weathered this formation is yellow-brown and the most common bed thickness is between 25 and 50 mm; some sandstone beds are much thicker (1 m and more). The strike of the beds within this formation varies mainly from about 005° to 020° ^{*}, and the beds range in dip from horizontal to vertical. Most of the tunnel and ancilliary structures will be excavated in weathered Dargile Formation.

TERTIARY

Werribee Formation - This formation was intersected below the basalt in holes 8 and 10 near the Queen Street-Lonsdale Street intersection. The material is an orange to white clayey silt with a 0.4 m thick gravel-silt layer marking the base of the Formation. It is a shallow water coastal marine deposit. At hole 10, this Formation occurs about 1 m below proposed tunnel invert level but it

* All bearings in this report and on the plates refer to grid north.

may be present at invert level a few metres eastwards. At hole 8 the Formation occurs from tunnel invert to crown level.

Older Volcanics - Basaltic lava flows occurred periodically throughout the deposition of the Werribee Formation. The basalt was intersected in drillholes 4, 5A and 6 in Queen Street and in hole 10 at the Lonsdale-Queen Street intersection. Drillcore shows the basalt to be variably weathered, mostly dense, and vesicular in parts (up to 40% vesicles were logged in a section of hole 5A). The basalt is confined almost entirely to the Queen Street sections of the route.

Brighton Group - This group is composed of shallow water marine and alluvial clayey sands and sandy clays, and was intersected in Queen Street in drillholes 6 and 8. The sediments are partly or poorly consolidated with a variable degree of limonite cementation.

QUATERNARY

Colluvium - The Colluvium at the Lonsdale and Russell St. intersection was recovered in drillholes 21A, 23, 23A and 24 and is mainly sand with some clay, but the sand/clay ratio varies laterally and vertically from place to place. Sand grains are sub-angular to angular (minor rounded). The Colluvium appears to fill a depression striking roughly in a northerly direction, across Russell, Lonsdale and Exhibition Streets. Weathered dyke material was recovered from drillholes 21A, 23 and 23A and the Colluvium filled gully may follow a bedrock weakness related to a series of weathered dykes.

Elizabeth Street - Formation This is a fluviatile deposit of soft to stiff sandy clay with some rounded sand and gravel. Drillholes 11, 12, 13, 14, 15, 16 and 17 intersected this Formation along Lonsdale Street down to a depth of 13.25 m. The mudstone underlying the thickest part of the Formation is generally not deeply and highly weathered, and moderately weathered rock occurs close to the mudstone - Elizabeth Street Formation contact.

Note: The upper surface of the Dargile Formation is irregular and the location of this geological boundary is likely to vary considerably from the approximate boundaries between drillholes shown in the accompanying sections.

4.3 STRUCTURE

4.3.1 Folding

The Dargile Formation has been folded into several major folds with many superimposed minor folds. The bedding in the drillcores varies greatly even over a few centimetres in the one drillhole. The fold axes generally strike close to north-south. Drag folding adjacent to dykes has been observed in the area, and a sharp change in the dip of bedding in drill core can sometimes be attributed to intrusion of a nearby dyke (e.g. core from drillhole 1).

Inferred fold axis locations are shown on Plates 1 to 8.

4.3.2 Faulting

Major faults of large displacement have not been found in the Melbourne City area and no evidence of any such faults was found in this investigation. Narrow (less than 1-2 m wide) faults, and sheared and fractures zones do occur in the mudstone (and sandstone) and such zones are to be expected in tunnelling. Sheared rock may be associated with dyke intrusions, and fractured or intensely jointed rock may occur in areas of tight folding.

4.3.3 Jointing

No statistical analysis of joint orientations in the mudstone was possible during this investigation due to lack of outcrop and the fact that only 2 core orientations were obtained.

Data on joint orientations have probably been collected from MURL excavations but are not available for this report. Generally however, the orientations of joint sets will be related to the folding and attitude of bedding. Jointing parallel to and normal to bedding planes will be the most prominent, and close jointing will be associated with tight folding and nearby intrusion.

At tunnel level, joints will mostly be closely spaced although joints in zone 3 and 4 mudstone may often be moderately close to moderately spaced (see Appendix 1 for definitions of joint spacing).

Joints in the basalt are often irregular and closely spaced; some are rough and open, and others are tight or cemented to varying degrees. Clay occurs in open joints especially where the basalt is highly weathered.

4.3.4 Dykes and sills

Devonian dykes and sills have intruded the Silurian rocks and a number were intersected in the drillholes. Most are probably aligned parallel to the main fold axis and most are near vertical. Bedding in the mudstone has been dragged adjacent to some of the intrusions and has caused some shearing, fracturing and close jointing near the contacts. They are weathered to varying degrees and depths; most are at least highly weathered (holes 14, 21 and 26) but some are moderately to slightly weathered (holes 21A, 23 and 23A). Known and interpreted dyke locations are shown on Plate 1.

4.4 GROUNDWATER CHEMISTRY

From 1965 to 1973 several hundred groundwater samples from MURL shafts and bores were chemically analysed to determine whether the groundwater was aggressive to construction materials. It was found that groundwater under the north and east parts of MURL in the vicinity of the proposed Telecom Tunnel is a slight to moderately aggressive sodium chloride type water. Detailed analyses are given by Brumley, 1977. Contours of the potentiometric surface prior to MURL excavations are shown on Plate 1.

4.5 SEISMICITY

An extract from the "Earthquake Risk Map of Australia (1978)" is included in Appendix 3 with a print out of earthquake data relevant to construction in Melbourne.

The best defined cluster of earthquake epicentres is near Wilsons Promontory about 150 km southeast of Melbourne City. Another cluster occurs to the southwest of the city off the Otway Coast. In southeast N.S.W., the return period of an earthquake of M5.5 (Richter) and 6.5 is about 30 years and 300 years respectively (Drake, 1976); the Melbourne area is probably less active than this. Although it is unlikely, it is not impossible that an earthquake of M6.5 or 7 could occur in the area. Ground displacement along faults is most unlikely but liquifaction associated with ground movements in saturated alluvial deposits (such as the colluvium in Russell and Lonsdale Streets) is possible, even with earthquakes lower than M5.5.

An isoseismal map of the 20/6/69 Gippsland Earthquake (M5.9 ML) with its epicentre about 30 km south of Morwell, shows Melbourne City to lie within zone III felt intensity (Modified Mercalli) (Wilkie, 1970).

Seismic risk calculations for a 50 year return period for Hastings (a few km south of Melbourne City) give peak horizontal accelerations of 85 cm/sec^2 , and a peak velocity of 5 cm/sec (Underwood, 1969).

5. ENGINEERING GEOLOGY

5.1 DARGILE FORMATION

Silurian mudstone (and sandstone) will comprise about 35 percent of the Queen Street tunnel (chainage 00 to 270), 70 percent of the Lonsdale Street tunnel, approximately 90 percent of the Russell Street tunnel, 80 percent of Exhibition Street tunnel and all of Rathdowne Street tunnel. Seventy percent of the entire project is located in this Formation. About 75 percent of the Dargile Formation is mudstone (siltstone and claystone) and about 25 percent is interbedded sandstone. Drilling and excavations indicate that the sandstone content will increase slightly east of Elizabeth Street, although at tunnel level most of the sandstone will be moderately weathered.

5.1.1 Weathering

The degree of weathering of the Dargile Formation at tunnel level varies considerably along the tunnel routes and may change from Zone 3 at invert to Zone 1 or 2 at crown at the same station.

An estimate of the percentage lengths of tunnel in the various weathering categories is given below:

Degree of weathering	Zone of mudstone weathering	Length (m)	Percent of Dargile Formation	Percent of tunnel
EW	1	110	9	6
EW-HW	1 to 2	294	23	16
HW	2	84	7	5
HW-MW	2 to 3	139	11	8
MW	3	542	43	30
MW-SW	3 to 4	92	7	5
	TOTAL	1261	100	70

NOTE: These lengths and percentages are approximate only as they rely on interpretation between widely spaced drillholes. In calculating these percentages, the stability of the tunnel crown has been considered; for example, if Zone 3 rock occurred up to crown level and was immediately overlain by Zone 1 rock, then the length of tunnel involved would be classed as Zone 1. Where more competent material above the springline, such as dry Elizabeth Street Formation, overlies damp Zone 1 rock, then for stability reasons, the section would be omitted from the Dargile Formation figures. The percentages given therefore, should be regarded as "effective" percentages with regard to crown stability.

Most of the Zone 3 mudstone at tunnel level and above tunnel crown occurs in Lonsdale Street between hole 17 and Swanston Street, and between Exhibition Street and Spring Street, with some Zone 4 mudstone at Spring Street; Zones 1 and 2 mudstones intersect the tunnel elsewhere.

The degree of weathering of the mudstone will play a major role in tunnel stability and method of excavation. Zones 1 and 2 can be regarded as incompetent rock (Appendix 1) as far as tunnel stability is concerned; Zone 3 rock is generally competent and Zone 4 rock is very competent but difficult to excavate without blasting.

Zones 1 and 2 mudstones are soft and have low strength; they are generally yellow-brown in colour with a high clay content, and bedding is almost always indiscernable. Hardness ranges (Mohs scale) for the mudstone are given in Appendix 1.

Zone 3 mudstone is of moderate strength and hardness; clay seams (extremely weathered beds) and clay-coated joint surfaces occur occasionally. The mudstone is generally pale brown-grey with clearly defined bedding.

Zone 4 mudstone is hard and strong, and defect surfaces are generally tight and clean; it is greyish in colour.

Zone 5 mudstone was not found in this investigation and is not expected to occur at tunnel level.

Test results show strength differences between samples of different degrees of weathering (6.1.3.1 and Appendix 2).

5.1.2 Rock strength

A number of samples from drillcore were tested at the Department of Construction Central Investigation and Research Laboratory (C.I. and R.L.) Melbourne. Parameters were obtained from cores in different states of weathering where possible. The ranges of the various parameters are summarised below. Full results are given in Appendix 2.

Degree of Weathering	Zone 1	Zone 2	Zone 3
Dry Density (kg/m^3)	1700 to 2000	2000 to 2300	2200 to 2500
Moisture Content (%)	7 to 20	5 to 10	3 to 8
**UCS (MPa)	-	1.3 to 1.6	4.1 to 10.1
UCS equivalents derived from		1.8 to 11.4	3.7 to 27.0
*Point load (MPa)		(mostly 3.2)	(mostly 8.0)
Shear Stress (kPa)	127(single test only)		

* Point Load values have been converted to UCS equivalents using a conversion factor of times 16 in accord with the results in Appendix 2.

** Unconfined compressive strength.

5.1.3 Groundwater

Groundwater levels and piezometer locations are shown on the geological sections (Plates 3 to 8) and in Appendix 6. MURL construction has lowered the groundwater levels to below tunnel invert, and it will be necessary to monitor groundwater movements after MURL excavations have been closed. Piezometers have been placed to monitor the recovery of the potentiometric surface.

Permeability of the mudstone varies considerably. The groundwater inflows that will affect tunnelling will be through open joints and fractures. Permeability in Zone 1 and 2 material will be low, possibly less than about 1×10^{-5} cm/sec, due to the high clay content. Water inflows into the tunnel through open and clean defects will be confined to Zone 3 or 4 rock where open fractures are more likely; these fractures may be associated with tight folding (and crumpling), fractured rock adjacent to dyke intrusions, or open jointed or fractured rock that is connected to a perched water table in Quaternary alluvial or colluvial deposits. A constant head permeability test in moderately weathered sandstone in hole 21 (13.3 to 14.6 m) gave a permeability of 6.96×10^{-4} cm/sec (using a flow rate 13 l/min)(see Appendix 2).

The presence of groundwater flow or seepage along clay-coated and poorly oriented defects in otherwise competent rock will decrease tunnel stability.

5.1.4 Rock quality

In order to give an indication of "rock quality" or degree of fragmentation of the mudstone, the core was assessed for rock quality designation (RQD)* for weathering Zones 2-3 and 3 and 4. The figures are given as percentages and are considered somewhat subjective due to the difficulty in deciding whether some bedding plane partings (in particular) were parted in situ, or were caused by drilling and handling of the core.

* See Appendix 1 for definition of RQD.

	RQD RATING					Length of core (m)
	0-25 (very poor)	25-50 (poor)	50-75 (fair)	76-90 (good)	90-100 (excellent)	
Zone 2 to 3	22%*	10%	35%	23%	10%	35.4
Zone 3 and 4	18%	30%	22%	10%	20%	123.0

* Length of core with this RQD category as a percentage of total length of core examined for the particular zones.

5.1.5 Rock defects

5.1.5.1 Bedding planes

Bedding planes are generally closely to moderately spaced, and vary from planar and smooth, to rough; some planes are tight, others are partly open and clay-coated and some are limonite cemented. Bedding attitudes are variable, and may vary from horizontal to vertical in the one drillhole.

In Zone 1, bedding planes are mostly indiscernable and in most instances are not expected to play a significant role in tunnel stability. Bedding planes in Zones 2, 3 and 4 are easily recognised and will affect tunnel stability where they are clay-coated.

Queen Street. Bedding attitude along Queen Street is expected to be 65° - 70° W/ 360° , and will intersect the tunnel alignment at about 20 degrees.

Lonsdale Street. Bedding attitudes vary considerably along this section of tunnel. From Queen Street (hole 10) to about Stn. 330 m (hole 16), bedding is generally expected to be steeply dipping ($>50^{\circ}$) but will depend on the inferred locations of the known fold axes near Elizabeth Street (Plate 1). Eastwards from hole 17 to beyond Swanston Street (hole 20), the beds probably dip east at about 35° . East of hole 20, the beds probably dip west at 20° to 30° , steepening to 80° towards Russell Street. Bedding to the east of Russell Street flattens to 20° to 35° west along the remainder of the tunnel to Spring Street. The dominant strike of the bedding is favourably oriented for tunnel stability but as the dip is variable, some sections of tunnel will intersect unfavourably oriented bedding planes. Some fracturing and crumpling of the rock may be present along fold axes.

Russell Street. Bedding attitude along Russell Street will probably be about 45° W/ 360° intersecting the tunnel alignment at about 20° . Open or clay-filled bedding planes may cause instability in the east wall and lead to some overbreak.

Exhibition Street. Comments as for Russell Street apply. In addition, if the overlying colluvium is wet, bedding plane failures in the Dargile Formation are likely to be more common.

Rathdowne Street. Bedding attitude will probably be about 35° W/ 360° , sub-parallel to tunnel alignment. Failures along bedding planes will be facilitated by the presence of joints, and should be confined to clay-coated continuous surfaces in the east wall. Major failures due to bedding planes are unlikely if the tunnel is correctly excavated and supported.

5.1.5.2 Joints

Joints are mostly closely spaced as indicated by a predominance of low RQD values in the drillcores.

Dip of bedding in Queen Street and the Queen Street end of Lonsdale Street is generally steep, and most joints will either follow the bedding or be perpendicular to the bedding (with the same strike).

Along Lonsdale Street, bedding plane joints will generally cross the tunnel line at angles greater than 45° , and dip will be variable. As bedding towards the eastern end of Lonsdale Street flattens, jointing normal to the bedding planes will steepen and be more favourably oriented to tunnel alignment.

Joint strengths will vary from weak to strong, depending on

- (i) degree of rock weathering
- (ii) degree of limonite cementation (stronger in Zone 3 and Zone 4 rock where many joints and incipient fracture planes are strongly cemented)
- (iii) orientation of joints relative to alignment of tunnel walls
- (iv) joint roughness (bedding planes joints often smooth and planar, whereas others may have rough surfaces).

The degree of limonite cementation is variable and will depend on the groundwater conditions and the mineralogy of the surrounding rocks (e.g. a higher percentage of limonite occurs in rock below the basalt flow in hole 5A). Strongly cemented defect planes are almost as strong as intact rock. Laboratory shear strength tests on joint or bedding planes were not made.

Clay is common on joint surfaces and will significantly reduce stability; clay may be more widespread on low angle planes in highly weathered rock.

Joint plane stability will depend largely on its degree of surface roughness, its tendency to dilate, the presence of clay, the grain size, and joint orientation to tunnel line. The drill logs give an

indication of surface roughness, grain size (i.e. claystone, siltstone or sandstone), presence of clay coatings, and dip from horizontal (vertical holes only), but the strike of joint planes is not available although some conclusions have been drawn from geological structure. Zone 1 and Zone 1-2 mudstone can be treated essentially as a clay soil and joints will generally have little effect on the stress-strain behaviour of the rock mass.

5.1.5.3 Faults, sheared and fractured zones

Several sheared or fractured zones were intersected in drilling even though most drillholes were vertical (e.g. holes 1, 12, 20, 21A, 26); others may not have been readily recognised in highly or extremely weathered rock.

Large fault zones were not detected in drilling. Faults, and sheared and fractured zones may be present between drillholes. Most will probably strike parallel to the major structural trends (005° to 025°). A large percentage of faults or shears will follow bedding trends and will dip at greater than 45° , but will be only a few centimetres wide.

5.1.5.4 Contacts between units

Contacts between the Dargile Formation and the other geological units will generally be weak and constitute possible failure planes. Over-break, such as crown slabbing of mudstone beneath sandstone beds, or over-break of mudstone up to the contact with the basalt may occur if the contact is near tunnel crown level (e.g. between holes 5A and 6 along Queen Street).

Contacts alone should not be assumed to cause catastrophic ground losses. Catastrophic failures would only occur during or immediately following a sudden and unexpected change from one unit to another vastly less competent material, such as from Zone 3 mudstone to water saturated colluvium. Most contacts between rock units should not contain large volumes of water.

5.2 ELIZABETH STREET FORMATION

Approximately 154 m of this formation will be tunnelled.

5.2.1 Formation properties

Approximate ranges of mechanical properties are given below. These figures have been used in assessments of rock loads and tunnel stability (section 6.2).

General material classification: mostly CH but variable (CL, SC).

Average moisture content: variable, mostly near 20%, but ranging to about 50%.

Wet density: $1500 - 2100 \text{ kg/m}^3$

Permeability: close to zero (estimated 10^{-6} to 10^{-8} cm/year), but variable.

Unconfined compressive strength (UCS): 300 - 350 kPa

Shear stress: about 300 kPa

The major clay minerals are kaolinite, illite and montmorillonite, with lesser amounts of mixed-layer clays (illite-montmorillonite).

5.2.2 Groundwater

When MURL excavations are closed up, recovery of the potentiometric surface may take one or more years. Recovery may be rapid in the more permeable (SC) layers close to the surface, and they could become charged with groundwater at tunnel level.

5.3 TERTIARY OLDER VOLCANICS

Approximately 188 m of this unit will be tunnelled.

5.3.1 Rock strength and weathering

Strength of the rock material is variable and depends on the degree of weathering. Thick sections of basalt were cored in holes 5A and 10. Weathering appears more advanced in the basalt from hole 5A, possibly due to the high percentage of vesicles that are generally clay-filled (c.f. hole 10). Where the basalt is dense as in the bottom of hole 5A and in most of hole 10, the basalt is hard and strong. However, the strength of the rock is weakened by closely spaced open joints and fractures.

Only 2 UCS tests of the basalt were made due to lack of suitably sized cores. Comparison of these tests with two point load results show a ratio between the two of 6.75, whereas 24 is generally accepted as ratio from other work, although a range from 10 to 30 may occur. Point load results in Appendix 2 have been converted to UCS equivalents by a factor of times 24 in line with that proposed by Broch & Franklin (1972). A summary of tests results is given below.

Dry density: 1760 to 2820 kg/m³

Moisture content: 30% to 1% (average 10%)

Point load: 0.10 to 1.36 Is(50) MPa

UCS: 2.02 to 5.26 MPa (Point load on these samples gave 0.26 and 0.82 Is(50) MPa respectively)

The maximum point load value of 1.36 MPa was obtained from slightly to moderately weathered basalt from hole 10, and is equivalent to 9.2 MPa(UCS) using a conversion of times 6.75.

The minimum value of 0.10 from highly weathered basalt from hole 5A, is equivalent to 0.75 MPa (UCS).

5.3.2 Joints

Core recovered from holes 5A and 10 is closely jointed and highly fractured in places. Some joints are limonite cemented but many

are open and clay-coated. The action of drilling has further fractured the core, probably along the numerous incipient partly healed fractures. Very low RQD values were logged for most of the basalt; however, the RQD values may be conservative as it is likely that many fractures in the core were intact prior to drilling.

5.3.3 Groundwater

The groundwater in the basalt may be perched on top of relatively impermeable highly weathered mudstone. It is unlikely that continuous inflows could be derived from the basalt. The basalt in hole 5A was dry at the time of drilling, but a complete loss of drilling water between 8 and 9 m gives an indication of the high permeability of the variably weathered vesicular basalt.

5.4 WERRIBEE FORMATION

Only a few metres of this formation is expected to be tunnelled, and will probably only be intersected in the Queen Street tunnel in the region of Little Bourke Street.

5.4.1 Formation strength

When drained of groundwater, the strength of this clayey silt formation is increased. In its damp state immediately after core recovery, strength readings of 0.3 MPa to 0.5 MPa were obtained using a pocket penetrometer (direct readings). The Werribee Formation was intersected in holes 8 and 10, but very little will occur in the tunnel as it lenses out towards hole 11. However, this formation may occur between holes 6 and 8 for a distance of about 25 m in the tunnel. No laboratory tests were done on this formation.

5.4.2 Groundwater

This formation is not expected to produce significant and continuous groundwater inflows, and any inflows are expected to fall off quickly to seepage from near the base of the formation.

If MURL excavations are closed before construction of this tunnel, then groundwater levels will probably be above or close to the level of this formation.

5.5 BRIGHTON GROUP

Up to about 38 m of tunnel may intersect the Brighton Group, and will be confined to the Queen Street tunnel in the region of Little Bourke Street.

5.5.1 Strength

The tunnel may intersect this group between holes 6 and 8. Mechanical properties will vary, especially strength, as the lower readings were obtained from a stiff, damp clayey silt layer (5.5 m, hole 8) and the higher readings from a limonite-cemented sand and silt layer (6.8 to 7.0 m, hole 8.) No strength tests were done on core from hole 6.

The range in values obtained from limonite cemented cores from hole 8 are as follows:

Dry density: 1890 - 2100 kg/m³

Moisture content: 11 - 16.5%

Point load strength: 0.21 to 0.72 Is(50) MPa (equivalent to about 5.04 to 17.28 MPa (UCS), using a conversion factor of times 24.

5.5.2 Groundwater

Some rise in the potentiometric surface level can be expected in this group before tunnelling commences, and although small inflows into the tunnel will occur initially, they will quickly reduce to seepage. As some beds in this group are permeable, rainfall may infiltrate and temporarily increase inflows into the tunnel, possibly causing some instability in the uncemented parts of the group.

5.6 DYKES

5.6.1 Rock strength and weathering

Hardness and strength of the dyke material is variable and will depend on mineral composition and degree of weathering. Most dykes will be highly weathered, soft and fairly weak. Direct pocket penetrometer readings in extremely to highly weathered dyke material range from about 100 kPa to 350 kPa. The strengths of less weathered dyke material will increase to a point where it will at least be as competent as the surrounding rock. Laboratory tests on dyke material were not carried out.

5.6.2 Joints

The dykes are generally closely jointed, although jointing in extremely and highly weathered dykes is partly or wholly obliterated, with joint surfaces and openings filled with weathered material and clay. Joints in moderately or less weathered dykes will be more significant as some will remain open and clay-filled, or only partly cemented. Attitudes of joints in the dykes have not been obtained, but rock cores indicate that at least 4 closely spaced sets exist. Open-jointed dykes with a greater groundwater permeability may have accelerated the weathering of the surrounding mudstone.

5.6.3 Faults

Faulting in rock adjacent to dykes is likely in some cases. More often, however, the bedding in the adjacent rock will be dragged or more closely jointed or fractured. In other instances no disturbance of the adjacent rock will have occurred.

5.6.4 Groundwater

Weathered dykes, where fractures and joints are filled with clay,

will be relatively impermeable. Moderately weathered (or less weathered) closely jointed dykes will be much more permeable, and will show limonite staining on fracture surfaces as in drillcore in holes 21A and 23A.

5.7 COLLUVIUM

5.7.1 General

This unit will occur in Lonsdale, Russell, Exhibition and possibly along Rathdowne Streets, as shown on the sections. It is potentially the worst material to be tunnelled in this project, and will occur in the tunnel for a distance of about 193 m.

5.7.2 Mechanical properties

The properties will vary with depth and the weakest material will be a fairly clean fine sand (50% clay) at tunnel level. Test results are shown in Appendix 2. A summary is given below:

Moisture content: 15% to 25%

Density: 1400 to 1700 kg/m³

Shear stress: 156 to 179 kPa

The major clay minerals are kaolinite and illite. The results of X-ray diffraction analysis of samples from holes 23, 23A and 24 are listed in Appendix 2. The classification of the material ranges from CL to SC.

5.7.3 Groundwater

Drainage of the MURL excavations has depressed the potentiometric surface to an unknown depth below tunnel invert. The water levels are being monitored and the potentiometric surface is expected to rise after closure of MURL excavations. These sediments would probably have been saturated at tunnel level prior to excavation of MURL.

A pump-in test in drillhole 23A between 5.5 and 13.0 m gave a figure for the permeability of the material of 3.9×10^{-4} cm/sec (for detail see Appendix 2).

6. TUNNEL EXCAVATION AND SUPPORT

6.1 DARGILE FORMATION

6.1.1 General rock conditions

About 32 percent (404 m) of the tunnel in the Dargile Formation will be located in Zones 1 and 1 to 2. The remainder of the tunnel in the formation will be driven through Zone 2 or less weathered rock. Only about 92 m of tunnel will be excavated in Zone 3 to 4 which could be considered

as hard rock tunnelling and constitutes only about 5 percent of the formation to be tunnelled (see also 5.1.1).

Attitudes of bedding and joint planes will affect tunnel stability particularly in Zone 2 and 3 or less weathered mudstone. Zones 1 and 1 to 2 will behave more like a soil. Assessment of structural attitudes and their effect on tunnel stability have been made on Plates 3 to 8. Harder and more competent sandstone beds in highly weathered mudstone may cause slabbing in the crown or walls (depending on orientation) due to weak bedding plane contacts; if thick enough, the sandstone bed may initially span the opening without failing.

Sharp changes in rock hardness and strength can be expected when dykes are intersected. There may be some indication of changing conditions such as drag of bedding, change in major joint orientations or an increase in the degree of weathering; however, in other instances the change may occur without warning.

Groundwater inflows through the mudstone should be mainly restricted to open joints and fractures in Zone 3 and 4 rock. Inflows from Zone 1 and 2 rock will be insignificant, although if groundwater is present, a marked decrease in strength and stability of the rock will be evident when compared with its dry behaviour. If groundwater is present, there will be a decrease in stability of clay-coated defects in Zone 3 and 4 mudstone; this probably will not apply to clean defects unless they were to carry groundwater under pressure, a situation that is considered most unlikely. Large groundwater inflows are not expected from the mudstone and any flows will be of "nuisance" value only.

6.1.2 Stand-up times

Stand-up times in the table below have been estimated by Bienawski's method (1974), using data from drillcores and mechanical tests performed on the core.

The stand-up time or bridge action period gives an indication of the time available after exposure to erect support before disintegration and loosening of the rock has progressed to the stage where fall-outs start to occur.

When considering the actual stand-up time values given here and on the accompanying plates, it should be noted that:

- (i) unsupported spans equal to the tunnel width are assumed (i.e. full face tunnelling);
- (ii) the values calculated apply to the rock obtained at a particular drillhole location, and conditions between holes are likely to vary considerably;

- (iii) no allowance has been made for the cohesive strength of extremely to highly weathered rock (particularly with respect to Zone 1 mudstone, which would be considered by Bienawski to be a soil and not a rock with its UCS of less than 1 MPa);
- (iv) joint orientations are not known with any certainty, and therefore the orientations have been assumed to be "fair to unfavourable" for rating purposes;
- (v) the area will be fairly well drained soon after excavation commences and inflows generally of less than 25 litres per hour have been assumed for rating purposes;
- (vi) stand-up time values given are considered conservative, particularly in Zone 1 and 1 to 2 mudstone due to (iii) above, and experience in the MURL tunnels would appear to confirm this; and
- (vii) in calculating stand-up times, the condition of the rock from tunnel invert to about 2 m above crown has been used.

The above comments regarding stand-up times apply to all rock types to be tunnelled in this project.

DARGILE FORMATION - ESTIMATED STAND-UP TIMES

HOLE NUMBER	WEATHERING ZONE	RATING *	ESTIMATED STAND-UP TIME	
1	Queen Street	1	20 (very poor)	less than 10 minutes
2A		3 (2 above crown)	48 (fair)	about 1 day
4		2 (1 above crown)	20	less than 10 minutes
11	Lonsdale Street	1 (Qe above crown)	13 (very poor)	less than 10 minutes
12		3	48	about 1 day
13		1 to 2 (Qe near crown)	13	less than 10 minutes
17		2 to 3 (1 above crown)	30 (poor)	less than 1 hour
19		3	58 (fair)	about 4 days
20		3	48	about 1 day
20A		2 (mainly)	40 (poor)	about 8 hours
21		1 to 2	24 (very poor)	less than 1 hour
25		3 (mainly)	33 (poor)	less than 3 hours
26		3	42 (poor)	about 8 hours
27	3 (mainly)	50 (fair)	about 1 day	
28	3	32 (poor)	less than 3 hours	
29	2 (mainly)	35 (poor)	less than 3 hours	
22	Russell** Street	2 to 3	48 (poor)	about 1 day

* Maximum possible rating is 100

** Colluvium occurs about 1 m above tunnel crown at this location. Stand-up time may be much less than calculated if the height of loosened rock arch reaches into the colluvium. The same applies to some other drillhole locations (e.g. holes 11 and 13).

Note: Effective use of shotcrete will generally obviate the use of heavy timber lagging between steel sets, with the possible exception of "very poor" conditions, mainly in zone 1 where the use of shotcrete may not be practical.

6.1.3 Settlement and rock loads

The experience of others (MURL) in the mudstone (Dargile Formation) indicates that downward deformation at the tunnel crown is unlikely to be greater than about 12 mm if steel sets and shotcrete are used as primary support. In addition, the zone of deformation is unlikely to extend beyond about 2 to 3 tunnel diameters above the crown.

The mudstone is subject to loosening loads and deterioration by water softening. Loading on the support system and settlement will depend on the amount of loosening that is allowed to take place and this will depend on the type of support, how quickly it is erected and how close to the face it is placed (hence the importance of the calculated stand-up times in the previous Table). The sooner the steel and shotcrete is applied, the less complete will be the formation of the ground arch (loosening) and the lighter the load being carried by the supports. Loosening will be greater if the tunnel is drilled and blasted than if it were excavated by mechanical means. Loads on steel and timber will be lower where shotcrete is also used, as the shotcrete will restrict loosening that would otherwise take place.

6.1.3.1 Vertical rock loads

Estimates of vertical rock loads are based on the extent of upbreak (Terzaghi, 1946). The estimates are probably conservative, especially if the tunnel is to be machine excavated. A range of rock load is given, which should cover all orientations of bedding and jointing.

Estimates for zone 3 mudstone have been calculated using the following assumptions:

Tunnel diameter: 3.5 m
 Cover above tunnel crown: > 3 tunnel diameters
 Average rock density: 2100 kg/m³
 Unconfined compressive strength (UCS): 10 MPa
 Traffic loads have not been considered

where: Hp = height of loosened rock arch
 P_z = total rock load
 B = tunnel width
 H = tunnel height

It has been assumed that shotcrete has not been used and that loosening loads have had time to develop. The height of loosened rock (Hp) is assumed to be zero initially, but increasing with time to 0.25 (B) to 0.35 (B + H).

$$H_p = (0.25) \cdot (3.5) \text{ to } (0.35) \cdot (7)$$

$$= 0.875 \text{ to } 2.45$$

$$P_z = 0.18 \text{ to } 0.51 \text{ kg/cm}^2$$

$$\text{or } 18 \text{ kPa to } 50 \text{ kPa}$$

These values can probably be reduced by about 50% if the tunnel is above the water table.

Face stability in Zone 1 and 1 to 2 mudstone

To determine the short term stability of the tunnel face it is assumed that the face will be stable if $P_z/c = < 6$, where c equals undrained shear strength (Deere, 1969).

Using overburden pressures of between 150 and 288 kPa (using initial terzaghi values of $H_p = (1.10 \text{ to } 2.10) (B + H)$):

$$\text{where wet: } 150/130 = 1.15$$

$$\text{or } 288/130 = 2.21$$

$$\text{where dry: } = 0.57$$

$$\text{or } = 1.10$$

In all cases the face should be stable initially, but a decrease in strength associated with dissipation of pore water pressure may reduce long term stability.

Final support loads in zone 1 mudstone will probably be carried by a ground cylinder.

Rock mass quality

According to Barton, Lien and Lunde (1974), the following calculations can be made:

$$\text{Using } Q = (RQD/J_n) (J_r/J_a) (J_w/SRF)$$

where Q = rock mass quality

RQD = rock quality designation

J_n = joint set number

J_r = joint roughness number

J_a = joint alteration number

J_w = joint water reduction factor

SRF = stress reduction factor

In zone 1 and 1 to 2 mudstone

$$Q = (10/15) (1/8) (1/5)$$

$$= 0.016$$

According to Barton et al., a Q figure of 0.016 corresponds to Terzaghi Class 7 (squeezing rock) with P_z between 1.54 and 2.94 kg/cm² (as calculated above); support pressure would be about 8.0 kg/cm² and this would correspond to their support category No. 35 i.e. steel sets, mesh and shotcrete as the primary support.

In zone 3 mudstone

$$Q = \left(\frac{60}{15}\right) \left(\frac{1.5}{2}\right) \left(\frac{1}{1}\right)$$

$$Q = 3.0$$

According to Barton et al., a Q value of 3.0 corresponds to Terzaghi Class 4 (moderately blocky and seamy) and agrees fairly well with Terzaghi's rock load assessment based on $H_p = 0.25 B$ to $0.35 (B + H)$ (see previous calculation). $Q = 3.0$ corresponds to a support pressure of about 1.0 kg/cm² which is on the borderline for requirement of support. Shotcrete with steel would probably be ideal for rock slightly poorer in quality, i.e. zone 2 to 3 and zone 2 mudstone.

6.1.3.2 Lateral (side) pressures and heave

Initially vertical rock loads are expected to be greater than lateral pressures, even in zone 1 mudstone where some swelling pressure may act on the side walls. If moderate lateral pressure were to occur, invert struts may be required (possibly in zone 1 mudstone).

An estimation of lateral pressure in zone 3 mudstone is given below.

In zone 3 mudstone

$$\begin{aligned} \text{Side pressure} &= 0.3 \times 2100 (0.5 \times 3.5 + 2.45) \\ &= 0.26 \text{ kg/cm}^2 \quad (\text{wet}) \\ &\quad (25 \text{ kPa}) \end{aligned}$$

Bottom heave as well as lateral pressure is possible if groundwater or surface water finds its way into the excavation and brings about the swelling and expansion of highly plastic clays. Highly plastic clays do occur in the mudstone (zone 1 mainly) and in the overlying colluvium and the Elizabeth Street Formation. Dissipation of the pore water pressure over a period of time may lead to swelling and a decrease in strength such that the ratio P_z/c may be greater than 6 and the face become unstable (Deere, 1969). Rapid advancement of the face through such material is therefore recommended.

6.1.4 Support

It is considered that the entire tunnel will require support during construction due to poor rock conditions, the shallow overburden, and the location of the tunnel under the streets of the city; however, there are sections of tunnel in zone 3 and 4 mudstone that would be self supporting for several days at least during construction (section 6.1.2. stand-up times).

The type of primary support required during construction will depend on the rock conditions, estimated stand-up times, rock loads, groundwater conditions and the method of excavation.

A concrete sub-invert may be necessary, especially where wet, and if the contractor uses rubber tyred equipment.

Steel sets spaced 1 to 1.5 m and shotcrete will probably be the most effective form of support in zones 2, 3 and 4 mudstone, and will be effective in reducing loosening loads on steel sets and timber lagging. Shotcrete will not be practical in zones 1 or 1 to 2 mudstone in which steel sets and timber lagging will be required. The quantity of timber lagging will increase with weathering of the mudstone; lagging in zone 1 mudstone will cover up to about 80% of the tunnel profile. Very short stand-up times have been estimated for zone 1 mudstone and forepoling may have to be applied, especially if the ground is wet.

If it is assumed that shotcreting of zone 1 mudstone is not practical and that steel sets and timber lagging are used for support, the following estimation of "pay" timber quantities can be made:

Length of Zone 1 and Zone 1 to 2 material in tunnel invert or springline to above crown: about 575 m
 Anticipated spacing of steel sets (RSJ): 1 m
 Percent of tunnel walls and crown covered by timber lagging: about 80%
 Estimated super feet of timber/foot of tunnel: 72
 Estimated super feet for 575 m: 136,000

Note: The above estimate is based on the following assumptions:

1. timber lagging in contact with the steel sets will be 6" x 4";
2. only timber bearing directly onto the steel sets is counted as "pay" timber; and
3. the tunnel diameter (to the outside of the steel sets) is about 3.2 m.

If shotcrete is not used in the mudstone section of the tunnel, and assuming an average of 40% lagging cover in zones 2, 3 and 4 rock (857 m of tunnel), an additional 200,000 super feet of timber will be required. The total timber quantity would therefore be about 336,000 super feet. This figure is considered conservative. If shotcrete is used in zones 2, 3 and 4 rock, but not in zones 1 and 1 to 2, the timber quantity would probably be less than about 236,000 super feet, assuming 80% coverage in zones 1 and 1 to 2 and 20 percent in the remainder.

The number of steel sets necessary in the mudstone section will be about 1260.

6.1.5 Methods of construction

6.1.5.1 Conventional mining

Although the conventional drill-blast-muck method is probably not the most practical method of excavation in the mudstone, it may be necessary in those sections where zone 3 to 4 or less weathered rock is encountered, particularly if the rock is not closely jointed. Up to about 250 m of zone 3 to 4 mudstone may require blasting.

Zone 1 mudstone will probably need to be excavated by hand or hand-operated excavating equipment without the use of explosives. Forepoling may be necessary, especially where the tunnel is below the water table.

Overbreak in blasted sections may be greater than in machine excavated sections, but will ultimately depend on the contractor's skill and the time taken to support the rock. Overbreak may increase with a decrease in degree of weathering, but will depend on the degree of cementation, continuity, spacing and orientation of defects.

Ground vibrations associated with blasting may also be a problem and the vibrations will need to be monitored.

The rate of progress of drilled and blasted sections will probably be less than in machine excavated sections, but greater than hand mining in zone 1 rock.

6.1.5.2 Tunnel excavating machine ("Road Header" type)

A Road Header type machine (such as the "Alpine AM 50") would be suitable for excavating zones 2 to 3 mudstone, as has been shown in MURL excavations. Zone 4 mudstone may prove too strong for a Road Header

unless the rock is highly fractured. Assessment of the drilling would indicate that about 60% or 765 m of the mudstone section could be successfully excavated by a Road Header machine; these figures are approximate due to the variable nature of the weathering, and the chance that combinations of zones 2, 3 and 4 rock may be present at a working face at any one time.

6.2 ELIZABETH STREET FORMATION

6.2.1 General Tunnelling conditions

Tunnelling conditions in this formation will depend largely on whether the tunnel is below or above the water table during excavation. Tunnelling conditions will be substantially better if the formation is dry. Approximately 154 m of tunnel will pass through this formation.

6.2.2 Properties and stand-up times

SPT, shear, and UCS tests show this formation to be very stiff in parts, with strengths between 200 and 400 kPa. However, the formation is soft in parts also, and the tunnelling conditions will be variable. Different strata may be exposed in the tunnel face such as silty sand overlying clayey sand, with part of the face being initially unstable (silt-sand, especially if wet) and the clayey sand initially stable, but likely to become unstable with time, especially if wet.

6.2.3 Stability

Stability calculations have been made using the following data:

Tunnel diameter	=	3.5 m
Cover above crown	=	> 3 tunnel diameters
Material density	=	1200 - 2000 kg/m ³
Undrained shear stress	=	200 - 300 kPa
Unconfined compressive strength	=	150 - 400 kPa

Vertical rock load

$$\begin{aligned}
 H_p &= 0.62 \text{ to } 1.38 (B + H) \\
 &= 4.35 \text{ to } 9.7 \\
 P_z &= 4.35 \times 2000 (\text{density}) \text{ to } 9.7 \times 2000 \\
 &= 8700 \text{ to } 19400 \text{ kg/m}^3 \\
 &= 0.87 \text{ to } 1.9 \text{ kg/cm}^2 \\
 &\quad \text{or } 85 \text{ to } 186 \text{ kPa } \left\{ \begin{array}{l} \text{wet} \\ \text{dry} \end{array} \right\} \\
 &\quad \quad \quad 42 \text{ to } 93 \text{ kPa } \left\{ \begin{array}{l} \text{wet} \\ \text{dry} \end{array} \right\}
 \end{aligned}$$

Lateral pressure

Assuming side pressure = $0.3 \gamma (\text{density}) (0.5 H + H_p)$

$$\begin{aligned} \text{Side pressure} &= 0.3 \times 2000 (1.75 + 9.7) \text{ (wet)} \\ &= 0.69 \text{ kg/cm}^2 \text{ (68 kPa) (wet)} \end{aligned}$$

Initially, side pressures are expected to be in the order of one-third of the vertical rock load.

Stability of face

Assuming stability if $P_z/c < 6$

(where c = undrained shear strength)

$$\text{then if wet: } 186/300 = 0.6$$

$$\text{if dry: } 93/300 = 0.3$$

Initially the face is stable where the tunnel is being excavated in the typical stiff dense Elizabeth Street Formation. The critical value of P_z/c may decrease with time especially if silt layers are present, as they are very sensitive to pore water pressures. The long term stability will be less than indicated in the above calculations, as dissipation of pore water pressure may cause swelling and result in a decrease in strength, particularly if the tunnel is below the water table and highly plastic clay is present.

Stand-up times have not been calculated, but they will be determined more by water content than any other factor. In general it is expected that stand-up times will be long enough for support to be erected before significant ravelling can occur. By the time the tunnel intersects this formation, the water table may have been lowered to near tunnel level if the tunnel is driven up-grade. Assuming the tunnel is above water table, the stand-up times for a 0.5 m wide strip of SC-GC material would be greater than about 1 hour, but for a silty sand with some clay binder it would be about 10 minutes.

6.2.4 Support

When excavated this formation will probably be damp. Steel sets spaced at about 1 m centres with timber lagging will be required. It is unlikely that side pressures will be great enough to require the use of invert struts, unless the water table is above tunnel level.

6.2.5 Methods of construction

In the worst possible case, which assumes that the formation is below the water table, and that the material is soft and weak and subject to swelling pressures, hand mining and forepoling would be required. The worst conditions are likely to be found in the lowest part of the tunnel near drillhole 16 in Lonsdale Street at chainage 310.

The most likely condition is for the material to be damp, and hand mining or a mechanical shovel would be the most effective excavation method.

It is considered that a Road Header, or similar machine, would be unsatisfactory due to the plasticity of the clay and the likely sloppy conditions of the invert. A concrete sub-invert may be required.

6.3 TERTIARY OLDER VOLCANICS

6.3.1 General rock conditions

Approximately 188 m of tunnel will pass through the basalt (see Plates 3 and 4). The competence of the basalt will vary considerably.

Drillhole 5A (Queen Street) shows the basalt to be mostly slightly to moderately weathered at tunnel level and for about 2 metres above tunnel crown level. Jointing is generally close and rough; some joints are clay filled.

In drillhole 6 (Queen Street), about 2 m of highly and extremely weathered basalt was intersected, and this was above tunnel crown level. At this location the tunnel is in zone 1 mudstone. Further north, towards hole 8, the tunnel intersects the Werribee Formation. The rock contacts mudstone-basalt, mudstone-Werribee Formation are weak and resulted in core losses.

The Lonsdale Street tunnel will be in basalt from drillhole 10 to about midway to drillhole 11. The basalt in the tunnel will be mostly slightly weathered, but is very closely jointed or fractured; however, many of the fractures in the drillcore were caused by drilling re-opening previously healed or partly healed natural fractures.

Tunnelling conditions in the basalt should generally be good, except where geological contacts occur close to tunnel crown (within about 2 m), such as in the vicinity of drillhole 6 where the basalt is more weathered close to its contact with the overlying Brighton Group.

6.3.2 Stand-up times

Stand-up times have been estimated using data from drillholes 5A, 6 and 10. Stand-up times derived from drillhole 6 data will probably only be applicable for a short section of tunnel where highly weathered basalt will occur in the crown region of the tunnel, just west of hole 6.

[illegible]

Sample Details				Unified Soil Classification	Classification Results						Unconfined Compressive Strength			Triaxial - Undrained						Direct Shear - Total Stress						Point Load							
Bore Hole No.	Depth (m)	Sample No. 13-0-	Lithology and/or Formation		Liquid Limit (w _L) %	Plastic Limit (w _p) %	Plasticity Index (I _p) %	Linear Shrinkage (LS) %	Passing 4.75 mm %	Passing 0.075 mm %	Unconfined Compressive Strength (σ ₁) MPa (*kPa)	Dry Density t/m ³	Moisture Content %	Cohesion (c) Angle of friction φ	Cell Pressures (σ ₃) kPa	Dry Density t/m ³	Moisture Content %	Effective cohesion (c ¹) Effective angle of friction (φ ¹)	Effective Stress (σ ₃ ¹) kPa	Dry Density t/m ³	Initial Moisture Content %	Cohesion (c) Angle of Friction (φ)	Normal Stress (σ ₁) kPa	Shear Stress (s) kPa	Initial Dry Density t/m ³	Initial Moisture Content %	Indicated Unconfined Compressive Strength MPa (Is (50) x 24)	Point Load Index Is (50), MPa	Diameter (mm) rock cores	Height (mm) rock cores			
15	1.5	66	Elizabeth Street Formation	CL	43	13	30	9.5	100	79				59/10	30/60/120	1.75	19.3	7/30	30/60/	1.73	19.3	88/19	Refer report sheet	1.73	18.3								
	3.0	3/1		SC	45	12	33	11.0	100	43																							
	7.5	3/2		CH	79	20	59	16.0	100	95	306*	1.48	29.7																				
16	6.0	8		CH	83	21	62	16.5	100	94	345*	1.55	26.2									-	115	312	1.55	27.0							
17	9.6	46	MW sandstone									2.34	6.5																				
	10.6	47											6.48	2.44	4.3																		
19	8.3	48	Z3 mudstone									6.38	2.37	3.9																			
	9.7	49											10.08	2.42	4.3																		
	11.0	50											9.07	2.37	5.3																		
20	0.5	67	Z1, mudstone	CL	44	18	26	11.0	91	86				56/22	10/20/40	1.77	17.4					76/37	Refer to 184 port sheet	1.84	17.4								
	7.6	51	Z3, mudstone									6.80	2.31	6.1																			
	9.5	52	MW sandstone									4.14	2.42	3.3																			
	11.0	53	Z3-4 mudstone									-	2.48	3.0																			
20A	7.8	54	HW-MW sandstone									3.13	2.15	12.3																			
	9.4	55											-	2.22	6.9																		
	10.1	56											-	2.16	9.1																		
	11.0	57		Z2, mudstone									1.61	2.13	10.0																		
21	1.5	68	soil	CL	37	15	22	10.0	100	94				48/9	30/60/120	1.7	18.7																
23	1.0	69	Colluvium	CH	52	15	37	12.0	100	76				74/16	20/40/80	1.61	24.0																
	3.0	6		CL	41	15	26	13.0	100	70				76/20	60/120/240	1.71	18.5																
23A	2.0	70	Colluvium	CH	54	19	35		100	78				64/10/160	40/80/160	1.52	27.8	25/22	40/80/160	1.57	25.8												
	4.0	2/1		CL	48	15	33	16.0	100	71																							
	5.5	2/2		SC	30	17	19	9.0	100	47													-	110	156	1.92	12.9						
24	1.5	71	Colluvium	CL	26	9	17	8.0	100	70				35/19	30/60/120	1.71	17.8	10/36	30/60/120	1.93	13.3	45/29	330/60/120	57/80	1.67/1.71	21.4/18.3/1.73	17.0						
	3.0	5		CH	63	20	43	13.5	100	85				24/16		1.77	16.0					117/13	60/120/240	124/154/179	1.58	26.0							
	5.5	60												140/0	110/220/440	1.67	21.6																
	6.0	61			CL	48	17	31	10.0	91	87				219/0	120/240/480	1.78	20.2															
26	8			Z3, mudstone																													
27	8		Z3, mudstone																														
28	11		MW sandstone																														

BASALT - ESTIMATED STAND-UP TIMES

HOLE NUMBER	DEGREE OF WEATHERING	@RATING	ESTIMATED STAND-UP TIME
5A	Slightly and moderately	47	About 1 day
6	Highly and extremely	31	About 1 hour
10	Slightly weathered (mostly)	35	Less than 5 hours

@ out of a possible 100

Note: These figures are regarded as conservative, and the assumptions applicable to this method should be referred to (6.1.2).

6.3.3 Rock Loads

The ultimate rock load will depend on the extent of the loosening of the arch. If shotcrete is used soon after excavation, the loads on steel sets will be smaller than if steel and timber lagging were used. Estimates of final loads are calculated below.

Vertical rock load for slightly weathered basalt

Assuming density = 2800 kg/m^3
 UCS = 5260 kPa
 tunnel diameter = 3.5 m

$H_p = 0.35 (7) \text{ to } 1.1 (7)$
 $= 2.45 \text{ to } 7.7$
 $P_z = 2.45 \times 2800 \text{ to } 7.7 \times 2800$
 $= 6850 \text{ to } 20150 \text{ kg/m}^2$
 or $0.68 \text{ to } 2.0 \text{ kg/cm}^2$ ($67 \text{ to } 196 \text{ kPa}$)

Vertical rock load for highly weathered basalt

Assuming density = 1750 kg/m^3
 UCS = 2000 kPa (drillhole 5A)

$P_z = 0.35 (7) \times 1750 \text{ to } 1.1 (7) \times 1750$
 $= 0.43 \text{ to } 1.35 \text{ kg/cm}^2$ ($42 \text{ to } 132 \text{ kPa}$)

Side pressures have not been calculated, but would be about one-third of the vertical loads calculated above.

The rock mass quality ratings have been calculated according to Barton et al. (1974) for highly to moderately weathered, and slightly weathered basalt.

Slightly weathered basalt (data from hole 10)

$$\begin{aligned} \text{using: } Q &= (RQD/J_n) (J_r/J_a) (J_w/SRF) \\ \text{then } Q &= (15/6) (3/2) (1/1) \\ &= 3.75 \text{ ("poor")} \end{aligned}$$

This Q value of 3.75 corresponds to a Terzaghi Class 4, and corresponds to a support pressure of about 0.5 kg/cm^2 or 49 kPa. According to Barton, using an ESR (Excavation Support Ratio) of 1.6 and a tunnel diameter of 3.5 m (ratio B/ESR where B is tunnel diameter), this figure for Q versus B/ESR would fall close to his "no support" category.

Highly to moderately weathered basalt (data from hole 5A)

$$\begin{aligned} Q &= (20/6) (1.5/6) (1/5) \\ &= 0.178 \text{ ("very poor")} \end{aligned}$$

This Q value of 0.17 corresponds to Terzaghi Class 5 and a support pressure according to Barton of about 3 kg/cm^2 (290 kPa). This corresponds to Barton's support category number 29. Shotcrete (5 cm thick) and steel sets (spaced at about 1 m centres) with some timber lagging would be a likely option for support for such material.

6.3.4 Support

As stated above, slightly weathered basalt would probably require support (although not immediately). Extremely to moderately weathered basalt would require steel and lagging support as soon as possible. If hand mining is required, then steel and timber lagging will need to be erected close to the face. In addition, shotcrete (5 cm to 7 cm thick) could be used if found to be practical in this tunnel, as it would reduce the amount of timber lagging required. An average "pay" timber coverage of 30 percent would amount to about 16,500 super feet of timber lagging.

6.3.5 Methods of construction

There appear to be three construction alternatives, of which the first is the most likely for most of the basalt section:

- (i) Road Header should be suitable especially where basalt is moderately to slightly weathered and closely jointed.
- (ii) Blasting may be required in isolated pockets of slightly weathered or fresh and less jointed rock (rare).

- (iii) Near the contact with the Brighton Group, the basalt is extremely and highly weathered, and hand mining is the likely option.

It is possible that the base of the basalt is more irregular in its shape than shown on the sections, and if this is the case, then competent rock may be interspersed with highly weathered basalt and possibly zone 1 mudstone.

6.4 WERRIBEE FORMATION

It is unlikely that this formation will intersect the tunnel between holes 10 and 11 in Lonsdale Street. It will occur between holes 6 and 8 in Queen Street rising from near invert level at hole 8 to crown level midway between holes 6 and 8 (Plate 3).

Excavation properties of the Werribee Formation should be similar to zone 1 mudstone unless it is making water, in which case it will flow into the tunnel. Hand mining or mechanical shovel would be satisfactory, but heavy timber lagging may be required behind the steel sets in order to contain the formation. Tunnel invert will be "sloppy" and a concrete sub-invert may be required.

6.5 BRIGHTON GROUP

This group will probably occur in the tunnel close to tunnel crown level between holes 6 and 8. As this group is more competent than the Werribee Formation, the excavation and support measures used for the underlying Werribee Formation would be adequate for the Brighton Group.

6.6 DYKES

Most dykes at tunnel level will probably be near vertical and will generally be soft and clayey. They may require hand mining if they are found to be highly plastic and wider than a metre or so. The amount of timber lagging in dyke sections will probably be more than in the adjacent mudstone, unless the mudstone is zone 1.

6.7 COLLUVIUM

6.7.1 General conditions

The Colluvium will be intersected in Lonsdale Street (154 m), Russell Street (7 m) and possibly Exhibition Street (45 m).

Tunnelling conditions will generally be poor through the colluvium. The density of the material will vary from loose to firm, but is generally expected to be fairly dense as indicated from SPT values.

Whatever the density, the colluvium will be unstable with very short stand-up times. Stability of the Colluvium will depend more on the water content than any other factor.

6.7.2 Rock loads

Calculation of final vertical loads according to Terzaghi have been based on the following formula:

$$H_p = 0.62 (B + H) \text{ to } 1.38 (B + H)$$

This assumes that (i) wet conditions ^{prevail} (below ground water level),
 @ (ii) colluvium is dense, and
 (iii) initial rock loads will be slightly less.

@ If the sand is loose, then initial rock loads will be a little higher, but final loads will be much the same as those calculated below. If loose sand occurs at and below invert, the vertical rock load may be greater than calculated due to compression of the base.

Calculation:

$$\begin{aligned} H_p &= 0.62 (7) \text{ to } 1.38 (7) \\ P_z &= 0.62 (7) \times 1400 \text{ to } 1.38 (7) \times 1400 \text{ (kg/m}^3\text{)} \\ &= 0.61 \text{ kg/cm}^2 \text{ to } 1.35 \text{ kg/cm}^2 \\ &\quad (60 \text{ kPa}) \quad (132 \text{ kPa}) \end{aligned}$$

Note: shear stress = 156 to 179 kPa (Appendix 2,)

Side pressure values have been calculated below:

$$\begin{aligned} \text{where: } P_h &= 0.3 \gamma (0.5 H + H_p) \\ P_h &= 0.3 \times 1400 (0.5 \times 3.5 + 9.7) \\ &= 0.48 \text{ kg/cm}^2 \\ &\quad (47 \text{ kPa}) \end{aligned}$$

This value is about one-third the higher limit of the vertical load calculated above.

6.73 Support and method of construction

There are two alternatives for this section of tunnel:

- (i) the tunnel may be constructed by the cut and cover method, or
- (ii) the formation may be tunnelled.

It has been stated that the cut and cover method is not practical as it would cause too much disruption to services.

If the tunnel in the colluvium is below groundwater level, the method of excavation and support would require either extensive grouting or the use of a tunnelling shield.

- (a) Grouting. Grouting may be carried out at tunnel level or from the surface, preferably prior to excavation. Cement-bentonite, or preferably a sodium silicate-sodium aluminate - sodium hydroxide mix could be used. If grouting is carried out from the ground surface, it may be advantageous to grout as soon as possible before groundwater levels build up in the area (assuming the effectiveness of the grout doesn't decrease with time). Grouting would also minimise any surface settlements, as loss of ground would be negligible. Additional information on the permeability of the colluvium and on alternative grouts should be acquired as soon as possible.

Excavation by hand mining or mechanical bucket with steel set support and timber lagging would be required.

- (b) Shield tunnelling. Because such a small section of tunnel is located in this formation, the use of a shield may not be economically feasible. Use of a shield would constantly support the advancing tunnel and allow the erection of the permanent lining without the necessity for temporary support. Final rock loads and settlements would also be reduced. The infiltrating water could either be drained by pumping from a sump (assuming there is no loss of ground through washing out of fines), or if conditions required it, compressed air could be used.

6.8 SETTLEMENTS

Settlements and the extent of loosening will depend on the tunneller's expertise and care, and suitability of the excavation method and type of support for the particular formation. Estimates of settlements are not given here, but it can be noted that:

- (1) Some loss of ground will be associated with each formation tunnelled and consequently some settlement at and above tunnel crown will occur. However, in all formations except possibly in saturated Elizabeth Street Formation, zone 1 mudstone and colluvium, the resultant surface settlements will probably be less than about 10 to 15 mm.
- (2) Loss of ground in the exceptions noted in (1) above may be more serious if groundwater is present, and poor tunnelling techniques fail to contain unstable ground.
- (3) The presence or absence of groundwater will probably be the most important factor in determining surface settlements. It should be possible to keep surface settlements in zone 1 mudstone to a minimum, assuming loss of ground doesn't occur through accident; however, larger settlement may occur where the clay is more plastic and subject to swelling that would bring about inward squeezing of the clays. Very little surface settlement would be expected in the Elizabeth Street Formation above the water table; if saturated, greater settlements may be associated with loss of strength and possibly with swelling clays. Grouting of the Colluvium is considered a prerequisite for minimum settlement.

7 CHAMBERS

7.1 GENERAL

Location and geology of the 12 chambers are shown on Plates 3 to 8 inclusive. The 2 loading coil chambers in Lonsdale Street are to be constructed as open cuts, as are the 3 terminating chambers (Lonsdale, Little Lonsdale and Victoria Streets). Regarding stand-up times, the comments and provisos set out in 6.1.2 will also apply to any discussion of stand-up times for the chambers.

7.2 QUEEN STREET CABLE CHAMBER

This chamber is located at chainage minus 16.4 (Plates 3 and 8).

The geology is essentially the same as for the nearby chamber described below (7.3) and the same comments apply. However, as this chamber is smaller in size, stand-up times, rock loads and stability will be marginally better, although excavation conditions are still considered to be poor.

7.3 QUEEN - LITTLE BOURKE STREET CABLE CHAMBER

This chamber is located at chainage 11.46 m (Plates 3 and 8).

The Werribee Formation will probably occur from below tunnel crown level to near invert. The remainder of the chamber is expected to be located in the Brighton Group. Initially groundwater may flow into the excavation, but flows should decrease rapidly to seepage.

Excavation conditions will be poor, although parts of the Brighton Group may be well cemented and reasonably competent. Steel sets and timber lagging will be necessary.

Vertical loads on the crown of the chamber will include all the material between the chamber and the road. Traffic loads will also need to be considered. Stand-up times can be expected to be short. Hand mining will probably be required. Grouting from the surface before excavation should be considered, assuming the permeability of the material makes it feasible. Additional permeability testing may be required to clarify the option.

The Brighton Group is variable in its compactness and strength, but the potential for loss of ground and settlement of the road surface is high. The presence or absence of groundwater will be crucial for stability. The groundwater content should be monitored.

7.4 QUEEN - LITTLE COLLINS STREET CABLE CHAMBER

This chamber is located at chainage 244 m (Plates 3 and 8).

The chamber crown will probably be located in highly weathered and fractured basalt which overlies zone 1 mudstone to about tunnel spring line. Zone 2 mudstone will probably occur below spring line. Water inflows should be negligible, but some seepage from faulty sewers may occur.

Excavation conditions will be poor and hand mining will probably be necessary. Steel sets and full timber lagging will be required.

Vertical rock loads will include all rock and soil from chamber crown and tunnel level to road surface (maximum depth of about 8 m). The vertical loads will be in the order of 220 kPa, but are potentially greater due to traffic loads. Stand-up time has been calculated at less than about 10 minutes, but will depend on the method of excavation and support.

Ground settlement above the chamber will probably be greater than that resulting from tunnelling on either side of the chamber, but will depend on the method of excavation and support.

7.5 LONSDALE - QUEEN STREET CABLE CHAMBER

This chamber is located at chainage zero (Plates 4 and 8).

The chamber is located entirely in the basalt, with the possibility of Werribee Formation close to tunnel invert. If the Werribee Formation is intersected, it may be necessary to pour a concrete sub-invert. Initial small groundwater flows are likely.

Although the basalt is hard and strong it has been weakened considerably by the high degree of fracturing. Excavation conditions are therefore expected to be fair, with an estimated stand-up time of less than about 5 hours. Vertical rock loads should be in the order of 170 kPa, but will be modified according to traffic loads.

Ground settlement may be greater than that caused by tunnelling adjacent to the chamber. Hand mining with some blasting will be required.

7.6 LONSDALE STREET LOADING COIL CHAMBER

This chamber is located at chainage 194 in Elizabeth Street Formation and zone 1 mudstone (Plates 4 and 8). Open cut excavation should be good, especially if above the groundwater table. The chamber walls will require support during construction; particular note should be taken of the chamber-tunnel junction where instability may be the greatest.

Unless groundwater recharge is very rapid between now and commencement of excavation, it is likely that the excavation will be dry.

7.7 LONSDALE-RUSSELL STREET CABLE CHAMBER

This chamber is located at chainage 704 in zones 1 and 2 mudstone with colluvium above chamber crown level (Plates 4 and 8).

Excavation conditions will be poor even if the excavation is above the groundwater table. Stand-up-times could probably be less than about 10 minutes. Full support with steel and timber lagging erected during hand mining operations will be required; shotcrete may not be practical, especially if the rock is wet. Loosening of the rock above chamber crown could potentially reach ground surface level if poor excavation techniques are used. Rock loads in the order of 120 kPa are possible if loosening up to the surface is allowed.

7.8 LONSDALE STREET LOADING COIL CHAMBER

This chamber is located at chainage 773 and will be by open cut excavation (Plates 5 and 8). It is located entirely in Colluvium.

Excavation conditions will be poor if the chamber is excavated without pre-grouting, particularly if the colluvium is water saturated. Pre-grouting from the surface should be considered in an attempt to prevent excess loss of ground and to assist in supporting the excavation walls. Piles and lagging or other methods of support will be required.

7.9 LONSDALE-EXHIBITION STREET CABLE CHAMBER

This chamber is located at chainage 937 in zone 3 mudstone, but it is likely that colluvium occurs close to chamber crown level (Plates 5 and 8). Leaky sewers have been reported in this area and therefore seepage other than groundwater may occur, but at a rate hard to assess. The mudstone will be closely jointed and has an estimated stand-up time of less than 10 minutes. Due to the proximity of the colluvium to the chamber crown, overbreak and subsequent settlement is potentially high. Vertical rock loads up to about 120 kPa can be expected. Steel, timber lagging and shotcrete support will be required.

7.10 LONSDALE-SPRING STREET TERMINATING CHAMBER

This chamber is located at about chainage 1197 and will be an open cut excavation (Plates 5 and 8). Most of the open cut will be located in fairly competent zone 3 mudstone. Initial groundwater inflows will be small and will decrease rapidly to seepage.

Excavation conditions should be good but the stability of the open cut walls will depend on joint and bedding plane orientations. Dip of bedding may be greater than the angle of friction, leading to the possibility of failure of wall sections. Assuming the beds dip west, then the west facing wall may be unstable. If the dip of the bedding is around 35° , then the factor of safety of the unfavourably oriented excavation wall will probably be less than 1.0.

With careful excavation, overbreak should be small. Rock bolts, mesh and shotcrete below about 2 m may give adequate support. Some overbreak may occur at the chamber-tunnel junction if not well supported with steel sets or rock bolts, particularly if the corner is cut by unfavourably oriented defect planes.

7.11 RUSSELL-LITTLE BOURKE STREET CABLE CHAMBER

This chamber is located at chainage 117 in Russell Street (Plates 6 and 8). The chamber crown will be in colluvium, overlying zone 2 to 3 mudstone. Small groundwater inflows from the colluvium will decrease rapidly to seepage.

The chamber crown will be unstable, and without support the stand-up times would be close to zero. Potential loss of ground and settlement is high but could be minimised by pre-grouting from the ground surface if practical. Steel sets and shotcrete with minimal lagging should be sufficient in the mudstone, but grout, steel and timber will be necessary in the crown to minimise loss of ground.

7.12 LITTLE LONSDALE STREET SOUTH CHAMBER, TELEPHONE EXCHANGE

This chamber is located in Little Lonsdale Street adjacent to the proposed Telephone Exchange (Plates 7 and 8), and will be excavated by open cut.

The excavation will generally be in fairly competent zone 2 and 3 mudstone. Bedding planes dipping greater than 35° are likely, resulting in potential failures in the west or north-west facing walls. Careful

excavation techniques together with rock bolts, mesh and shotcrete will minimise overbreak and adequately support the excavation. The chamber-tunnel junction should be well supported with steel sets and possibly rock bolts.

7.13 VICTORIA-RATHDOWNE STREET TERMINAL CHAMBER

This chamber is located in Victoria Street (Plates 7 and 8) and will be almost entirely in zone 1 mudstone. It will be an open cut excavation.

Excavation conditions will be fair, with some improvement towards invert level. Little if any groundwater inflows will occur, and at worst the excavation will be damp. Piles and timber lagging or other support methods will be required to support the walls. The tunnel-chamber junction will need to be supported with steel sets and timber lagging.

8. SHAFTS

Locations and brief geological descriptions of each shaft are shown on Plates 3 to 8.

8.1 QUEEN STREET CONSTRUCTION SHAFT, CHAINAGE-2.54

From near surface to tunnel crown level the shaft will be located in the Brighton Group. At this location most of the Brighton Group will consist of poorly consolidated sandy clay although some hard limonite cemented bands will occur.

Excavation conditions will be poor, especially if material is water saturated. Steel rings and full timber lagging will be required.

The shaft tunnel junction will occur close to the boundary between the Brighton Group and the underlying Werribee Formation and instability and loss of ground is potentially high. Some thought should be given to grouting the area from the surface if the material permeability is great enough.

8.2 QUEEN STREET VENTILATION SHAFT, CHAINAGE 30.0

This shaft will be in soft, poorly consolidated Brighton Group sediments. There should not be any problems in drilling the shaft to its full diameter and casing the hole to prevent collapse.

8.3 QUEEN STREET CONSTRUCTION SHAFT, CHAINAGE 269.4

The top 3 to 4 m will be located in fill and extremely weathered basalt, overlying zone 1 mudstone. Continuous groundwater inflows are unlikely.

Excavation conditions will be poor. Steel rings and full timber lagging will be required to prevent loss of ground. The tunnel-shaft junction will need to be well supported with steel and timber and possibly shotcrete (in zone 2 material).

8.4 MANHOLE, LONSDALE STREET, CHAINAGE 204

The manhole will be located in the Elizabeth Street Formation, and could either be drilled to full diameter and cased, or the open cut for the nearby chamber could be extended to the manhole position. Drilling and casing a hole would be relatively inexpensive and quick, especially in the poorly consolidated Elizabeth Street formation.

8.5 MANHOLE - LONSDALE STREET, CHAINAGE 334.5

Most of this manhole will be in the Elizabeth Street Formation. Some zone 1 or even zone 3 mudstone may be intersected close to the manhole-tunnel junction. There should be no problems associated with drilling and casing a hole at this location.

8.6 MANHOLE AND VENTILATION SHAFT, LONSDALE STREET, CHAINAGE 541.5 and 551.5 RESPECTIVELY

Both structures will intersect zones 1 and 2 mudstone and no problems associated with drilling and casing the holes are anticipated. If the shaft is to be excavated by means other than boring, then steel ribs and full timber lagging would be necessary to prevent excess loss of ground.

8.7 MANHOLE, LONSDALE STREET, CHAINAGE 757

The full depth of this manhole (6 m) will be located in the colluvium. There should be no problems associated with drilling and casing the hole, even if the colluvium has not been drained or stabilized by grouting. As an alternative, the manhole could be included in the open cut excavation for the nearby chamber.

9. TUNNEL PORTAL

The portal is located adjacent to Leichardt Street (Plate 7), and will be part tunnel and part open cut (ramp).

The tunnel section will be located in competent zone 3 mudstone with an estimated stand-up time of 8 hours. Support in the form of steel sets and shotcrete will be required. Groundwater inflows will be negligible. Bedding will probably dip in a westerly direction and if prominent may result in a ragged tunnel profile on the northeast wall. The open cut section of the portal will be in zone 1 and 2 mudstone to 3 to 4 m, underlain by zone 3 mudstone. The excavation in zone 3 mudstone could be near vertical, but the top 3 to 4 m should be sloped flatter than about 1:1. Instability is probable in the zone 3 mudstone at any batter slope greater than about 30° - 35° , but will depend on the dip of the bedding and jointing. Assuming the bedding dips towards the west, the west facing wall will be potentially unstable if the bedding or jointing dips into the excavation steeper than the angle of friction. Mesh, anchored by rock bolts, possibly with shotcrete should adequately support the open cut excavation and the portal face from crown level to ground surface.

10. RECOMMENDATIONS

1. Additional permeability tests could be considered in the Colluvium, in addition to the tests already done in drillholes 23A and 21.
2. All existing piezometers must be continually monitored, even during construction.
3. If permeabilities in the Colluvium are high enough to allow successful grouting, then the appropriate sections of tunnel should be grouted prior to construction.
4. Four large auger hole inspection pits for tenderers would be useful. The pits could be located as follows:
 - (i) Near drillhole 19 - to exposure the range of degrees of weathering of the mudstone (z1 to z3).
 - (ii) At the manhole located at chainage 204, Lonsdale Street - Located in the Elizabeth Street Formation.
 - (iii) At the manhole located at chainage 30, Queen Street - Located in the Brighton Group.

- (iv) At the manhole located at chainage 757, Lonsdale Street -
 Located in the Colluvium. It may be advantageous to drill
 this pit after grouting.
5. Due to probable surface settlements along the route, a detailed survey of the ground surface should be carried out prior to construction.
 6. During excavations of the tunnels and appurtenant works, the rock conditions should be regularly monitored and logged by an engineering geologist.

11 ACKNOWLEDGEMENTS

The authors wish to thank John Brumley and John Nielson (Mines Dept Victoria) for their co-operation in providing information on the geology of the Melbourne City area and J. Bailey* for supervising the drilling and logging of the cores during the absence of G. Trand in August and September 1977.

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* Geologist, John Connell-Mott-Hay & Anderson, Hatch-Jacobs (Consulting Engineers).

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APPENDIX 1

DEFINITION OF TERMS

APPENDIX 1

DEFINITION OF TERMS

Rock Mass

Rock mass is a body of material which is not effectively homogenous, that is, the rock substance is crossed by natural defects such as joints, faults, seams etc.

Rock Substance

This is defined as intact, effectively (for engineering purposes) homogenous rock. Repeated mechanical tests on the material would give acceptable coefficients of variations (e.g. uniform results).

Sheared Rock

Consists of rock intersected by close (< 1 cm) slightly curving intersecting fracture planes; the fracture surface may be smooth, polished, slickensided or coated with clay.

Crushed Rock

Consists of rock which is mechanically disintegrated but not obviously chemically decomposed.

Fractured Rock

Consists of rock which is intensively jointed in several directions. Fracture surfaces are often clay coated.

Faulted Rock

Faults can be sheared, crushed or fractured rock and where relative displacement of rock can be seen. Unless evidence for faulting is quite definite the term should not be used.

Defect Spacing

Very close	- joints spaced < 5 cm
Close	- joints spaced 5 cm to 30 cm
Moderately close	- joints spaced 30 cm to 1 m
Wide	- joints spaced 1 m to 3 m
Very Wide	- joints spaced > 3 m

Joint Aperture

This describes the amount of separation of the joint surfaces. Joints may be open or tight. If two joint faces fit perfectly it is probable that the joint in the rock mass was tight (or closed). However, if they do not fit it probably means that the joint was open; or possibly filled with clay that has been washed away during drilling.

Bedding

- Laminated - < 10 mm thick
- Thinly bedded - 10 mm to 100 mm thick
- Thickly bedded - > 100 mm thick

Grainsize

- Coarse-grained - 1 mm to 4 mm in diameter
- Medium-grained - $\frac{1}{2}$ mm to 1 mm in diameter
- Fine-grained - < $\frac{1}{4}$ mm in diameter

Rock Quality Designation (RQD)

RQD is the ratio (expressed as a percentage) of length of core recovered to the total length of core run, counting only those pieces of hard and sound rock 10 cm in length or longer.

Rock Competence

The terms "competent" and "incompetent" are relative ones, combining properties such as weathering, degree of fracturing, and ultimately estimated stand-up times. The terms also relate to tunnelling in the Melbourne City area such that zone 3 mudstone may be termed competent in Melbourne but would be considered incompetent in comparison with tunnelling through dacites in Canberra.

Zones 1 and 1-2 mudstone are incompetent due to a high degree of weathering, softness and very short stand-up times. Zone 2 is more competent than zones 1 and 1 to 2 but less competent than zone 3, unless zone 3 is highly fractured with a shorter stand-up time. For this tunnel, rock with a stand-up time of more than about 8 hours is considered competent.

DEGREES OF ROCK WEATHERING

- FRESH : No discolouration or loss in strength.
- FRESH STAINED : Limonitic staining along fractures; rock otherwise fresh and shows no loss of strength.
- SLIGHTLY WEATHERED : Rock is slightly discoloured, but not noticeably lower in strength than the fresh rock.
- MODERATELY WEATHERED : Rock is discoloured and noticeably weakened; N-size drill core generally cannot be broken by hand across the rock fabric.
- HIGHLY WEATHERED : Rock is discoloured and weakened; N-size drill can generally be broken by hand across the rock fabric.
- EXTREMELY WEATHERED : Rock is decomposed to soil but the original rock fabric is mostly preserved.

Zone Number	Degree of Weathering	Material Type	Typical Colour *	Mohs' Hardness	Reaction to Blow from 2 lb. Hammer	Visibility of Bedding	Soil or Rock **
1A	Extreme	Silty clay or sandy clay (usually stiff to hard)	Yellow brown	Max 0.5	-	Bedding	Soil
1B		Silty clay or sandy clay containing harder rock fragments					
2	High	Soft mudstone, with clay seams common. Clay is often from decomposition of mudstone beds; often it is in joints, with iron oxide also. Strength low.	Yellow brown	0.5-1.0	Shatters easily with light blow.	indiscernible	Rock
3	Moderate	Moderately hard mudstone. Thin mudstone bands weathered to clay are known, but uncommon. Joints sometimes carry thin clay deposits, or often iron oxide. Strength moderate.	Pale brown & pale grey mottled	1.0-1.5	Only fractures with light blow. Shatters with fairly heavy blow.	Bedding mostly discernible	
4	Slight	Hard mudstone. Joints sometimes contain thin clay films and often iron oxide staining. Strength fairly high.	Pale grey	1.5-2.5	Shatters only with very heavy blow.	Bedding clearly visible	
5	Fresh	Very hard mudstone. Joints clean or with pyrite films or occasionally calcite. Strength very high.	Dark blue grey	> 2.5	Fractures, but not shatters, by very hard hammer blow.		

* Colour can be much paler if leaching has occurred.

** In engineering sense.

Weathering Zone in Melbourne Silurian Mudstone (Neilson 1970)

APPENDIX 2

SUMMARY OF LABORATORY AND FIELD TEST RESULTS

ON SOIL AND ROCK SAMPLES

TELECOM TUNNEL - X-RAY DIFFRACTION ANALYSES

A series of X-ray diffraction analyses was carried out in order to determine the clay mineralogy of various geological formations associated with the Telecom Tunnel project.

The results of the tests are given on the attached table. These results were obtained on samples of material passing the 75 μm sieve and dried at 50°C. Duplicate samples were prepared and glycolated in order to assist in the identification of swelling type clay minerals.

Borehole No.	Depth (m)	Material type	Clay type constituents		Traces	Other major constituents
			Major	Minor		
6	6.0	Weathered basalt	Kaolinite	Montmorillonite	Illite-montmorillonite (mixed layer)	Alkali feldspar
13	6.0	Z ₁ silurian	Kaolinite montmorillonite	Illite-montmorillonite (mixed layer)	Illite (?)	Muscovite, quartz
	8.0	Z ₂ silurian	Kaolinite montmorillonite		Goethite	Feldspar (traces)
16	1.0	Elizabeth Street formations	Kaolinite illite		Goethite, illite-montmorillonite (?)	Feldspar and quartz
	2.0	"			Goethite, illite-montmorillonite and montmorillonite	Feldspar and quartz
	3.0	"	Kaolinite, illite, montmorillonite	Illite-montmorillonite (mixed layer)		Quartz, feldspar, goethite
	4.0	"	"	"		"
	5.0	"	"	"		"
	6.2	"	Kaolinite, illite	Montmorillonite, illite-montmorillonite (mixed layer)	Feldspar	Quartz, goethite

Borehole No.	Depth (m)	Material type	Clay type constituents		Traces	Other major constituents
			Major	Minor		
16 (cont.)	7.0	Elizabeth Street formations	Kaolinite, illite, montmorillonite	Montmorillonite-illite (mixed layer)	Felspar	Quartz, goethite
	8.0	"	Kaolinite, illite	Illite-montmorillonite (mixed layer)	Montmorillonite	Quartz, goethite
	9.0	"	Kaolinite, illite	Illite-montmorillonite (mixed layer)	Felspar	Quartz, goethite
	10.0	"	"	"	"	"
	11.0	"	"	"	"	"
21	11.5	Dyke	"	"	Illite-montmorillonite (mixed layer)	Albite, quartz
23	5.5	Colluvium	Kaolinite, illite	"	Illite-montmorillonite (mixed layer)	Quartz, goethite
	6.3	"	Kaolinite	Illite, montmorillonite (mixed layer)	"	Quartz, goethite

Borehole No.	Depth (m)	Material type	Clay type constituents		Traces	Other major constituents
			Major	Minor		
23A (cont.)	7.0	Colluvium	Kaolinite, illite		Montmorillonite (?), illite- montmorillonite (mixed layer?), felspar	Quartz, goethite
	8.0 - 8.3	"	Kaolinite	Illite	Illite- montmorillonite (mixed layer?)	Quartz, felspar
	9.0 - 9.3	"	"	Illite, illite- montmorillonite	Montmorillonite (?)	Quartz
	10.0	"	"	Illite- montmorillonite		"
	11.0	"	Kaolinite, illite	Montmorillonite, illite- montmorillonite (mixed layer)		Quartz, felspar, goethite
	12.0	"	"	"		"

PERMEABILITY TESTS

PUMPIN TEST - DRILLHOLE 23A, CHAINAGE 788, LONSDALE STREET,

MATERIAL TESTED - SAND AND CLAYEY SAND LAYER:

BASE OF HYDRAULIC PACKER 5.5 m
BASE OF BOREHOLE 13.0 m
PRESSURE IN PACKER 600 kPa

PRESSURE GAUGE Reading (kPa)	FLOW METER Reading (l)	TIME (mins)	FLOW RATE l/min
50	130	0	
	160	1	30
	180	2	20
	208	3	28
	233	4	25
	260	5	27
100	980	0	
	1006	1	26
	32	2	26
	58	3	26
	82	4	24
	1108	5	26
150	34	6	26
	1284	0	
	1310	1	26
	35	2	25
	60	3	25
	84	4	24
100	1410	5	26
	1642	0	
	67	1	25
	92	2	25
100	1717	3	25
	1742	4	25
	67	5	25
50	1886	0	
	1912	1	26
	38	2	26
	62	3	24
	87	4	25
25	2108	0	
	34	1	26
	59	2	25
	84	3	25
	2210	4	26
300	2422	0	
	80	1	58
	2538	2	58
	96	3	58
	2656	4	60
200	2796	0	
	2854	1	58
	2908	2	54
	62	3	54

N.B. : When water pressure was raised to 300 kPa the section of the borehole above the packer was filled with water. The readings for 300 kPa should be ignored as the ground obviously was fissured by such high pressure.

As the flow rate was nearly constant at all pressures the best choice of head pressure is that value nearest natural conditions. Thus in calculating permeability of the alluvial sand layer the gauge pressure of 25 kPa with a flow reading of 25 l/min is used.

$$k = \frac{Q}{LH} \times \frac{\ln \frac{L}{r}}{2 \pi}$$

k = hydraulic conductivity

Q = flow = 25 l/min = 416.0 cm³/sec

L = length of test section = 750.0 cm

H = gauge pressure + height between gauge and middle of test section

= 25 kPa + 9.25 m (1 m head = 9.796 kPa)

= 255 + 925 cm

= 1180 cm

r = radius of borehole = 3.8 cm

$$k = \frac{416.0}{1180 \times 750} \times \frac{\ln \frac{750}{3.8}}{2 \pi}$$

= 3.9 x 10⁻⁴ cm/sec.

CONSTANT HEAD TEST, DRILLHOLE 21, CHAINAGE 631; LONSDALE STREET

MATERIAL TESTED - WELL JOINTED SANDSTONE

BASE OF PNEUMATIC PACKER 13.3 m

BASE OF BOREHOLE 14.6 m

FLOW RATE = 13 l/min = 216 cm³/sec

$$k = \frac{Q}{HL} \times \frac{\ln \frac{L}{r}}{2 \pi}$$

H = 1500 cm

L = 130 cm

r = 2.5 cm

$$k = \frac{216}{1500 \times 130} \times \frac{\ln \frac{130}{2.5}}{2 \pi}$$

= 6.96 x 10⁻⁴ cm/sec.

APPENDIX 3

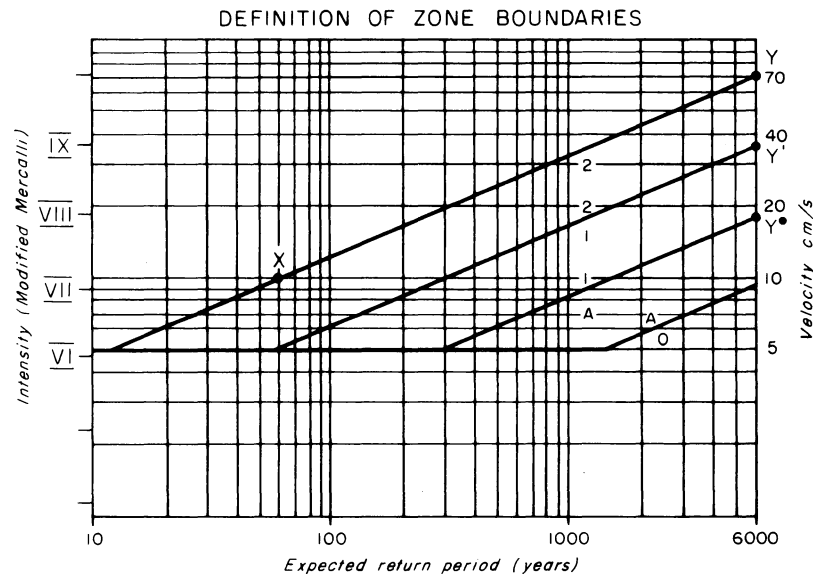
EARTHQUAKE RISK MAP OF VICTORIA (1978)

EARTHQUAKE RISK MAP OF AUSTRALIA (1978)

SCALE 1 : 5 000 000



Simple Conic Projection with Standard Parallels 18° S and 36° S



SELECTED POPULATED PLACES

Capital City	.....	SYDNEY	
30 000-250 000 Persons	.....	BENDIGO	
20 000-30 000	.....	KALGOORLIE	
5 000-20 000	.....	Woomera	
1 000-5 000	.....	Bega	
Under 1 000	.....	Bodalla	

HYDROGRAPHY

Perennial River	.....	
Intermittent River	.....	
Perennial Lake	.....	
Intermittent Lake	.....	
Dry Lake	.....	
Flood Area	.....	
Swamp	.....	
Reef	.....	

CONTOURS (approximate)

Bathymetric in metres (1964) 2000

BOUNDARIES

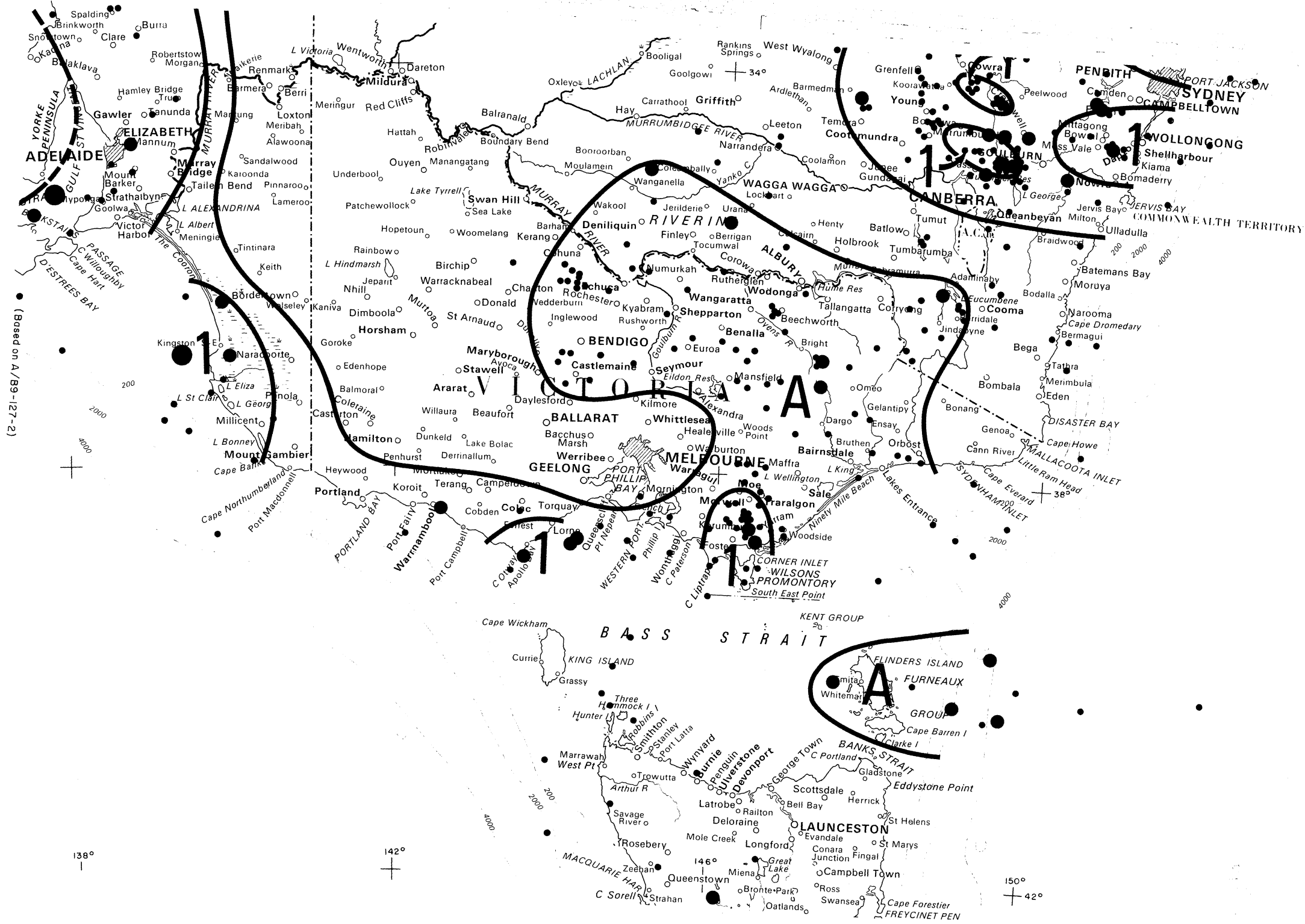
State
Limits of State Sovereignty
over included Islands

EARTHQUAKE EPICENTRES

Magnitude

3.0 < 5.0	
5.0 - 5.9	
> 5.9	

Topographic base map by Division of National Mapping (NMP 66/107-1)
Drawn in the Cartography Section, Bureau of Mineral Resources.



(Based on A/B9-127-2)

A/B9-135A

Explanatory Notes

The map shows earthquake risk zones for Australia and is the basis for the map contained in AS-2121-1978 — Australian Standard Rules for the Design of Earthquake-resistant Buildings. The zoning is applicable to 'normal' buildings as defined in that Standard. Different zoning criteria, and therefore zones, apply to domestic dwellings and special purpose structures. These notes are intended to inform users of the basis for the derivation of the map.

Data Sources. The main data source was the earthquake data file maintained at the Bureau of Mineral Resources, (Denham et al., 1975). This now contains the locations and magnitudes of all known Australian earthquakes from 1897 through 1976. Data are reasonably complete from 1960 for magnitudes greater than 4; earlier, the data are complete only for larger earthquakes ($M \geq 5$).

Analysis. The shaking at a site during an earthquake was assumed to be related to the hypocentral distance and magnitude according to the empirical formula $Y = ae^{bMR^c}$, where: Y is the maximum value of ground acceleration, velocity, or the anti-logarithm of Modified Mercalli intensity; M , the earthquake magnitude; R , a function of the distance from the hypocentre to the site; and a , b , and c are constants. The primary measures of ground shaking were the peak ground-particle velocity and the Modified Mercalli intensity; these are shown on the diagram defining the zone boundaries, and were taken to be related approximately as follows: 5 cm/s = MMVI, 10 cm/s = MMVII, 20 cm/s = MMVIII etc. The constants used were based on those obtained by Esteva & Rosenblueth (1964) and Esteva & Villaverde (1973) for 'average' sites. However, because of variations in site and source conditions there can be a large scatter between the observed and predicted values. No consideration has been given to the effects due to the differences between actual and average sites, and the designer/engineer should consider such factors where these might give rise to shaking above the regional average.

Zoning. The zones encompass places considered to have similar earthquake risk. Adjacent zone boundaries are defined on the graph by points for which the velocity (intensity) of ground motion is halved at a particular return period (corresponding approximately with the halving of the zone factor, Z , in the Standard). Thus a region where the return period for a ground-particle velocity of 40 cm/s is 6000 years or less is defined as Zone 2 (Point Y') and 20 cm/s at the same return period

is Zone 1 (Point Y*). The slopes of the zone boundaries follow the rate of increase in shaking with lengthening return period obtained from seismic studies.

Shaking of less than 5 cm/s (MMVI) is not expected to cause structural damage to normal buildings and so velocities below this figure can be ignored for present purposes. Buildings designed with full seismic provision (as for instance the Unified Building Code, Zone 3) should not be damaged by twice this shaking (10 cm/s). A region where the return period of 10 cm/s ground-particle velocity is 60 years or less, would be above the Zone 2 upper boundary (Point X on figure at right). This means that in such a region, there is about a 60% probability that a building will be shaken at least this amount during its design life of 60 years. In addition a building in this region should at least be able to resist collapse (by drawing on reserves of ductility above its elastic strength limit) at Intensity X (about 70 cm/s); it has been assumed that a 1% probability that this shaking will be exceeded in the design life-time of 60 years represents the same acceptable degree of risk (Point Y). This definition of the Zone 2 upper boundary is expressed in the diagram. No region in Australia is presently believed to exceed this boundary.

Zone A, is distinguished from the numbered zones by explicit recognition of two design alternatives to withstand collapse, namely, the provision of either reserve ductility or adequate elastic strength. Zone A covers those areas where the shaking expected should be satisfactorily withstood by buildings that possess ductility (as defined in the Code) without specific design for lateral forces due to earthquakes. In these areas, non-ductile buildings (as defined in the Code) which may collapse if their elastic strength is exceeded in the course of an earthquake, are required to have a certain minimum elastic strength to resist lateral forces due to earthquakes.

Zone O includes all areas not otherwise zoned, although significant shaking may arise in any part of this zone at some time in the future.

The zones delineated on the map are based on the work of McCue (1973, 1975, and 1977) and McEwin et al. (1976) and the analytical methods and criteria described above, incorporating a knowledge of seismic history and regional tectonics. The uncertainty of the seismicity in several regions has led to simplified zone boundaries such as that near Brisbane. In these, more than in most areas, accuracy of the boundaries is low.

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BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

CANBERRA

AUSTRALIA

REQUEST FROM EARTHQUAKE DATA FILE

SELECTIONS

AREA LATITUDE 36S TO 42S

 LONGITUDE 145E TO 149E

TIME 19 101 TO 761231

MAGNITUDE 4.0 TO 9.9

DATE RUN 11/05/78

DESCRIPTION OF TABLE HEADINGS

DATA SOURCE PUBLICATION FROM WHICH SOME OR ALL OF THE DATA WERE OBTAINED. NUMBER FOLLOWING CGS INDICATES THE PDE NUMBER (SEE ALSO RATING/AUTH.)

DATE UT YEAR, MONTH, DAY
 TIME UT HOUR, MINUTE, SECOND : COMPUTED, OR OBSERVED IF CONTROLLED EXPLOSION WITH SHOT TIMED
 GEOGRAPHIC LOCATION LATITUDE, LONGITUDE - TO 3 DECIMAL PLACES - THIS ACCURACY NOT NECESSARILY APPLICABLE
 DEPTH (KM) FOCAL DEPTH (SEE ALSO DEPTH CONTROL)

MAGNITUDES BODY WAVE M(L/C) MEASURED MAGNITUDE FROM BODY WAVE L/C LOWER CASE
 SURF WAVE M(U/C) MEASURED MAGNITUDE FROM SURFACE WAVE U/C UPPER CASE
 M(L/C) = $2.9 + 0.56M(U/C)$ IASPEI RECOMMENDATION
 INTERNATIONAL ASSOCIATION OF SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR
 OTHER SOURCES = MAGNITUDES FROM OTHER AUTHORITIES
 RICHTER/LOCAL = RICHTER LOCAL MAGNITUDE (ML) (UP TO 600KM)

ASSOC. PHENOMENA: PHYSICAL : DIASTROPHISM : F = SURFACE FAULTING
 U = UPLIFT/SUBSIDENCE
 D = FAULTING AND UPLIFT/SUBSIDENCE
 L = LANDSLIDE
 TSUNAMI T = TSUNAMI GENERATED
 ? = POSSIBLE SEICHE
 VOLCANISM V = EARTHQUAKE ASSOCIATED WITH VOLCANISM
 NON-TECTONIC: R = ROCKBURST
 C = COALBURST OR ROCKBURST IN COAL MINE
 M = METEORITIC SOURCE
 E = EXPLOSION, ACCIDENTAL, CONTROLLED OR SUSPECTED EXPLOSION
 I = COLLAPSE
 L = LIGHTS OR VISUAL PHENOMENA SEEN
 A = ATMOSPHERIC EXPLOSION
 OTHER WAVES : T = T-WAVE
 A = ACOUSTIC WAVE
 G = GRAVITY WAVE
 B = BOTH A AND G
 MAN C, D, F = REPORTED CASUALTIES, DAMAGE OR FELT INFORMATION

INTENSITY MAX M.M. = MAXIMUM MODIFIED MERCALLI INTENSITY FELT
 ISOSEISMAL MAP BY = AUTHORITY ISSUING ISOSEISMAL MAP

QUALITY DEPTH CONTROL N = HOLD AT 33KM (NORMAL DEPTH), WHEN DATA NOT SENSITIVE TO DEPTH FOR A SHALLOW FOCUS
 R = DEPTH RESTRAINED BY GEOPHYSICIST
 D = RESTRAINED DEPTH BASED ON 2 OR MORE REPORTED PPS IDENTIFIED AS SUCH

COLUMN OF NUMBERS REPRESENTS THE NUMBER OF P AND/OR P_n ARRIVALS USED IN HYPOCENTRE SOLUTION (NUMBER OF STATIONS).

:- RATING AUTHORITY = ASSIGNED TO CGS SOLUTIONS FOR WHICH POOR AZIMUTH, DEPTH CONTROL AND OTHER FACTORS CONTRIBUTE TO A LESS RELIABLE SOLUTION
 F = HYPOCENTRE/EPICENTRE DETERMINED BY PASADENA
 B = HYPOCENTRE/EPICENTRE DETERMINED BY BERKELEY
 H = HYPOCENTRE/EPICENTRE DETERMINED BY HAWAIIAN VOLCANO OBSERVATORY
 A = SOURCE PARAMETERS SUPPLIED BY AEC
 E = SOURCE PARAMETERS OF OTHER EXPLOSIONS LISTED RATHER THAN COMPUTED SOLUTION

F-E GEOG. REG. = FLINN-ENGDAHL GEOGRAPHIC REGION NUMBER

EARTHQUAKE DATA FILE

DATA SOURCE	DATE GMT			TIME GMT			GEOGRAPHIC LOCATION		DEPTH KM	SOURCE MAGNITUDES BODY SURF WAVE WAVE	MAGNITUDES		ASSOC PHENOMENA PHYSICAL MAN	INTENSITY		QUALITY	F-E GEOG REG.
	YR	MO	DAY	HR	MM	SEC	LATITUDE	LONGITUDE			OTHER SOURCES	RIHTER /LOCAL		MAX	ISO-			SEIS-	U
*HOLMES	32	09	02	18	22	30.0	36.250S	145.000E	10			4.50 ML MEL	F	V BMR	G	3	
*ADE	59	05	18	06	13	00.2	36.120S	148.580E	0	5.52		5.30 ML RIV		VII		5	
*CAN	60	01	28	23	37	50.3	36.850S	147.170E	21	4.72		5.00 ML CAN				6	
*CAN	60	06	01	05	18	47.6	36.760S	145.350E	12	4.52		3.50 ML CAN				5	
*CAN	60	10	20	20	22	04.6	38.560S	146.450E	8	4.72		4.72 ML CAN				5	
*CAN	60	10	21	14	47	57.0	38.900S	146.500E	0	4.60		3.90 ML CAN			G	5	
*CAN	61	04	11	00	35	23.4	36.280S	146.470E	46	4.72		4.72 ML CAN				4	
*ROBUND	61	10	09	23	43	14.3	39.211S	145.862E	49	4.72		4.00 ML CAN				2	
*ROBUND	61	10	10	13	36	00.	39.210S	145.880E	0	4.72		4.00 ML CAN				0	
*CAN	62	01	10	05	40	.	38.500S	146.500E	0	4.50		3.80 ML CAN			G	0	
*CAN	62	03	27	17	54	22.2	37.920S	146.550E	6	4.50		3.80 ML CAN				5	
*CAN	63	06	14	19	23	47.6	38.660S	146.430E	2	5.22		4.80 ML CAN				6	
*CAN	64	11	17	21	16	18.5	38.420S	146.350E	16			4.00 ML CAN				4	
*ISC	66	05	03	19	07	54.0	37.100S	147.170E	024	4.30		5.70 ML CAN		V		27	623
*CAN	66	10	17	17	12	30.8	37.880S	146.200E	18	4.60		3.80 ML CAN				6	
*CAN	67	08	17	16	29	22.6	36.380S	146.650E	0			4.00 ML CAN			G	8	
*CAN	68	10	08	10	23	48.0	36.780S	146.120E	6	4.10		4.30 ML CAN				7	
*BMR	69	06	20	11	15	28.3	38.470S	146.300E	0	5.0		5.90 ML CAN		VI	R	27	
*CAN	69	06	22	16	29	13.3	38.540S	146.340E	0			5.00 ML CAN			G	10	
*CAN	69	06	22	16	37	43.5	38.410S	146.270E	0			4.00 ML CAN			G	9	
*CAN	70	05	31	01	50	01.	38.520S	146.220E	0			4.10 ML CAN			G	11	
*CAN	70	12	31	13	01	23.	36.680S	147.820E	0			4.10 ML CAN			G	6 *	

*CAN	71 02 08	14 49 11.7	36.010S 145.020E	22
*CAN	71 06 21	01 11 44.8	36.230S 148.790E	1
*GIBSON	71 07 06	21 55 00.	36.423S 145.113E	43
*CAN	71 12 31	15 42 42.	36.000S 145.950E	0
*BMR	76 09 03	04 21 38.3	36.770S 146.250E	25

27 EVENTS PRINTED

4.30 FL CAN		9
4.00 FL CAN	VI	9
	PD VI BMR	18
4.10 FL CAN	G	11
4.00 FL TGO		0

ABBREVIATIONS

ADE ** UNIVERSITY OF ADELAIDE, SOUTH AUSTRALIA
AUST AUSTRALIAN BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS CANBERRA
BOLT BOLT, R.A., SEISMIC TRAVEL TIMES IN AUSTRALIA, J.ROY. SOC. N.S.W., VOL 92, 1958
BURK BURK-GAFFNEY, T.N.(S.J.), SEISMICITY OF AUSTRALIA, J.PROC.R.SOC.N.S.W., 85, PP47-52, 1951
BMR AUSTRALIAN BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS CANBERRA
CAN ** AUSTRALIAN NATIONAL UNIVERSITY, CANBERRA, A.C.T.
CGS COAST AND GEODETIC SURVEY
DES DOYLE, H.A., EVERINGHAM, I.B., AND SUTTON, D.J., SEISMICITY OF AUSTRALIAN CONTINENT, J.GEOL.SOC.AUSIRAL., 55, PT2, PP295-312,
DUDA DUDA, S.J., SECULAR SEISMIC ENRGY RELEASE IN THE CIRCUM-PACIFIC BELT, TECTONOPHYSICS, 2, NOS, PP429-452, 1965
GUTRIC GUTENBERG, B., AND C.F. RICHTER, SEISMICITY OF THE EARTH, THE PRINCETON UNIVERSITY PRESS, 1954
GS ** GS = NOS = ERL
IGS INSTITUTE OF GEOLOGICAL SCIENCES EDINBURGH, SCOTLAND
ISC INTERNATIONAL SEISMOLOGICAL CENTRE EDINBURGH SCOTLAND
ISS INTERNATIONAL SEISMOLOGICAL SUMMARY, KEW OBSERVATORY ENGLAND
MUN MUNDARING GEOPHYSICAL OBSERVATORY, MUNDARING WESTERN AUSTRALIA
PMG FORT MURESBY GEOPHYSICAL OBSERVATORY, PORT MORESBY, PAPUA NEW GUINEA
RAB CENTRAL VULCANOLOGICAL OBSERVATORY, RABUAL, PAPUA NEW GUINEA
STOBER STOVER, C.W., SEISMICITY OF THE INDIAN OCEAN, J.GEOPHYS.RES., 7, PP 2575-2581, 1966
SYKES SYKES, L.R., SEISMICITY OF THE INDIAN OCEAN AND A POSSIBLE MASCENT ISLAND ARC, J.GEOPHYS.RES., 75, PP5241-5255, 1970
WEL DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, WELLINGTON NEW ZEALAND
JONES JONES, U.A., QUEENSLAND EARTHQUAKES AND THEIR RELATION TO STRUCTURAL FEATURES, J.PROC.R.SOC.N.S.E., VOL 92, 1959
JOKLIK JOKLIK, G.F. AND CASEY, J.N., GUNNING DISTRICT, N.S.W., EARTH TREMOR NOV 1952, BUR.MINER.RESOUR.AUST.REC. 1952/91
ROTHE ROTHE, J.P., THE SEISMICITY OF THE EARTH 1953-1965, UNESCO 1969
FISHER FISHER, R.L. ET AL WORLDWIDE COLLECTION AND EVALUATION OF SEISMICITY FOR 1960 AND 1963 PREPARED BY TEXAS INSTRUMENTS 1964
IBE IBE = MUN
TASUNI ** UNIVERSITY OF TASMANIA
E.T. EVERINGHAM, I.B. AND TILBURY, L. W.A. EARTHQUAKES FOR 1849-1900 AND 1923-60 BUR.MINER. RESOUR. AUST. REC. 19710 42
ERL ENVIRONMENTAL RESEARCH LABORATORIES, NATIONAL EARTHQUAKE INFORMATION CENTER, BOULDER, COLORADO 80302 USA
NOS NOS = ERL
ROBUND UNDERWOOD, R. STUDIES OF VICTORIAN SEISMICITY PROC. ROY. SOC. VICT. 85, PT.1, PP27-48, 1972
ISSBMR BMR SOLUTIONS USING DATA FROM ISS BULLETINS
COTTON COTTON, L.A., NOTE ON EARTHQUAKES AT MUKRUMBATENAN, MAR-APR 1924 AND JAN-APR 1925, J. PROC. ROY. SOC. N.S.W. 55, PP63-124, 1926

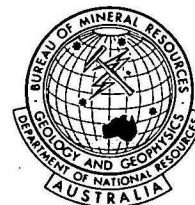
** CURRENT NON-BMR CONTRIBUTORS

GEOG, REG, = REFERS TO AREAS DEFINED IN - A PROPOSED BASIS FOR GEOGRAPHICAL AND SEISMIC REGIONALIZATION BY
FLINN E.A. AND E.R. ENGLAHL, REVIEWS OF GEOPHYSICS, VOL 3, NO 1, PP123-149 FEBRUARY 1965

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MELBOURNE CABLE TUNNELS

GEOLOGICAL INVESTIGATIONS 1977-78

VOL. 2

by

D.C. Purcell and G. Trand

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1978/16
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APPENDIX 4

DRILL CORE PHOTOGRAPHS

DEPTH.

BORE HOLE 4.

4.6 - 6.1	
6.1 - 7.6	
7.6 - 9.8	7.6 ← .40 LOSS → 8.0 Loss Loss 20cm
9.8 - 10.6	
10.6 - 12.1	
12.1 - 13.0	

BORE HOLE 2A.

2.4 - 2.7	
10.0 - 11.5	
11.5 - 13.0	
13.0 - 14.5	
14.5 - 16.0	
16.0 - 17.2	

BORE HOLE 1.

1.4 - 2.9	
2.9 - 4.4	
4.4 - 5.9	
5.9 - 7.4	
7.4 - 8.9	
8.9 - 10.4	
10.4 - 11.9	
11.9 - 13.4	
13.4 - 14.9	
14.9 - 16.4	
16.4 - 17.9	
17.9 - 19.0	

BORE HOLE 5A

20-69	
69-95	
95-110	
110-125	
125-134	
134-149	
149-159	
159-171	
171-186	
186-201	
201-216	
216-231	
231-246	
246-261	
261-276	
276-291	
291-306	

BORE HOLE 8

5.0 - 6.3	
6.3 - 8.0	
8.0 - 9.5	
9.5 - 10.8	
10.8 - 12.3	
12.3 - 13.6	
13.6 - 14.0	
14.0 - 15.6	
15.6 - 17.0	
17.0 - 18.5	
18.5 - 19.8	

BORE HOLE 6

5.0 - 6.5	
6.5 - 7.4	
7.4 - 8.9	
8.9 - 10.4	
10.4 - 11.9	
11.9 - 13.4	
13.4 - 14.9	
14.9 - 16.0	
16.0 - 17.5	
17.5 - 19.0	
19.0 - 20.0	

BORE HOLE II

4.5 - 6.2	
6.2 - 7.4	
7.4 - 8.6	
8.6 - 10.0	

BORE HOLE IO

1.5 - 4.7	
4.7 - 6.1	
6.1 - 7.6	
7.6 - 8.8	
8.8 - 10.4	
10.4 - 12.0	
12.0 - 13.5	
13.5 - 15.0	
15.0 - 16.3	

BORE HOLE 12.

3.5-5.0	
5.0-5.8	
5.8-7.3	
7.3-8.8	
8.8-10.3	
10.3-11.8	
11.8-13.3	
13.3-14.8	
14.8-16.3	
16.3-17.8	
17.8-18.3	

BORE HOLE 13 BORE HOLE 15 BORE HOLE 16 BORE HOLE 17

5.0 - 6.5	
6.5 - 8.0	
8.0 - 9.5	
9.5 - 10.9	
13.0 - 14.5	
14.5 - 14.9	
14.9 - 16.2	
16.2 - 17.4	
17.4 - 19.0	
9.0 - 10.5	
10.5 - 12.0	
12.0 - 13.5	
13.5 - 13.9	
3.5 - 5.0	
5.0 - 6.5	
6.5 - 7.8	
7.8 - 8.7	
8.7 - 10.2	
10.2 - 11.5	

BORE HOLE 20

0.8 - 2.3	
2.3 - 3.8	
3.8 - 5.3	
5.3 - 6.8	
6.8 - 8.3	
8.3 - 9.8	
9.8 - 11.3	
11.3 - 12.8	
12.8 - 13.7	

BORE HOLE 19.

3.5 - 5.0	
5.0 - 6.5	
6.5 - 8.0	
8.0 - 9.5	
9.5 - 11.0	
11.0 - 12.5	
12.5 - 14.0	
14.0 - 15.5	
15.5 - 17.0	
17.0 - 18.5	
18.5 - 19.7	
19.7 - 20.95	

19. 18.85 - 19.2

BORE HOLE 21.

2.3 - 3.8	 CORE LOSS 58
3.8 - 5.3	 CORE LOSS
5.3 - 6.8	 CORE LOSS
6.8 - 8.3	 CORE LOSS
8.3 - 9.8	 CORE LOSS
9.8 - 11.3	 CORE LOSS
11.3 - 12.8	 CORE LOSS
12.8 - 13.6	 CORE LOSS
13.6 - 14.6	 CORE LOSS
	 CORE LOSS
14.6 - 16.0	 CORE LOSS
16.0 - 17.5	 CORE LOSS
17.5 - 18.9	 CORE LOSS
18.9 - 19.4	 CORE LOSS

BORE HOLE 20A

1.5 - 3.0	 CORE LOSS
3.0 - 4.5	 CORE LOSS
4.5 - 6.0	 CORE LOSS
6.0 - 7.5	 CORE LOSS
7.5 - 9.0	 CORE LOSS
9.0 - 10.5	 CORE LOSS
10.5 - 12.0	 CORE LOSS
12.0 - 13.5	 CORE LOSS
13.5 - 15.0	 CORE LOSS
15.0 - 16.5	 CORE LOSS
16.5 - 18.0	 CORE LOSS
18.0 - 19.5	 CORE LOSS

BORE HOLE 23A

13.0-14.5	
14.5-16.0	
16.0-17.5	
17.5-18.5	
18.5-20.0	

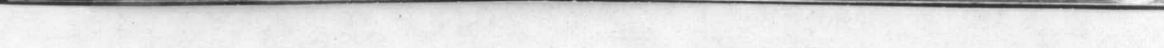
BORE HOLE 22

3.5-5.0	
5.0-6.5	
6.5-8.0	
8.0-9.5	
9.5-10.75	
10.75-11.7	

BORE HOLE 21A

0.5-2.0	
2.0-3.5	
3.5-5.0	
5.0-6.5	
6.5-8.0	
8.0-9.0	
9.0-10.5	
10.5-12.0	
12.0-13.5	
13.5-15.0	
15.0-15.5	
15.5-17.0	
17.0-18.5	

BORE HOLE 25

3.0-7.5	
7.5-9.0	
9.0-10.0	
10.0-11.5	
11.5-13.1	
13.1-14.6	
14.6-16.1	
16.1-17.25	
17.25-18.75	
18.75-20.4	
20.4-21.94	
21.94-23.4	
23.4-24.9	
24.9-26.35	
	
26.35-27.9	

BORE HOLE 24

3.5-5.0	
5.0-6.5	
6.5-8.0	
8.0-9.5	
9.5-11.0	
11.0-12.5	
12.5-14.0	
14.0-15.4	

BORE HOLE 27

1.5 - 3.0	1.50 WASH 2
3.0 - 4.5	
4.5 - 6.0	
6.0 - 7.5	6.0
7.5 - 9.0	
9.0 - 10.5	
10.5 - 12.0	10.5
12.0 - 13.5	12.0
13.5 - 15.0	
15.0 - 16.5	15.0
16.5 - 18.0	
18.0 - 19.7	19.7

BORE HOLE 26

2.0 - 3.5	
3.5 - 5.0	
5.0 - 6.5	
6.5 - 8.1	
8.1 - 8.5	
8.5 - 10.0	
10.0 - 11.5	10.0
11.5 - 13.0	11.5
13.0 - 14.0	
14.0 - 15.5	
15.5 - 17.0	17.0
17.0 - 18.5	
18.5 - 20.0	20.0

BORE HOLE 29

0.5 - 2.0	1.5
2.0 - 3.5	3
3.5 - 5.0	
5.0 - 6.5	
6.5 - 8.0	
8.0 - 9.5	2
9.5 - 11.0	1
11.0 - 12.5	

BORE HOLE 28

0.5 - 2.0	1
2.0 - 3.5	
3.5 - 5.0	
5.0 - 6.5	
6.5 - 8.0	
8.0 - 9.5	
9.5 - 11.0	
11.0 - 11.9	

APPENDIX 5

GEOLOGICAL LOGS OF DRILLHOLES

GEOLOGICAL LOG OF DRILL HOLE

DIRECTION —
R L OF COLLAR 6.1 m

SHEET 1 OF 2

Drilling information					Rock Substance		Rock Mass (defects)						
Method	Drilling rate	Casing	Water	Pressure test * (megapascals)	Lift B % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Point load strength (kN)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Rock condition No (interpretive)
DIAMOND						0	Δ Δ	Fill					
						1.0	Δ Δ						
						1.4	Δ Δ						
						100	Δ Δ	Stiff, dark brown clay.					
						2.0	Δ Δ						
						75	Δ Δ					P.P. 300-400 kPa	
						2.5	Δ Δ						
						2.7	Δ Δ	Silurian siltstone				Highly folded at 3.3-3.6, bedding 65°-70°	
						3.0	Δ Δ		Z1				
						100	Δ Δ						
NOT DONE						4.0	Δ Δ						
						4.1	Δ Δ						
						4.3	Δ Δ	Silurian mudstone & siltstone.				Joints EW and soft (150-300 kPa). Occasional thin beds of Sandstone. Bedding constant at 65°-70°	
						80	Δ Δ		Z1				
						5.0	Δ Δ						
						100	Δ Δ						
						6.0	Δ Δ	Silurian siltstone & sandstone.	Z1			Occasional mudstone bands EW + soft.	
						100	Δ Δ						
						7.0	Δ Δ						
						7.4	Δ Δ						
						8.0	Δ Δ	Silurian mudstone	Z1			Occasional chips of sandstone. Mudstone soft (generally P.P. 300 kPa).	
						30	Δ Δ						
						88	Δ Δ	Silurian sandstone & mudstone.	Z3		100	Alternating soft mudstone and sandstone.	
						80	Δ Δ		Z1				
						10.0	Δ Δ						

Drill type J10 A GEMCO
ed. HYDRAULIC
Core barrel type NMLC
TRIPLE TUBE
PTV LTD
SOIL MECH. MCTD
Initiated 1/8/77
Completed 2/8/77
Logged by G. TRAND
D. PURCELL
Scale 2 cm 1 m

Weathering P.P. Pocket Penetrometer reading
Fr. Fresh (Z5)
SW. Slightly weathered (Z4)
MW. Moderately weathered (Z3)
HW. Highly weathered (Z2)
EW. Extremely weathered (Z1)
Notes
Bedding & joint angles — Angles are measured relative to the plane normal to the core axis
* Water Pressure Tests — values in megapascals should be read in conjunction with computation sheets

Water
10 Sept 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No.
Depth m Black & White Colour
5277 N
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information					Rock Substance		Rock Mass Defects							
Method	Drilling rate	Casing	Water	Pressure test * (megapascals)	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics colour, structure, minor components	Weathering	Point load strength (kPa) 100-150 kPa	Defect spacing (cm) 100-300	R.O.D.	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Rock condition (unfractured)
				28/8/77		10.0			Z2					
					100			Mudstone - sandstone	Z1					
						11.0		Silurian sandstone	EW					
					100			Silurian siltstone	Z1					
						12.0								
					100				Z2-3					
						13.0								
						14.0								
					100			Silurian sandstone and mudstone						
						15.0		Silurian sandstone and mudstone						
					100				MOSTLY Z1 - SOME Z2					
						16.0								
					100									
						17.0								
					100									
						18.0		Mudstone						
					100				Z3					
						19.0								
						20.0		End of hole at 19.3 m (RL - 12.8 m)						

Bit type: 110 A GEMCO
Tool: HYDRAULIC
Core barrel type: NMLC
TRIPLE TUBE
Driller: SOIL MECH. PTY LTD
Commenced: 1/8/77
Completed: 2/8/77
Signed by: G. TRAND
D. PURCELL
Sketch scale: 2 cm : 1 m

Weathering: P.P. Pocket Penetrometer weight
(Z5) Reading
FW: Fresh (Z4)
SW: Slightly weathered (Z4)
MW: Moderately weathered (Z3)
HW: Highly weathered (Z2)
EW: Extremely weathered (Z1)

NOTES

Bedding & Joint planes - Angles are measured relative to plane normal to the core axis

* Water Pressure tests - Values in megapascals should be read in conjunction with computation sheets

Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph negative file
Depth in m

S277 N
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance		Rock Mass Defects					
Method	Drilling rate	Casing	Water	Pressure test (megapascals)	Lift & % core recovery	Depth (metres)	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Point load strength (500 N/mm ²)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Particular	General
CORED						0	Fill						
						10							
AUGER						20	Sandy clay, brown soft.				P.P. 100 kPa.		
					100	30							
						40							
						50							
						60	Silurian Dargile Formation						
						70					Weak, soft rock Easily eroded		
						80		Z1-2					
						90							
						100		Z2					

Drill type MINDRILL
Feed HYDRAULIC
Core barrel type N.M.S.
DOUBLE TUBE
(SOIL MECH)
Driller J. JAMES
Commenced 17.10.77
Completed 18.10.77
Logged by J. D. BAILEY
b. PUNCELL
Vertical scale 2 cm = 1 m

Weathering R.P. Pocket Penetrometer
Fr - Fresh (Z5) Reading
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)
Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
Water Pressure Tests - Values in lugeons should be read in conjunction with computation sheets

10 Oct 73 water level data shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No
Depth (m) Black & White Colour
5277 P
(D.C. Mells)

GEOLOGICAL LOG OF DRILL HOLE

Drilling information						Rock Substance		Rock Mass Defects																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
Litho	Drilling rate	Casing	Water	Pressure test (kg/cm ²)	Lift & % core recovery	Depth (metres)	Graphic log of core loss	Substance description min type grain characteristics colour, structure, minor components	Weathering	Point load strength (MPa)	Defect spacing (cm)	n	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Rock condition as intersected																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
															0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3	12.5	12.7	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.5	15.7	15.9	16.1	16.3	16.5	16.7	16.9	17.1	17.3	17.5	17.7	17.9	18.1	18.3	18.5	18.7	18.9	19.1	19.3	19.5	19.7	19.9	20.1	20.3	20.5	20.7	20.9	21.1	21.3	21.5	21.7	21.9	22.1	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.7	23.9	24.1	24.3	24.5	24.7	24.9	25.1	25.3	25.5	25.7	25.9	26.1	26.3	26.5	26.7	26.9	27.1	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	28.9	29.1	29.3	29.5	29.7	29.9	30.1	30.3	30.5	30.7	30.9	31.1	31.3	31.5	31.7	31.9	32.1	32.3	32.5	32.7	32.9	33.1	33.3	33.5	33.7	33.9	34.1	34.3	34.5	34.7	34.9	35.1	35.3	35.5	35.7	35.9	36.1	36.3	36.5	36.7	36.9	37.1	37.3	37.5	37.7	37.9	38.1	38.3	38.5	38.7	38.9	39.1	39.3	39.5	39.7	39.9	40.1	40.3	40.5	40.7	40.9	41.1	41.3	41.5	41.7	41.9	42.1	42.3	42.5	42.7	42.9	43.1	43.3	43.5	43.7	43.9	44.1	44.3	44.5	44.7	44.9	45.1	45.3	45.5	45.7	45.9	46.1	46.3	46.5	46.7	46.9	47.1	47.3	47.5	47.7	47.9	48.1	48.3	48.5	48.7	48.9	49.1	49.3	49.5	49.7	49.9	50.1	50.3	50.5	50.7	50.9	51.1	51.3	51.5	51.7	51.9	52.1	52.3	52.5	52.7	52.9	53.1	53.3	53.5	53.7	53.9	54.1	54.3	54.5	54.7	54.9	55.1	55.3	55.5	55.7	55.9	56.1	56.3	56.5	56.7	56.9	57.1	57.3	57.5	57.7	57.9	58.1	58.3	58.5	58.7	58.9	59.1	59.3	59.5	59.7	59.9	60.1	60.3	60.5	60.7	60.9	61.1	61.3	61.5	61.7	61.9	62.1	62.3	62.5	62.7	62.9	63.1	63.3	63.5	63.7	63.9	64.1	64.3	64.5	64.7	64.9	65.1	65.3	65.5	65.7	65.9	66.1	66.3	66.5	66.7	66.9	67.1	67.3	67.5	67.7	67.9	68.1	68.3	68.5	68.7	68.9	69.1	69.3	69.5	69.7	69.9	70.1	70.3	70.5	70.7	70.9	71.1	71.3	71.5	71.7	71.9	72.1	72.3	72.5	72.7	72.9	73.1	73.3	73.5	73.7	73.9	74.1	74.3	74.5	74.7	74.9	75.1	75.3	75.5	75.7	75.9	76.1	76.3	76.5	76.7	76.9	77.1	77.3	77.5	77.7	77.9	78.1	78.3	78.5	78.7	78.9	79.1	79.3	79.5	79.7	79.9	80.1	80.3	80.5	80.7	80.9	81.1	81.3	81.5	81.7	81.9	82.1	82.3	82.5	82.7	82.9	83.1	83.3	83.5	83.7	83.9	84.1	84.3	84.5	84.7	84.9	85.1	85.3	85.5	85.7	85.9	86.1	86.3	86.5	86.7	86.9	87.1	87.3	87.5	87.7	87.9	88.1	88.3	88.5	88.7	88.9	89.1	89.3	89.5	89.7	89.9	90.1	90.3	90.5	90.7	90.9	91.1	91.3	91.5	91.7	91.9	92.1	92.3	92.5	92.7	92.9	93.1	93.3	93.5	93.7	93.9	94.1	94.3	94.5	94.7	94.9	95.1	95.3	95.5	95.7	95.9	96.1	96.3	96.5	96.7	96.9	97.1	97.3	97.5	97.7	97.9	98.1	98.3	98.5	98.7	98.9	99.1	99.3	99.5	99.7	99.9	100.1	100.3	100.5	100.7	100.9	101.1	101.3	101.5	101.7	101.9	102.1	102.3	102.5	102.7	102.9	103.1	103.3	103.5	103.7	103.9	104.1	104.3	104.5	104.7	104.9	105.1	105.3	105.5	105.7	105.9	106.1	106.3	106.5	106.7	106.9	107.1	107.3	107.5	107.7	107.9	108.1	108.3	108.5	108.7	108.9	109.1	109.3	109.5	109.7	109.9	110.1	110.3	110.5	110.7	110.9	111.1	111.3	111.5	111.7	111.9	112.1	112.3	112.5	112.7	112.9	113.1	113.3	113.5	113.7	113.9	114.1	114.3	114.5	114.7	114.9	115.1	115.3	115.5	115.7	115.9	116.1	116.3	116.5	116.7	116.9	117.1	117.3	117.5	117.7	117.9	118.1	118.3	118.5	118.7	118.9	119.1	119.3	119.5	119.7	119.9	120.1	120.3	120.5	120.7	120.9	121.1	121.3	121.5	121.7	121.9	122.1	122.3	122.5	122.7	122.9	123.1	123.3	123.5	123.7	123.9	124.1	124.3	124.5	124.7	124.9	125.1	125.3	125.5	125.7	125.9	126.1	126.3	126.5	126.7	126.9	127.1	127.3	127.5	127.7	127.9	128.1	128.3	128.5	128.7	128.9	129.1	129.3	129.5	129.7	129.9	130.1	130.3	130.5	130.7	130.9	131.1	131.3	131.5	131.7	131.9	132.1	132.3	132.5	132.7	132.9	133.1	133.3	133.5	133.7	133.9	134.1	134.3	134.5	134.7	134.9	135.1	135.3	135.5	135.7	135.9	136.1	136.3	136.5	136.7	136.9	137.1	137.3	137.5	137.7	137.9	138.1	138.3	138.5	138.7	138.9	139.1	139.3	139.5	139.7	139.9	140.1	140.3	140.5	140.7	140.9	141.1	141.3	141.5	141.7	141.9	142.1	142.3	142.5	142.7	142.9	143.1	143.3	143.5	143.7	143.9	144.1	144.3	144.5	144.7	144.9	145.1	145.3	145.5	145.7	145.9	146.1	146.3	146.5	146.7	146.9	147.1	147.3	147.5	147.7	147.9	148.1	148.3	148.5	148.7	148.9	149.1	149.3	149.5	149.7	149.9	150.1	150.3	150.5	150.7	150.9	151.1	151.3	151.5	151.7	151.9	152.1	152.3	152.5	152.7	152.9	153.1	153.3	153.5	153.7	153.9	154.1	154.3	154.5	154.7	154.9	155.1	155.3	155.5	155.7	155.9	156.1	156.3	156.5	156.7	156.9	157.1	157.3	157.5	157.7	157.9	158.1	158.3	158.5	158.7	158.9	159.1	159.3	159.5	159.7	159.9	160.1	160.3	160.5	160.7	160.9	161.1	161.3	161.5	161.7	161.9	162.1	162.3	162.5	162.7	162.9	163.1	163.3	163.5	163.7	163.9	164.1	164.3	164.5	164.7	164.9	165.1	165.3	165.5	165.7	165.9	166.1	166.3	166.5	166.7	166.9	167.1	167.3	167.5	167.7	167.9	168.1	168.3	168.5	168.7	168.9	169.1	169.3	169.5	169.7	169.9	170.1	170.3	170.5	170.7	170.9	171.1	171.3	171.5	171.7	171.9	172.1	172.3	172.5	172.7	172.9	173.1	173.3	173.5	173.7	173.9	174.1	174.3	174.5	174.7	174.9	175.1	175.3	175.5	175.7	175.9	176.1	176.3	176.5	176.7	176.9	177.1	177.3	177.5	177.7	177.9	178.1	178.3	178.5	178.7	178.9	179.1	179.3	179.5	179.7	179.9	180.1	180.3	180.5	180.7	180.9	181.1	181.3	181.5	181.7	181.9	182.1	182.3	182.5	182.7	182.9	183.1	183.3	183.5	183.7	183.9	184.1	184.3	184.5	184.7	184.9	185.1	185.3	185.5	185.7	185.9	186.1	186.3	186.5	186.7	186.9	187.1	187.3	187.5	187.7	187.9	188.1	188.3	188.5	188.7	188.9	189.1	189.3	189.5	189.7	189.9	190.1	190.3	190.5	190.7	190.9	191.1	191.3	191.5	191.7	191.9	192.1	192.3	192.5	192.7	192.9	193.1	193.3	193.5	193.7	193.9	194.1	194.3	194.5	194.7	194.9	195.1	195.3	195.5	195.7	195.9	196.1	196.3	196.5	196.7	196.9	197.1	197.3	197.5	197.7	197.9	198.1	198.3	198.5	198.7	198.9	199.1	199.3	199.5	199.7	199.9	200.1	200.3	200.5	200.7	200.9	201.1	201.3	201.5	201.7	201.9	202.1	202.3	202.5	202.7	202.9	203.1	203.3	203.5	203.7	203.9	204.1	204.3	204.5	204.7	204.9	205.1	205.3	205.5	205.7	205.9	206.1	206.3	206.5	206.7	206.9	207.1	207.3	207.5	207.7	207.9	208.1	208.3	208.5	208.7	208.9	209.1	209.3	209.5	209.7	209.9	210.1	210.3	210.5	210.7	210.9	211.1	211.3	211.5	211.7	211.9	212.1	212.3	212.5	212.7	212.9	213.1	213.3	213.5	213.7	213.9	214.1	214.3	214.5	214.7	214.9	215.1	215.3	215.5	215.7	215.9	216.1	216.3	216.5	216.7	216.9	217.1	217.3	217.5	217.7	217.9	218.1	218.3	218.5	218.7	218.9	219.1	219.3	219.5	219.7	219.9	220.1	220.3	220.5	220.7	220.9	221.1	221.3	221.5	221.7	221.9	222.1	222.3	222.5	222.7	222.9	223.1	223.3	223.5	223.7	223.9	224.1	224.3	224.5	224.7	224.9	225.1	225.3	225.5	225.7	225.9	226.1	226.3	226.5	226.7	226.9	227.1	227.3	227.5	227.7	227.9	228.1	228.3	228.5	228.7	228.9	229.1	229.3	229.5	229.7	229.9	230.1	230.3	230.5	230.7	230.9	231.1	231.3	231.5	231.7	231.9	232.1	232.3	232.5	232.7	232.9	233.1	233.3	233.5	233.7	233.9	234.1	234.3	234.5	234.7	234.9	235.1	235.3	235.5	235.7	235.9	236.1	236.3	236.5	236.7	236.9	237.1	237.3	237.5	237.7	237.9	238.1	238.3	238.5	238.7	238.9	239.1	239.3	239.5	239.7	239.9	240.1	240.3	240.5	240.7	240.9	241.1	241.3	241.5	241.7	241.9	242.1	242.3	242.5	242.7	242.9	243.1	243.3	243.5	243.7	243.9	244.1	244.3	244.5	244.7	244.9	245.1	245.3	245.5	245.7	245.9	246.1	246.3	246.5	246.7	246.9	247.1	247.3	247.5	247.7	247.9	248.1	248.3	248.5	248.7	248.9	249.1	249.3	249.5	249.7	249.9	250.1	250.3	250.5	250.7

Drill type MINDRILL

Feed HYDRAULIC

Core barrel type NMS

DOUBLE TUBE

Driller J. JAMES

Commenced 17-10-77

Completed 18-10-77

Logged by J. D. BAILEY

Vertical scale 2cm = 1m

Weathering

Fr - Fresh (Z5)

SW Slightly weathered (Z4)

MW Moderately weathered (Z3)

HW Highly weathered (Z2)

EW Extremely weathered (Z1)

(S18)

Bedding & Joint Planes - Angles are measured relative to plane normal to the core axis

* Water Pressure Tests - values in kg/cm² should be used in conjunction with computation sheets

Water

10 Oct 73 water level date shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photograph Negative No.

Depth m Black & White Colour

S277 P

(O.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

ANAL. Calcd. for $C_{10}H_{10}O$: C, 88.10%; H, 11.90%. Found: C, 88.1%; H, 11.9%.

- 50°

(1978) 6, 110-124.

H. OF COLLAR 13.6 m

Page 2

Logging information				Rock Test Data		Rock Mass Details	
Drilling rate	Casing	Water	Pressure test	Logging log	Weathering	Defect spacing	Notes
Loggers	Loggers	Loggers	Loggers	Loggers	Loggers	Loggers	Loggers
				0	Fill		
				1.0	Brown stiff silty clay.		
				2.0	Possibly Evt. Basin		
				3.0			
				4.0			
				4.6			
				5.0	Mudstone - siltstone		
				6.0			
				7.0			
				8.0			
				9.0			
				10.0	Sandstone, mudstone		

1. Type 110 A GEMCO HYDRAULIC Core barrel type NMLC	2. Weathering P.P. Pocket Penetrometer Fr. Fresh (25) Reading SW Slightly weathered (24) MW Moderately weathered (23) HW Highly weathered (22) EW Extremely weathered (21)	3. Water  10 20 30 40 50 60 70 80 90 100 Water level Partial drying water loss complete drying water loss	4. One P.P. probe Negative for Depth in Blk B White Soil
5. SOIL MECH PTY LTD. 6. Dated 26/7/77 7. Submitted 26/7/77	8. Bedding 11 units in ones 9. Note Pressure tests values in columns should be read in conjunction with computation sheets	10. 5277 P (D.C. Melb)	

GEOLOGICAL LOG OF DRILL HOLE

Logging Information				Rock Substance		Rock Mass (Defects)			
Drilling rate	Casing	Water	Pressure test (kg/cm ²)	Depth (metres)	Substance description rock type, grain characteristics, colour, structure, mineral components	Weathering	Point load strength (N/mm ²)	Defect spacing (cm)	Defect description fracture, type, inclination, planarity, roughness, scaling, strength, zoning
				10.0	Sandstone and mudstone				
				100					
				11.0	Siltstone				
				100					
				12.0					
				100					
				13.0	End of hole at 13m. (R.L. 0.6m)				

110A GEMCO HYDRAULIC NMLC SOIL MECH PTY LTD 26/7/77 26/7/77 G. TRAND D. PORCELA 2cm: 1m	Weathering Fresh (Z5) W. Highly weathered (Z4) MW. Moderately weathered (Z3) W. High, weathered (Z2) W. Extreme, weathered (Z1) Notes Headings: ...	Water Water level Water flow Water temperature Water quality	5277 P (D.C. Melb)
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GEOLOGICAL LOG OF DRILL HOLE

Drilling Information					Rock Substance		Rock Mass Defects							
Method	Drilling rate	Casing	Water	Pressure test * (megapascals)	Lift & % core recovery	Depth (metres)	Graphic log B core loss	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Point load strength (MPa) 0 3 10 30 100 150 (kg/cm²)	Defect spacing (cm) 0 20 40 60 80 100	R O D	Defect description thickness, type, inclination, planarity, roughness, coating, strength Particular General	Rock condition No (interpretive)
AUGER								Bitumen						
								Brown sandy clay (Fill)						
						1.0								
						2.0								
						3.0		Tertiary Older Volcanics - Basalt	HW to EW					
						4.0								
						5.0		Basalt, highly vesicular, brown, 30-40% vesicles with yellow montmorillonite filling vesicles.	HW 60%				Core highly fractured due partly to drilling.	
						6.0			EW 40%				Sample No 13-0-11/1	
						7.0		Basalt, slightly vesicular, grey, minor clay in vesicles.					Core highly fractured due to drilling. This material is closely jointed in situ.	
						8.0			SW to MW					
DIAMOND						9.0								
						10.0		Tuff, purple with green clay mineral.						

Drill type MINDRILL DIAMOND

Feed HYDRAULIC

Core barrel type NMS

DOUBLE TUBE

Driller J. JAMES

Commenced 16-8-77

Completed 24-8-77

Logged by J. D. BAILEY

D. PURCELL

Vertical scale 2cm:1m

Weathering

F - Fresh

SW - Slightly weathered

MW - Moderately weathered

HW - Highly weathered

EW - Extremely weathered

Notes

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - Values in megapascals should be read in conjunction with computation sheets

Water

10 Oct 73 water level data shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photograph Negative No

Depth (m) Black & White Colour

S277 A + S277 D

(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Logging Information				Rock Substance		Rock Mass Details			
Drilling rate (m/min)	Logging notes	Pressure tests (yes/no)	Core recovery (%)	Depth (metres)	Substance description Rock type, grain characteristics, texture, structure, mineral composition	Weathering	Point load strength (MPa)	Defect spacing (cm)	Defect description Thickness, type, orientation, frequency, roughness, sealing, strength
			50	10.0	Highly vesicular 40% Clay fills most vesicles	HW 60%		20	Joints close 40°, rough, open, clean, weakly cemented
				11.0	As above with orange clay in vesicles	EW 40%			
			100	12.0	As above with green clay in vesicles	HW 60%		40	Joints close to very close, open, rough, 0-5mm, Limonite. Dip 65°
				13.0	Basalt slightly vesicular, brown to red brown, green montmorillonite in vesicles vesicles 40%	HW 40%			Sample N° 13-0-11/2
			100	14.0	Basalt slightly vesicular grey brown, 5% clay filled vesicles	HW 40%		20	Joints 25° close to very close, rough, open, 1-2mm Limonite and clay 0-10mm very weakly cemented.
			100	15.0	Basalt, grey to grey-brown, blue grey dense, onion weathered with fresh cores	SW to MW		30	Joints very close to close, rough, open, Limonite 2-5mm. Dip 63°, 55°
			100	16.0	Basalt, grey to brown, dense onion weathered	SW 40%		0	Joints open, rough, very close Limonite 2-5mm. Dip 65°
			100	17.0	Basalt, grey to brown, dense onion weathered	SW to MW		30	Joints rough, Limonite 2-5mm, close, open, 60°, 50°, 10°. Weakly cemented 7mm(?) montmorillonite on joint at 17.95m.
				18.0	Basalt, dense, brown			0	
				19.0	Core loss.			0	
			66	20.0	Basalt dense, blue-grey to dark brown onion skin weathering	FR 20%		8	Joints close 60°, 20°, open rough, Limonite 2-8mm weakly cemented.

Type MINDRILL DIAMOND

Rod HYDRAULIC

Core barrel type: NMS
DOUBLE TUBE

Operator J. JAMES

Commenced 16/8/77

Completed 24/8/77

Signed by J. D. BAILEY

Drill depth 20.0m

Weathering

Fr. Fresh

SW Slightly weathered

MW Moderately weathered

HW Highly weathered

EW Extremely weathered

Notes

Bedding at 18.0m - 19.0m Angles are measured relative to plane normal to the core axis

Note: Pressure tests values in parentheses should be used in conjunction with uniaxial test sheets

Water

Water

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Plot - grade Negative No.

Depth m. Block B. Water. Count.

5277A, D

Log Information					Rock Substance		Rock Mass Defects			
Drilling rate	Casing	Water	Pressure test (megapascals)	Wt. % core recovery	Depth (metres)	Substance description Rock type, grain characteristics, color, structure, minor fragments	Weathering	Point load strength (MPa)	Defect spacing (mm)	Defect description Thickness, type, orientation, planarity, roughness, scaling, strength
					20.0					
					21.0	Basalt, grey, brown, dense, onion weathered	SW 60%			Joints close, planar and irregular, limonite 1-4mm, weakly cemented 70°, 45°, 35°
				100	22.0	Buff bleached yellow, slightly vesicular	MW 40%		25	
					23.0	Core loss	SW to MW		80	Joints irregular, close, Limonite 1-5mm, weakly to strongly cemented.
				0	24.0	Dargile Formation mudstone, with minor interbedded sandstone.				Bedding very close, smooth, weakly cemented, wavy, clay 0-3mm. P.P. 1000 kPa. - 600 kPa
				100	25.0	Slump bed - sandstone and mudstone brachiopod in SST. Mudstone grey to buff, minor SST, 8mm	Z1-2			Bedding 75°, smooth, very close, clay 0-3mm. Bedding very close, tight. Rough to smooth, weakly cemented. Clay 0-1mm. Limonite 0-15mm P.P. > 1500 kPa
				83	26.0		Z2		APPLICABLE	
					27.0				NOT	Joints irregular to planar, smooth to rough, close to moderate, clay 0-2mm. Limonite 0-5mm, weakly cemented. Dips 75° 25° 10° P.P. 400-500 kPa
				100	28.0	3mm Quartz filling joint planes.				
					29.0	Mudstone, green-brown	Z2-3		53	Joints strongly cemented by Limonite.
				100	30.0		Z3			Bedding very close, tight, strongly cemented by Limonite 0-5mm. Dip 85°. Joints close, rough. Strongly cemented by Limonite 5mm. Tight, 75°, 70°, 60°.
							Z2-3		100	

MINDRILL DIAMOND

HYDRAULIC

NMS

DOUBLE TUBE

J. JAMES

16/8/77

24/8/77

J. D. BAILEY

2cm 1m

PP POCKET PENETROMETER

Fresh (Z5)

SW Slightly weathered (Z4)

MW Moderately weathered (Z3)

HW Highly weathered (Z2)

EW Extreme weathered (Z1)

Bedding is joint - angles

Water pressure tests

READING

Water level

Partial drilling water loss

Complete drilling water loss

Core Photo graph Negative for

Depth -

Black is White

5277 A, D

GEOLOGICAL LOG OF DRILL HOLE

Drilling information						Rock Substance		Rock Mass Defects					
Method	Drilling rate	Casing	Water	Pressure test (megapascals)	Lift B % core recovery	Depth (metres)	Substance description rock type, grain characteristics colour, structure, mineral inclusions	Weathering	Point load strength 300 N 500 N 1000 N 1500 N 2000 N	Defect spacing (cm)	n n n	Defect description fractures, type, orientation, planarity roughness, coating, strength	Rock condition (interpretive)
					80	30.0	Mudstone light brown as above	Z2-3		100		Core loss due to failure of core lifter	
						31.0	End of hole 30.6m (R.L. 296m)						

Drill type MINDRILL DIAMOND
Tool HYDRAULIC
Core barrel type NMS
DOUBLE TUBE
Driller J. JAMES
Commenced 16/8/77
Completed 24/8/77
Logged by J. D. BAILEY
Revised by R. PURCELL
Revised date 2 cm 1 m

Weathering
F Fresh
SW Slightly weathered
MW Moderately weathered
HW Highly weathered
EW Extremely weathered
Notes

Bedding & joint planes Angles are measured relative to a plane normal to the core axis
Water Pressure Tests Values in megapascals should be read in conjunction with computation sheets

Water



Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photo grade Negative No.
Depth m This is White

S277 A, D

GEOLOGICAL LOG OF DRILL HOLE

DIRECTION
R L OF COLLAR 22.1 m

SHEET 1 OF 2

Drilling Information						Rock Substance		Rock Mass Defects						
Method	Drilling rate	Casing	Water	Pressure test # (logons)	Lift & % core recovery	Depth (metres)	Graphic log & core logs	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Pore load strength 300 100 50 (kPa)	Defect spacing (cm)	R O D	Defect description thickness, type, inclination, planarity, roughness, coating, strength Particular General	Rock condition No. (interpretive)
AUGER						0		Fill						
						1.0		Grey stiff sandy clay, gradually becoming light grey and soft with depth.						
						2.0		Probably Brighton Group.						
						3.0								
						4.0								
						5.0								
						80		Short sequence of grey sandy clay followed by hard sandstone Brighton group.					See tests on undisturbed sample, N° 13-0-9	
						66								
						60								
						100								
DIAMOND						7.0								
						100								
						25								
						80								
						100		Sandstone-ferruginous	EW				Dip of bedding probably 70°	
						100								
					90									
					100									
					100									
					100			Silurian mudstone light grey.	ZI				Clay P.P. 150-450 kPa.	
					100									

Drill type - 110 A GEMCO

Feed - HYDRAULIC

Core barrel type - NMLC

Driller - SOIL MECH. PTY LTD

Commenced - 27/7/77

Completed - 29/7/77

Logged by - G. TRAND

Vertical scale - 2cm - 1m

Weathering P.P. Pocket penetrometer Water

Fr - Fresh (Z5) reading.

SW - Slightly weathered (Z4)

MW - Moderately weathered (Z3)

HW - Highly weathered (Z2)

EW - Extremely weathered (Z1)

Notes

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - Values in logons should be read in conjunction with computation sheets

10 Oct 73 water level data shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photograph Negative No.

Depth in Black & White - 100m

S277 M

(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (θ) - 90
COORDINATES

DIRECTION —
R. OF COLLAR 22.1 m

PAGE 2 OF 2

Drilling Information				Rock Substrata		Rock Mass Effects	
Depth	Drilling Rate	Logging	Water	Pressure Test	Substrata Description	Weathering	Defect Spacing
10.0					Silurian mudstone, light grey.		
100							
11.0							
100							
12.0					Mudstone with thin sandstone beds.		
100							
13.0							
100							
14.0							
15.0							
100							
16.0							
100							
17.0							
100							
18.0					Mudstone with sandstone fragments		
100							
19.0					Sandstone and mudstone, sandstone beds 1-3cm thick. End of hole at 20.0m (R.L. 2.1 m)		
100							
20.0							

110A GEMCO HYDRAULIC NMLC	PP POCKET PENETROMETER (Z5) (Z3) (Z2) (Z1)	READING 	5277 M (D.C. Melb)
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GEOLOGICAL LOG OF DRILL HOLE

DIRECTION —
R L OF COLLAR 22.89 m

SHEET 1 OF 2

Drilling Information						Rock Substance		Rock Mass Defects				
Method	Drilling rate	Casing	Water	Pressure test * (kg/cm ²)	Core recovery	Depth (metres)	Substance description rock type, grain characteristics colour, structure, minor components	Weathering	Point load strength 0-100 100-500 500-1000 1000-2000 2000-3000	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, sealing, strength Particular General	Rock condition No. 1-10
AUGER						0	Concrete					
						0.5	BRIGHTON GROUP					
						1.0	Sandy clay					
						1.5	Sand					
						2.0	Sandy clay, silt sand.					
						3.0	Sandy clay, sand.					
						4.0	Ironstone and sand					
						5.0	Ironstone, dark brown					
						6.0	Clayey silt, white, few sandstone fragments at 5.6 m.	X				
						7.0	Ferruginous sandy silt with ironstone bands, light brown, white to red brown.	XX				
DIAMOND						0	Core loss.					
						8.0	Silty clay, grey.					
						9.0	WERRIBEE FORMATION					

Drill type — MINDRILL —
Feed — HYDRAULIC —
Core barrel type — N.M.S. —
DOUBLE TUBE —
Driller — J. JAMES —
Commenced — 13-8-77 —
Completed — 20-8-77 —
Logged by — G. TRAND —
Vertical scale — 2cm = 1m

Weathering P.P. Pocket Penetrometer Reading
Fr - Fresh (25)
SW - Slightly weathered (24) Rx Piezometer
MW - Moderately weathered (23)
HW - Highly weathered (22)
EW - Extremely weathered (21)
Notes:
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests - Values in megapascals should be read in conjunction with computation sheets

10 Oct 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No.
Depth (m) Black & White Colour
5277 F
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information					Rock Description		Rock Mass Effects				Yt Bore Condition Interpret
Notes	Drilling rate	Casing	Water	Pressure test + lugages	Core recovery % G.O.	Core description Type, grain, bedding, texture, structure, mineral ingredients	Weathering	Defect spacing (cm)	Defect description Type, size, orientation, frequency, roughness, bedding, strength		
DIAMOND	TUNNEL				100	Silty clay Mudstone Formation					
					0	Core loss					
					11.0	Dargile Formation clay, grey, minor light brown & purple staining with 10.0mm thick sandstone beds Bedding indicated only by near vertical colour banding.	Z1		Damp, very stiff Bedding tight, planar, smooth Dip 85° P.P. 11m - 250 kPa 11.5m - 400 kPa 11.8m - 500 kPa 12.5m - 600 kPa 13.0m - 800 kPa		
					100						
					12.0						
					13.0						
					100						
					14.0	Mudstone, grey to light brown, very weak clayey material (rock)	Z1.2		Bedding tight, smooth, Limonite staining. Joints not evident P.P. 13.5m - 1000 kPa 13.8m - 1400 kPa		
					0	Core loss					
					15.0	Mudstone, buff to light brown, very weak.			35	Bedding very close, smooth to rough, Limonite 0-5mm weakly to strongly cemented Dip 80° Joints smooth, close, 90°. P.P. 500- > 1500 kPa	
NOT					100						
					16.0	Sandstone bed at 16.4m	Z1.2		60	Bedding 80° P.P. 1200-1500 kPa	
					17.0						
					100						
					18.0		Z2		56	Bedding very close, tight, irregular, smooth, clay 0-3mm Dip 80°-90° and weakly cemented. Joints moderately spaced, Dip 0°, 30°, 70°, rough, Limonite 1-3 mm, strongly cemented.	
					95	Sandstone band 12mm thick.			77	P.P. > 1500 kPa	
					19.0						
					20.0	T.D. 19.8m. (P.L. 3.04m)					

MINDRILL Type: HYDRAULIC Core type: NMLC Soil Mech Dated: 13/8/77 Operator: 20/8/77 J.D. RAILEY G.P. 1000 2cm = 1m		Weathering F1 Fresh (Z5) SW Slightly weathered (Z4) MW Moderately weathered (Z3) HW Highly weathered (Z2) FA Extreme weathered (Z1) Notes: Bedding, fault, etc. - Angles are measured relative to the horizontal line * All pressure test values & logs should be accompanied with original sheets		Water Water level Water flow Partial flowing water loss Complete flowing water loss		5277 F (D.C. Mellb)
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GEOLOGICAL LOG OF DRILL HOLE

PROJECT: TELLCOM TUNNEL
LOCATION: LONSDALE - QUEEN STS.
STATION: 14 C
ANGLE FROM HORIZONTAL (°): 90°
COORDINATESDIRECTION: -
R.L. OF COLLAR: 22.34 m

HOLE NO. 10

SHEET 1 OF 2

Drilling Information					Rock Substrata		Rock Mass Defects				
Vendor	Drilling rate	Logging	Work	Pressure test (megapascals)	Core recovery	Depth (metres)	Drill pipe	Drill bit	Drill string	Drill collar	Drill pipe
NO. 2											
						1.0					
						2.0					
						3.0					
						4.0					
						5.0					
						6.0					
						7.0					
						8.0					
						9.0					
						10.0					
						11.0					
						12.0					
						13.0					
						14.0					
						15.0					
						16.0					
						17.0					
						18.0					
						19.0					
						20.0					
						21.0					
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						87.0					
						88.0					
						89.0					
						90.0					
						91.0					
						92.0					
						93.0					
						94.0					
						95.0					
						96.0					
						97.0					
						98.0					
						99.0					
						100.0					

Drill type: GEMCO DIAMOND

Feed: HYDRAULIC

Drill pipe type: NMS.

DOUBLE TUBE

Driller: J. JAMES

Commenced: 21-8-'77

Completed: 28-8-'77

Signed by: J. D. BAILEY

Drill bit: 2cm x 1m

Weathering: P.P. POCKET PENETROMETER

Fresh

SW: Slightly weathered

MW: Moderately weathered

HW: Highly weathered

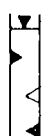
LW: Extremely weathered

Notes:

Bedding is 30° to 45°

Water stress tests

READING



73 water level date shown

Water level

Partial drilling water loss

Complete drilling water loss

Drill bit type: Regular bit

Depth: 100 m

5277 Gt

(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information					Rock Substance		Rock Mass Defects				
Method	Drilling Rate	Casing	Water	Pressure Test (kg/cm ²)	Depth (m)	Substance Description Rock type, grain characteristics Fracture, structure, minor components	Weathering	Defect spacing (cm)	Defect Description Type, thickness, orientation, planarity, roughness, scaling, strength	Rock Condition	Notes
DIAMOND	18/8/77	TESTED	NOT		10.0	Basalt, brown slightly vesicular, onion weathered	Z1		Sample N° 13-O-41 Joints very close, rough, weakly cemented, open 0-1mm. Limonite 3-5mm irregular horizontal 30° 60°		
					11.0	Buff, pink to buff, highly vesicular	Z1		Sub horizontal joints, close weakly cemented by 1mm limonite		
					20	Werribee formation orange clayey silt grading to white.			Sample N° 13-O-42 P.P. 300-460 kPa		
					12.0						
					76	Gravelly clayey silt, angular quartz & S.S.T. gravel white.			P.P. 350 kPa		
					13.0	Clay white to orange completely weath. in stone. Mudstone buff, green to purple.	Z1 Z2		P.P. 300 kPa PP 1000 kPa P.P. > 1500 kPa. Bedding very close, 90° tight irregular smooth, weakly cemented. Joints very close to close, rough, Limonite 0-5mm strongly cemented, minor weakly, Dip 5°, 10°, 30° (Rock mass solid due to Limonite cementation)		
					14.0						
					91						
					150	Mudstone buff to light brown, grey-green S.S.T. band 10mm thick.	Z2-3		Bedding 87° irregular Limonite 0-4mm on S.S.T. smooth, (rough on S.S.T.) Tight strongly to weakly cemented.		
					100	Clay on joints 2-3mm.	Z2		Joints close, tight, rough strongly cemented Limonite 1-4mm.		
					16.0		Z2-3				
					170	End of Hole 16.3m (R.L. 6m)					
					180						
					190						

Tool type GEMCO DIAMOND

Feed HYDRAULIC

Core barrel type NMS
DOUBLE TUBE

Drill J. JAMES

Initiated 21-8-77

Completed 28-8-77

Logged by J. D. BAILEY

Scale 2cm = 1m

Weathering

F. Fresh (Z5)

SW Slightly weathered (Z4)

MW Moderately weathered (Z3)

HW Highly weathered (Z2)

LW Extremely weathered (Z1)

Fractures

Bedding is vertical in this section. Angles are measured in degrees from the horizontal.

Water Pressure Tests: values are given in kg/cm² (convert to MPa by multiplying by 0.1)

Notes

1. 13 water tests were done.

Water in SW

Flowed during water test

Complete during water test

Rock mass strength

Sample N° 13-O-41

5277 G

GEOLOGICAL LOG OF DRILL HOLE

DIRECTION —
R. OF COLLAR 18.9 m

SHEET 1 OF 1

Drilling information						Rock Substance		Rock Mass Defects				
Method	Drilling rate	Casing	Water	Pressure test (megapascals)	Core recovery	Depth (metres)	Substance description rock type, grain characteristics, texture, structure, major components	Weathering	Defect spacing (cm)	Defect description fractures, type, orientation, persistence, roughness, coating, strength	Rock mass condition	
DIAMOND	NOT CORED	XXX	Tunnel	DONE	Px	0	Fill					
						1.0						
						2.0	— ? — ? — ? — ? — ? — ?					
							Possibly Elizabeth St.					
						3.0						
						4.0						
						5.0	Sandy clay colluvial deposits Brown, Elizabeth St. Formation (?)			PP. 430 kPa		
						6.0	Silurian mudstone with hard ferruginous sandstone (minor)			PP. 140 kPa		
						7.0	Mudstone and sandstone	Z1		PP. 390 kPa, angle of dip not visible. Very weak rock.		
						8.0				NOT APPLICABLE		
9.0				Core totally fragmented.								
10.0	End of hole at 10.0 (R.L. 8.9m)											

Drill type 210 B. GEMCO
Feed HYDRAULIC
Core barrel type NMLC
Driller SOIL MECH. PTY LTD
Commenced 26/7/77
Completed 27/7/77
Logged by G. TRAND
D. PURCELL
Vertical scale 2cm - 1m

Weathering PP. Pocket Penetrometer Water
Fr. Fresh (25) reading.
SW Slightly weathered (24) Rx Piezometer
MW Moderately weathered (23)
HW Highly weathered (22)
EW Extremely weathered (21)
Notes
Bedding & joint angles - Angles are measured relative to a plane normal to the core axis
* Water pressure tests - Values in megapascals should be read in conjunction with computer or sheets



10.0 - 7.5 water level shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core photograph, Negative File
Depth m Bulk & White Log
5277 A
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Drilling information						Rock Substance						Rock Mass Defects					
Method	Drilling rate	Casing	Water	Pressure test + (lugons)	U/L & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Plum wood strength 0-100 (50 being avg)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength Particulars (if needed)	Rock condition No. (interpretive)				
DIAMOND						0		Fill									
						1.0	Brown sandy clay, firm.										
						2.0	Possibly Elizabeth Street Formation.										
						3.0						Sample No 13-0-4					
						4.0	Silurian mudstone, a few thin sandstone beds.	Z2			Beds dip 80° - 90°.						
						5.0		Z3			Core fractured, clay filled at 4 of 30° followed by a dip of 65° - 70°. Rock improves markedly from 6m. Below 6m joints moderately spaced, rough but fairly tight.						
						6.0						Sample No 13-0-43					
						7.0		X									
						8.0		X			Hard sandstone bands in the mudstone dipping 85°-90° are fractured with cemented joints. Two joint sets dipping 45° - 70°						
						9.0		Z3			Sample No 13-0-44						
						10.0											
						11.0											

Drill type 210 B GEMCO
Feed HYDRAULIC
Core barrel type NMLC
Driller SOLE MECH PTY LTD
Commenced 4/8/77
Completed 5/8/77
Logged by G. TRAND
D. PURCELL
Vertical scale 2cm - 1m

Weathering
Fr - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
Water Pressure Tests - Values in lugons should be read in conjunction with compilation sheets

Water
10 Oct 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No
Depth (m) Black & White Colour
S406 A
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance							Rock Mass Defects				
Method	Drilling rate	Logging	Water	Pressure tests (psi, kg/cm ²)	Core recovery	Depth (m)	Substance description Rock type, grain characteristics Structure, texture, fragments	Weathering	Point load strength (MPa)	Uniaxial compressive strength (MPa)	Defect spacing (cm)	Defect description Thickness, type, inclination, planarity, roughness, sealing, strength	Rock condition (no interpretation)				
DIAMOND				Not Tested	100	10.0	Mudstone, occasional bands of sandstone	Z 4			100	Slight jointing at 45° Bedding near vertical					
						11.0											
						12.0											
						12.0	Mudstone, occasional beds of sandstone.	Z 2			10	Weathered seam of mudstone.					
						13.0											
						13.0											
						14.0											
						14.0											
						15.0											
						15.0											
						16.0											
						16.0											
						17.0	Siltstone and mudstone	Z 2 - 3			50	Fracturing along joints & tendency of fracturing along bedding planes.					
						17.0	Siltstone.				95	Jointing at 45° poorly cemented joints.					
						18.0											
						18.0											
						19.0											
						20.0											
						20.0	End of Hole 18.5m (R.L. -1.7m)										

210B GEMCO

Feet HYDRAULIC
Drilling type NMLC

Soil SOIL MECH

Summer 4/8/77

Summer 5/8/77

Driller G. GRAND
D. PURCELL
Scale 1:100 2cm = 1m

Weathering

F Fresh (Z5)

SW Slightly weathered (Z4)

MW Moderately weathered (Z3)

HW Highly weathered (Z2)

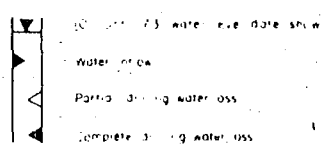
EA Extremely weathered (Z1)

Notes

Bedding is jointed planes. Angles are measured relative to plane normal to the hole axis.

Water Pressure tests: Water pressure should be added in conjunction with temperature sheets.

Water



Core description Negative No.

Depth in Data is White Colour

5406 L

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°) -30°
(U) COORDINATESDIRECTION
R L OF COLLAR 13.6m

SHEET 1 OF 2

Drilling Information					Rock Substance		Rock Mass Defects				
Method	Drilling rate	Casing	Water	Pressure test & loggers	Depth (metres)	Substance description rock type, grain characteristics colour, structure, minor components	Weathering	Point load strength D 3000 N 1000 K 5000 MPa	Defect spacing (cm)	Defect description fracture type, inclination, planarity, roughness, coating, strength	Rock condition No. (intermediate)
DIAMOND					0	Fill					
					1.0	Dark brown stiff clay undisturbed sample at 1.5			← Sample No 13-0-65		
					2.0						
					3.0	Probably Elizabeth Formation					
					4.0	Elizabeth St Formation Chips of sandstone gravel and sand in soft clayey matrix.				Wet soft, no structure visible.	
					5.0	Silurian siltstone and mudstone.			5.3 - 5.5 fractured with clay infilling Dip 70°		
					6.0						
					7.0				Core fragmented Alternating sandstone and clay seams (21 mudstone) Sample No 13-0-7/1		
					8.0						
					9.0				Rock condition improves markedly below 8.5m. Beds dip at 55°-30° Possible minor fold axis at 8.6m. Tight joints parallel to bedding. Sample No 13-0-7/2		
					10.0						
					10.0						

Drill type 2103 GEMCO

Feed HYDRAULIC

Casing type NMLC

Driller SOIL MECH. PTY LTD

Commenced 27/7/77

Completed 28/7/77

Signed by G. TRAND

Scale 2cm = 1m

Weathering

F Fresh (25)

SW Slightly weathered (24)

MW Moderately weathered (23)

HW Highly weathered (22)

EW Extremely weathered (21)

Notes

Bedding is at right angles

Water Pressure Tests

Rx Piezometer

Angles are measured relative to plane normal to the core axis.

Values in parentheses should be read in conjunction with comparative sheets

Water

No. 73 water level shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photograph Negative No.

Depth m Black & White 100m

S277 C

(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (θ) -90°
CO-ORDINATESDIRECTION -
R.L. OF COLLAR 13.6m

SHEET 2 OF 2

Drilling Information						Rock Substance		Rock Mass Defects					
Method	Drilling rate	Casing	Water	Pressure test - meters	Loss of core recovery	Depth (meters)	Grain size loss	Substance description rock type, grain characteristics mineral, structure, matrix components	Weathering	Porosity strength modulus	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength fractures, joints, etc.	Rock condition interpretation
DIAMOND				NOT DONE	100	10.0		Silurian mudstone	Z2 to 3		100	Many joint attitudes. Dips vary between 40° - 80°	
					100	11.0		End of hole 11.5m R.L. 2.1m.					

Drill type - 210 B GEMCO

Feed - HYDRAULIC

Core barrel type - NMLC

Driller - SOIL MECH. PTY. LTD

Commenced 27/7/77

Completed 28/7/77

Liquor by G. TRAND

Vertical scale 2 cm - 1m

Weathering

Fr - Fresh (Z5)

SW - Slightly weathered (Z4)

MW - Moderately weathered (Z3)

HW - Highly weathered (Z2)

LW - Extremely weathered (Z1)

Notes

Bedding & Joint Planes Angles are measured relative to a plane normal to the core axis

Water Pressure Tests values in megapascals should be read in conjunction with computation sheets

Water

10 Oct 75 water level data shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photograph Negative No

Depth in Black & White Colour

5277C

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information							Rock Substance		Rock Mass Defects				
Method	Drilling rate	Casing	Water	Pressure test + (loggers)	Lit B % core recovery	Depth metres	Grain size B core loss	Substance description rock type grain characteristics colour, structure, mineral composition	Weathering	Point load strength 100 ± 50 (kPa)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength Particular	Rock condition No. interpretive
						0		Fill					
						1.0		ELIZABETH STREET FORMATION					
						2.0		Sandy gravelly clay grey-brown				Firm, damp.	
						3.0		Clayey sand, grey brown				Firm, damp.	
						4.0		Gravelly clayey sand orange				Soft, damp	
						5.0		Gravelly sandy clay, light brown.				Soft, damp.	
						6.0		Sandy clay with fragments of sandstone possibly silurian surface.	ZI			Stiff, damp.	
						7.0		Igneous dyke, grey clay and muscovite to 5mm diam.	EW			minor limonite staining.	
						8.0						SPT TEST 14 blows / 15 cm 24 blows / 30 cm	
						9.0	Px	Clay and sandstone fragments moderately weathered.	ZI			NB. 1. Logging of bagged samples only. 2. Piezometer installed at 9m.	
						10.0		End of Hole 10m (R.L. 11.3 m)					

Drill type GEMCO 210 B

Feed - HYDRAULIC

Core barrel type - NMLC

(SOIL MECH.)

Driver J. WAGER

Commenced 30-7-77

Completed 30-7-77

Signed by J. BAILEY

D. PURCELL

2cm - 1m

Weathering

Fr - Fresh (Z5)

SW - Slightly weathered (Z4)

MW - Moderately weathered (Z3)

HW - Highly weathered (Z2)

EW - Extreme, weathered (Z1)

Notes

Bedding & joint planes - Angles are measured relative to a plane normal to the core axis

Water Pressure tests - Values in loggers should be read in conjunction with computer sheets

← Sample location

Rx Piezometer

Water

0 Oct 73 water level date shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core photo-graph negative No.

Depth m Back B White Colour

5277 C

GEOLOGICAL LOG OF DRILL HOLE

Drilling information						Rock Substance		Rock Mass Defects					
Method	Drilling rate	Casing	Water	Pressure test (megapascals)	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substrate description rock type, grain, sand, silt, clay colour, structure, mineral inclusions	Weathering	Point load strength (kN/m ²)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength, general	Rock core No. (interpretive)
AUGER						0		FILL					
						1		Elizabeth Street Formation				Sample No 13-0-66	
						2							
						3						Sample No 13-0-3/1	
						4							
						5							
						6							
						7							
						8						Sample No 13-0-3/2 SPT 7.7m : 4 blows / 15 cm	
						9						9.0 m (mudstone) SPT 30 blows / 15 cm P.P. 200-450 kPa	
DIAMOND CORE						9		Clay, Damp, Soft	Z1			Bedding at 50° Irregular and close, strongly cemented but smooth and clay coated planes at 9.35m, 9.55m, 10m, 10.1m, 10.5m, 10.7m.	
						10		Dargile Formation. Mudstone with interbedded sandstone Green brown - brown	Z3				

Core type GEMCO
Feed HYDRAULIC
Core barrel type NMLC
Driver SOIL MECH
Commenced 30/7/77
Completed 30/7/77
Logged by J. BAILEY
Vertical scale 2cm = 1m

Weathering
F1 Fresh (Z5)
S1 Slightly weathered (Z4)
M1 Moderately weathered (Z3)
H1 Highly weathered (Z2)
E1 Extreme, weathered (Z1)

Notes

Bedding is shown in cores. Angles are measured relative to the core axis.
Water pressure tests: values in parentheses are calculated from plots with computation sheets.

Water

10.0m - 7.5 water level data shown
Water flow
Partial drilling water loss
Complete drilling water loss

Refractive index (negative for
Depth in metres Barrels of water

5277 C
(Dept Const. Melbourne)

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance		Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test (megapascals)	Lift & % core recovery	Depth (metres)	Substance description rock type, grain characteristics, colour, structure, trace components	Weathering	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Rock condition to depth (m)
DIAMOND CORE						0					
						11					
						12					
						13					
						14	End of hole 13.9m. (R.L. -2.75)				

Drill type - GEMCO
Feed - HYDRAULIC
Core barrel type - NMLCDriller - SOIL MECH
Commenced - 30/7/77
Completed - 30/7/77
Logged by - J. BAILEY
Vertical scale - 2cm = 1mWeathering - Px
F - Fresh (Z5) -
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)Notes
Bedding & Joints - Angles are measured relative to a plane normal to the core axis
Water Pressure Tests - values in megapascals should be read in conjunction with computer sheets

Water

10 Oct 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water lossCore Photograph Negative No.
Depth in - Back to white - colour

5277 C

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance		Rock Mass Defects					
Method	Drilling rate	Casing	Water	Pressure test # (megapascals)	Lift & % core recovery	Depth (metres)	Substance description rock type, grain characteristics colour, structure, major components	Weathering	Point load strength 0.5 1 2 3 5 10 15 30 50 100 150 300	Defect spacing (cm)	R.O.C.	Defect description thickness, type, inclination, planarity roughness, coating, strength Particular	Rock condition No. (interpretive)
AUGER						1	FILL					Clay mineralogy sample	
						2	Elizabeth Street Formation					Clay mineralogy sample	
						3	Sandy gravelly clay sand, clay, angular sandstone and rounded quartz up to 5mm diameter					Clay mineralogy sample	
						4						Clay mineralogy sample	
						5						Clay mineralogy sample	
						6						Sample N ^o 13-0-8 Clay mineralogy sample	
						7						SPT 7 blows / 15 cm 9 blows / 30 cm 14 blows / 45 cm Clay mineralogy sample	
						8						Clay mineralogy sample	
						9						Clay mineralogy sample	
						10						Clay mineralogy sample	

Drill type GEMCO
Feed HYDRAULIC
Core barrel type NMLC

Driller SOIL MECH

Commenced 30 JULY 1977

Completed 31 JULY 1977

Logged by J. BAILEY

Vertical scale 2cm = 1m

Weathering

F Fresh

W1 Slightly weathered

W2 Moderately weathered

W3 Highly weathered

F4 Extremely weathered

Notes

Bleeding & Joint Water

• Water Pressure Tests

P_x Piezometer

Water

F Fresh

W1 Slightly weathered

W2 Moderately weathered

W3 Highly weathered

F4 Extremely weathered

Notes

Bleeding & Joint Water

• Water Pressure Tests

F Fresh

W1 Slightly weathered

W2 Moderately weathered

W3 Highly weathered

F4 Extremely weathered

Notes

Bleeding & Joint Water

• Water Pressure Tests

Depth in metres
10.54m

5277 R

(D.C. Melb)

HOL F NO 16

SHEET 2 of 2

Logging information					Rock Substrate		Rock Mass Defects				
Drilling core	Casing	Notes	Pressure test loggers	Wt % core recovery	Depth (metres)	Substrate description rock type, grain characteristics colour, stain hole, major constituents	Weathering	Pore space strength % S ₂ , N ₂ , O ₂	Defect spacing (cm)	Defect description Disseases, type, orientation, pattern, etc. roughness, cracking, strength etc.	Notes
		18/8/77			10.0						
		NOT TESTED			11.0						
					12.0	Elizabeth St. Formation Sandy gravelly clay sand, clay, angular sandstone + rounded quartz up to 5mm dia.					- Clay mineralogy sample Cohesive wet. P.P. 200 kPa
				100	13.0						
				100	14.0	Dargile formation Mudstone, minor sandstone bands (0mm) Green-brown	23			41	Bedding 50-60° very close, tight, smooth-rough. Strongly cemented, minor weakly cemented. Clay on bedding 0-5mm at 13.4, 13.65, 13.85, 13.95 Limonite 0-2mm Joints moderately spaced, 30° smooth to rough, weakly cemented clay 0-3mm, Limonite 0-1mm. Weak joints dip 40°
					15.0	Sandstone, light brown Mudstone - as above					
					15.0	Siltstone, mudstone	23			95	
					15.0	Sandstone	23			60	Hard band, clay filled joints Sum thick at the end of sequence
					16.0	Mudstone, siltstone / sandstone	24			0	Broken core. Mostly loose joints some clay filled poorly cemented.
					17.0	sandstone	23			0	jointing parallel to the bedding. Also vertical jointing partly clay filled. Dip 40°. Slight fracturing normal to the bedding.
					17.0	Mudstone some bends of sandstone	22-3			85	
					18.0	Mudstone sandstone siltstone & clay.	22			10	Bedding Dips 40°, multidirectional fracturing. Uncemented joints Dip 50° at end of the sequence.
					19.0	End of hole 18.9m (R.L. - 7.36m)					Oriented core at 18.9m gave strike 28°N dip 50E.
					20.0						

Type: GEMCO Test: HYDRAULIC Core barrel type: NMLC Soil Mech. Pty. Ltd. Completed: 30/7/1977 Completed: 31/7/1977 By: D. PUNCEY By: J. BAILEY Scale: 2cm = 1m	Weathering: P.P. POCKET PENETROMETER Fresh (25) SW: Slightly weathered (24) MW: Moderately weathered (23) HW: Highly weathered (22) EA: Extremely weathered (21) Reading: P _x Piezometer  Reading is in degrees. Angles are measured relative to the vertical in the core logs. Water Pressure Tests: Values are to be read in conjunction with computer charts.	Depth: 2.5 water level data shown Water: clear Part of log water loss Complete log water loss 5277 R
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GEOLOGICAL LOG OF DRILL HOLE

Drilling information					Rock Substance		Rock Mass Defects										
Method	Drilling rate	Casing	Water	Pressure test * (megapascals)	Log of core recovery	Depth (metres)	Substance description rock type, grain characteristics colour, structure, mineral components	Weathering	Point load strength (N/mm ²) P ₁ P ₂ P ₃ P ₄ P ₅ P ₆ P ₇ P ₈ P ₉ P ₁₀ P ₁₁ P ₁₂ P ₁₃ P ₁₄ P ₁₅ P ₁₆ P ₁₇ P ₁₈ P ₁₉ P ₂₀	Defect spacing (cm)	C.O.D. or a.c.d.	Defect description thickness, type, inclination, planarity, roughness, coating, strength Remarks Remarks	Rock condition No interpretive				
DIAMOND	NOT CORED	Tunnel		P _x	NOT DONE	0	Fill							Core Sampled every metre.			
						1.0											
						1.5											
						2.0	Elizabeth St. formation Yellow grey silty clay.										
						3.0											
						4.0											
						4.8											
						5.0											
						6.0	DARGILE FORMATION Chips of Sandstone clay	Z1			P.P. 240-420 kPa		core totally fragmented.				
						6.75											
7.0	Silurian sandstone - mudstone.	Z1			P.P. 500 kPa												
8.0																	
9.0		Z2 to 3			Bedding Dips 45° Joints EW up to 5cm wide; tight vertical jointing also. Rock condition improves below 8m.												
10.0	End of hole 10.9m (R.L. 0.92m)				Sample NR 13-0-46 Point load test at 10.6m												
10.6m Sample NR 13-0-47																	

Drill type: HQ A. GEMCO
Feed: HYDRAULIC
Core barrel type: N.M.L.C.
Driller: SOIL MECH. PTY. LTD.
Commenced: 6/8/77
Completed: 7/8/77
Logged by: G. TRAND
D. PURCELL
Vertical scale: 2cm - 1m

Weathering
Fr - Fresh (Z5) R.P. Pocket Penetrometer reading.
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3) P_x Piezometer
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)
Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
a - Water Pressure Tests - values in megapascals should be read in conjunction with computation sheets

Water
10 Oct 73 water over core shown
Water: none
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No
Depth: Black & White Colour
5277 R
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance								Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test % (lugons)	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Point load strength 0-3 100 1000 10000 100000 1000000 10000000 100000000 1000000000 10000000000 100000000000 1000000000000 10000000000000 100000000000000 1000000000000000 10000000000000000 100000000000000000 1000000000000000000 10000000000000000000 100000000000000000000 1000000000000000000000 10000000000000000000000 100000000000000000000000 1000000000000000000000000 10000000000000000000000000 100000000000000000000000000 1000000000000000000000000000 10000000000000000000000000000 100000000000000000000000000000 1000000000000000000000000000000 10000000000000000000000000000000 100000000000000000000000000000000 1000000000000000000000000000000000 10000000000000000000000000000000000 100000000000000000000000000000000000 1000000000000000000000000000000000000 10000000000000000000000000000000000000 100000000000000000000000000000000000000 1000000000000000000000000000000000000000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 100 100 1000 100 1000 100 1000 100 1000 100 1000 100 1000 1000 100 1000 100 1000 100 1000 1000 100 1000 1000 100 1000 100 1000 100 1000 100 1000 100 100							

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°) -90°
CO-ORDINATESDIRECTION
R. L. OF COLLAR 14.7 m

SHEET 2 OF 3

Drilling information					Rock Substance		Rock Mass Defects				
Method	Drilling rate	Casing	Water	Pressure test * (megapascals)	Lift B % core recovery	Depth (metres)	Substance description rock type, grain characteristics, colour, structure, mineral components	Weathering	Defect spacing (cm)	Defect description thickness, type, orientation, planarity, roughness, coating, strength	Rock condition code
DIAMOND	Tunnel			TESTED	NOT	100					
						100					
						110					
						100					
						120					
						130	Mudstone; green-brown very minor thin sandstone bands.	Z3			
						100	Mudstone - sandstone ratio 3:1				
						140					
						100					
						150					
						160		Z3-4			
						100		Z3			
						170					
						93					
						180					
						100	Sandstone/Mudstone 1:5.				
						190					
						100	Sandstone/Mudstone 1:10				
						200		Z4			

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMS
DOUBLE TUBE
Drillist J. JAMES
DESPENDED
Commenced 29-10-77
Completed 30-10-77
Logged by J.D. BAILEY
D.C. PURCELL
Vertical scale 2cm = 1m

Weathering
Fr - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)

Notes
Bedding & joint planes Angles are measured relative to a plane normal to the core axis
* Water pressure tests values in megapascals should be read in conjunction with completion sheets

Water
10 Jan 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photo grain Negative No
Depth m Bu x B White Colour

\$277 E

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

PROJECT TELECOM TUNNEL
LOCATION LONSDALE ST. MELBOURNE
STATION 432
ANGLE FROM HORIZONTAL (θ) - 90°
CO-ORDINATES
DIRECTION
R.L. OF COLLAR 14.7m

HOLE NO. 19

GEOLOGICAL LOG OF DRILL HOLE

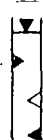
SHEET 3 OF 3

Drilling information						Rock Substance		Rock Mass (defects)						
Method	Drilling rate	Casing	Water	Pressure test * (megapascals)	Lift B % core recovery	Depth (metres)	Graphic log B core loss	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Point load strength 100 is 50 MPa	Defect spacing (cm)	COR	Defect description thickness, type, inclination, planarity, roughness, coating, strength Particular General	Rock condition No (interpretive)
DIAMOND					100	20.0		Sandstone/mudstone ratio 1:6	Z4				As Above	
									Z3-4			94		
						21.0		End of hole 20.95m. (R.L. -6.25 m)						

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMS
DOUBLE TUBE
Driller J. JAMES
DEEPENED 29-10-77
Commenced
Completed 30-10-77
Logged by J.D. BAILEY
D.C. PURCELL
Vertical scale 2cm = 1m

Weathering
Fr - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)

Water



10 Oct 73 water level data shown
Water inflow
Partial drilling water loss
Complete drilling water loss

NOTES
Bedding & Joint planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests - values in megapascals should be read in conjunction with computation sheets

Core Photograph Negative No
Depth, m Black & White Colour
5277 E

GEOLOGICAL LOG OF DRILL HOLE

Drilling information				Rock Substance		Rock Mass Defects						
Drilling rate	Casing	Water	Pressure test (lugons)	lit. B % core recovery	Depth (metres)	Grain size log B core loss	Substance description rock type, grain characteristics, texture, structure, mineral components	Weathering	Point load strength (N/mm ²)	Defect spacing (cm)	Defect description fracture type, orientation, planarity, roughness, coating, strength	Spacing or no interference
							Bitumen					
							Concrete					
							Bargile Formation	Z1 (EW)			Sample N ^o 13-0-67	
							Mudstone, white				Bedding just discernible, stiff clay with sandstone fragments P.P. 150-350 kPa	
				100	10		Sandstone, white to light brown, Mudstone white				Bedding very close, dip 30°, clay 1-40mm, smooth, weakly cemented P.P. 10-400 kPa Joints 0°, 5°	
				100	20		Mudstone with minor Sandstone bands 20mm Light brown, mainly extremely weathered.	Z1-Z2				
				100	30		Sandstone, Light brown to white	HW		10	Bedding very close to close, smooth, clay 0-10mm, tight to open, dip 30°. Joints, close to very close, open 1-2 mm, clay 0-3mm, 30°, 20°	
				100	40		Mudstone, siltstone interbedded, clay, white to light brown siltstone, minor sandstone	Z1-Z2			Bedding very close, smooth, clay 0-70 mm, weakly cemented.	
				100	50		Sandstone, Light brown	HW			Bedding & joints close, rough, clean to 3mm clay, open, not cemented, Joints 85°	
				100	60		Mudstone, light brown	Z2, Z2-3			Bedding tight, smooth to rough, clay 0-10mm Limonite 0-1mm, weakly cemented, clay 1mm joints open and weakly cemented.	
				100	70		Sandstone, light brown	Z2-3		30	Bedding planar to irregular, very close, Limonite 0-1mm, clay 2-10mm at 4.9m 52m, Tight, strongly cemented (minor weakly). Beds dip at 30°	
				100	80		Mudstone, light brown				Joints close, tight, rough, irregular, Limonite 1-3mm, strongly cemented (minor weakly) Dip 80°, 50°	
				100	90		Sandstone, light brown	MW		0	Highly fractured, clay 1-15mm on joints & bedding planes joints dipping 70°	
				100	100		Mudstone, light brown as above.	Z2-3		12	Sample N ^o 13-0-51 clay 3mm on bedding.	
				100	110		Sandstone (40mm)	Z3	X		Bedding at 30° planar to irregular, close, strongly cemented (minor weakly) Limonite 0-1mm, joints close, tight, rough Limonite 1-5mm strongly cemented (minor weakly) 6mm clay on bedding at 7.96m joints 40° 70° (opp. to bedding)	
				100	120		Mudstone, light brown to green brown.			50		
				100	130		Sandstone	MW		0	3mm clay on bedding.	
				100	140		Mudstone, green-brown, minor sandstone.	Z3		17	Joints very close, open 1mm, Limonite 1-4 mm,	
				100	150		Sandstone, light brown	MW	X	83	Bedding close to very close, strongly cemented. Joints 85° 62°, clay 5mm at 9.75 m	
				100	160						Sample N ^o 13-0-52	

Drill type GEMCO - DIAMOND	Weathering P.P. POCKET PENETROMETER READING	Water	Core Fracture Negative No.
rod HYDRAULIC	Fr - Fresh (25)	10 Jct 73 water ever date show	Depth Bore B White Colour
core barrel type NMLC	SW Slightly weathered (24)	Water inflow	
TRIPLE TUBE	MW Moderately weathered (23)	Partial drilling water loss	
operator J. WAGER	HW Highly weathered (22)	Complete drilling water loss	
commenced 13-2-1977	EW Extremely weathered (21)		5277 B
completed 14-8-1977	Notes Bedding & joint planes Angles are measured relative to the normal to the core axis		(D.C. Melb)
checked by J. D. BAILEY	Water Pressure Tests values & signs should be in accordance with computation sheets		
scale 2.0m = 1cm			

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance		Rock Mass Defects				
Method	Drilling rate	Casing	Water	Pressure test # (megapascals)	Lift & % core recovery	Depth (metres)	Substance description rock type grain characteristics colour, structure, minor components	Weathering	Point load strength (MPa)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Rock condition No. (intermediate)
DIAMOND	TUNNEL		2 1/8" / 77	NOT TESTED	100	10.0	Mudstone Green-brown	Z3		80		
							Sandstone Light brown	MW		0	Bedding close, rough, weakly cemented. Limonite 0-1mm. Joints open 1mm. Rough 55°, 85°. Bedding 27°, 10mm clay, joints smooth. Sample No 13-0-53	
						11.0	Mudstone Green-brown					
							Mudstone Green-brown with thinly interbedded light brown Sandstone. clay 20mm on bedding.					
						12.0	Shear - no clay bedding dip 90° - 18°	Z3		37	Bedding very close smooth to rough, strongly cemented. (minor weakly) Limonite 0-2mm. Planar to irregular. Dip 27°. Joints close, irregular to planar, rough, Limonite 1-2mm. mostly strongly cemented. Dips 55°, 75°.	
					100	13.0	Highly weathered on bedding plane.			40	Bedding 28° Joints 70°, 50°, 30°, 70°	
							End of hole at 13.7m (R.L. 2.79m)					

Drill type GEMCO DIAMOND

Feed HYDRAULIC

Core barrel type NMLC

TRIPLE TUBE

Driller J. WAGER

Commenced 13-8-77

Completed 14-8-77

Logged by J. D. BAILEY

D. PURCELL

2cm = 1in

Weathering

F - Fresh (25)

SW - Slightly weathered (24)

MW - Moderately weathered (23)

HW - Highly weathered (22)

EW - Extremely weathered (21)

Notes

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - Values in megapascals should be read in conjunction with computation sheets

Water

10 Oct 73 water level data shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photograph Negative No.

Depth in Black & White Colour

5277 B

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°) -45°
CO-ORDINATES
DIRECTION 060° MAG
R.L. OF COLLAR 17.5 m

SHEET 1 OF 2

Drilling information					Rock Substance		Rock Mass Defects					
Method	Drilling rate	Casing	Water	Pressure test # (megapascals)	Lift & % core recovery	Depth (metres)	Substance description rock type, grain characteristics colour, structure, minor components	Weathering	Point load strength (MPa)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Rock condition (temperature)
NON CORE						0	Fill					
						1.0	Dargile Formation mudstone and sandstone	Z1				
DIAMOND						0						
						2.0	Interbedded mudstone and sandstone white to light brown Ratio of SST to mudstone 1:5 Sandstone HW-MW	Z1			Bedding 30°, very close, barely discernible. Sandstone joints very close, rough, open Limonite 0-1mm P.P. 100-350 kPa in mudstone	
DIAMOND						0						
						4.0	Mudstone with thin sandstone bands (20%) light brown	Z2				
DIAMOND						0						
						5.0	Mudstone with minor sandstone, light brown	Z2			Vein quartz 30mm thick at 4.8m. Bedding, 10° very close, rough, weakly to strongly cemented by Limonite 1-10mm, 20mm clay at 4.9, 5.1. Joints close to moderate (very close in sandstone), rough, strongly cemented. Limonite 1-5mm, Dip 75°, 90° Bedding 15°	
DIAMOND						0						
						6.0						
DIAMOND						7.0	Sandstone, light brown	MW to HW			Clay 20mm at 7.15, 7.20m on bedding planes. Sample N° 13-0-54 (Bedding 20° increasing with depth to 55° close, rough, strongly cemented by limonite 1-5mm Joints very close, 0°, 60°, 70°, rough, strongly cemented by limonite 1-10mm.	
						8.0						
DIAMOND						0						
						9.0						
DIAMOND						0						
						10.0						

Drill type MINDRILL Feed HYDRAULIC Core barrel type NMS DOUBLE TUBE (SOIL MECH) Driller J. JAMES Commenced 24-9-77 Completed 29-9-77 Reported by J. D. BAILEY D. PURCELL Vertical scale 2 cm = 1 m	Weathering P.P. Pocket Penetrometer Reading. In Fresh (Z5) SW Slightly weathered (Z4) MW Moderately weathered (Z3) HW Highly weathered (Z2) EA Extreme weathered (Z1) Bedding is 10° to 15° Any angles measured relative to plane normal to the core axis Note: Pressure tests values & depths should be noted in conjunction with lithological sheets	Water 2.5" water level date shown Water flow Pore fluid water loss Complete to 1.2 m with loss 5277 S (D.C. Melb)
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GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance		Rock Mass Defects						
Method	Drilling rate	Casing	Water	Pressure Test: * (megapascals)	W. B. % core recovery	Depth (metres)	Graphic log of core loss	Substance description rock type, grain characteristics colour, structure, minor components	Weathering	Point load strength (MPa)	Defect spacing (cm)	R.O.D.	Defect description thickness, type, inclination, planarity, roughness, coating, strength Particulars	Rock condition No. (interpretive)
DIAMOND						10.0		Mudstone light brown minor white-grey	Z2				Sample No 13-0-50 Bedding, 55°, very close, rough, strongly cemented by limonite 1-15mm thick. Minor weakly cemented Joints 42°, close, rough planar strongly cemented by limonite 0-15mm. 5mm of clay on joint at 11.1m.	
					100	11.0		Few thin sandstone bands 5-20mm thick moderately weathered.					Sample No 13-0-57	
						12.0								
					100	13.0								
						14.0		Sandstone to mudstone. Ratio 1:8				Applicable	Bedding 55° Joints 40°	
						15.0						Not		
					100	16.0							Bedding 46°	
						17.0								
					92	18.0		Mudstone with minor sandstone.	Z1				Crumbly.	
						100	19.0		Mudstone and interbedded sand- stone. SST/Mudst. 1:5. Light brown with minor grey.	Z1 2			Crumbly. Bedding 55°-68°, very close, smooth to rough, weakly to strongly cemented, limonite 1-8mm. 3mm clay on bedding planes at 18.6m Joints 30°-45°, close to very close, (open in sandstone), irregular to planar, strongly to weakly cemented by limonite 1-10mm	
						20.0		End of hole 19.5m. (R.L. -3.7m)						

Drill type MINORILL

Feed HYDRAULIC

Core barrel type NMS

DOUBLE TUBE

Driver J. JAMES

Commenced 24.9.77

Completed 25.9.77

Logged by J.D. BAILEY

D. PURCELL

Vertical scale 2cm : 1m

Weathering

Fr - Fresh (Z5)

SW - Slightly weathered (Z4)

MW - Moderately weathered (Z3)

HW - Highly weathered (Z2)

EW - Extremely weathered (Z1)

Notes

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - values in megapascals should be read in conjunction with computation sheets

Water

Fr - Fresh

SW - Slightly weathered

MW - Moderately weathered

HW - Highly weathered

EW - Extremely weathered

Notes

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - values in megapascals should be read in conjunction with computation sheets

Core Photograph Negative No.

Depth (m) Black & White Colour

5277 S

GEOLOGICAL LOG OF DRILL HOLE

Drilling Information						Rock Substance		Rock Mass Details					
Method	Drilling rate	Casing	Water	Pressure test + (megapascals)	Core recovery	Depth (metres)	Substance description rock type, grain characteristics colour, structure, minor components	Weathering	Point load strength (MPa)	Defect spacing (cm)	Defect description thickness, type, inclination, planarity, roughness, coating, strength	Rock condition (interpret)	
AUGER						0	Bitumen Concrete						
						10							
						20	Sandy Clay				Sample No. 13 0.68		
						30	Dargile formation Sandstone, white, minor Limonite staining, clay 10-30mm on horizontal joints very weak cementation of grains	EW to HW			Bedding barely discernible close, open, 80° Joints, close, 0°, 90° not cemented. P.P. 350 kPa		
						40							
						43							
						50	Sandstone white, minor brown, weak cementation of grains Sandstone, white, soft, with mudstone white.	Z1			Bedding & joints not cemented P.P. 710 kPa Sandstone P.P. 300-500 kPa Mudstone P.P. 200 kPa Bedding very close joints weakly cemented joints open, not cemented.		
						60	Mudstone white with sandstone light brown				P.P. 1200 kPa		
						70	Sandstone, white with brown staining, weak cementation of grains.	HW			Bedding 80° moderately spaced, clay coated up to 20mm. Joints very close to close, planar, smooth, clay 0-3mm open 1-2mm, at 15-20°, 5° (not cemented)		
						80							
DIAMOND						90	Interbedded sandstone light brown with white mudstone, siltstone completely weathered to clay.	Z1			Bedding very close 80-90° wavy, smooth clay 0-10mm weakly to strongly cemented (Limonite 0-5mm) Joints very close not cemented, open, clay 0-5mm 5° 30° P.P. 100-300 kPa mudstone P.P. 700-1500 kPa S.T.		
						100	Sandstone	EW					

Drill type GEMCO DIAMOND
Feed HYDRAULIC
Core barrel type NMLC
TRIPLE TUBE
Operator J. WAGER
Commenced 20-8-1977
Completed 21-8-1977
Logged by J. D. BAILEY
D. PURCELL
2cm = 1m

Weathering P.P. Pocket Penetrometer
1. Fresh (Z5) Reading.
SW Slightly weathered (Z4)
MW Moderately weathered (Z3)
HW Highly weathered (Z2)
LW Extreme weathered (Z1)
Notes
Bedding, etc. - see index. Angles are measured relative to plane normal to the core axis.
* Water Pressure Tests. Values in megapascals should be used in conjunction with compaction sheets.

Water
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 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1018. 1019. 1020. 1021. 1022. 1023. 1024. 1025. 1026. 1027. 1028. 1029. 1030. 1031. 1032. 1033. 1034. 1035. 1036. 1037. 1038. 1039. 1040. 1041. 1042. 1043. 1044. 1045. 1046. 1047. 1048. 1049. 1050. 1051. 1052. 1053. 1054. 1055. 1056. 1057. 1058. 1059. 1060. 1061. 1062. 1063. 1064. 1065. 1066. 1067. 1068. 1069. 1070. 1071. 1072. 1073. 1074. 1075. 1076. 1077. 1078. 1079. 1080. 1081. 1082. 1083. 1084. 1085. 1086. 1087. 1088. 1089. 1090. 1091. 1092. 1093. 1094. 1095. 1096. 1097. 1098. 1099. 1100. 1101. 1102. 1103. 1104. 1105. 1106. 1107. 1108. 1109. 1110. 1111. 1112. 1113. 1114. 1115. 1116. 1117. 1118. 1119. 1120. 1121. 1122. 1123. 1124. 1125. 1126. 1127. 1128. 1129. 1130. 1131. 1132. 1133. 1134. 1135. 1136. 1137. 1138. 1139. 1140. 1141. 1142. 1143. 1144. 1145. 1146. 1147. 1148. 1149. 1150. 1151. 1152. 1153. 1154. 1155. 1156. 1157. 1158. 1159. 1160. 1161. 1162. 1163. 1164. 1165. 1166. 1167. 1168. 1169. 1170. 1171. 1172. 1173. 1174. 1175. 1176. 1177. 1178. 1179. 1180. 1181. 1182. 1183. 1184. 1185. 1186. 1187. 1188. 1189. 1190. 1191. 1192. 1193. 1194. 1195. 1196. 1197. 1198. 1199. 1200. 1201. 1202. 1203. 1204. 1205. 1206. 1207. 1208. 1209. 1210. 1211. 1212. 1213. 1214. 1215. 1216. 1217. 1218. 1219. 1220. 1221. 1222. 1223. 1224. 1225. 1226. 1227. 1228. 1229. 1230. 1231. 1232. 1233. 1234. 1235. 1236. 1237. 1238. 1239. 1240. 1241. 1242. 1243. 1244. 1245. 1246. 1247. 1248. 1249. 1250. 1251. 1252. 1253. 1254. 1255. 1256. 1257. 1258. 1259. 1260. 1261. 1262. 1263. 1264. 1265. 1266. 1267. 1268. 1269. 1270. 1271. 1272. 1273. 1274. 1275. 1276. 1277. 1278. 1279. 1280. 1281. 1282. 1283. 1284. 1285. 1286. 1287. 1288. 1289. 1290. 1291. 1292. 1293. 1294. 1295. 1296. 1297. 1298. 1299. 1300. 1301. 1302. 1303. 1304. 1305. 1306. 1307. 1308. 1309. 1310. 1311. 1312. 1313. 1314. 1315. 1316. 1317. 1318. 1319. 1320. 1321. 1322. 1323. 1324. 1325. 1326. 1327. 1328. 1329. 1330. 1331. 1332. 1333. 1334. 1335. 1336. 1337. 1338. 1339. 1340. 1341. 1342. 1343. 1344. 1345. 1346. 1347. 1348. 1349. 1350. 1351. 1352. 1353. 1354. 1355. 1356. 1357. 1358. 1359. 1360. 1361. 1362. 1363. 1364. 1365. 1366. 1367. 1368. 1369. 1370. 1371. 1372. 1373. 1374. 1375. 1376. 1377. 1378. 1379. 1380. 1381. 1382. 1383. 1384. 1385. 1386. 1387. 1388. 1389. 1390. 1391. 1392. 1393. 1394. 1395. 1396. 1397. 1398. 1399. 1400. 1401. 1402. 1403. 1404. 1405. 1406. 1407. 1408. 1409. 1410. 1411. 1412. 1413. 1414. 1415. 1416. 1417. 1418. 1419. 1420. 1421. 1422. 1423. 1424. 1425. 1426. 1427. 1428. 1429. 1430. 1431. 1432. 1433. 1434. 1435. 1436. 1437. 1438. 1439. 1440. 1441. 1442. 1443. 1444. 1445. 1446. 1447. 1448. 1449. 1450. 1451. 1452. 1453. 1454. 1455. 1456. 1457. 1458. 1459. 1460. 1461. 1462. 1463. 1464. 1465. 1466. 1467. 1468. 1469. 1470. 1471. 1472. 1473. 1474. 1475. 1476. 1477. 1478. 1479. 1480. 1481. 1482. 1483. 1484. 1485. 1486. 1487. 1488. 1489. 1490. 1491. 1492. 1493. 1494. 1495. 1496. 1497. 1498. 1499. 1500. 1501. 1502. 1503. 1504. 1505. 1506. 1507. 1508. 1509. 1510. 1511. 1512. 1513. 1514. 1515. 1516. 1517. 1518. 1519. 1520. 1521. 1522. 1523. 1524. 1525. 1526. 1527. 1528. 1529. 1530. 1531. 1532. 1533. 1534. 1535. 1536. 1537. 1538. 1539. 1540. 1541. 1542. 1543. 1544. 1545. 1546. 1547. 1548. 1549. 1550. 1551. 1552. 1553. 1554. 1555. 1556. 1557. 1558. 1559. 1560. 1561. 1562. 1563. 1564. 1565. 1566. 1567. 1568. 1569. 1570. 1571. 1572. 1573. 1574. 1575. 1576. 1577. 1578. 1579. 1580. 1581. 1582. 1583. 1584. 1585. 1586. 1587. 1588. 1589. 1590. 1591. 1592. 1593. 1594. 1595. 1596. 1597. 1598. 1599. 1600. 1601. 1602. 1603. 1604. 1605. 1606. 1607. 1608. 1609. 1610. 1611. 1612. 1613. 1614. 1615. 1616. 1617. 1618. 1619. 1620. 1621. 1622. 1623. 1624. 1625. 1626. 1627. 1628. 1629. 1630. 1631. 1632. 1633. 1634. 1635. 1636. 1637. 1638. 1639. 1640. 1641. 1642. 1643. 1644. 1645. 1646. 1647. 1648. 1649. 1650. 1651. 1652. 1653. 1654. 1655. 1656. 1657. 1658. 1659. 1660. 1661. 1662. 1663. 1664. 1665. 1666. 1667. 1668. 1669. 1670. 1671. 1672. 1673. 1674. 1675. 1676. 1677. 1678. 1679. 1680. 1681. 1682. 1683. 1684. 1685. 1686. 1687. 1688. 1689. 1690. 1691. 1692. 1693. 1694. 1695. 1696. 1697. 1698. 1699. 1700. 1701. 1702. 1703. 1704. 1705. 1706. 1707. 1708. 1709. 1710. 1711. 1712. 1713. 1714. 1715. 1716. 1717. 1718. 1719. 1720. 1721. 1722. 1723. 1724. 1725. 1726. 1727. 1728. 1729. 1730. 1731. 1732. 1733. 1734. 1735. 1736. 1737. 1738. 1739. 1740. 1741. 1742. 1743. 1744. 1745. 1746. 1747. 1748. 1749. 1750. 1751. 1752. 1753. 1754. 1755. 1756. 1757. 1758. 1759. 1760. 1761. 1762. 1763. 1764. 1765. 1766. 1767. 1768. 1769. 1770. 1771. 1772. 1773. 1774. 1775. 1776. 1777. 1778. 1779. 1780. 1781. 1782. 1783. 1784. 1785. 1786. 1787. 1788. 1789. 1790. 1791. 1792. 1793. 1794. 1795. 1796. 1797. 1798. 1799. 1800. 1801. 1802. 1803. 1804. 1805. 1806. 1807. 1808. 1809. 1810. 1811. 1812. 1813. 1814. 1815. 1816. 1817. 1818. 1819. 1820. 1821. 1822. 1823. 1824. 1825. 1826. 1827. 1828. 1829. 1830. 1831. 1832. 1833. 1834. 1835. 1836. 1837. 1838. 1839. 1840. 1841. 18

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°) 90°
CO-ORDINATESDIRECTION
R L OF COLLAR 18.49m

SHEET 2 OF 2

| Logging information | | | | | | Rock substance | | Rock Mass (defects) | | | | |
|---------------------|---------------|---------|-------|-------------------------|---------------|----------------|--|---------------------|---------------------|--|---|--|
| Method | Drilling rate | Coating | Water | Pressure test (pascals) | Core recovery | Depth (metres) | Substance description
Rock type, grain, texture, fossils, colour, structure, mineral components | Weathering | Defect spacing (cm) | Defect description
Thickness, type, orientation, planarity, roughness, scaling, strength | Rock condition | |
| | | | | | | 10.0 | Sandstone, white to buff, cementation of grains weak | EW | | Bedding 80°, close, weakly to not cemented. Clay 0.5mm open 1mm | | |
| | | | | | | 10.5 | Clay 50mm horizontal | | | Joints open 1-2mm Not to strongly cemented 15° 65° 90° | | |
| | | | | | | 11.0 | Igneous Dyke.
Light brown, soft clayey material with fine texture evident. | EW | | Joints close to weakly cemented. | | |
| | | | | | | 12.0 | | minor HW | | P.P. 100 kPa
200 kPa
300 kPa
350 kPa
Sample for clay mineralogy at 11.5 m | | |
| | | | | | | 13.0 | | | | | | |
| | | | | | | 14.0 | Sandstone minor mudstone clay 30mm | HW to MW | | Bedding 45°-60° smooth to rough, weakly to strongly cemented. | | |
| | | | | | | 14.5 | Sandstone, brown strongly cemented grains. | | 55 | Bedding 80°-90° Wavy very close, strongly cemented rough, Limonite 1-2mm, joints strongly cemented | | |
| | | | | | | 15.0 | Sandstone, minor mudstone | MW | | Vertical dipping beds. Alternating sandstone & mudstone, Horizontal joints mostly open or uncemented | | |
| | | | | | | 16.0 | Core loss.
Sandstone, minor mudstone, ferruginous mineralization | | | 30 | | |
| | | | | | | 17.0 | | MW to SW | | 98 | Vertical dipping beds, occasional horizontal joints. Indications of minor folding (probably due to the dyke intrusion). Hard, massive appearance. | |
| | | | | | | 18.0 | Mudstone predominant | Z3 to Z4 | | | | |
| | | | | | | 19.0 | End of Hole 18.1m (R.L. -0.2m) | | | Oriented core at 18.5m : strike 25°N dip 78°W | | |

Drill type GEMCO DIAMOND

Feed HYDRAULIC

Core barrel type NMLC
TRIPLE TUBE

Driller J. WAGER

Commenced 20-8-77

Completed 21-8-77

Supervised by J.D. BAILEY
G. FRANK 14-6-1977m
Velocity 2cm = 1m.

Weathering

F. Fresh

SW Slightly weathered

MW Moderately weathered

HW Highly weathered

E.W. Extremely weathered

Notes

Bedding & joint planes

Water Pressure Tests

Water

2.5 water level shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core sample grade, frequency for

Depth in Holes White (cm)

5277 0

Angles are measured relative to a plane normal to the core axis

Values in parentheses should be read in conjunction with computation sheets

GEOLOGICAL LOG OF DRILL HOLE

| Drilling Information | | | | | Rock Substance | | Rock Mass Details | | | | |
|----------------------|--------|-------|-------------------------------------|-----------------------|----------------|--|-------------------|---------------------|---|-------------------------|--|
| Drilling core | Casing | Water | Pressure test (kg/cm ²) | U & B % core recovery | Depth (meters) | Substance description
rock type, grain characteristics
colour, structure, minor components | Weathering | Defect spacing (cm) | Defect description
thickness, type, orientation, planarity,
roughness, coating, strength | Rock condition (meters) | |
| | | | | | 0 | Fill | | | | | |
| | | | | | 1.0 | Sandy clay, brown, quartz grains (sub angular) | | | Damp, soft.
P.P. 250-350 kPa | | |
| | | | | | 2.0 | Sand, minor clay, white. | | | Damp, soft.
P.P. 250-350 kPa | | |
| | | | | | 3.0 | | | | Damp firm.
P.P. 600-750 kPa | | |
| | | | | | 4.0 | | | | | | |
| | | | | | 50 | Sand, minor clay white | | | P.P. 300-700 kPa | | |
| | | | | | 6.0 | Minor Limonite staining | | | | | |
| | | | | | 7.0 | Coarse grains with few pebbles. | | | | | |
| | | | | | 8.0 | Sandy clay white to orange. | | | P.P. 150-400 kPa
SPT. 40 blows/30cm | | |
| | | | | | 9.0 | SPT | | | | | |
| | | | | | 10.0 | Dargile Formation mudstone and inter-bedded sandstone. (S.S.T. HW - MW) | ZI | | Bedding 15°, very close. Joints 60°, 90° very close to close. Bedding and joints smooth, clay 0-40mm. | | |
| | | | | | 11.0 | | | | P.P. 200-400 kPa | | |
| | | | | | 12.0 | Sandstone light brown | MW | | Bedding and joints close clay on bedding. 50mm at 9.3m. | | |
| | | | | | 13.0 | Core lifter failed. | | | | | |
| | | | | | 14.0 | Sandstone with minor mudstone. | HW | | Bedding and joints very close, open clay 0-20mm weakly cemented. | | |

Drill type GEMCO 110 A
HYDRAULIC
Barre type NMS
DOUBLE TUBE
(SOIL MECH.)
J. JAMES
Dated 29-9-77
Completed 30-9-77
Designed by J.D. BAILEY
D. CURRAN
Scale 2cm = 1m

Weathering P.P. Pocket Penetrometer Reading
Z5
SW Slightly weathered (Z4)
MW Moderately weathered (Z3)
HW Highly weathered (Z2)
LW Extremely weathered (Z1)
Bedding 15° joints 60° angles are measured relative to bedding and joints to the rock mass
Water pressure tests values in kg/cm² should be at conjunction with computer sheets

10 73 water level date shown
Water inflow
Partial drying water loss
Complete drying water loss

Depth m Bore hole White

5277 I
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

| Drilling information | | | | | | Rock Substance | | Rock Mass Defects | | | | | |
|----------------------|---------------|--------|-------|-------------------------------------|---------------|----------------------------------|--|-------------------|---------------------|---|-------------------------------|--|--|
| Method | Drilling rate | Casing | Water | Pressure test (kg/cm ²) | Core recovery | Depth (metres) | Substance description
rock type, grain characteristics
colour, structure, minor components | Weathering | Defect spacing (cm) | Defect description
thickness, type, orientation, planarity,
roughness, coating, strength | Rock condition (interpretive) | | |
| DIAMOND | TESTED | | | | 100 | 10.0 | Mudstone with interbedded sandstone. | Z3 | 0 | Bedding 25°, very close, rough (minor smooth with clay 10mm). Limonite 1-2mm, strongly to weakly cemented. | | | |
| | | | | | | 11.0 | sandstone. | MW | 30 | Joints close to very close, mainly rough, strongly cemented, (minor smooth, clay coated). | | | |
| | | | | | | 12.0 | Mudstone, minor sandstone. | Z3 | 40 | 40mm clay on bedding. | | | |
| | | | | | | 13.0 | Sandstone. | MW | 60 | Bedding 40° close, rough, joints 70° close, rough, open 0-1mm. Limonite 1-2mm, weakly to strongly cemented. | | | |
| | | | | | | 14.0 | Mudstone. | MW | 60 | Joints close 40°, 25°, rough, Limonite and pyrolusite 1-2mm, weakly cemented. | | | |
| | | | | | | 15.0 | Mudstone light brown to dark-grey with minor sandstone bands. | Z3 | 84 | Bedding 40°, very close, planar and irregular, rough, limonite 0-4mm, strongly cemented. Joints 25°, close, rough. Limonite 4mm, strongly cemented. | | | |
| | | | | | | 16.0 | Grey mudstone, some ferruginous zones. | Z3-4 | 85 | Dip 45°-50°. Slightly observable joints, normal to the dip. Fractured zone at 16.3 - 16.4m. | | | |
| | | | | | | 17.0 | Brown mudstone, sandstone & clay. | Z2 | 0 | Fractured zone and weathered joints up to 35cm thick partly clay filled. | | | |
| | | | | | | 18.0 | | | | | | | |
| | | | | | | 19.0 | | | | | | | |
| | | | | | | End of Hole 18.5m.
(R.L. 11m) | | | | | | | |

Drill type - GEMCO 110A
Tool - HYDRAULIC
Core barrel type - N.M.S.
DOUBLE TUBE
Driller - J. JAMES
Commenced - 29-9-77
Completed - 30-9-77
Logged by - TRAND/BAILLEY
Vertical scale - 2cm:1m

Weathering

Ff - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)

Water

10 Oct 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No

Depth (m) Black & White Colour

5277 1

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - values in sugons should be read in conjunction with computation sheets

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (θ) - 90°
CO-ORDINATESDIRECTION
R.L. OF COLLAR 16.4m

SHEET 1 OF 2

| Drilling Information | | | | | | Rock Substance | | Rock Mass Defects | | | | | |
|----------------------|---------------|--------|-------|--|--------------------------|----------------|----------------------------|---|------------|---------------------------------|---------------------------|---|---|
| Method | Drilling rate | Casing | Water | Pressure test
test #
(megapascals) | Loss of
core recovery | Depth (metres) | Graphic log
B core loss | Substance description
rock type, grain characteristics,
colour, structure, minor components | Weathering | Point load
strength
(MPa) | Defect
spacing
(cm) | Defect description
thickness, type, inclination, planarity,
roughness, coating, strength | Rock
condition log
(interpretive) |
| AUGER | | | | | | 0 | | Fill | | | | | |
| | | | | | | 10 | | | | | | | |
| DIAMOND | | | | | | 20 | | | | | | | |
| | | | | | | 30 | | | | | | | |
| | | | | | | 40 | | Sandy Grey clay.
COLLUVIUM | | | | P.P. 240 - 500 kPa | |
| | | | | | | 50 | | | | | | | |
| | | | | | | 60 | | | | | | | |
| | | | | | | 70 | | Silurian siltstone | Z2 | | | Chips of siltstone in clayey
matrix. | |
| | | | | | | 80 | | Silurian mudstone. | Z2-3 | | | Weathered joints, some of
them clay filled.
Cross bedded
dip - 45°
8.3m-8.6m thick joint
-clay filled. | |
| | | | | | | 90 | | | | | | | |
| | | | | | | 100 | | | | | | | |
| | | | | | | | | | | | | | |

Drill type 210 B GEMCO
Feed HYDRAULIC
Core barrel type N.M.L.C.
Driller SOIL MECH. PTY. LTD.
Commenced 1/8/77
Completed 2/8/77
Compiled by G. TRAND
Vertical scale 2 cm = 1 m

Weathering P.P. POCKET PENETROMETER READING
Fr Fresh (Z5)
SW Slightly weathered (Z4)
MW Moderately weathered (Z3)
HW Highly weathered (Z2)
LW Extremely weathered (Z1)
Notes
Bedding & joint planes Angles are measured relative to a plane normal to the core axis
Water Pressure tests values in megapascals should be read in conjunction with compilation sheets

10 Oct 73 water eye date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No.
Depth in Bore & White Colour
S277 K
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°)
CO ORIENTATES

-30°

DIRECTION

H L OF COLLAR 16.4m

SHEET 2 OF 2

| Drilling Information | | | | | | Rock Substance | | Rock Mass Defects | | | | | |
|----------------------|---------------|--------|-------|----------------------------|-----------------------|----------------------------------|-------------------------|---|------------|--|---------------------|---|----------------------------------|
| Method | Drilling rate | Casing | Water | Pressure test + (optional) | U/L & % core recovery | Depth (metres) | Graphic log & core loss | Substance description
rock type grain characteristics
colour, structure, mineral components | Weathering | Pore load strength
0 100 200 300 is (Schmidt) | Defect spacing (cm) | Defect description
thickness, type, inclination, longevity, roughness, coating, strength
Particular General | Rock condition No (intermediate) |
| DIAMOND | | | | NOT TESTED | | 10.0 | | | | | | | |
| | | | | | | 11.0 | Mudstone | 22-3 | | | 0 | Vertical joints, most of them open and fractured. | |
| | | | | | | End of hole 11.7 m.
R.L. 4.7m | | | 50 | Moderately jointed not cemented. | | | |
| | | | | | | 12.0 | | | | | | | |

Drill type 210.B. GEMCO
Feed HYDRAULIC
Core barrel type NMLC
Driller SOIL MECH. PTY. LTD.
Commenced 1/8/77
Completed 2/8/77
Logged by G. TRAND
Vertical scale 2cm = 1m.

Weathering

F - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)

Notes

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - Values in parentheses should be read in conjunction with computation sheets

Water

10 Oct 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No

Depth (m) Black & White Colour

5277 K

GEOLOGICAL LOG OF DRILL HOLE

DIRECTION
H.L. OF COLLAR 19.95m

SHEET 1 of 2

| Drilling Information | | | | Rock Substance | | Rock Mass Defects | | | |
|----------------------|---------------|--------|-------|-------------------------------------|---------------|-------------------|--|------------|---------------------|
| Method | Drilling rate | Casing | Water | Pressure test (kg/cm ²) | Core recovery | Depth (metres) | Substrate description | Weathering | Defect spacing (cm) |
| | | | | | | | | | |
| | | | | | | 1.0 | Road Metal Fill | | |
| | | | | | | 2.0 | Sandy clay dark brown. | | |
| | | | | | | 3.0 | | | |
| | | | | | | 4.0 | | | |
| | | | | | | 5.0 | Sandy clay, brown | | |
| | | | | | | 6.0 | Clayey sand light brown. | | |
| | | | | | | 7.0 | | | |
| | | | | | | 8.0 | Sand, light brown, fine angular quartz grains. | | |
| | | | | | | 9.0 | Sand with very minor clay light brown. | | |
| | | | | | | 10.0 | | | |

| | | | |
|--|---|--|----------------------------------|
| <p>GEMCO 210 B
HYDRAULIC</p> <p>Soil Mech.</p> <p>JAMES</p> <p>28-7-77</p> <p>28-7-77</p> <p>J. BAILEY</p> <p>P. RUSSELL</p> <p>2cm - 1m</p> | <p>Weathering</p> <p>X^P Piezometer</p> <p>→ Bagged sample location</p> <p>SW: slightly weathered</p> <p>MW: moderately weathered</p> <p>HW: highly weathered</p> <p>CA: fully weathered</p> <p>Bedrock</p> <p>Water level test</p> | <p>Water</p> <p>Water level</p> <p>Water level</p> <p>Water level</p> <p>Water level</p> | <p>5277 K</p> <p>(O.C. Melb)</p> |
|--|---|--|----------------------------------|

GEOLOGICAL LOG OF DRILL HOLE

| Geological description | | Rock description | | Rock mass etc. | | Notes |
|------------------------|--------------|--------------------------------------|----------------|--------------------|--------------------------------------|-------|
| Depth (m) | Interval (m) | Rock description | Rock mass etc. | Defect spacing (m) | Notes | |
| 10.0 | 11.0 | Sand, grey-brown | | | | |
| 12.0 | 13.0 | Clayey sand, light brown | | | Firm damp. | |
| 14.0 | 15.0 | Possible NW Dyke material recovered. | | | | |
| 16.0 | | End of hole 15.5m (RL + 4.5m) | | | | |
| | | | | | N.B. Logging of bagged samples only. | |

GEMCO 210B
HYDRAULIC
J. JAMES
28-7-77
28-7-77
D. BAILEY
D. Pungell
2cm = 1m

Sample locations

1. Fresh
2. 1/2 way weathered
3. 3/4 way weathered
4. 1/2 way weathered
5. 3/4 way weathered
6. 1/2 way weathered
7. 3/4 way weathered
8. 1/2 way weathered
9. 3/4 way weathered
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99. 3/4 way weathered
100. 1/2 way weathered

Note



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96. 3/4 way weathered
97. 1/2 way weathered
98. 3/4 way weathered
99. 1/2 way weathered
100. 3/4 way weathered

Scale 1:1000

S277 K

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°) - 90° DIRECTION --
R. OF COLLAR 20.2

SHEET 1 OF 2

| Drilling Information | | | | Rock Description | | Rock Mass Details | | | |
|----------------------|---------|-------|----------|------------------|--|-------------------|------|--------|--|
| Drilling Rate | Logging | Water | Pressure | Depth (m) | Stratigraphic | Weathering | Unit | Defect | Notes |
| | | | | | | | | | |
| | | | | 0.0 | Fill | | | | |
| | | | | 1.0 | Sand clay, dark grey angular sand grains. | | | | Damp soft. |
| | | | | 2.0 | Sandy clay grey-brown. | | | | 1 litre of water added while Augering. |
| | | | | 3.0 | Clay samples for mineralogy taken from the following depths: 5.5, 6.3, 7.0, 8.0, 9.0, 10.0, 11.0 and 12.0 m. | | | | Tube sample N° 13-0-10 Stiff damp. |
| | | | | 4.0 | | | | | Tube sample N° 13-0-41 Stiff damp. |
| | | | | 5.0 | | | | | 1 litre of water added. |
| | | | | 6.0 | Clayey sand light brown. | | | | Tube sample N° 13-0-2/2 Stiff dry. |
| | | | | 7.0 | Sand, white. | | | | 1 litre of water added. |
| | | | | 8.0 | Gravelly clayey sand light brown. | | | | SPT 48 blows/300mm |
| | | | | 9.0 | Sand white to light brown. | | | | SPT 28 blows/300mm Sand wet. |
| | | | | 10.0 | Sand white clean mostly angular quartz. | | | | SPT 75 blows/300mm |

GEMCO 110 A
HYDRAULIC
NMS
DOUBLE TUBE
(SOIL MECH)
J. JAMES
1-10-77
3-10-77
J. D. BAILEY
D. P. BAILEY
2cm 1m

Weathering
Fresh
Slightly weathered
Moderately weathered
Highly weathered
Fully weathered
Disintegrated

Water
Fresh
Slightly weathered
Moderately weathered
Highly weathered
Fully weathered
Disintegrated

S277 K
(O.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

| Drilling Information | | | | | | Rock Substance | | Rock Mass Defects | | | | | | |
|----------------------|---------------|--------|-------|--------------------------|------------------------|----------------|---|-------------------|---------------------------|---------------------|--------|--|-----------------------------------|--|
| Method | Drilling rate | Casing | Water | Pressure test * (lugons) | Lift & % core recovery | Depth (metres) | Substance description
rock type grain characteristics
colour, structure, minor components | Weathering | Point load strength (MPa) | Defect spacing (cm) | R.O.D. | Defect description
thickness, type, inclination, planarity,
roughness, coating, strength
Particular General | Rock condition No. (interpretive) | |
| AUGER | | | | | | 10.0 | Sand, white. | | | | | Dry. | | |
| | | | | | | 11.0 | | | | | | - Sample for clay mineralogy | | |
| | | | | | | 12.0 | Clayey silty sand
red brown to brown | | | | | - Damp
Sample for clay mineralogy | | |
| | | | | | | 13.0 | Igneous dyke
Brown silty clay. | EW | | | | | | |
| | | | | | | 14.0 | Igneous dyke,
white to brown,
fine to medium
grained
Quartz, feldspar. | HW | | | | Joints close, open,
smooth to rough, clay
0-50mm, quartz 0-3mm.
Dip 78°, 18°, 50°.
Weakly
cemented in places. | | |
| | | | | | | 15.0 | | | | | | | | |
| | | | | | | 16.0 | Igneous dyke,
light brown,
limonite replaced
Pyrite, quartz,
feldspar. | MW | | | | Joints close to moderate
rough, planar. Limonite
2-5mm, clay 0-7mm
Weakly to strongly
cemented.
Dip 60°, 70°, 30°, 50°. | | |
| | | | | | | 17.0 | | | | | | | | |
| | | | | | | 18.0 | | | | | | Joints close with dip.
75°, 43°.
Rough, limonite 2-15mm
weakly to strongly
cemented. | | |
| | | | | | | 19.0 | | | | | | | | |
| Core | | | | | | 20.0 | End of hole 20.0m
(R.L. 0.2.) | | | | | | | |

Drill type GEMCO 11A
Feed HYDRAULIC
Core barrel type NMS
DOUBLE TUBE
Driller J. JAMES
Commenced 1-10-77
Completed 3-10-77
Signed by J. D. BAILEY
D. W. ACCELL
Vertical scale 2cm = 1m

Weathering
F. Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered
Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests - values in lugons should be read in conjunction with computation sheets

Water
10 Oct 73 water level data shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Use Photograph Negative No.
Depth 1m Black & White Colour
5277 K

GEOLOGICAL LOG OF DRILL HOLE

DIRECTION
R L OF COLLAR 21.1 m

SHEET 1 OF 2

| Drilling Information | | | | | | | Rock Substance | | Rock Mass Defects | | | | |
|----------------------|---------------|--------|--------|-------------------------------------|------------------------|----------------|------------------------|---|----------------------|---------------------|---|--------|--------|
| Method | Drilling Time | Casing | Water | Pressure Test (kg/cm ²) | Lit. B % core recovery | Depth (metres) | Grains of G. core logs | Substance description
rock type grain characteristics
colour, structure, these components | Weathering | Defect spacing (cm) | Defect description
Defect size (cm)
No. Mass type orientation dip/slope
roughness, coating, strength
Particular | Defect | Defect |
| DIAMOND | NOT | CORED | TUNNEL | DONE | NOT | 0 | | Fill | | | | | |
| | | | | | | 1.0 | | Soft sandy clay and brown clay | | | Sample N° 13-0-71 | | |
| | | | | | | 2.0 | | | | | See tests on undisturbed samples. | | |
| | | | | | | 3.0 | | | | | Sample N° 13-0-5 | | |
| | | | | | | 4.0 | | Grey-brown sandy, gravelly clay. Poorly sorted material ranging from clay to gravel; grains of quartz. | | | | | |
| | | | | | | 5.0 | | | | | | | |
| | | | | | | 6.0 | | Firm clay alternating grey and brown. | | | Clay horizontally layered. | | |
| | | | | | | 7.0 | | | | | Sample N° 13-0-60 | | |
| | | | | | | 8.0 | | | | | Sample N° 13-0-61 | | |
| | | | | | | 9.0 | | | | | Material soft. | | |
| DIAMOND | NOT | CORED | TUNNEL | DONE | NOT | 10.0 | | Top of the silurian mudstone. A few chips of ferruginous sandstone. Alternating hard S.S.T. bands with E.W. mudstone. | Z1 | | Increasing amount of ferruginous sandstone with depth. Dip of beds is 30° | | |
| | | | | | | 11.0 | | Sandstone minor mudstone. | EW to HW
HW to MW | | Fractured sandstone Dip 30°-40°
Mudstone more weathered. | | |

Drill type 210 B GEMCO
Feet. HYDRAULIC
Core barrel type NMLC
Driver SOIL MECH. PTY. LTD
Commenced 2/8/77
Completed 3/8/77
Logged by G. TRAND
D. FURCELL
Vertical scale 2cm - 1m

Weathering
F Fresh (Z5)
SW Slightly weathered (Z4)
MW Moderately weathered (Z3)
HW Highly weathered (Z2)
EW Extremely weathered (Z1)

Notes
Bedding is Joint Planes. Angles are measured relative to a plane normal to the core axis.
Water Pressure Tests. Values in brackets should be read in conjunction with computation sheets.

Water

10. 50. 75 water level date shown
Water inflow
Partial during water loss
Complete during water loss

Core Photograph Negative No.
Depth m Black & White Colour

5277 J

(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

DIRECTION
R L OF COLLAR 21:1 m

SHEET 2 OF 2

| Drilling Information | | | | | | | Rock Substance | | Rock Mass Defects | | | | | | |
|----------------------|---------------|--------|-------|---------------------------------------|---------------------------|--|--|------------|--------------------------|---------------------|---|---|------------|---------|-------|
| Memo | Drilling rate | Casing | Water | Pressure test * (kg/cm ²) | Lithology & core recovery | Depth (metres) | Substance description:
rock type grain characteristics
colour, structure, minor components | Weathering | Pore load strength (MPa) | Defect spacing (cm) | Defect description:
thickness, type, inclination, planarity,
roughness, coating, strength | | Particular | General | Notes |
| DIAMOND | | | | | DONE | 8.2m to 13.0 m
Broken rock, numerous short runs | Sandstone and mudstone. | ZZ | | | | Jointing at 80°-90°
Bedding at 25°. Joints partly open. Joint at 12.4 is extremely weathered.
One joint set is normal to the bedding. | | | |
| | | | | | NOT | 100 | Sandstone, minor mudstone. | | | | | | | | |
| | | | | | 100 | | | MW | | | | | | | |
| | | | | | 100 | | | | | | | | | | |
| | | | | | | 15.0 | End of Hole 15.4 m
(R.L. 4.7 m) | | | | | | | | |
| | | | | | | 16.0 | | | | | | | | | |

Drill type 210 B GEMCO

Feed - - HYDRAULIC - -

Core barrel type NMLC - - -

Drilling SOIL MECH. PTY. LTD

Commenced 2/8/77

Completed 3/8/77

Issued by G. TRAND

2000-2001

weathering

Fi - Fresh (25)

SW - Slightly weathered (Z4)

MW - Moderately weathered (23)

HW Highly weathered (22)

EW Extremely weathered (Z1)

NOTES

Bedding & Joint Pinges - Angles are measured relative to a plane normal to the core axis.

A Water Pressure Tests values in lugans should be read in conjunction with computation sheets

Water

10 Oct 73 water level date shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photograph Negative No

Depth (m). Block B White Colour

S277 J

HOF NO 25

Sheet 1 of 3

| | | |
|--|---|--|
| Drill Type MINDRILL DIAMOND
Feed HYDRAULIC
Core Barrel Type NMS
DOUBLE TUBE
Driller J. JAMES
Commenced 8-8-77
Completed 15-8-77
Logged by J. D. BAILEY
D. ARGENT
Drill Hole Size 2 cm x 1 m | Weathering
Fr. Fresh (Z5)
SW. Slightly weathered (Z4)
MW. Moderately weathered (Z3)
HW. Highly weathered (Z2)
LW. Extreme weathered (Z1)
Faults
Bedding W. 30° N. 30° E. Angles are measured relative to a plane normal to the core axis.
• Water Pressure Tests values in parentheses should be read in conjunction with computer or sheets | Core Strength grade (negative for
Depth 1.5 m Block is white 0.00

5277 H
(D.C. Melb) |
|--|---|--|

GEOLOGICAL LOG OF DRILL HOLE

| Drilling information | | | | | Rock Substance | | Rock Mass Defects | | | | |
|----------------------|---------------|-----------|-------|-------------------------------------|----------------|--|-------------------|---------------------|---|---------------------|--|
| Method | Drilling core | Core size | Water | Pressure test (kg/cm ²) | Core recovery | Substance description
rock type, grain, colour, texture, structure, mineral composition | Weathering | Defect spacing (cm) | Defect description
the degree, type, orientation, periodicity, roughness, scaling, strength | Rock mass condition | |
| DIAMOND | TUNNEL | TESTED | NOT | | 100 | Sandstone with clay
5mm thick on bedding
planes at 10.50, 10.65,
10.8. | MW | 10 | Bedding 38°, smooth to rough;
clean to clay 5mm, planar;
close to very close.
Joints very close, open
86° 66° | | |
| | | | | | | Sandstone mudstone
Slump bed, brown
Thin Mudstone 15mm
silty sandstone
thinly bedded. | Z2
HW | 0
54 | Close to very close bedding
strongly to weakly
cemented.
Joints very close to close, 90°
66° rough, open. Bedding rough,
Limonite stained strongly cemented. | | |
| | | | | | | Sandstone light brown
Thinly bedded. | | 16 | Closely jointed clean to
Limonite stained, open, 85° 65°
Bedding tight to open (1mm)
rough, Limonite 0-1mm
weakly to strongly
cemented.
Bedding at 38° | | |
| | | | | | | Thin mudstone. | | | | | |
| | | | | | | Sandstone mudstone
slump beds
(Sandstone band)
brown to green brown | MW | 40 | Joints 45° Limonite 1-2mm
open, close, rough. | | |
| | | | | | | Sandstone thinly
bedded, light brown | | 45 | Bedding very close, rough, tight
to open 0.5mm
Strongly to
weakly cemented, joints
close to very close rough open
1mm, Limonite 0-1mm
90°, 80°, 60°
2mm clay on joint 90° | | |
| | | | | | | Mudstone with minor
thin siltstone inter-
bedded. | | 38 | Bedding, very close, tight to rough
35° Strongly to
weakly cemented. Joints close
tight, rough SST joints very
close. | | |
| | | | | | | Sandstone bed.
Mudstone with minor thin
siltstone interbedded.
Mudstone with minor
sandstone - mudstone
slump material at top and
base of bed. | Z3 | 90 | Bedding tight, close, rough,
Strongly to
weakly cemented
jointing and bedding. | | |
| | | | | | | Sandstone, light brown | MW | 16 | Bedding very close to close,
rough, weakly to strongly
cemented, 34°
Joints close to very close,
open 1mm, weakly to strongly
cemented.
85° 60° 65°
Clay on bedding at 19.20, 5mm. | | |
| | | | | | | Mudstone, green-brown
to brown. | Z3 | 56 | Bedding as above.
Joints moderately
spaced
Strong to weakly cemented | | |

Drill type MINDRILL DIAMOND

Feed HYDRAULIC

Core barrel type NMLC

Driller SOIL MECH. PTY LTD.

Commenced 8-8-77

Completed 15-8-77

Supplied by J. D. BAILEY
D. FORCELL
vertical scale 2cm = 1m

Weathering

Fr. Fresh

SW Slightly weathered

MW Moderately weathered

HW Highly weathered

EW Extremely weathered

Notes

Bedding & Joint planes

Water Pressure Tests

Water

100% 7.5 water level data shown

Water inflow

Partial drilling water loss

Complete drilling water loss

Core Photo page Negative No.

Depth 8 ft 8 in

5277 H

Angles are measured relative to plane normal to the core axis
Values in depths should be filled in conjunction with compilation sheets

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (Ø) 30°
CO-ORDINATESDIRECTION 030° MAG
R.L. OF COLLAR 21.08 m

SHEET 3 OF 3

| Drilling Information | | | | | Rock Substance | | Rock Mass Details | | | |
|----------------------|---------------|--------|-------|-------------------------------------|----------------|--|-------------------|---------------------------|---------------------|--|
| Method | Drilling rate | Casing | Water | Pressure test (kg/cm ²) | Depth (metres) | Substance description
rock type, grain characteristics, colour, structure, minor components | Weathering | Point load strength (MPa) | Defect spacing (cm) | Defect description
fracture type, inclination, frequency, roughness, sealing, strength |
| DIAMOND | TESTING | | | | 20.0 | Mudstone minor sandstone slump bed | Z3 | | | Bedding poorly developed |
| | | | | | 100 | Sandstone | MW | | | 39 Bedding close to mod. at 34°, Joints close, 55°-85° open 1mm rough weakly cemented. |
| | | | | | 21.0 | Mudstone minor sandstone slump bed | | | | 54 Bedding poorly developed joints open 1mm, rough, weakly cemented |
| | | | | | 22.0 | Mudstone green-brown to brown with minor S.S.T. bands 10-15mm thick. | | | | 32 Bedding very close, 34° tight, rough, 0-1mm Limonite, minor weakly to strongly cemented. Joints close-moderate spacing, 50°-65°. Strongly cemented, rough Limonite 1mm. Joints very close, open in S.S.T. |
| | | | | | 23.0 | | | | | |
| | | | | | 24.0 | Mudstone green-brown with minor sandstone bands 10mm thick | Z3 | | | Joints 45°-75° |
| | | | | | 25.0 | Evidence of shearing dip 70° Highly fractured | | | | 10 Bedding, very close, tight, smooth to rough; Strongly cemented, some weakly cemented. Clay 3mm on S.S.T. bed at 24.9m. Dip 34°. Joints tight to open 0.5mm. |
| | | | | | 26.0 | Mudstone, green-brown | | | | 0 Rough weakly to strongly cemented 45°-90°-75° |
| | | | | | 27.0 | minor S.S.T. band 10mm | | | | 82 Bedding planar, tight, strongly cemented, very close, Limonite 0-2mm. Dip 40°. Joints tight, strongly cemented, close, Limonite 1-2mm, rough, 40°-60°-80° |
| | | | | | 28.0 | Mudstone, green-brown to grey | | | | |
| | | | | | 29.0 | minor S.S.T. band 10mm at 27.0m. | Z3-4 | | | 80 Bedding irregular to planar at 34°, strongly cemented, very close. Joints close to moderate tight to open 1mm, rough weakly to strongly cemented Limonite 1-2mm, 65°-45° |
| | | | | | 30.0 | End of hole 27.9m (R.L. 7.93m) | | | | |

Drill type MINDRILL DIAMOND
Feed HYDRAULIC
Core barrel type HMS
DOUBLE TUBE
Driller SOIL MECH. PTY LTD.
Commenced 8-8-77
Completed 15-8-77
Signed by J.D. BAILEY
D. P. BAILEY
2cm 1m

Weathering

F - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
LW - Extremely weathered (Z1)

Notes

Bedding & Joint planes - Angles are measured relative to the normal to the core axis.
Water Pressure Tests - Values of strength should be noted in conjunction with compaction tests.

Water

100% 7.5 water level date shown.
Water inflow
Partial drying water loss
Complete drying water loss

Photograph negative file

Depth m. Block is white. Colour

5277 H

GEOLOGICAL LOG OF DRILL HOLE

| Drilling Information | | | | | Rock Substance | | Rock Mass Defects | | | | |
|----------------------|---------------|--------|-------|-------------------------------|------------------------|----------------|--|------------|---------------------|--|--------------------------------|
| Method | Drilling rate | Casing | Water | Pressure test # (megapascals) | Lift B % core recovery | Depth (metres) | Substance description
rock type, grain characteristics
colour, structure, mineral components | Weathering | Defect spacing (cm) | Defect description
the angles, type, inclination, planarity,
roughness, coating, strength
Particulars | Rock condition no. interpreted |
| DIAMOND | | | | TESTED | | 0 | Fill | | | | |
| | | | | | | 1.0 | Sandy clay, brown. | | | Stiff, damp
PP. 700-900 kPa | |
| | | | | | | 2.0 | | | | | |
| | | | | | | 3.0 | Dargile Formation
mudstone and
sandstone fragments
white clay. | Z1 | | Core very crumbly
Structure not visible. | |
| | | | | | | 4.0 | Interbedded mudstone
white with light brown
Sandstone (HW)
SST/Mudstone 1:3 | | | Bedding very close, 15°, greasy
clay 0-100mm, weakly
cemented. Joints very close
to close. Smooth to greasy,
clay 0-50mm weakly to
not cemented PP. (mudstone)
200-500 kPa. | |
| | | | | | | 5.0 | Mudstone with minor
sandstone (10%)
light brown. | Z2-3 | | Bedding 25°, very close;
clay 0-5mm, weakly to strongly
cemented, irregular to planar.
Joints 55°, 80°, smooth to
rough, clay 0-5mm, Limonite
0-1mm, weakly cemented
close to very close. | |
| | | | | | | 6.0 | Mudstone, light brown. | Z2 | | Highly fractured, crumbly
with clay up to 40mm on joints. | |
| | | | | | | 7.0 | Mudstone, minor
sandstone, light brown
Fault - clay, 80mm | Z3 | | Bedding very close, tight 30°-90°
Joints 50° 60° 90°, smooth to
rough, weakly cemented. | |
| | | | | | | 8.0 | Clay+mica
Mudstone with minor
sandstone. (10%) | EW
Z3 | | DYKE
Bedding very close, 30° tight
planar to irregular rough.
Limonite 0-1mm clay on
bedding 2mm at 7.40mm.
Joints 70°, 35° close to very close
(SST) Rough to smooth clay 0-20
weakly cemented. Limonite 0-1mm
Point Load sample. | |
| | | | | | | 9.0 | Beds of extremely
weathered mudstone
50-10mm thick at
8.7, 9.1m | Z3 | | Bedding 26°
Joints 40°, 70°, 90° | |
| | | | | | | 93 | | | | Bedding 20° | |
| | | | | | | 100 | | | | | |

Drill type: MINDRILL
Feed: HYDRAULIC
Core barrel type: NMS
DOUBLE TUBE
(SOIL MECH.)
Driller: J. JAMES
Commenced: 19-9-1977
Completed: 21-9-1977
Logged by: J. D. BAILEY
D. PURCELL
Vertical scale: 2cm = 1m

Weathering: P.P. Pocket Penetrometer
Reading:
Fr - Fresh (Z5)
SW Slightly weathered (Z4)
MW Moderately weathered (Z3)
HW Highly weathered (Z2)
EW Extremely weathered (Z1)

Water:
10 Oct 73 water level data shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No.
Depth in m: Back B White Colour
5277 L
(D.C. Melb)

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests - values in megapascals should be read in conjunction with computer sheets

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°) -45°
CO ORDINATESDIRECTION 060° MAG
R.L. OF COLLAR 27.6m

SHEET 2 OF 2

| Drilling Information | | | | | | Rock Substance | | Rock Mass (Defects) | | | | |
|----------------------|---------------|--------|-------|-------------------------------------|------------------------|----------------|--|---------------------|---------------------------|---------------------|---|-------------------------------|
| Method | Drilling rate | Casing | Water | Pressure test (kg/cm ²) | Lift B % core recovery | Depth (metres) | Substance description
rock type, grain characteristics
colour, structure, minor components | Weathering | Point load strength (MPa) | Defect spacing (cm) | Defect description
thickness, type, inclination, planarity,
roughness, coating, strength | Rock condition (interpretive) |
| DIAMOND | Tunnel | ↑ | | TESTED | | 10.0 | Mudstone with minor interbedded sandstone (10%) Light brown to Green-brown. | Z3 | 10000 | 30 | Bedding 25°, tight, irregular, very close, rough, limonite 0-1mm. Clay 4mm at 10.2 m strongly cemented. Joints 65°, 80°, irregular to planar. Close to very close, rough. Limonite 1mm strongly to weakly cemented. | |
| | | | | | | 100 | | | | | | |
| | | | | | | 11.0 | | | | | | |
| | | | | | | 12.0 | | | | | | |
| | | | | | | 13.0 | | | | | | |
| | | | | | | 14.0 | Mudstone, grey green to brown with minor interbedded sandstone (5%) | Z3-4 | 10000 | 33 | Bedding very close 20°. Joints close 70°, 80°. Limonite 1-2mm, mostly strongly cemented. | |
| | | | | | | 15.0 | | | | | | |
| | | | | | | 16.0 | | | | | | |
| | | | | | | 17.0 | | | | | | |
| | | | | | | 18.0 | | | | | | |
| | | | | | | 19.0 | | | | | | |
| | | | | | | 20.0 | | | | | | |
| | | | | | | | End of hole 20.0m (R.L. 13.5m) | | | | 5mm clay on bedding at 19.7m. | |

Drill type MINDRILL
Feed HYDRAULIC
Core barrel type N.M.S.
DOUBLE TUBE
Driver J. JAMES
Commenced 19-9-1977
Completed 21-9-1977
Logged by J.D. BAILEY
P. PURCELL
Vertical scale 2cm = 1m

Weathering
Fr - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EW - Extremely weathered (Z1)

Notes

Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis

* Water Pressure Tests - values in kg/cm² should be read in conjunction with compilation sheets

Water

10 Oct 73 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photograph Negative No.
Depth m Black & White Colour

5277 L

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (°) -45° DIRECTION 060° MAG
E.O. COORDINATES R.L. OF COLLAR 31.6 m

SHEET 1 OF 2

| Drilling Information | | | | | Rock Substrance | | Rock Mass Details | | | |
|----------------------|---------------|--------|-------|--------------------------|-----------------|----------------|--|------------|---------------------|---|
| Method | Drilling rate | Casing | Water | Pressure test - supports | Core recovery | Depth (metres) | Substrance description
Rock type, grain characteristics
Structure, mass, impurities | Weathering | Defect spacing (cm) | Defect description
Fracture type, orientation, planarity,
roughness, scaling, strength |
| DIAMOND | Not Core | | | | | 0 | Fill | | | |
| | | | | | | 10 | | | | |
| DIAMOND | Not Tested | | | | | 20 | | | | |
| | | | | | | 30 | Clay orange-brown
clay, white
Dargile formation
mudstone with
minor interbedded
sandstone (10%)
brown. | Z1 | | Damp firm.
R.P. 350 180a |
| | | | | | | 40 | | Z2 | | Bedding 30°, very close, open
clay, 1-30mm, smooth,
weakly cemented.
Joints 10°, 90°, very close,
open, clay 0-4mm,
Pyrolusite 0-1mm
weakly cemented |
| | | | | | | 50 | | Z3 | | Bedding 35°, very close,
weakly to strongly
cemented
smooth to rough
clay at 4.0, 4.5m (5mm thick)
Limonite 0-10mm
Joints 55°, 70°, 90°, close to
very close, (S.S.T.) open
1mm, weakly to strongly
cemented, Limonite 1-2mm |
| | | | | | | 60 | 50mm thick clay seam
parallel to bedding. | | | Clay 3-10mm on bedding
at 4.8, 5.0, 6.0m
Clay 3mm on joints at 6.0m |
| | | | | | | 70 | | | | Bedding 30° very close
weakly to strongly cemented
smooth (minor) to rough,
planar to irregular.
Limonite 0-2mm, clay 1-3mm
at 8.35, 8.70m.
Joints 75°, 50°, close,
weakly to strongly
cemented, rough, limonite
1-2mm. Smooth clay
coated 1-3mm at 8.35,
8.70m. |
| | | | | | | 80 | | Z2 | | |
| | | | | | | 90 | | Z3 | | Point load sample |
| | | | | | | 100 | | Z3-4 | | Clay 3mm on joints at
9.7m. |
| | | | | | | 100 | | | | |

Unit type MINDRILL
Feed HYDRAULIC
Core barrel type NMS
DOUBLE TUBE
(SOIL MECH.)
Driver J. JAMES
Commenced 21-9-1977
Completed 23-9-1977
Logged by J. D. BAILEY
D. PURCELL
Vertical scale 2cm = 1m

Weathering R.P. Pocket Penetrometer
Reading.
Fr. Fresh (Z5)
SW. Slightly weathered (Z4)
MW. Moderately weathered (Z3)
HW. Highly weathered (Z2)
EW. Extremely weathered (Z1)

Water
10 11 73 water eye date shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core Photo-graph Negative No.
Depth m. 5277 U

(D.C. Melb)

Bedding & Joint Planes - Angles are measured relative to plane normal to the core axis
Water Pressure Tests - values in ugeans should be read in conjunction with computation sheets

GEOLOGICAL LOG OF DRILL HOLE

| Drilling Information | | | | | Rock Substrata | | Rock Mass (effects) | | | |
|----------------------|---------------|---------------|-------------------|----------------------|--|------------|---------------------|--|------------|----------------|
| Drill type | Drilling rate | Drilling time | Drilling pressure | Drilling temperature | Substrata description
rock type, grain characteristics,
color, structure, other components | Weathering | Defect spacing (cm) | Defect description
thickness, type, inclination, frequency,
roughness, scaling, strength | Rock color | Rock condition |
| DIAMOND | T.M.C. | 100 | 100 | 100 | Mudstone, light brown to grey. | Z3-4 | | Limonite on bedding and joints 1-5mm, rough. Mostly strongly cemented. | | |
| | | | | | Few sandstone bands 5mm thick. | Z3 | 43 | | | |
| | | | | | | Z3-4 | 73 | Joints 70° moderately spaced.
40mm clay on bedding at 12.7m. | | |
| | | | | | Few sandstone bands 5-30mm thick. | Z3 | 60 | Joints in sandstone very close, rough, strongly cemented, Limonite 1-3mm. | | |
| | | | | | | Z3-4 | 90 | | | |
| | | | | | | Z3 | 27 | Bedding and joints very close to close, weakly to strongly cemented smooth to rough. Dip 30° Joints in sandstone. Some open. Dip 70°, 60°, 90°, 45°. | | |
| | | | | | Sandstone bands (10%) from 5-70mm thick. | Z3-4 | 41 | 10mm clay on bedding at 18.4m. | | |
| | | | | | | Z3 | | Bedding and joints mostly strongly cemented. | | |
| | | | | | | Z3-4 | | | | |
| | | | | | End of hole 19.7m. (R.L. 17.7m) | | | | | |

Drill type MINDRILL
Feed HYDRAULIC
Core barrel type NMS
DOUBLE TUBE
Driller J. JAMES
Commenced 21-9-77
Completed 23-9-77
Logged by J. D. BAILEY
D. PURCELL
checked by J. D. BAILEY

Weathering

F. Fresh (Z 5)
SW. Slightly weathered (Z 4)
MW. Moderately weathered (Z 3)
FW. Highly weathered (Z 2)
EA. Extremely weathered (Z 1)
None

Bedding & joint traces. Angles are measured relative to a plane normal to the core axis.
Water Pressure Tests. Values in parentheses should be used in conjunction with computation sheets.

Water

0. 0. 73 water level date shown
Water inflow
Partial flowing water loss
Complete flowing water loss

Core Photograph Negative No.

Depth m. Back to White. Color.

5277 U

GEOLOGICAL LOG OF DRILL HOLE

| Drilling Information | | | | | Rock Substance | | Rock Mass (Defects) | | | | |
|----------------------|---------------|--------|-------|---------------------|----------------|---|---------------------|---------------------------|---------------------|--|---------------------------------|
| Method | Drilling rate | Casing | Water | Pressure test (top) | Depth (metres) | Substance description
rock type, grain characteristics,
colour, structure, minor components | Weathering | Point load strength (MPa) | Defect spacing (cm) | Defect description
thickness, type, inclination, planarity,
roughness, coating, strength
(Particular General) | Rock condition & interpretation |
| DIAMOND | | | | | 0 | Fill | | | | | |
| | | | | | 1.0 | Sandy clay, coarse sand grains, brown | | | | Damp soft, stiff
P.P. 350-500 kPa | |
| | | | | | 2.0 | Sandy clay light brown | | | | Damp soft
P.P. 200 kPa | |
| | | | | | 3.0 | Sand and gravel. | | | | Damp stiff
P.P. 500-600 kPa | |
| | | | | | 4.0 | Sandy clay, grey to light brown. | | | | Damp soft
P.P. 300 kPa | |
| | | | | | 5.0 | Ironstone fragments | | | | | |
| | | | | | 6.0 | Dargile Formation mudstone, white | Z1 | | | Damp, stiff
P.P. 500 kPa | |
| | | | | | 7.0 | Sandstone, Light brown. | MW | | | Bedding 38°, very close to close, planar, open 0-0.5mm, smooth, mainly clean, (uncemented) | |
| | | | | | 8.0 | Mudstone, brown. | Z3 | | | Joints 70°, 45° very close to close, open, 0-0.5mm, planar to irregular, smooth to rough, uncemented to weakly cemented, clay 0-30mm but mostly clean. | |
| | | | | | 9.0 | Sandstone light brown | MW | | | Clay on bedding and joints 30mm | |
| | | | | | 10.0 | Mudstone, brown. | Z3 | | | Bedding 42°, smooth to rough, weakly to strongly cemented. | |
| | | | | | | Sandstone, brown. | MW | | | Limonite 0-1 mm, some clay. | |

Unit type GEMCO 110 A
Feed HYDRAULIC
Core barrel type N M S
DOUBLE TUBE
(SOIL MECH)
Driver J. JAMES
Commenced 27-9-77
Completed 27-9-77
Logged by J. D. BAILEY
D. PURRELL
Vertical scale 2cm = 1m

Weathering PP Pocket Penetrometer
Fr. Fresh (Z5) Reading.
SW Slightly weathered (Z4) R. Penetrometer
MW Moderately weathered (Z3)
HW Highly weathered (Z2)
LW Extremely weathered (Z1)

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
Note: Pressure Tests - values in parentheses should be read in conjunction with computer sheets

Water
10 to 73 water level data shown
Water flow
Partial drilling water loss
Complete drilling water loss

Core Plot graph Negative to
Depth in Box B White

5277 T
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL (H) - 90°
CO-ORDINATES

SHEET 2 OF 2

| | | |
|--|---|--|
| Skin type GEMCO 11QA
Feed HYDRAULIC
Core barrel type NMS
DOUBLE TUBE
Operator J. JAMES
Completed 27/9/77
Logged 27/9/77
Logged by J. D. BAILEY
D. PURCELL
Core size 2 cm = 1m | Weathering
Fr - Fresh (Z5)
SW - Slightly weathered (Z4)
MW - Moderately weathered (Z3)
HW - Highly weathered (Z2)
EA - Extreme weathered (Z1)
Notes
Heading 14.5° to the right. Angles are measured relative to the plane normal to the core axis.
v - Note: Pressure tests - values in brackets should be used in conjunction with compressive strengths | Water:
 1. 0.1 - 0.3 water level date shown
Water inflow
Partial drilling water loss
Complete drilling water loss
Core status: Negative for
Depth: 8 ft 10 in White
5277 T |
|--|---|--|

GEOLOGICAL LOG OF DRILL HOLE

| Drilling Information | | | | | | Rock Substance | | Rock Mass Details | | | | |
|----------------------|---------------|--------|-------|------------------------|---------------|----------------|---|-------------------|---------------------------|--|---|----------------|
| Remarks | Drilling rate | Casing | Water | Pressure test (logons) | Core recovery | Depth (metres) | Substance description
rock type, grain characteristics
structure, texture, other components | Weathering | Point load strength (kPa) | Defect spacing (cm) | Defect description
the angles, type, inclination, planarity,
roughness, scaling, strength | Rock condition |
| DIAMETER | | | | | 0 | 0 | Fill | | | | | |
| | | | | | | 10 | Sandy clay, brown, coarse rounded quartz. with few pebbles | | | | Damp stiff
PP 600-900 kPa | |
| | | | | | | 2.0 | Dargile Formation mudstone with interbedded sandstone | Z1 | | | Damp firm to stiff
P.P. 400-800 kPa | |
| | | | | | | 3.0 | Mudstone with interbedded sandstone bands, 100-300mm thick. | Z1-2 | | | Bedding 35° close to very close, smooth. | |
| | | | | | | 4.0 | Mudstone/sandstone 1:1 White to light brown. | | | Joints 70° Open, weakly cemented, clay coated | | |
| | | | | | | 5.0 | Soft crumbly SST with clay. | | | P.P. (Mudstone) 300-500 kPa | | |
| | | | | | | 6.0 | Mudstone with minor thin sandstone beds brown. | Z2 | | | Bedding 30° tight irregular very close, smooth, clay 0-5mm, weakly cemented. | |
| | | | | | | 7.0 | | | | Joints 70° close (open SST) weakly cemented, smooth to rough, limonite 0-2mm clay 0-2mm. | | |
| | | | | | | 8.0 | Mudstone, white | Z1 | | | 60mm clay on bedding. | |
| | | | | | | 9.0 | Mudstone with interbedded sandstone light brown | Z1-2 | | | Bedding 33° irregular, smooth to rough, clay 0-50mm, weakly cemented. | |
| NOT TESTED | | | | | 100 | 10.0 | | | | Joints 70° close, rough, limonite 0-3mm (open SST) mostly tight. | | |

Drill type GEMCO 110A
Feed HYDRAULIC
Core barrel type NM-S
DOUBLE TUBE
(SOIL MECH)
Driver J. JAMES
Commenced 28/9/77
Completed 28/9/77
Logged by J. D. BAILEY
D. Purcell
2cm x 1m

Weathering P.P. Pocket Penetrometer Water
Fr. Fresh (Z5) Reading
SW Slightly weathered (Z4)
MW Moderately weathered (Z3)
HW Highly weathered (Z2)
EW Extremely weathered (Z1)
Notes
Bedding & joint planes. Angles are measured relative to a plane normal to the core axis.
* Water Pressure Tests values in logons should be read in conjunction with computation sheets

10 75 water eye date shower
Water flow
Partial drying water loss
Complete drying water loss

Core Photograph Negative No.
Depth m Black & White colour

S277 Q
(D.C. Melb)

GEOLOGICAL LOG OF DRILL HOLE

SHEET 2 OF 2

| Drilling Information | | | | | | Rock Substance | | Rock Mass Defects | | | |
|----------------------|---------------|--------|-------|---------------------|--------------------------|----------------|--|-------------------|---------------------------|---------------------|---|
| Method | Drilling rate | Casing | Water | Pressure test (Mpa) | Split Bore core recovery | Depth (metres) | Substance description
rock type, grain characteristics
colour, structure, mineral components | Weathering | Point load strength (MPa) | Defect spacing (cm) | Defect description
thickness, type, inclination, planarity,
roughness, ending, strength
strike-slip |
| DIAMOND | | | | Not Tested | | 10.0 | Mudstone, grey, light brown with minor sandstone bands. | ZZ | | | Bedding 35°, very close, smooth to rough
Limonite 0-3mm, clay
Joints 50°, close, rough
Limonite 3mm. |
| | | | | | | 110 | | | | | |
| | | | | 3/10/77 | | 120 | Sandstone, light brown. | MW | | 45 | Bedding 35°, close, clay
0-30mm, Limonite 3mm
Joints 50°, 90°, very close to close, rough, Limonite 1-2 mm, weakly cemented |
| | | | | | | 130 | End of hole 12.5m (R.L. approx. 16.88m) | | | | |

Drill type GEMCO 110 A
Feed HYDRAULIC
Core barrel type N.M.S.
DOUBLE TUBE
Driller J. JAMES
Commenced 28/9/77
Completed 28/9/77
Signed by J. D. BAILEY
B. PURCELL
Vertical scale 2cm = 1m

Weathering
F Fresh (Z 5)
SW Slightly weathered (Z 4)
MW Moderately weathered (Z 3)
HW Highly weathered (Z 2)
EW Extremely weathered (Z 1)

Water
0 0.1 0.2 0.3 water level shown
Water inflow
Partial drilling water loss
Complete drilling water loss

Core and sample negative for
Depth in Black B, White

5277 Q

Bedding, Joint, Fracture Angles are measured relative to plane normal to the core axis
Note: Pressure Tests - values in Mpa should be used in conjunction with computer or sheets

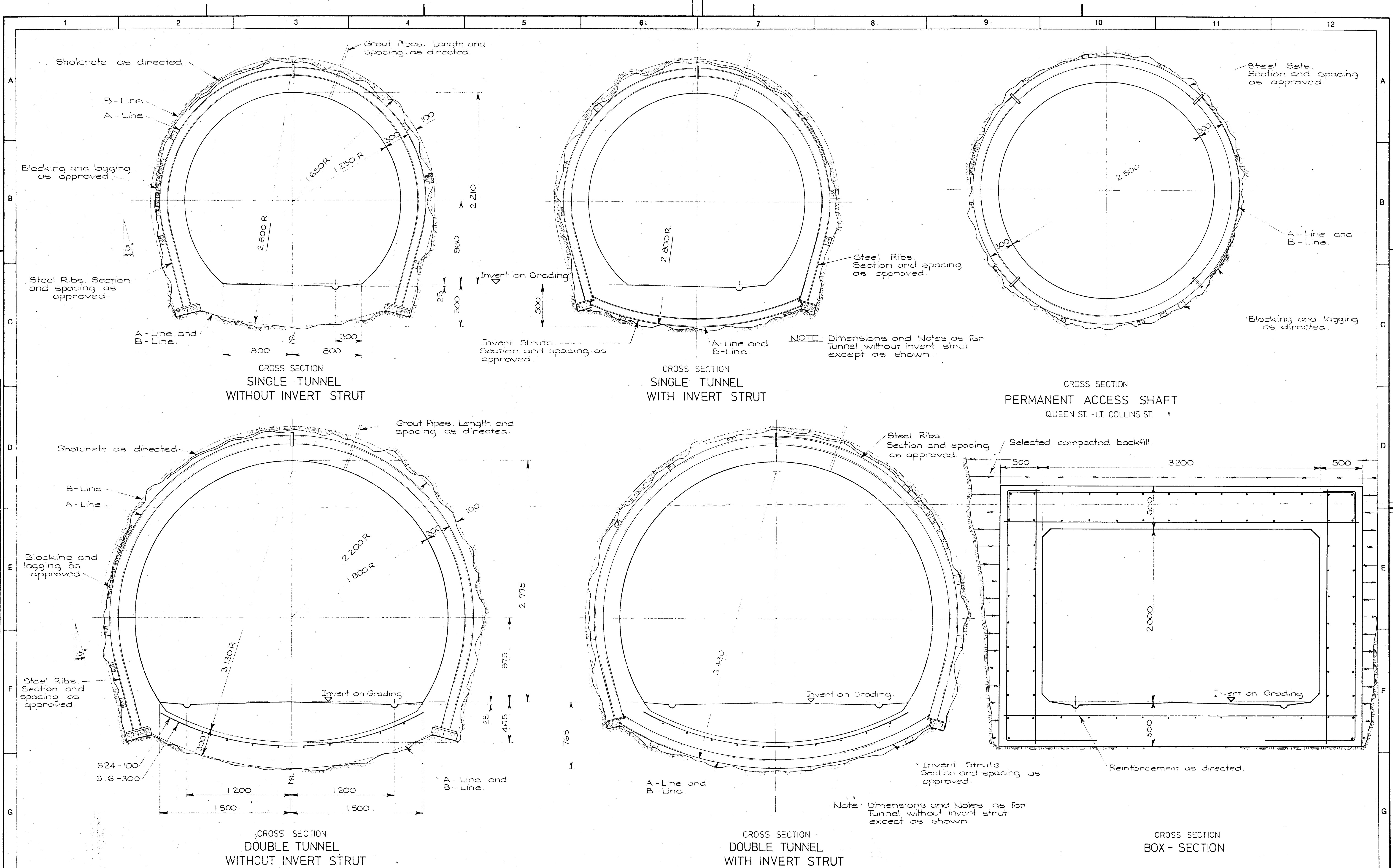
APPENDIX 6

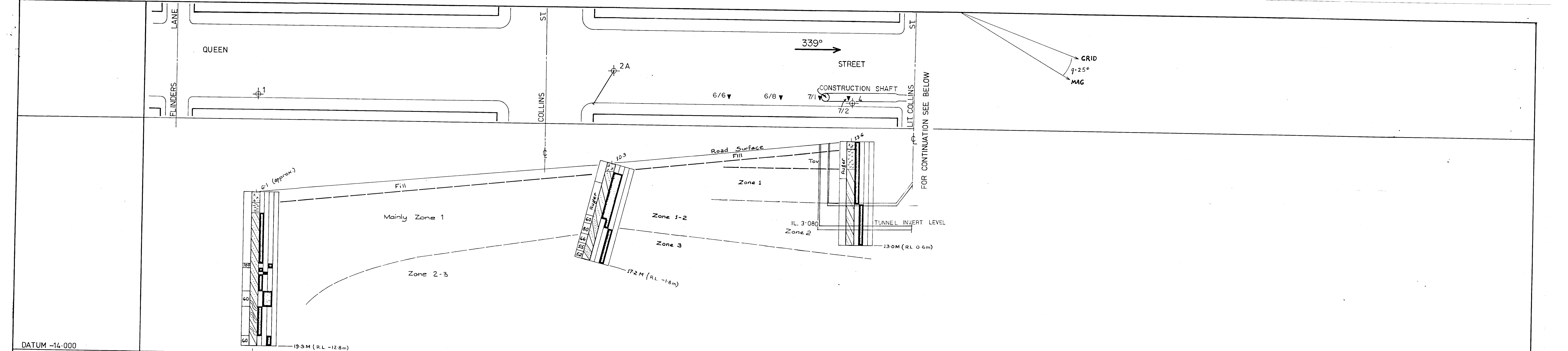
LIST OF PIEZOMETERS

LONSDALE STREET

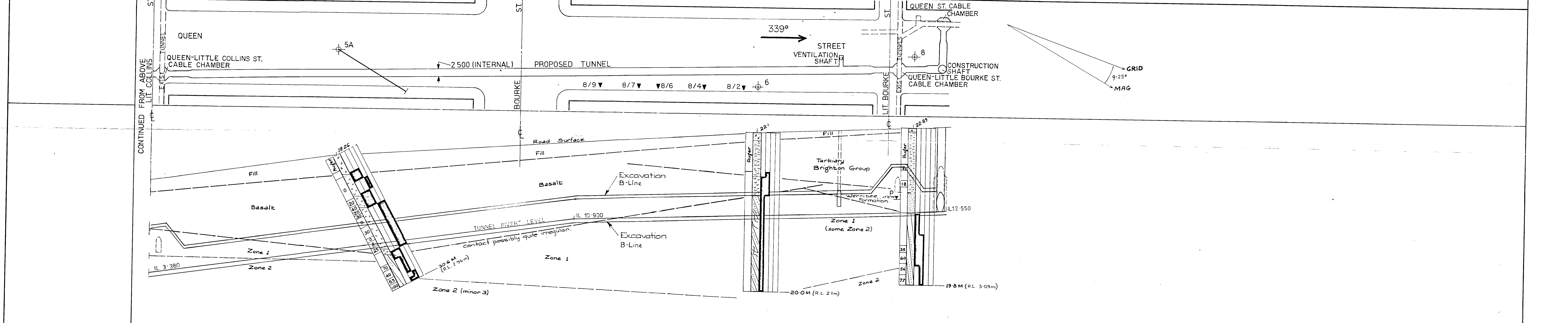
| Hole No. | Depth to
Piezometer
(m) | R.L. of
Piezometer
(m) | Date and
Depths to water (m) | | | | | |
|----------|-------------------------------|------------------------------|---------------------------------|----------|---------|---------|--------|--------|
| | | | 3/11/77 | 11/11/77 | 27/2/78 | 12/4/78 | 1/5/78 | 8/5/78 |
| 8 | 8.1 | 14.8 | - | - | Dry | Dry | Dry | Dry |
| 11 | 5.1 | 13.8 | Dry | Dry | Dry | Dry | Dry | Dry |
| 14 | 8.6 | 2.7 | - | Full | Dry | 0.5 | 0.8 | 0.9 |
| 15 | 11.7 | - 0.55 | Dry | Dry | Dry | Dry | 10.2 | 10.2 |
| 16 | 8.5 | 3.04 | Dry | Dry | Dry | Dry | Dry | Dry |
| 16 | 16.60 | - 5.06 | - | - | - | Dry | Dry | 10.00 |
| 17 | 4.2 | 7.62 | Dry | 3.5 | Dry | Dry | Dry | Dry |
| 17 | 6.6 | 5.22 | Dry | 7.8 | Dry | Dry | Dry | Dry |
| 19 | 6.0 | 8.7 | 6.0* | - | Dry | Dry | Dry | Dry |
| 21 | 10.4 | 8.1 | - | Dry | Full | Dry | Dry | Dry |
| 21A | 16.7 | 2.9 | Dry | Dry | Dry | Dry | Dry | Dry |
| 23A | 16.9 | 3.3 | Dry | Dry | Dry | Dry | Dry | 2.25 |
| 23A | 10.1 | 10.1 | Dry | Dry | Dry | Dry | Dry | Dry |
| 28 | 4.7 | 18.3 | - | - | Full | 4.1 m | Full | 0.55 |

* Hole caved to this depth.





| | | | | |
|---------------------------------|-----|-----|--------|-----|
| DATUM -14.000 | 449 | 336 | 269.44 | 262 |
| TRAVERSE CHAINAGE | | | | |
| MATERIAL HARDNESS AND STRENGTH | | | | |
| ROCK MASS DEFECTS | | | | |
| PREDICTED TUNNELLING CONDITIONS | | | | |
| PREDICTED OVERBREAK | | | | |
| PREDICTED SUPPORT | | | | |
| PREDICTED GROUNDWATER INFLOWS | | | | |



| | | | | | | | | | | |
|---------------------------------|--------|-----|-------|--------|----|-------|-------|-----|-----|------|
| DATUM -5.000 | 244.05 | 187 | 128.5 | 111.46 | 56 | 29.86 | 11.46 | 7.0 | 0.0 | -2.4 |
| TUNNEL CHAINAGE | | | | | | | | | | |
| MATERIAL HARDNESS AND STRENGTH | | | | | | | | | | |
| ROCK MASS DEFECTS | | | | | | | | | | |
| PREDICTED TUNNELLING CONDITIONS | | | | | | | | | | |
| PREDICTED OVERBREAK | | | | | | | | | | |
| PREDICTED SUPPORT | | | | | | | | | | |
| PREDICTED GROUNDWATER INFLOWS | | | | | | | | | | |

DRILL HOLE SUMMARY LOG

1) R.Q.D. (Rock Quality Designation)

Percentages not given for extremely weathered rock.

2) GRAPHIC LOG

Concrete, bitumen and fill

Colluvium and/or clay (Qcc)

Elizabeth Street Formation (Qe)

3) ROCK WEATHERING

E Extremely weathered

H Highly weathered

M Moderately weathered

SF Slightly weathered or fresh

When dealing with mudstone:

E Zone 1

H Zone 2

M Zone 3

SF Zone 4 or 5

Water level in drill hole

Location of piezometer

4) GEOLOGICAL BOUNDARY

Position approximate

5) WEATHERING BOUNDARY

Position approximate

Sheared rock

6) MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification CL, CH, SC, etc.

2) Direct Shear Stress s, kPa, (depth)

3) Unconfined Compressive Strength - Soil, σ_1 , kPa (depth)

4) Unconfined Compressive Strength - Rock, σ_1 , MPa (depth)

5) Point Load Index σ_{pl} , MPa, (depth)

6) Penetration Resistance SPT (depth in m) N₆₀ of blows/length of hole (cm)

STAND-UP TIME: Most figures given are considered to be conservative (see text).

NOTE: These sections must be read in conjunction with the appropriate parts of the written report.

All bearings refer to Grid North

AMENDMENTS

28-6-78

GEOLOGIST

G. Ford

CHECKED

D. C. Purcell

DATE

24 MAY 1978

DRAWING NUMBER

J55/A5/3

TITLE

PROPOSED TELECOM CABLE TUNNEL

GEOLOGICAL SECTIONS

QUEEN STREET

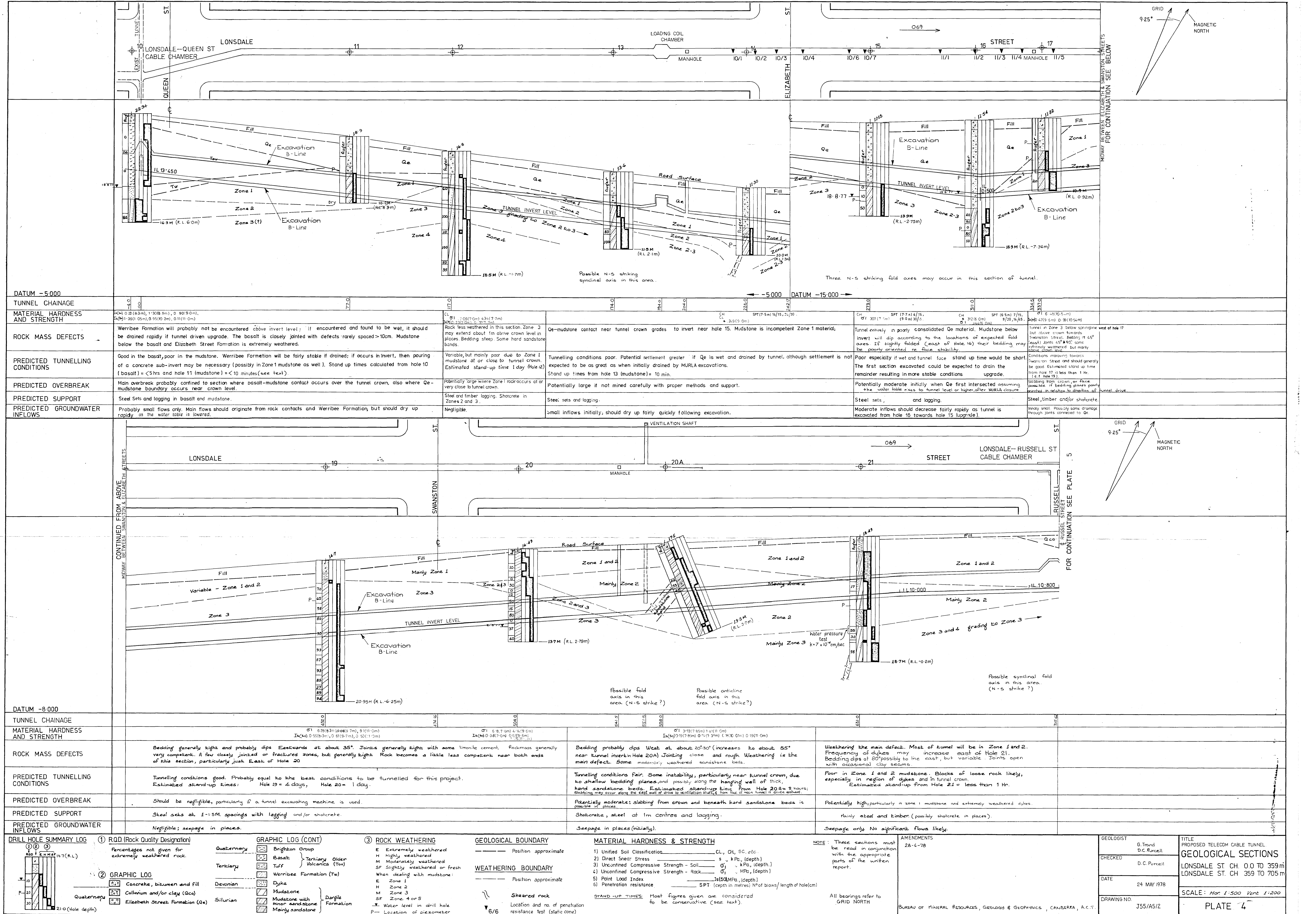
SCALE

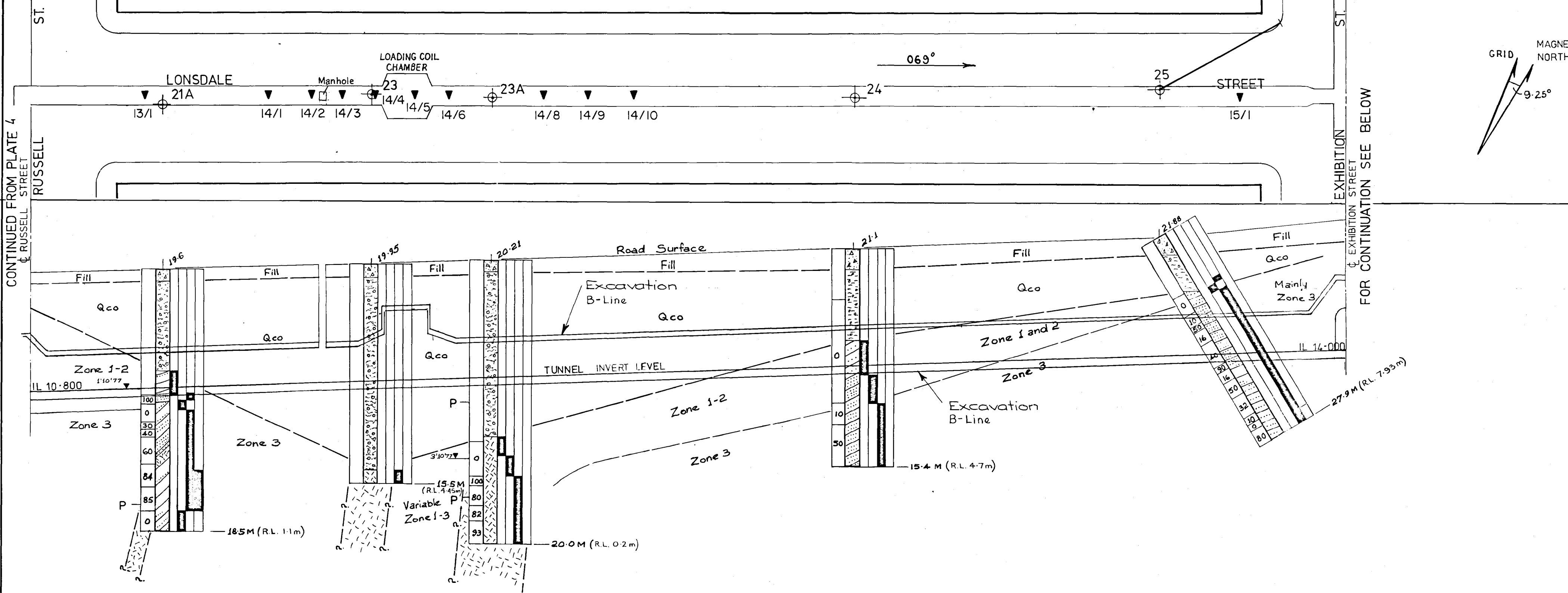
Hor 1:500 Vert 1:200

PLATE

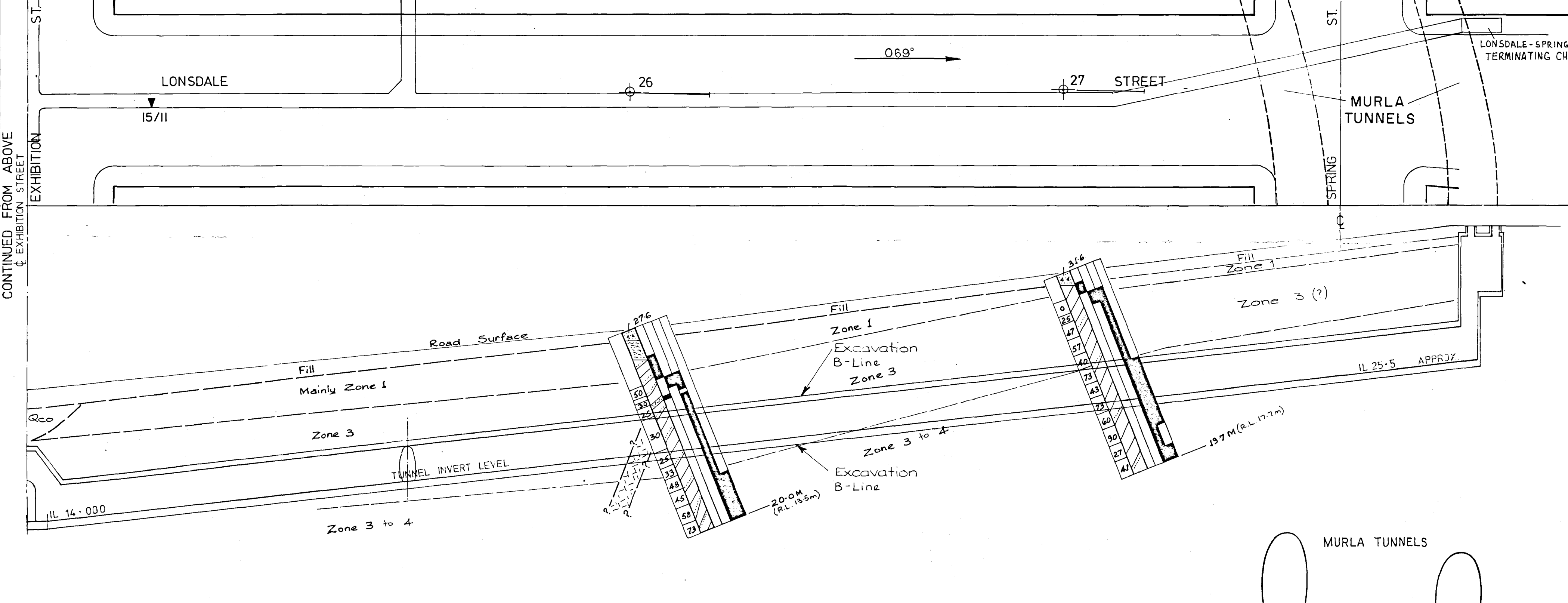
3

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA, ACT





| | |
|-----------------|--|
| DATUM -5.000 | |
| TUNNEL CHAINAGE | 135.6 137.2 138.0 139.0 140.0 141.0 142.0 143.0 144.0 145.0 146.0 147.0 148.0 149.0 150.0 151.0 152.0 153.0 154.0 155.0 156.0 157.0 158.0 159.0 160.0 161.0 162.0 163.0 164.0 165.0 166.0 167.0 168.0 169.0 170.0 171.0 172.0 173.0 174.0 175.0 176.0 177.0 178.0 179.0 180.0 181.0 182.0 183.0 184.0 185.0 186.0 187.0 188.0 189.0 190.0 191.0 192.0 193.0 194.0 195.0 196.0 197.0 198.0 199.0 200.0 201.0 202.0 203.0 204.0 205.0 206.0 207.0 208.0 209.0 210.0 211.0 212.0 213.0 214.0 215.0 216.0 217.0 218.0 219.0 220.0 221.0 222.0 223.0 224.0 225.0 226.0 227.0 228.0 229.0 230.0 231.0 232.0 233.0 234.0 235.0 236.0 237.0 238.0 239.0 240.0 241.0 242.0 243.0 244.0 245.0 246.0 247.0 248.0 249.0 250.0 251.0 252.0 253.0 254.0 255.0 256.0 257.0 258.0 259.0 260.0 261.0 262.0 263.0 264.0 265.0 266.0 267.0 268.0 269.0 270.0 271.0 272.0 273.0 274.0 275.0 276.0 277.0 278.0 279.0 280.0 281.0 282.0 283.0 284.0 285.0 286.0 287.0 288.0 289.0 290.0 291.0 292.0 293.0 294.0 295.0 296.0 297.0 298.0 299.0 300.0 301.0 302.0 303.0 304.0 305.0 306.0 307.0 308.0 309.0 310.0 311.0 312.0 313.0 314.0 315.0 316.0 317.0 318.0 319.0 320.0 321.0 322.0 323.0 324.0 325.0 326.0 327.0 328.0 329.0 330.0 331.0 332.0 333.0 334.0 335.0 336.0 337.0 338.0 339.0 340.0 341.0 342.0 343.0 344.0 345.0 346.0 347.0 348.0 349.0 350.0 351.0 352.0 353.0 354.0 355.0 356.0 357.0 358.0 359.0 360.0 361.0 362.0 363.0 364.0 365.0 366.0 367.0 368.0 369.0 370.0 371.0 372.0 373.0 374.0 375.0 376.0 377.0 378.0 379.0 380.0 381.0 382.0 383.0 384.0 385.0 386.0 387.0 388.0 389.0 390.0 391.0 392.0 393.0 394.0 395.0 396.0 397.0 398.0 399.0 400.0 401.0 402.0 403.0 404.0 405.0 406.0 407.0 408.0 409.0 410.0 411.0 412.0 413.0 414.0 415.0 416.0 417.0 418.0 419.0 420.0 421.0 422.0 423.0 424.0 425.0 426.0 427.0 428.0 429.0 430.0 431.0 432.0 433.0 434.0 435.0 436.0 437.0 438.0 439.0 440.0 441.0 442.0 443.0 444.0 445.0 446.0 447.0 448.0 449.0 450.0 451.0 452.0 453.0 454.0 455.0 456.0 457.0 458.0 459.0 460.0 461.0 462.0 463.0 464.0 465.0 466.0 467.0 468.0 469.0 470.0 471.0 472.0 473.0 474.0 475.0 476.0 477.0 478.0 479.0 480.0 481.0 482.0 483.0 484.0 485.0 486.0 487.0 488.0 489.0 490.0 491.0 492.0 493.0 494.0 495.0 496.0 497.0 498.0 499.0 500.0 501.0 502.0 503.0 504.0 505.0 506.0 507.0 508.0 509.0 510.0 511.0 512.0 513.0 514.0 515.0 516.0 517.0 518.0 519.0 520.0 521.0 522.0 523.0 524.0 525.0 526.0 527.0 528.0 529.0 530.0 531.0 532.0 533.0 534.0 535.0 536.0 537.0 538.0 539.0 540.0 541.0 542.0 543.0 544.0 545.0 546.0 547.0 548.0 549.0 550.0 551.0 552.0 553.0 554.0 555.0 556.0 557.0 558.0 559.0 560.0 561.0 562.0 563.0 564.0 565.0 566.0 567.0 568.0 569.0 570.0 571.0 572.0 573.0 574.0 575.0 576.0 577.0 578.0 579.0 580.0 581.0 582.0 583.0 584.0 585.0 586.0 587.0 588.0 589.0 590.0 591.0 592.0 593.0 594.0 595.0 596.0 597.0 598.0 599.0 600.0 601.0 602.0 603.0 604.0 605.0 606.0 607.0 608.0 609.0 610.0 611.0 612.0 613.0 614.0 615.0 616.0 617.0 618.0 619.0 620.0 621.0 622.0 623.0 624.0 625.0 626.0 627.0 628.0 629.0 630.0 631.0 632.0 633.0 634.0 635.0 636.0 637.0 638.0 639.0 640.0 641.0 642.0 643.0 644.0 645.0 646.0 647.0 648.0 649.0 650.0 651.0 652.0 653.0 654.0 655.0 656.0 657.0 658.0 659.0 660.0 661.0 662.0 663.0 664.0 665.0 666.0 667.0 668.0 669.0 670.0 671.0 672.0 673.0 674.0 675.0 676.0 677.0 678.0 679.0 680.0 681.0 682.0 683.0 684.0 685.0 686.0 687.0 688.0 689.0 690.0 691.0 692.0 693.0 694.0 695.0 696.0 697.0 698.0 699.0 700.0 701.0 702.0 703.0 704.0 705.0 706.0 707.0 708.0 709.0 710.0 711.0 712.0 713.0 714.0 715.0 716.0 717.0 718.0 719.0 720.0 721.0 722.0 723.0 724.0 725.0 726.0 727.0 728.0 729.0 730.0 731.0 732.0 733.0 734.0 735.0 736.0 737.0 738.0 739.0 740.0 741.0 742.0 743.0 744.0 745.0 746.0 747.0 748.0 749.0 750.0 751.0 752.0 753.0 754.0 755.0 756.0 757.0 758.0 759.0 760.0 761.0 762.0 763.0 764.0 765.0 766.0 767.0 768.0 769.0 770.0 771.0 772.0 773.0 774.0 775.0 776.0 777.0 778.0 779.0 780.0 781.0 782.0 783.0 784.0 785.0 786.0 787.0 788.0 789.0 790.0 791.0 792.0 793.0 794.0 795.0 796.0 797.0 798.0 799.0 800.0 801.0 802.0 803.0 804.0 805.0 806.0 807.0 808.0 809.0 810.0 811.0 812.0 813.0 814.0 815.0 816.0 817.0 818.0 819.0 820.0 821.0 822.0 823.0 824.0 825.0 826.0 827.0 828.0 829.0 830.0 831.0 832.0 833.0 834.0 835.0 836.0 837.0 838.0 839.0 840.0 841.0 842.0 843.0 844.0 845.0 846.0 847.0 848.0 849.0 850.0 851.0 852.0 853.0 854.0 855.0 856.0 857.0 858.0 859.0 860.0 861.0 862.0 863.0 864.0 865.0 866.0 867.0 868.0 869.0 870.0 871.0 872.0 873.0 874.0 875.0 876.0 877.0 878.0 879.0 880.0 881.0 882.0 883.0 884.0 885.0 886.0 887.0 888.0 889.0 890.0 891.0 892.0 893.0 894.0 895.0 896.0 897.0 898.0 899.0 900.0 901.0 902.0 903.0 904.0 905.0 906.0 907.0 908.0 909.0 910.0 911.0 912.0 913.0 914.0 915.0 916.0 917.0 918.0 919.0 920.0 921.0 922.0 923.0 924.0 925.0 926.0 927.0 928.0 929.0 930.0 931.0 932.0 933.0 934.0 935.0 936.0 937.0 938.0 939.0 940.0 941.0 942.0 943.0 944.0 945.0 946.0 947.0 948.0 949.0 950.0 951.0 952.0 953.0 954.0 955.0 956.0 957.0 958.0 959.0 960.0 961.0 962.0 963.0 964.0 965.0 966.0 967.0 968.0 969.0 970.0 971.0 972.0 973.0 974.0 975.0 976.0 977.0 978.0 979.0 980.0 981.0 982.0 983.0 984.0 985.0 986.0 987.0 988.0 989.0 990.0 991.0 992.0 993.0 994.0 995.0 996.0 997.0 998.0 999.0 1000.0 |



| | |
|-----------------|--|
| DATUM 7.000 | |
| TUNNEL CHAINAGE | 135.6 137.2 138.0 139.0 140.0 141.0 142.0 143.0 144.0 145.0 146.0 147.0 148.0 149.0 150.0 151.0 152.0 153.0 154.0 155.0 156.0 157.0 158.0 159.0 160.0 161.0 162.0 163.0 164.0 165.0 166.0 167.0 168.0 169.0 170.0 171.0 172.0 173.0 174.0 175.0 176.0 177.0 178.0 179.0 180.0 181.0 182.0 183.0 184.0 185.0 186.0 187.0 188.0 189.0 190.0 191.0 192.0 193.0 194.0 195.0 196.0 197.0 198.0 199.0 200.0 201.0 202.0 203.0 204.0 205.0 206.0 207.0 208.0 209.0 210.0 211.0 212.0 213.0 214.0 215.0 216.0 217.0 218.0 219.0 220.0 221.0 222.0 223.0 224.0 225.0 226.0 227.0 228.0 229.0 230.0 231.0 232.0 233.0 234.0 235.0 236.0 237.0 238.0 239.0 240.0 241.0 242.0 243.0 244.0 245.0 246.0 247.0 248.0 249.0 250.0 251.0 252.0 253.0 254.0 255.0 256.0 257.0 258.0 259.0 260.0 261.0 262.0 263.0 264.0 265.0 266.0 267.0 268.0 269.0 270.0 271.0 272.0 273.0 274.0 275.0 276.0 277.0 278.0 279.0 280.0 281.0 282.0 283.0 284.0 285.0 286.0 287.0 288.0 289.0 290.0 291.0 292.0 293.0 294.0 295.0 296.0 297.0 298.0 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797.0 798.0 799.0 800.0 801.0 802.0 803.0 804.0 805.0 806.0 807.0 808.0 809.0 810.0 811.0 812.0 813.0 814.0 815.0 816.0 817.0 818.0 819.0 820.0 821.0 822.0 823.0 824.0 825.0 826.0 827.0 828.0 829.0 830.0 831.0 832.0 833.0 834.0 835.0 836.0 837.0 838.0 839.0 840.0 841.0 842.0 843.0 844.0 845.0 846.0 847.0 848.0 849.0 850.0 851.0 852.0 853.0 854.0 855.0 856.0 857.0 858.0 859.0 860.0 861.0 862.0 863.0 864.0 865.0 866.0 867.0 868.0 869.0 870.0 871.0 872.0 873.0 874.0 875.0 876.0 877.0 878.0 879.0 880.0 881.0 882.0 883.0 884.0 885.0 886.0 887.0 888.0 889.0 890.0 891.0 892.0 893.0 894.0 895.0 896.0 897.0 898.0 899.0 900.0 901.0 902.0 903.0 904.0 905.0 906.0 907.0 908.0 909.0 910.0 911.0 912.0 913.0 914.0 915.0 916.0 917.0 918.0 919.0 920.0 921.0 922.0 923.0 924.0 925.0 926.0 927.0 928.0 929.0 930.0 931.0 932.0 933.0 934.0 935.0 936.0 937.0 938.0 939.0 940.0 941.0 942.0 943.0 944.0 945.0 946.0 947.0 948.0 949.0 950.0 951.0 952.0 953.0 954.0 955.0 956.0 957.0 958.0 959.0 960.0 961.0 962.0 963.0 964.0 965.0 966.0 967.0 968.0 969.0 970.0 971.0 972.0 973.0 974.0 975.0 976.0 977.0 978.0 979.0 980.0 981.0 982.0 983.0 984.0 985.0 986.0 987.0 988.0 989.0 990.0 991.0 992.0 993.0 994.0 995.0 996.0 997.0 998.0 999.0 1000.0 |

DRILL HOLE SUMMARY LOG

1 R.Q.D. (Rock Quality Designation)

Percentages not given for extremely weathered rock.

W = water

P = Piezometer

2 GRAPHIC LOG

Concrete, bitumen and fill

Colluvium and/or clay (Qco)

Elizabeth Street Formation (Qe)

Quaternary

3 ROCK WEATHERING

E Extremely weathered

H Highly weathered

M Moderately weathered

SF Slightly weathered or fresh

When dealing with mudstone:

E Zone 1

H Zone 2

M Zone 3

SF Zone 4 or 5

W Water level in drill hole

P Location of piezometer

4 GEOLOGICAL BOUNDARY

Position Approximate

WEATHERING BOUNDARY

Position Approximate

Sheared Rock

6/6 Location and no. of penetration resistance test (static cone).

5 MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification

2) Direct Shear

3) Unconfined Compressive Strength - Soil

4) Unconfined Compressive Strength - Rock

5) Point Load Index

6) Penetration Resistance

STAND-UP TIMES: Most figures given are considered to be conservative (see text).

NOTE: These sections must be read in conjunction with the appropriate parts of the written report.

All bearings refer to GRID NORTH

AMENDMENTS

28-6-78

GEOLOGIST

G. Grand

D.C. Purcell

CHECKED

D.C. Purcell

DATE

24 MAY 1978

DRAWING NUMBER

J55/A5/B

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA, A.C.T.

TITLE

PROPOSED TELECOM CABLE TUNNEL

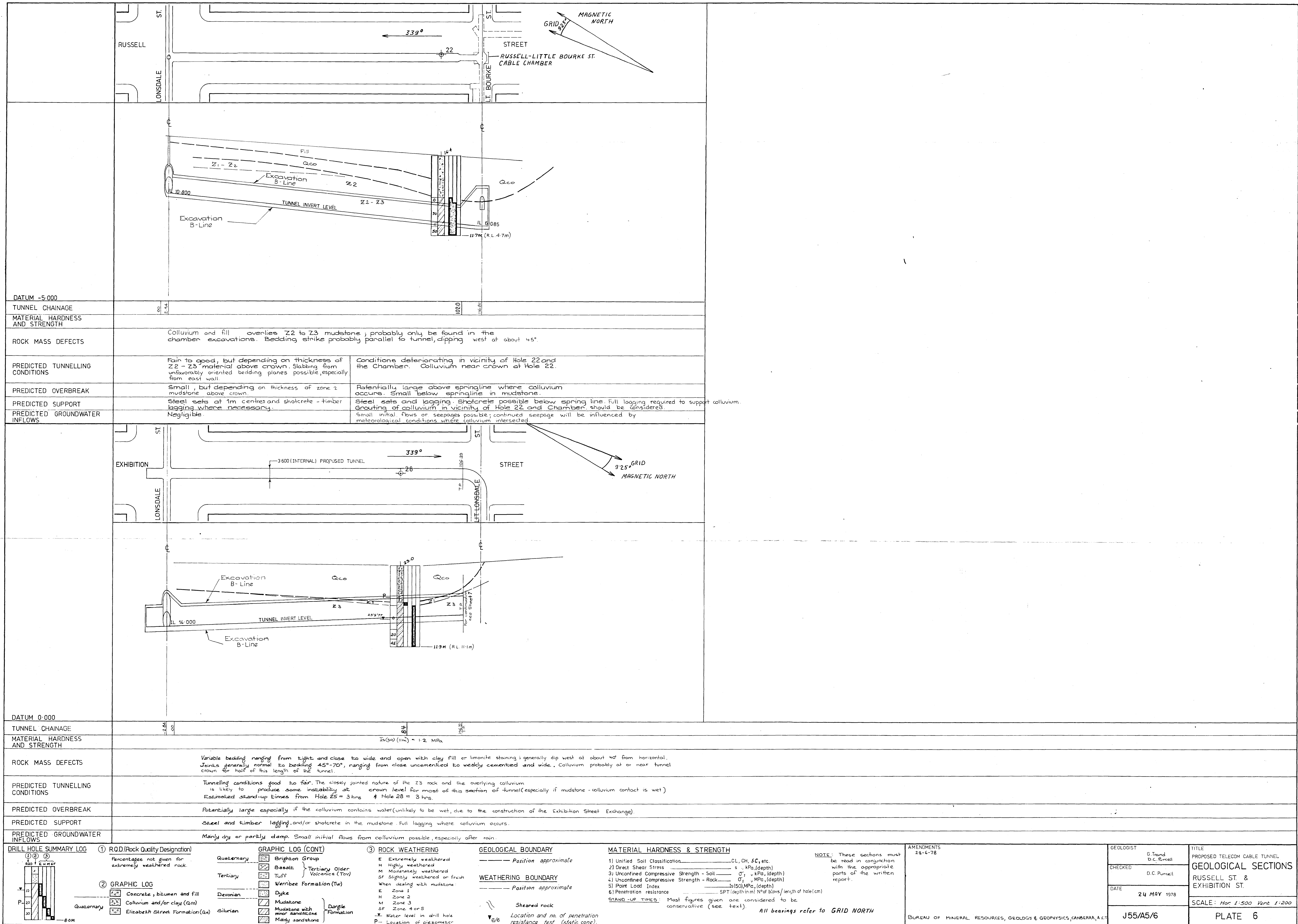
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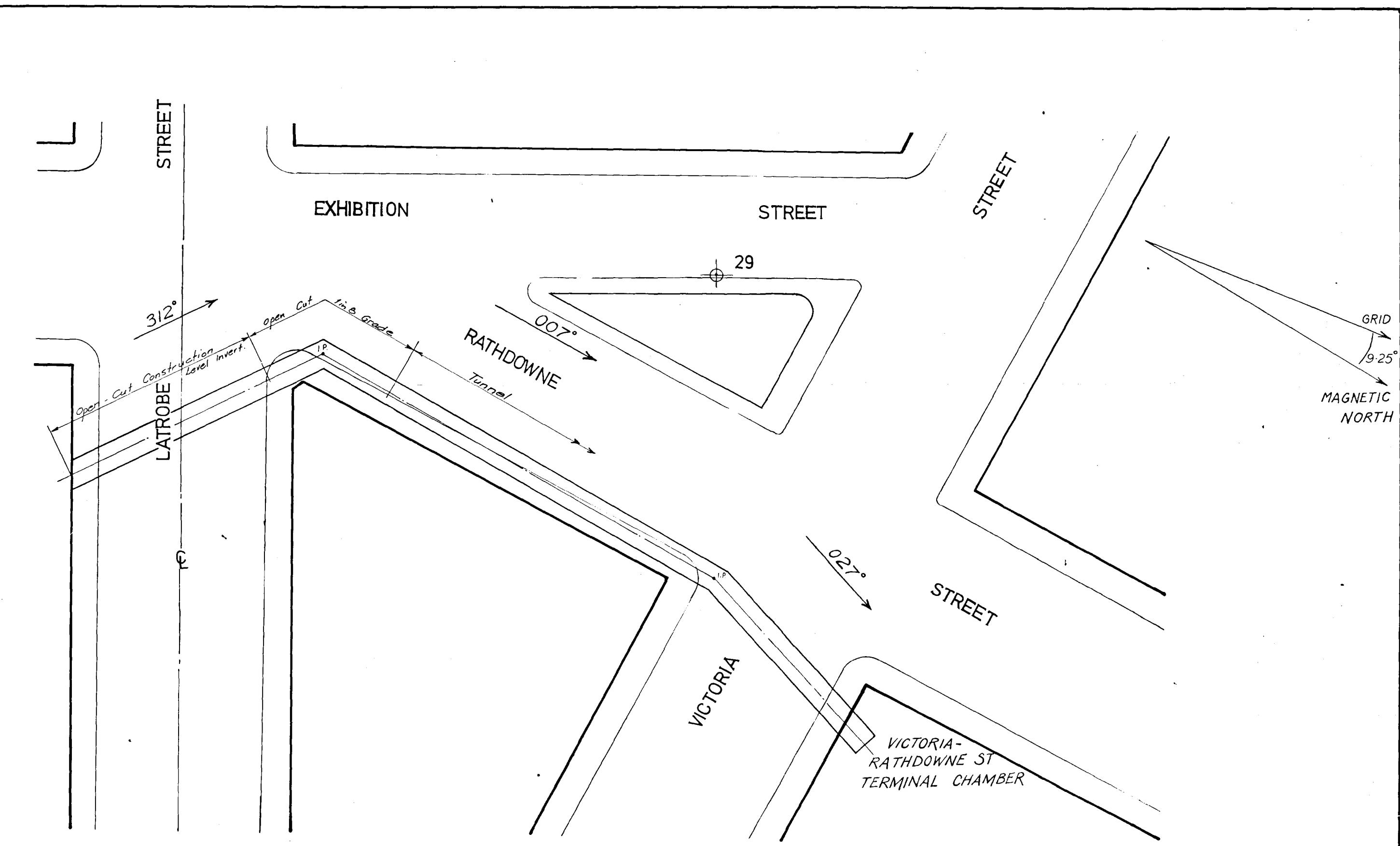
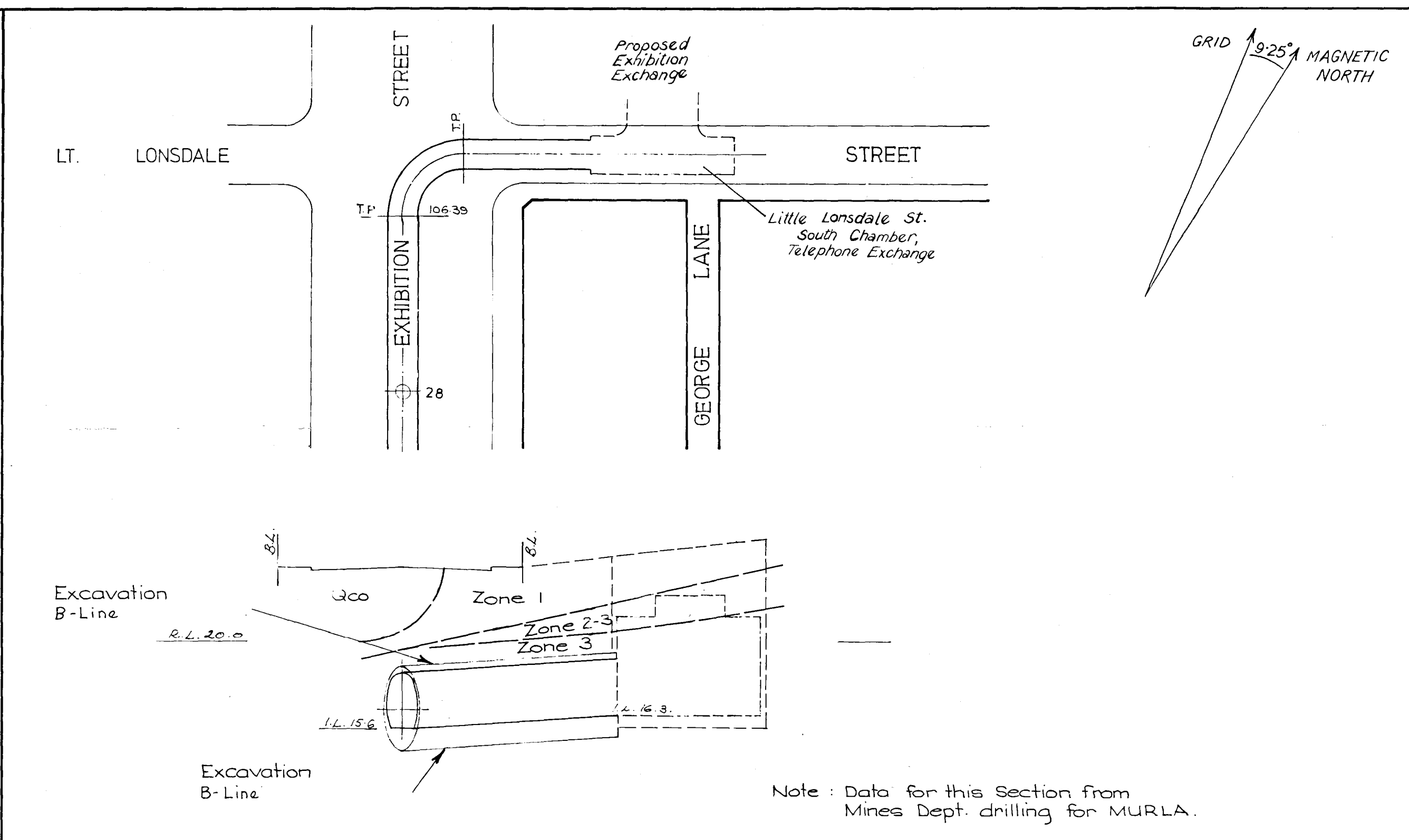
LONSDALE ST CH. 705 TO 937m

LONSDALE ST CH. 937 TO 1197m

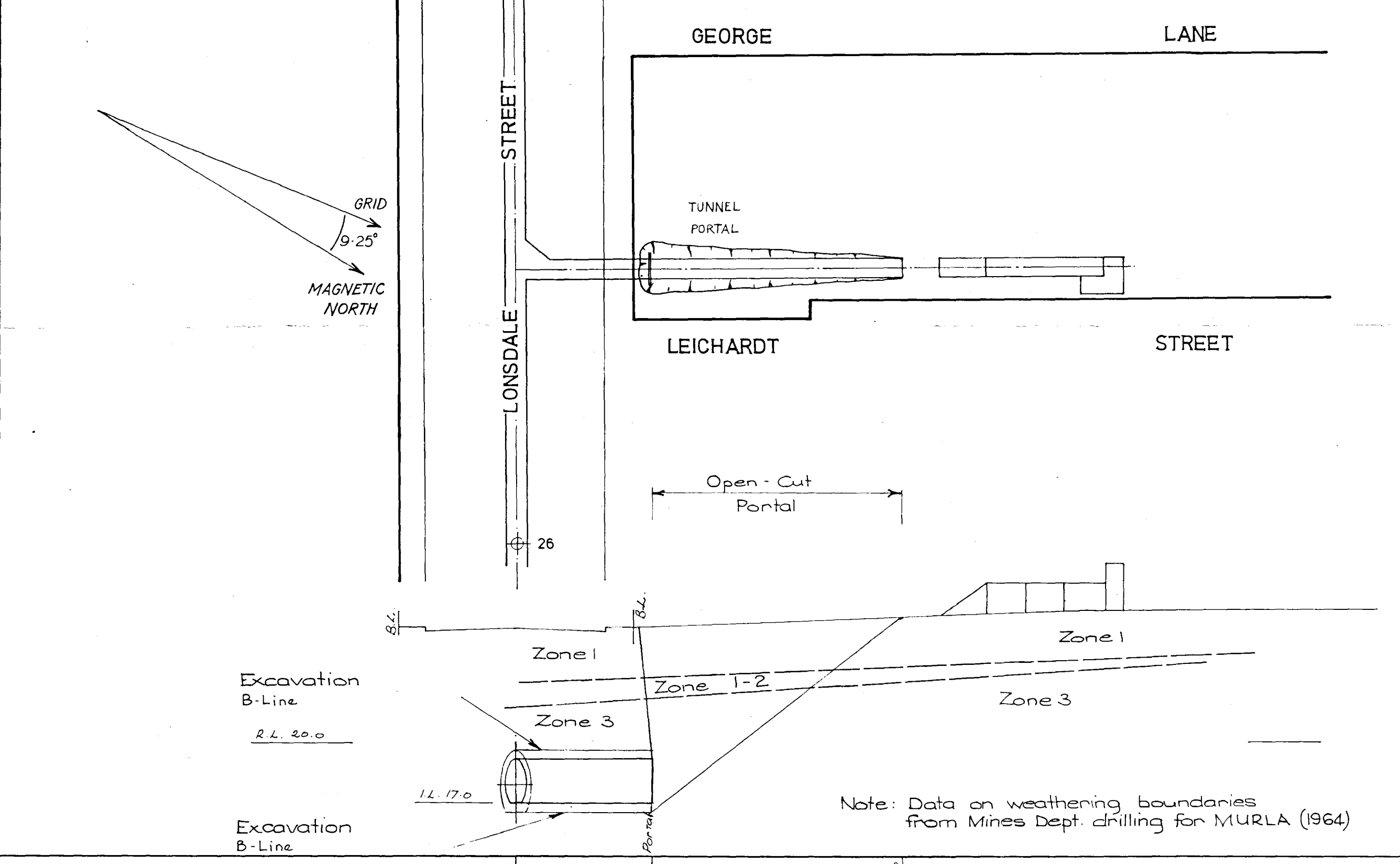
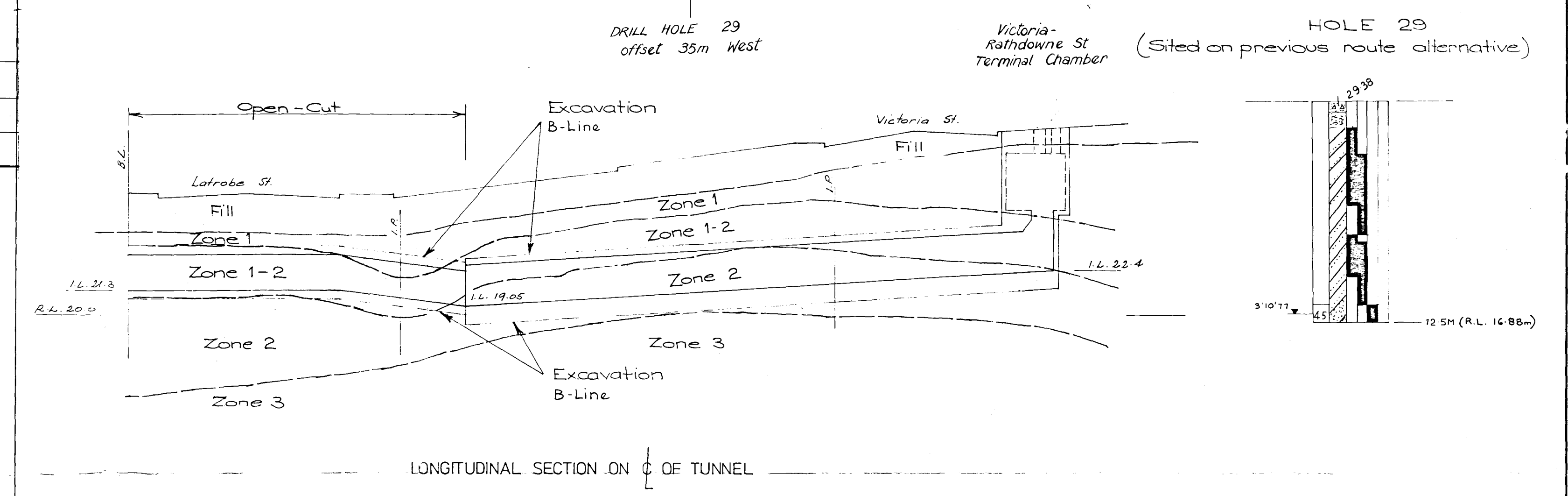
SCALE: Hor 1:500 Vert 1:200

PLATE 5





| | | | |
|---------------------------------|---|--------|--------|
| TUNNEL CHAINAGE | 106.30 | 107.20 | 108.20 |
| MATERIAL HARDNESS AND STRENGTH | | | |
| ROCK MASS DEFECTS | Bedding dips 35°-60° to the west. Jointing mainly close. Dyke possibly occurs in vicinity of the chamber. | | |
| PREDICTED TUNNELLING CONDITIONS | Generally good in Zone 2 and 3. Mudstone. | | |
| PREDICTED OVERBREAK | Will depend on distance of tunnel crown to Zone 1 material. Probably small, if excavated by machine. | | |
| PREDICTED SUPPORT | Steel sets at 1m centres, shotcrete, some lagging. | | |
| PREDICTED GROUNDWATER INFLOWS | Negligible - seepage in places. | | |



| | | | |
|---------------------------------|--|-----|-----|
| TUNNEL CHAINAGE | 170 | 171 | 172 |
| MATERIAL HARDNESS AND STRENGTH | COMMENTS FOR TUNNEL STATION 00 TO 170 | | |
| ROCK MASS DEFECTS | Beds probably dip west at 30°, strike near parallel to tunnel alignment. Joints close and weakly cemented. | | |
| PREDICTED TUNNELLING CONDITIONS | Generally good. Estimated stand-up time from Hole 26 = 8 hrs. | | |
| PREDICTED OVERBREAK | Small, especially if machine excavated. | | |
| PREDICTED SUPPORT | Steel sets at 1m centres, shotcrete, some timber lagging. | | |
| PREDICTED GROUNDWATER INFLOWS | Negligible. | | |

| | | | |
|---------------------------------|--|-----|-----|
| TUNNEL CHAINAGE | 170 | 171 | 172 |
| MATERIAL HARDNESS AND STRENGTH | COMMENTS FOR OPEN CUT, STATION 170 TO 490 | | |
| ROCK MASS DEFECTS | Competent rock below about 3m; Stiff clay above. Bedding and jointing may be unfavourably oriented with respect to one side of open-cut, assuming beds dip west. | | |
| PREDICTED TUNNELLING CONDITIONS | Instability of east wall possible, as joints and bedding plane steeper than the angle of friction will probably occur (allowing planar and/or wedge failures). Tunnel Portal face should be fairly stable. | | |
| PREDICTED OVERBREAK | East wall overbreak potentially large if not correctly supported. | | |
| PREDICTED SUPPORT | Bolts mesh and shotcrete for excavation of walls and tunnel portal face. | | |
| PREDICTED GROUNDWATER INFLOWS | Negligible. | | |

DRILL HOLE SUMMARY LOG

1 R.Q.D. (Rock Quality Designation)

2 GRAPHIC LOG

3 ROCK WEATHERING

4 GEOLOGICAL BOUNDARY

5 MATERIAL HARDNESS & STRENGTH

6 WEATHERING BOUNDARY

7 STAND-UP TIMES

GRAPHIC LOG (CONT)

Quaternary

Tertiary

Devonian

Silurian

Dargile Formation

WEATHERING BOUNDARY

Position approximate

Position approximate

Sheared rock

Location and no. of penetration resistance test (static cone)

MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification

2) Direct Shear Stress

3) Unconfined Compressive Strength - Soil

4) Unconfined Compressive Strength - Rock

5) Point Load Index

6) Penetration Resistance

STAND-UP TIMES: Most figures given are considered to be conservative. (See text).

WEATHERING BOUNDARY

Position approximate

Position approximate

Sheared rock

Location and no. of penetration resistance test (static cone)

STAND-UP TIMES

Most figures given are considered to be conservative. (See text).

AMENDMENTS

28-4-78

GEOLOGIST

G. Trand

CHECKED

D. C. Purcell

DATE

24 MAY, 1978

DRAWING NO.

J55/A5/7

TITLE

PROPOSED TELECOM CABLE TUNNEL

GEOLOGICAL SECTIONS

EXHIBITION ST. & RATHDOWNE ST.

SCALE: Hor 1:500 Vert 1:200

PLATE 7

