1980/15. Subsurface investigations at the Guide River dam site.

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Abstract

Subsurface investigations at the proposed Guide River dam site have shown that weathered basalt with some unweathered basalt overlies Precambrian mudstone and sandstone. On part of the eastern abutment, clayey boulder beds and sandy and silty clay sediments are interbedded with the weathered basalt.

Water pressure tests in diamond drill holes show moderate to high leakages in several sections. This will necessitate special measures to prevent large water losses from the dam *e.g.* a deep cut off, possibly grouting, and/or an impermeable upstream apron.

Shear strength tests on the weathered basalt, weathered Precambrian and weathered silty clay of the Tertiary sediments show comparatively high values.

Although conditions at the dam site are far from ideal, it seems likely that with careful design and construction, a dam could be safely built. An earth fill or possibly rock fill with a clay core are probably the only types of construction suitable for the site. The stability of the dam and the area surrounding the dam should be studied closely when designing the embankment.

Although some tests have been undertaken on the possible construction material (weathered basalt), further tests should be conducted on its suitability (*e.g.* compaction tests).

INTRODUCTION

Following a brief geological survey of the area around the proposed dam site [CQ965349] and a seismic survey in the area of the dam (Matthews, 1979*a*;1979*b*), subsurface investigations have been undertaken. These have included the digging of ten test pits with a trench digger to a maximum depth of 5.2 m, seven diamond drill holes to a maximum depth of 28 m, and twelve auger holes to a maximum depth of 9.1 m. Water pressure tests were undertaken in the diamond drill holes so that approximate values of permeability could be calculated. Water was pumped into some of the test pits from the Guide River to collect information on the leakage rates. Undisturbed samples were obtained from some of the auger holes so that strength measurements could be undertaken, with strength tests also being made on some of the disturbed material from these holes. One consolidation test was performed.

From surface inspection, the dam site is not regarded as an ideal area from a geological aspect. The site is in deeply weathered Tertiary basalt, and from observations surrounding the proposed dam area, it was apparent that sediments would probably be interbedded with the basalt. Such sediments could allow large leakage rates if they consisted of clean sand or gravel. The presence of clay sediments could result in a lower strength and support. The eastern abutment appeared to be the most suspect and small old landslip features occur just upstream from it. The bench forming the abutment has some resemblance to a large old landslip, however a bench also occurs at a similar level on the western side of the Guide River. These may be a weathering feature or may be due to differential weathering between two basalt flows.

It was apparent from the seismic survey and general observations that a cut off to reasonably sound bedrock would be difficult. Because of the great variation in weathering of the basalt, interpretation of the seismic spreads was difficult and the level of definite bedrock was not determined with certainty over much of the dam area. Some organisations throughout Australia try to avoid construction of dams where a cut off cannot be extended to bedrock. However as there are few suitable dam sites in the Burnie Municipality and there are aspects associated with this site which would produce cheap operational costs, it may be possible to spend more on dam construction to counteract any adverse conditions that may be determined. The advantage of this site over other sites is its ability to gravity feed to the present reservoir. Other sites have this ability, but not the storage or catchment area.

The triaxial strength test and the consolidation test were undertaken by the Materials and Research Laboratory of the Department of Main Roads. R. Woolley of the Department of Mines undertook Atterberg tests and B. Cox and E. Johnson of the Department of Mines operated the auger drill. The diamond drilling and water pressure tests were performed by G. Baker of the Department of Mines.

The investigations were conducted in several stages. Firstly, test pits were dug to obtain an overall picture of the materials underlying the dam site. This work was concentrated mainly on the eastern abutment, with only two holes dug on the western side of the river. Steepness of the western abutment prevented extension of this work to higher levels. Diamond drilling and water pressure testing was then commenced. It was hoped to use an auger drill to extend the information obtained from the diamond drill holes as drilling proceeded. Near surface basalt boulders and narrow unweathered zones in the basalt prevented drilling in some selected areas.

TEST PITS

All but two of these pits were dug around the abutments of the proposed dam. The first two were dug upstream on the eastern side of the Guide River in an attempt to locate *in situ* Precambrian sediments that were thought to underlie the area. Float derived from Precambrian sediments can be seen on the surface. The test pits only encountered soil, clay and boulders derived from the weathering of basalt and failed to locate any *in situ* Precambrian rocks. The fragments of Precambrian seen in the soil may be derived from outcrop at higher levels or may be derived from similar boulder beds containing Precambrian fragments exposed near the dam site. The boulder beds at the dam site contain abundant quartz grit which appears to be absent where the initial test pits were dug.

At the dam site, pits were sited down the abutment so that a complete section down the slope could be obtained. In this way any persistent bed with a horizontal aspect could be located. The results and materials struck in these pits are shown in Figure 2, with detailed logs given in Appendix 1.

Pit 3 encountered boulder beds made up of quartz fragments, slate boulders and weathered basalt boulders between 0.6 and 2.7 m. The material has a fine matrix throughout and is probably not particularly permeable. Underlying the boulder bed is over two metres of apparently *in situ* weathered basalt. Again it is not expected to be highly permeable. At the base of the pit were some slate fragments which may represent the start of another boulder bed, or they may have fallen down the hole from the upper parts of the pit (a nearby diamond drill hole encountered clayey sand at about the level of the pit base but failed to find signs of the upper boulder bed which nearby Auger Hole 3 also struck).

Pit 4 struck a gravelly clay layer between 2.3 and 3.1 m from the surface and this was underlain by weathered basalt. Pit 6 struck sediments, probably Tertiary in age, at 4.6 m from the surface. These consisted of micaceous clayey sand and black sandy silty clay. Above this was weathered scoriaceous basalt, perhaps agglomerate (?), with some distinct planar slip surfaces.

Pit 7 encountered Precambrian sediments at 4.9 m with probable deeply weathered Precambrian sediments from 3.1 m depth. The contact with the overlying basalt slopes north. Pockets of pebbly clay (quartz fragments) up to 0.3 m thick occur on the contact. The probable weathered Precambrian sediments were fairly soft and were crossed by numerous limonite veins. The remainder of the pits encountered weathered basalt or soil and boulders derived from the weathering of basalt.

Water was pumped into three of the pits to examine seepage rates. Because of the irregularity of the pits it is not possible to determine permeability with any accuracy. Pit 6 was filled to within 1.8 m of the surface, the top water mark having the dimensions of 4.7 x 0.9 m. The level dropped to 1.87 m in 32 minutes, 1.99 m in 89 minutes and to 2.07 m in 124 minutes, which amounts to a water loss of about 5, 10, and 10 *l*/min respectively through an area above the water table of about 20.6 m^2 and between 9.3 - 14 m^2 below the water table.

Pit 7 was filled to within 0.99 m of the surface and fell to 1.03 m in 15 minutes, and to 1.11 m in a further 42 minutes. The top dimension of the water level was 4.4 m x 0.9 m, which corresponds to a loss at the rate of about 10 and 7 *l*/min. The area of the pit sides would have approximated 22.5 m^2 above the probable water table level to the top water mark, with perhaps about the same area below the probable water table level.

Pit 9 was filled to within about 2.13 m of the surface and fell to 2.22 m after 30 minutes, 2.31 m after a further 55 minutes and to 2.34 m after a further 15 minutes. The dimensions of the upper surface of the water level were about 2.7 m x 0.9 m and these losses represent rates of about 7, 4 and 4 *l*/min respectively. The water table may have been at about 3.6 m, so the area of the hole above the water table in contact with the pumped water would approximate 11 m^2, with perhaps 14 m^2 below it.

Pits 8 and 10 both made water and approximate rates were measured. In Pit 8 the water table was about two metres from the surface and in one hour made about 360 *l* of water. In Pit 10, the water table was at about 2.13 m and in 75 minutes the hole made about 1150 *l* of water or about 16 *l*/min. The base of this pit is well below river level.

AUGER HOLES

A tractor powered auger was used to drill to a maximum depth of 9.1 m. One of the disadvantages of this drill is that the material coming to the surface is very disturbed, particularly after the water table has been penetrated, and there is some delay after the material is drilled before it comes to the surface.

The principal purpose of the drilling was to examine the possibility of permeable quartz sand or gravel occurring in the sequence of interbedded volcanic and sedimentary deposits and also to collect undisturbed samples for strength testing by attaching drive tubes. Permeable sand or gravel were not found in any of the auger holes and the boulder bed, known to occur near Test Pit 3, was not obvious from the sample return, apart from a few fine quartz fragments. The bed appears to be associated with a pinkish-red clayey silt, and similar material was encountered in other holes. Holes 4 and 9 were the only other holes where definite pebbles were recognised in the sample return, but Holes 5, 6, 7 and 8 have red clayey silt which is probably the matrix material for the boulder bed or its equivalent. Samples from Hole 3 near Test Pit 3 did not indicate a lower clayey gravel horizon as was suggested from the test pit (and was found in DDH 1).

Auger hole 8 was the only hole where probable Precambrian rock was struck, with some clayey quartz gravel overlying it. Many attempts were made to drill holes in areas surrounding Test Pit 7, where Precambrian rocks were struck in the bottom, and Pit 6 where sediments were encountered, but basalt boulders or less weathered zones of basalt prevented the drill from reaching the target.

It was suspected that there may have been some sedimentary material in Hole 10 when drilled, although it was sited at a lower level than the boulder bed that can be seen in the road cutting. A hole near Hole 10 was sampled continuously with a tube sampler in the zone concerned (from 2.7 m to 5.5 m). The material in this section is definitely weathered basalt and similar material continues to 7.3 m. It had previously been fairly definite from the drilling of Hole 10 that weathered basalt occurred from 7.3 to 9.1 m.

DIAMOND DRILLING

Diamond drilling has been used to establish more definitely the subsurface rock distribution, its nature when in a relatively undisturbed state, and for water pressure tests, so that approximate permeabilities could be determined. The nature of the material made complete recovery difficult in many holes; alternations of hard and soft bands over short intervals makes complete recovery of core almost impossible. The basalt, when deeply weathered, is a fairly friable material and is easily erodable when in contact with moving water. Not all sections in the bores were water pressure tested because of the difficulty in obtaining a seal with the packers. Pneumatic packers were tried but were not successful, owing to a lack of adequate pressure in the gas cylinders supplied.

The main features exposed by the diamond drilling were the deeply weathered nature of the basalt for much of most holes and the interbedded sediments, particularly on the eastern abutment. There was very little fresh to only slightly weathered basalt in Holes 1, 3 and 7, and only a little relatively unweathered basalt at the base of Hole 2. The basalt below about 5.5 m in Hole 4, about 4 m in Hole 5 and about 10 m in Hole 6 is either largely unweathered or much less so than in the other holes. The upper sections of all holes are composed of deeply weathered basalt which is weathered to a fragmental clay with an obvious igneous texture and weathered vesicles. Between this deeply weathered state and fresh basalt are variable stages of weathering. The fresher basalt consists of a fine grained dark rock to relatively coarse grained basalt. Olivine, a mineral common to many Tasmanian basalts, can be seen in some core sections.

The basalt in most parts of the core is vesicular and these vesicles have been filled or partially filled by secondary minerals such as zeolite and calcite. Some remain unfilled. There are occasional zones of fine dark material in the core which may be weathered zeolite or weathered volcanic glass (*e.g.* 60 mm in Hole 1 in the run from 20.8 - 22.3 m). Where the basalt is deeply weathered, the vesicles are all filled and any vesicles originally unfilled have probably collapsed.

Sediments and boulder beds within the basalt occur mainly on the eastern abutment. Hole 1 encountered boulder beds between 5.3 and 7.4 m, mudstone and basalt fragments between about 13.3 and 14.0 m, boulder beds between 22.3 and 23.9 m, and 0.2 m of intermixed basalt and clayey sand between 24.2 and 24.6 m. In Hole 2, 0.13 m of sediment was recovered between 7 and 8.5 m, while in Hole 3, silty clay, sandy clay and sand intermixed with basalt boulders occur at about 8.7 - 11.8 m from the surface. About 80 mm of basalt and clayey grit occurs in Hole 4 at about 11.5 m from the surface, with a possible 30 mm of clayey sediment at 10.27 m. Similar hard clayey sediment occurs in Hole 5 at 7.7 - 7.8 m. No sediments were recognised in Hole 6 and only a few near-surface quartz grit fragments were in core from Hole 7.

Definite Precambrian sediments were struck at the base of Holes 2, 3 and 7 and probable Precambrian sediments in Hole 1. These sediments consisted of broken pieces of mudstone, sandstone and siltstone. The material struck in Hole 1 is white and fairly soft and clayey, and does not have the bedding or foliation that the other occurrences display; it is likely to be deeply weathered Precambrian.

Water pressure tests

Water pressure tests were conducted as the holes were being drilled. In some sections, seals by the packers were not attainable, probably due to irregularities in the hole walls, so there is no information on these areas. It was not possible to get water loss measurements from 6.8 - 13.3 m in Hole 1.

The calculated permeabilities are moderate to quite high* in some sections of some holes. Moderate values were obtained in the top two sections of Hole 1, with relatively low values below 16.3 m. Low values were obtained for all of Hole 2. Hole 3 had high to moderately high values for the four middle sections for which tests were possible, with the shallowest from 4 - 7 m and the deepest from 16 - 25 m being low. The circulation water was lost at 9 m from the surface during the drilling of Hole 3, and this was the only recorded complete loss of drilling water. This section of the hole is within the sediment which includes sandy clay, sand and boulder beds. High permeabilities were calculated for Hole 4 from 2.5 - 10 m, with much lower values at lower levels. Moderate permeabilities were found to 10 m in Hole 5, with again much lower values for the rest of the hole. Very high permeabilities were calculated for Hole 6 from 2.5 - 5.5 m and are still fairly high to a depth of at least 10 m. Below 13 m permeabilities are low. Hole 7 has moderate to high permeabilities throughout.

It is apparent that leakage from a dam through the foundation will be quite high without adequate precautions. Such measures would probably include a deep cut off across the axis of the dam to 9 m where possible. Where fairly fresh rock with high permeabilities is closer to the surface, as in Holes 4 and 5 (basalt), grouting should be considered. Such a cut off may encounter Precambrian rocks with relatively high permeabilities at shallow depths in which grouting should be possible. In addition, an apron of compacted clay could be placed upstream of the dam. Such measures would decrease the overall water loss, and where a complete cut off was not possible (perhaps on the east and west extremities of the dam wall), the length of the leakage path would be increased greatly by these measures.

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* Losses of 1 - 5 Lugeons are regarded as low, 5 - 20 μL as moderate and > 20 μL high.

Water table position in the dam area

Water levels have been measured in the drilled holes (Table 1), in the auger holes up to about one day after completion and in the diamond drill holes on three separate occasions since completion. Profiles for two of these measurements for the diamond drill holes are shown on the cross sections (fig. 2). The third and final set of measurements fall in the range of the earlier two profiles for most of the holes, although the level in Holes 4 and 7 is higher than previously measured, while it is lower in Hole 6.

The water table rises markedly under the abutments away from the stream. This situation should aid in reducing the possible water loss near the dam as well as from the storage area. The difference in water level between Holes 3 and 7 is of particular interest. It is apparent that Hole 3 is sited within a fairly permeable zone which allows the water to flow away more readily.

Table 1. WATER LEVEL MEASUREMENTS IN DRILL HOLES

Hole	Completion (m)		17.12.79 (m)	20.3.80		27.5.80	
				level (m)	depth (m)	level (m)	depth (m)
DDH 1	8.5		10.0	11.58	25.4	10.82	25.2
2	4.0		4.0	7.54	27.05	4.95	26.9
3	8.0		8.6	9.45	23.17	8.53	23.2
4	3.0		4.0?	3.05	14.9	1.98	14.6
5	3.7		3.2	3.58	18	3.2	17.8
6	7.2		7.0	8.69	22.9	9.3	22.8
7	5.8		5.8	5.56	15.55	5.18	14.55
AH 1	1.3	1.3 (10-24 hours)		5.94+	fallen in		
2	3.6	3.3 (10-24 hours)		6.93+	fallen in		
3	6.2	5.9 (10-24 hours)		6.70+	fallen in		
4	5.5	4.1 (10-24 hours)		6.63+	fallen in		
5	3.8	3.7 (10-24 hours)		closed			
6	3.7	3.6 (5 hours)					
7	7.5			7.6+	fallen in		
8		2.6 (24 hours)	dry				
9		4.6+ (dry)	dry	4.56+	fallen in		
10		4.0 (24 hours)	5.4	5.41			
11		2.7 (2 hours)	3.4				
12		3.3 (1 hour)	3.6				

GEOLOGY

As a result of the subsurface investigations, much more is now known of the geology than was obtained from surface observations. At the dam site itself, the only definite outcrops are in excavations such as road cuttings. These outcrops consist of weathered basalt in the road cuttings near each abutment and a boulder bed consisting of boulders of Precambrian mudstone and basalt with rounded quartz pebbles in a clay matrix on the east abutment. Apart from these materials, the whole dam site area is underlain by soil with basalt boulders and clay derived from basalt weathering. Precambrian sediments occur upstream on the eastern side of the dam and fragments occur in the soil within about 200 m of the dam site which are probably weathered from near surface outcrops. Test pits failed to encounter the Precambrian rocks in this area, but the *in situ* material may occur further up the slope from the pits. An alternative explanation may be that the fragments are broken up pieces from boulder beds, as in the cutting near the dam site.

The sections (fig. 2) indicate the presence of Precambrian sediments made up of slaty mudstone and minor sandstone at depth underneath the eastern abutment. These rocks were not reached in holes under the western abutment or near the river, but there is little doubt that the Precambrian occurs at deeper levels than penetrated with the drill. The Precambrian tends to be fairly broken, but resulted in only small to moderate water losses where tested for permeability. Locally it is weathered to a soft silty clay as in Test Pit 7 and DDH 1 and DDH 7. In the diamond drill holes this material was almost white and compact, whereas in the test pit it was red and porous with many iron oxide veins. The surface of the Precambrian is uneven, as indicated by the sections (fig. 2).

Overlying the Precambrian rocks is a sequence of basalt and sediments (sediments mainly on the eastern abutment). Sediments in the form of clayey gravel overly the Precambrian directly in Test Pit 7 and possibly in Test Pit 6 and DDH 1. Above this level, DDH 1 shows an alternation of variable sediments and basalt, suggesting a number of flows of basalt. A number of flows may be represented in other holes, but sediments have not been deposited between the individual flows. A zone where these sediments are most common includes Test Pits 3, 4, 6 and 7, Diamond Drill Holes 1, 3 and 7 (in DDH 7 the material may have moved downslope), and Auger Holes 3, 4 and possibly 5, 7, 8 and 9. Possible minor sediment intercalations occur in DDH 4 and 5.

It is apparent that this zone of basalt and interbedded sediments mark the course of the river at various times. It is only a narrow zone and it is usually difficult to correlate beds between holes. Deposition would only take place in some parts of the stream at any time, and sediments would be very localised. In other parts of the stream bed erosion would take place rather than deposition, so that in these areas basalt from two flows would be in contact without any intercalated sediments. In other areas away from the stream, later flows would be in contact with earlier ones. Only minor shifts of the stream bed due to succeeding flows must have taken place, as evidenced by the narrow zone of the eastern abutment where these rocks occur.

Interpretation of the geology from the seismic survey proved difficult because of the variable nature of the weathering of the basalt, both laterally and vertically. It is apparent from Spread 7 that relatively unweathered rock is close to the surface near the river and this is also indicated by the east-west traverses. The drilling and test pits have confirmed this. The depth to a refractor under the eastern half of Spread 1 is a little difficult to correlate with the results of diamond drilling. DDH 1 and DDH 2 located some slightly less weathered zones of basalt about the level indicated by the seismic interpretation, and as the refractor velocity is relatively low, this may be the explanation. Deeply weathered basalt occurs under this slightly less weathered material in each hole. The depth of weathered basalt encountered in DDH 6 approximates that indicated in the seismic interpretation for this area of Spread 2. The Precambrian, located only a few metres below the surface in Test Pit 7, may be indicated by the interpretation under Spread 3, although the velocity of 5000 m/s seems a little high for the material encountered in the test pit.

STRENGTH OF MATERIAL IN FOUNDATION OF PROPOSED DAM

Because of the deeply weathered nature of much of the basalt underlying the dam site, some doubt existed on the ability of this material to withstand the load of the dam. For this reason shear strength tests and one consolidation test have been undertaken.

One consolidated undrained triaxial test was successfully completed. Attempts were made on several other samples of undisturbed material from auger holes but were unsuccessful, some because of the material collected and occasionally due to malfunction of the testing device. The result of the successful test is given in Figure 3. The value of ϕ' is 33° and C' is 24 kPa.

Weathered basalt from some of the auger holes, two samples of clayey silt from the boulder beds and one sample of weathered Precambrian material has been sheared in a shear box under varying loads. One of the tests was on an undisturbed sample, the others being on disturbed samples. One sample of weathered basalt was remoulded and worked for about five minutes before placing in the shear box. The Precambrian sample was collected from the surface spoil remaining some months after the pits were dug (Test Pit 7) and would have been subject to some leaching over this period, although its appearance was similar to when it was dug from the pit.

All samples were consolidated overnight for a period of about 15 hours before being sheared under the lowest load. Most samples were sheared in both directions and then consolidated again overnight under increased load and sheared again. This process was repeated three times, except in the case of a sample from DDH 6 which was sheared under four different loads. In one case (AH M2), the sample was consolidated under the highest load for two days. This did not appear to deviate the result to any marked extent. The reverse shear in each case was undertaken directly after the forward shear was completed.

The three points resulting from a plot of normal load against shear stress produced reasonably straight lines in five of the samples, if the reverse and forward shear results are averaged, while in two samples three points did not form a particularly good straight line. These samples were an undisturbed sample of weathered basalt and the disturbed sample of weathered Precambrian consisting of silty clay. In these two cases, what is probably a minimum ϕ' value with resulting cohesion has been calculated. The plots of the results are shown in Figures 4-10. The values of the strength factors are given in Table 2.

Table 2. SHEAR STRENGTH TESTING RESULTS

Hole	Depth (m)	Sample state	ϕ'	C' (kPa)	Possible minimum values ϕ'	C (kPa)
AH3	1.8-2.7	disturbed	35°	5		
AH4	1.8-2.7	disturbed	35°	8		
AH7	3 -3.7	disturbed & remoulded	38°	0		
AH7	3.7-4.0	undisturbed	32°	27	29°	52
AH12	2.7-2.8	disturbed	39°	1		
AH M2	1.8-3.7	disturbed	37°	14		
TP7	3.1-4.9	disturbed	29°	19	21°	48

Materials from AH3 and AH4 are the reddish silty clay which occurs within the near surface boulder beds on the eastern abutment. The material from AH12, AH7 and AH M2 consists of deeply weathered basalt, while the material from TP7 is weathered Precambrian. The last mentioned material has only been intersected once. In other holes (diamond drill holes) similar material has not been recovered above the less weathered Precambrian rocks.

The values of Ø' are high and even the possible minimum values of the two samples are fairly high. It is apparent that the material, although deeply weathered and appearing soft where cored or auger drilled, still has considerable strength. The values obtained from the shear box tests are comparable with those obtained from the triaxial strength test.

As outlined above, weathered basalt, silty clay from boulder beds, and deeply weathered Precambrian material has been tested for strength. In DDH 3 from about 8.7 m to 10.5 m and in the bottom of Test Pit 6 at 4.6 - 4.9 m from the surface are thin zones of brown, dark grey and almost black carbonaceous silty and sandy clay for which no strength measurements have been obtained. Several attempts were made to auger to that level so that undisturbed samples could be obtained. However near surface boulders or less weathered zones in the basalt prevented the appropriate depth being reached. Strength tests on this material would be useful, as it is possible that it has a much lower value than the materials tested. These sedimentary clayey beds are likely to have only a limited extent however and even if the shear strength is lower than the materials already tested, their overall effect may be small.

Consolidation test

One consolidation test has been undertaken on deeply weathered basalt to a total load 800 kPa. The sample was contained in the same tube from which the triaxial strength test results were obtained. The plot of the consolidation test is shown in Figure 11. Other samples of undisturbed material were collected for possible consolidation testing, but the samples proved unsuitable, as did some of the samples for triaxial shear tests.

Weathered basalt is thus the only material on which there is some information. Although volume changes were not monitored during the consolidation and shearing of the shear box samples, all except the weathered Precambrian material from Test Pit 7 failed to show any unexpected compaction. The weathered Precambrian material, from inspection in the hand specimen, is probably mainly silt size material, and leaching during this weathering process may have increased the void ratio considerably. As this red, deeply weathered siltstone was struck at only one location, any undue settlement as a result of loading from the dam will probably be localised.

STABILITY

One of the factors that will have to be examined closely in the design of the dam is the stability of the dam itself and the surrounding area. The hummocky nature of the area just upstream from the eastern abutment suggests that some small scale landslips have taken place in this area, although none of the movements are recent. It is apparent that with the changed situation with regard to the water table once the dam is full, stability may also change, particularly if rapid drawdown were to occur. In the normal operation of the dam, however, such rapid movements in water level are unlikely to occur.

The level of the water table in the abutments downstream from the dam axis will also change and this could affect the stability. This appears to apply more to the eastern abutment than the western one. If low safety factors are calculated for these areas it may be necessary to lower the slope angles, as movements here will endanger the dam itself.

The strengths determined in the triaxial tests and the shear box tests should act as a guide for use in stability analyses where weathered basalt and weathered Precambrian materials are concerned. As mentioned previously sandy and silty clay sediments in DDH 3 and TP 6 have not been subjected to shear strength tests. If, as recommended later, trenching is undertaken in the design stage to obtain a continuous profile across the dam axis and to ascertain the most suitable location for the cut off, it would be useful to obtain some of this material for strength tests because if low values are obtained, modifications in design may be necessary.

TYPE OF DAM AND CONSTRUCTION MATERIAL

Because of the very weathered nature of the basalt at the dam site, it is apparent that an earth fill dam would be the most suitable type. This may be either of the homogeneous type or the zoned embankment type. Other types are probably not appropriate for the site, except perhaps rockfill with an impermeable core. Obviously the kind of construction will depend on the materials available. There is abundant weathered basalt in the storage area of the proposed dam which could be used for the first type, subject to tests to prove its suitability, and if a zoned embankment is used, weathered basalt could be compacted for use as the impervious core (again subject to tests). It may be possible to obtain Precambrian rock in varying stages of weathering from nearby quarries. If an homogeneous dam is constructed, the upstream and downstream faces will require protection and rock would probably be the best means of doing this.

As the above types of dam are the only ones likely to be considered suitable for the proposed site, an adequate spillway will be required. Overtopping of an earth or rock fill dam would almost certainly destroy it. Because there is no solid rock near the surface, the spillway will have to be lined to prevent erosion.

Although further tests will be required to determine the suitability of the weathered basalt for dam construction, some Atterberg tests on some of the typical materials around the dam are given below. Three auger holes M1, M2 and M3 were drilled upstream of the dam in an area that may be used to obtain material to construct the dam. Compaction tests and further strength tests will probably be necessary for the weathered basalt if it is planned to use it in the dam construction.

Atterberg Limits

Atterberg limit tests have been undertaken on several samples from around the dam and also from an area where there is a possibility of obtaining material for dam construction (Table 3).

Table 3. RESULTS OF ATTERBERG LIMIT TESTS

Hole	Depth (m)	Liquid limit	Plastic limit	Plasticity index	Linear shrinkage
AH3	1.8-2.7	120.5	27.8	92.7	25
AH4	1.8-2.7	132.4	29.5	102.9	25
AH7	3.7	104.5	27.0	77.6	20
AH11	1.8-2.7	103.8	27.4	76.4	20
TP7	3.1-4.9	70.2	32.4	37.8	12
AH M1	0 -1.8	90.4	26.9	63.5	20
AH M2	1.8-3.7	85.9	29.5	56.4	17
AH M3	0 -1.8	112.8	27.6	85.2	23

As mentioned above, material from AH3 and AH4 consists of silty clay from the boulder beds, TP7 is red silty material derived from the weathering of Precambrian rocks, while the remainder is deeply weathered basalt. The silty clay from the boulder beds is probably finer grained than the weathered basalt and this may account partly for the higher PI. The sample from TP7 is silty and may have a considerable fine quartz content and this is probably the reason for the lower PI.

CONCLUSIONS AND RECOMMENDATIONS

Surface observations, a seismic survey and subsurface investigations show the proposed dam site to be in an area of deeply weathered Tertiary basalt. Sediments consisting of clayey boulder beds, clayey sand, and sandy and pebbly clay occur interbedded with the basalt on part of the eastern abutment. Precambrian sediments underly the dam site area, but were only encountered in holes on the eastern abutment.

Water pressure testing has shown some zones of the foundations across the axis to have moderate to high permeabilities. This will probably necessitate a deep cut off if relatively large losses are to be avoided. Other measures that may be used to prevent this loss would be to grout zones where bedrock is closer to the surface, *e.g.* near the floor of the valley where relatively unweathered basalt occurs within about 3.5 m of the surface, and on part of the eastern abutment where relatively unweathered Precambrian rocks may be encountered in the base of the cut off. The placement of an impermeable apron upstream from the dam would also aid in decreasing the water losses by increasing the length of leakage paths.

Although some small old landslip-like features occur upstream from the proposed dam on the east abutment, shear strength measurements on a variety of materials at the dam site suggest that they have relatively high strengths. However stability analyses should be performed on the dam itself and surrounding area as part of the design procedure. The one consolidation test on weathered basalt indicates that the settlement due to loading should not be a problem where this material is concerned. Locally small thin zones of deeply weathered Precambrian rocks may be subject to greater settlement, but because of the limited extent, may not present a serious problem.

Although sediments are interbedded with the basalt on the east abutment, the individual horizons appear to have limited lateral extent. High permeability zones (one probable such zone was encountered at about 9 m in DDH 3) are likely to be of limited extent. Materials with lower strength, such as clayey sediments, are also likely to have occurrences over narrow zones.

From the above, it is apparent that the foundation conditions are not without some problems. However with adequate precautions in design and construction, there seems little doubt that a dam can be safely built. It is apparent that the site is most favourable for an earth fill dam, although rock fill may be possible.

The siting of the cut off, particularly on the eastern abutment, will be important. From the subsurface investigations it is apparent that the most favourable location will be in the vicinity of DDH 7, TP 7 and AH 8. In this area it should be possible to reach the Precambrian rocks with the cut off. Because of the variable nature and uncertain extent of the sediments interbedded with the basalt, and the likely variability of the top of the Precambrian rocks, it will be necessary to have continuous trenching done in the early stages of the dam design. This should extend right across the dam axis and should provide information on any foundation problems that may not have been found in the investigations to date.

Testing of the materials for construction will have to be undertaken by an organisation competent in this work (*e.g.* H.E.C.). This refers to the clay forming the embankment or core as well as any rock used as a fill or facing. Compaction tests, possibly further classification tests and strength tests will be required.

REFERENCES

MATTHEWS, W.L. 1979*a*. Geology around a proposed damsite on the Guide River. *Unpubl.Rep.Dep.Mines Tasm.* 1979/4.

MATTHEWS, W.L. 1979*b*. Seismic survey at a proposed dam site at the Guide River. *Unpubl.Rep.Dep.Mines Tasm.* 1979/20.

[4 June 1980]

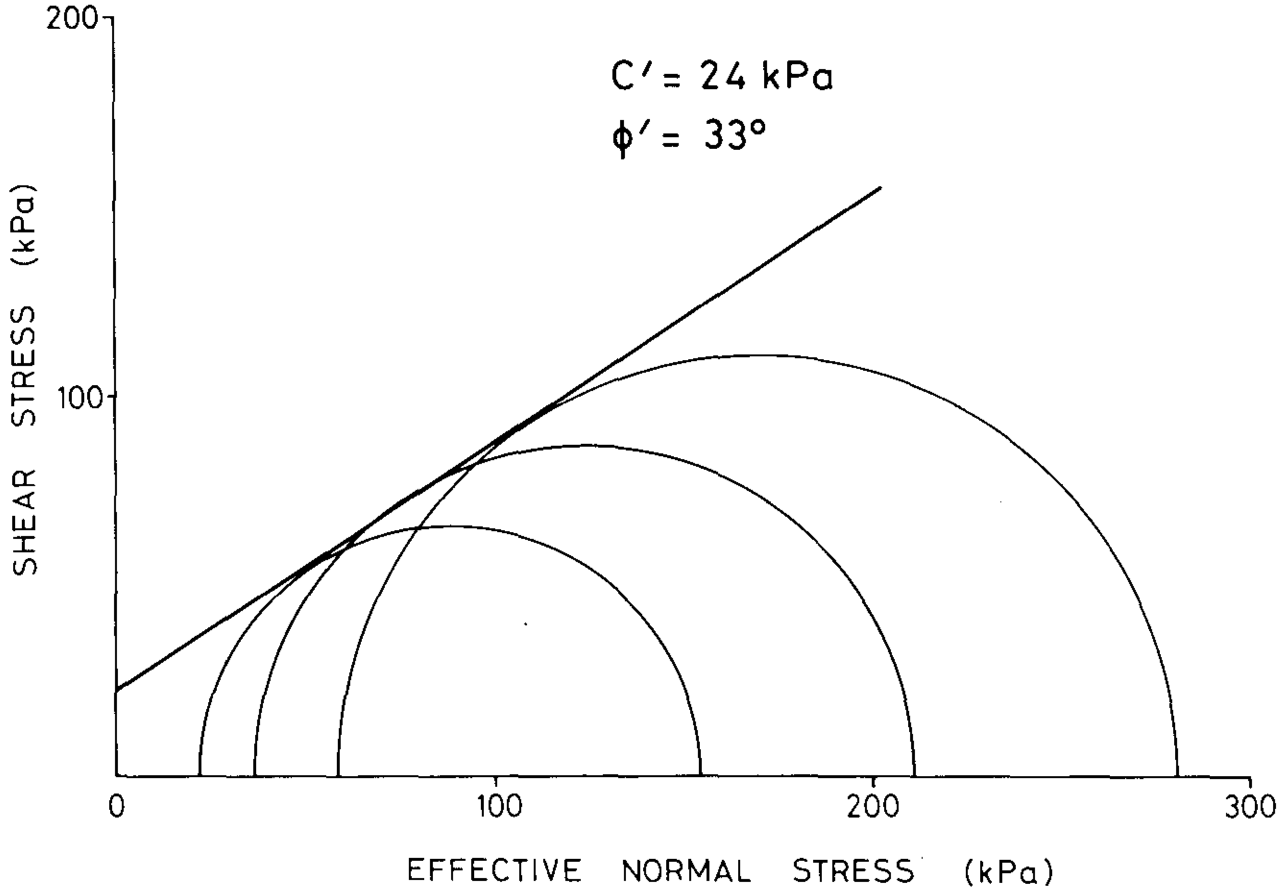
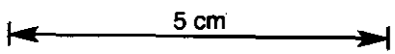


Figure 3. *Consolidated undrained triaxial test, weathered basalt, Guide River*



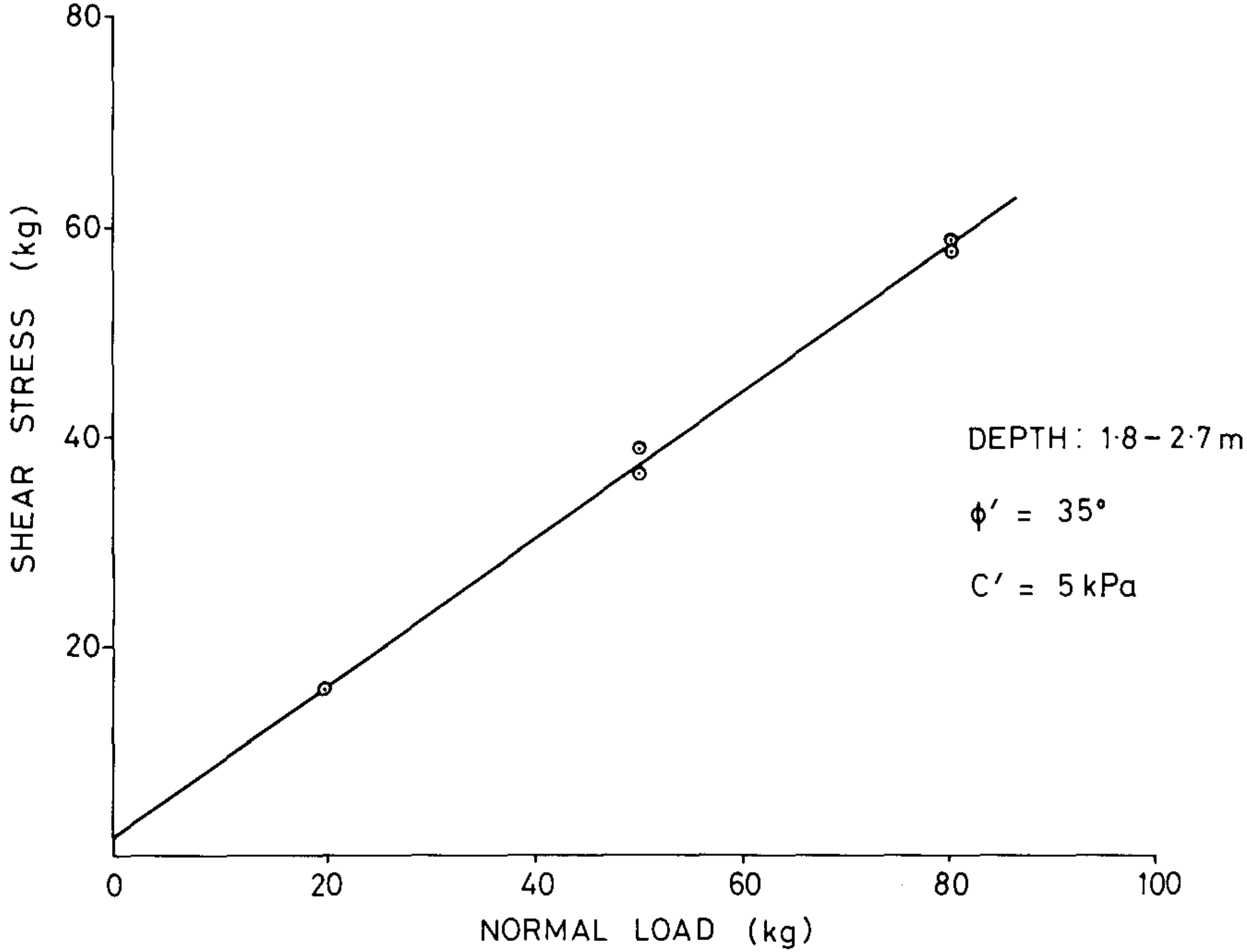


Figure 4. *Shear box strength test, disturbed sample, AH3*

5 cm

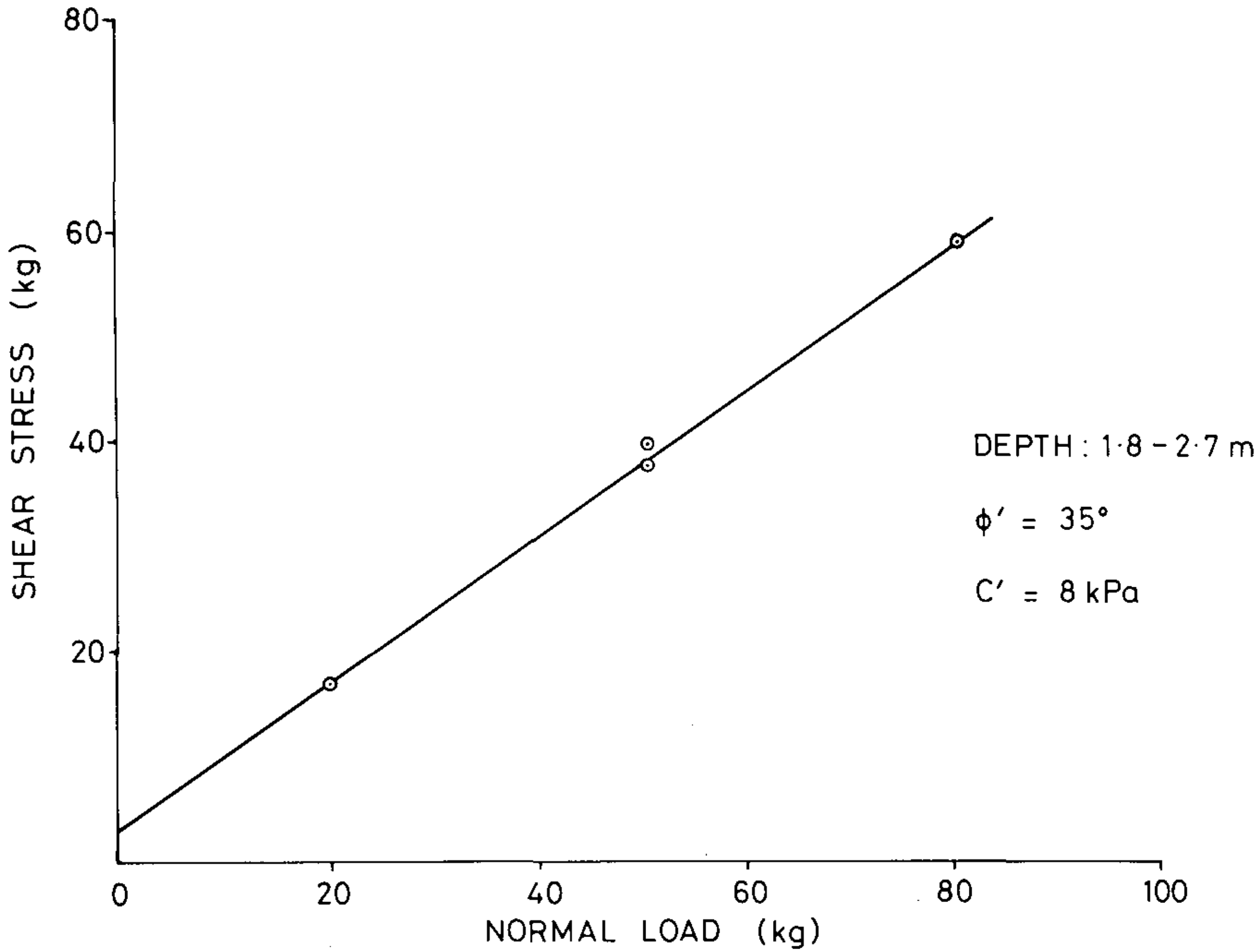


Figure 5. *Shear box strength test, AH4*

5 cm

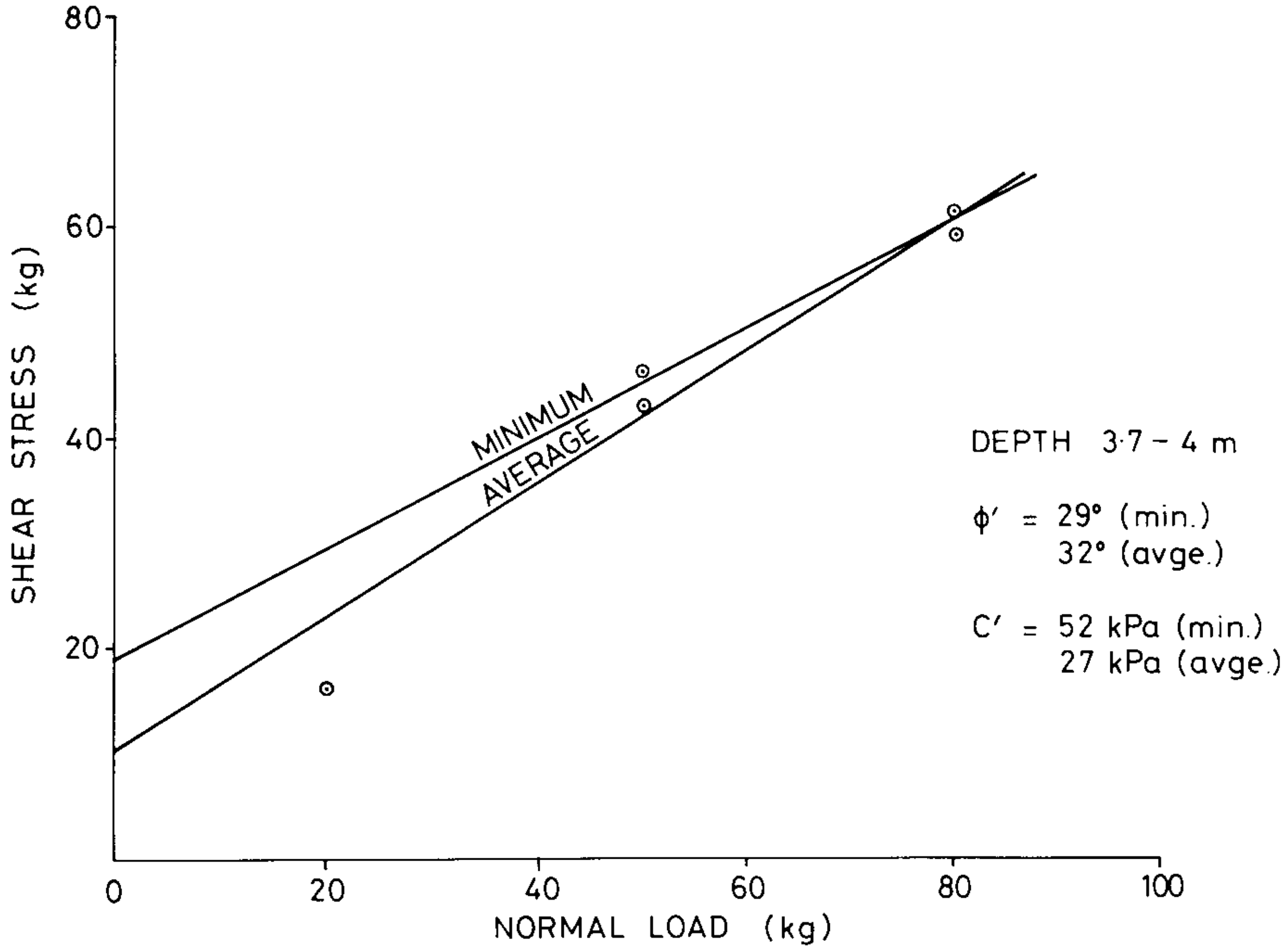


Figure 6. *Shear box strength test, undisturbed sample, AH 7*

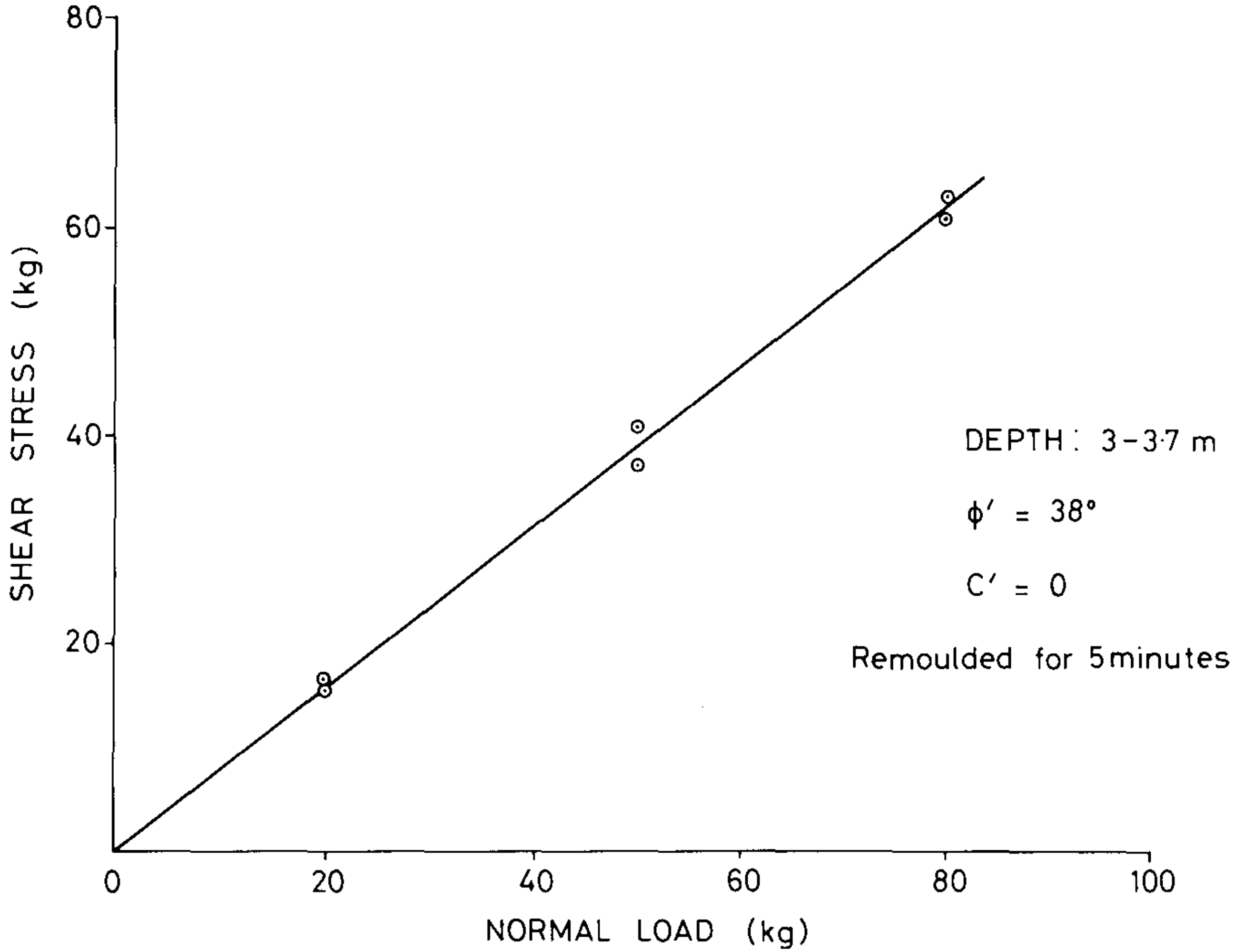


Figure 7. *Shear box strength test, disturbed and remoulded sample, AH 7*

5 cm

15-17

17/45

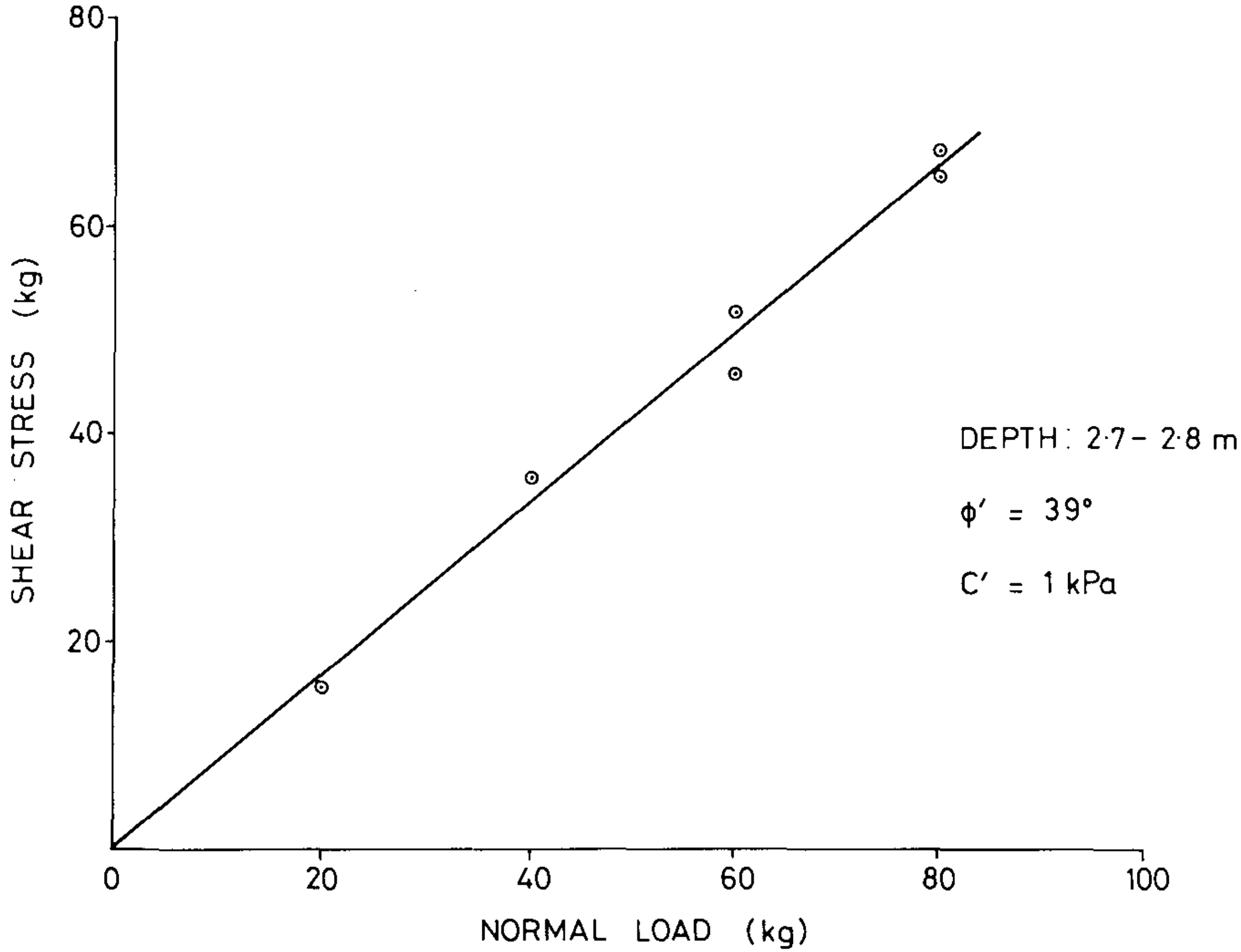
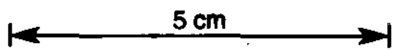


Figure 8. *Shear box strength test, disturbed sample, AH 12*



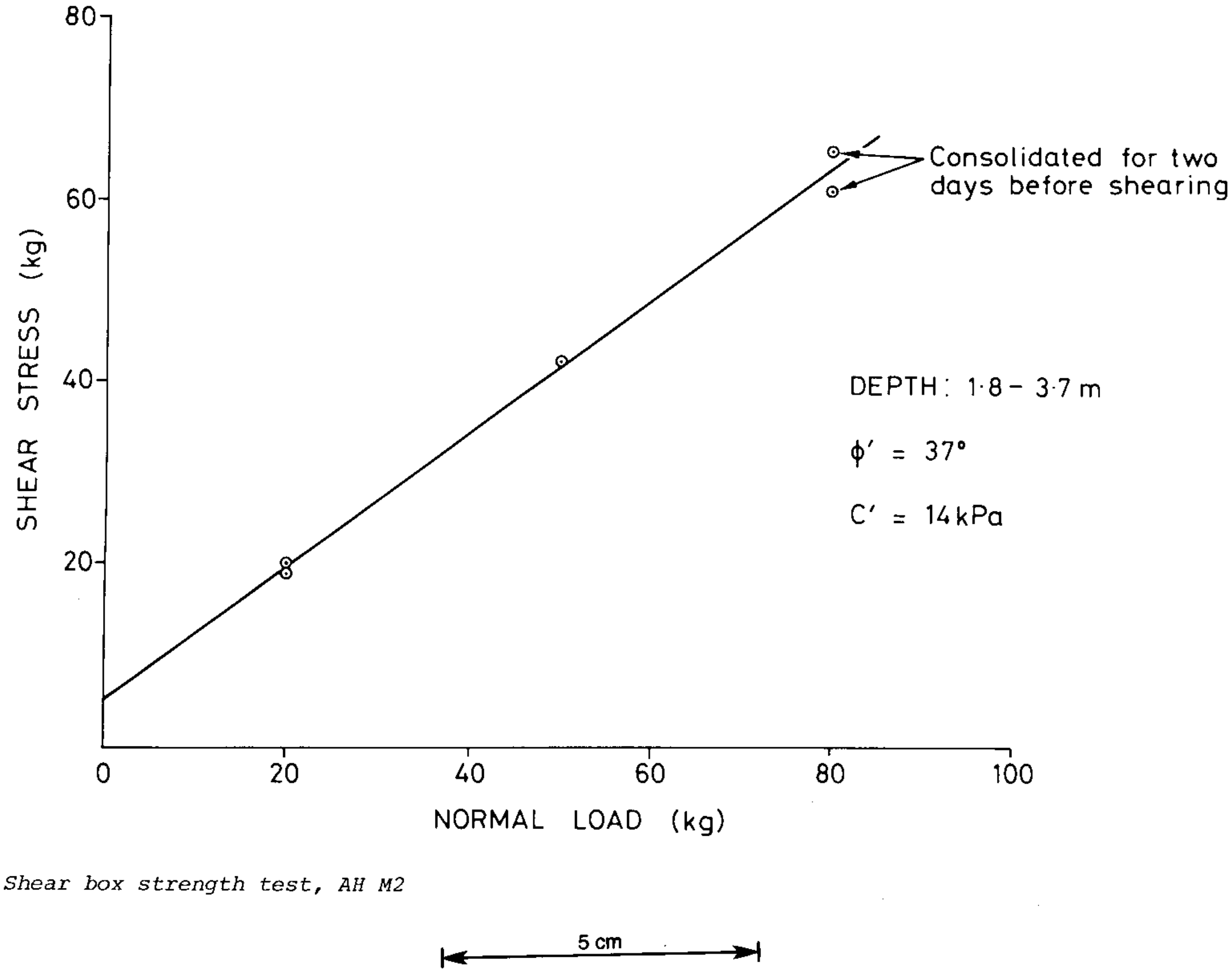


Figure 9. *Shear box strength test, AH M2*

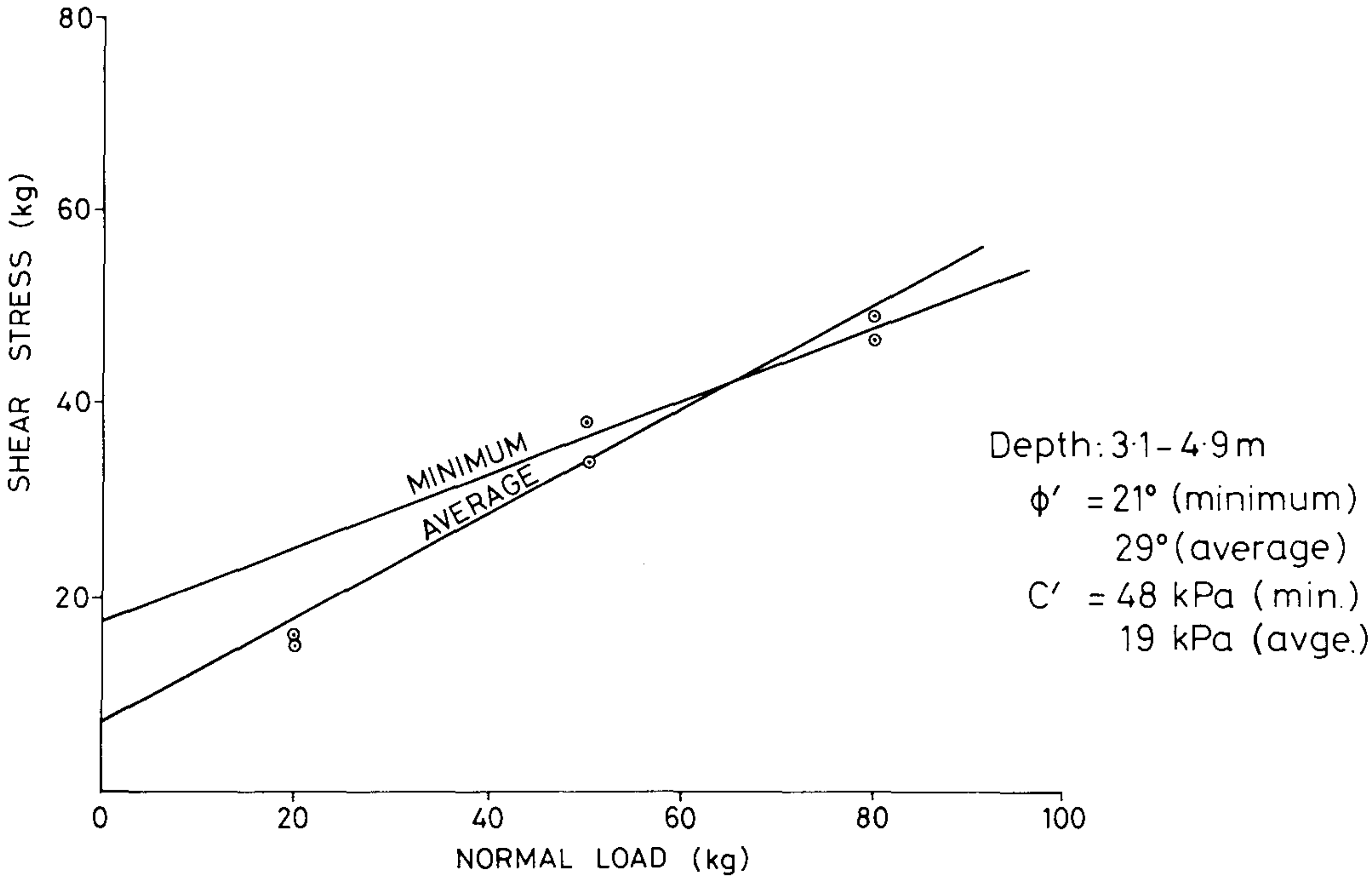


Figure 10. *Shear box strength test, weathered Precambrian, TP 7*

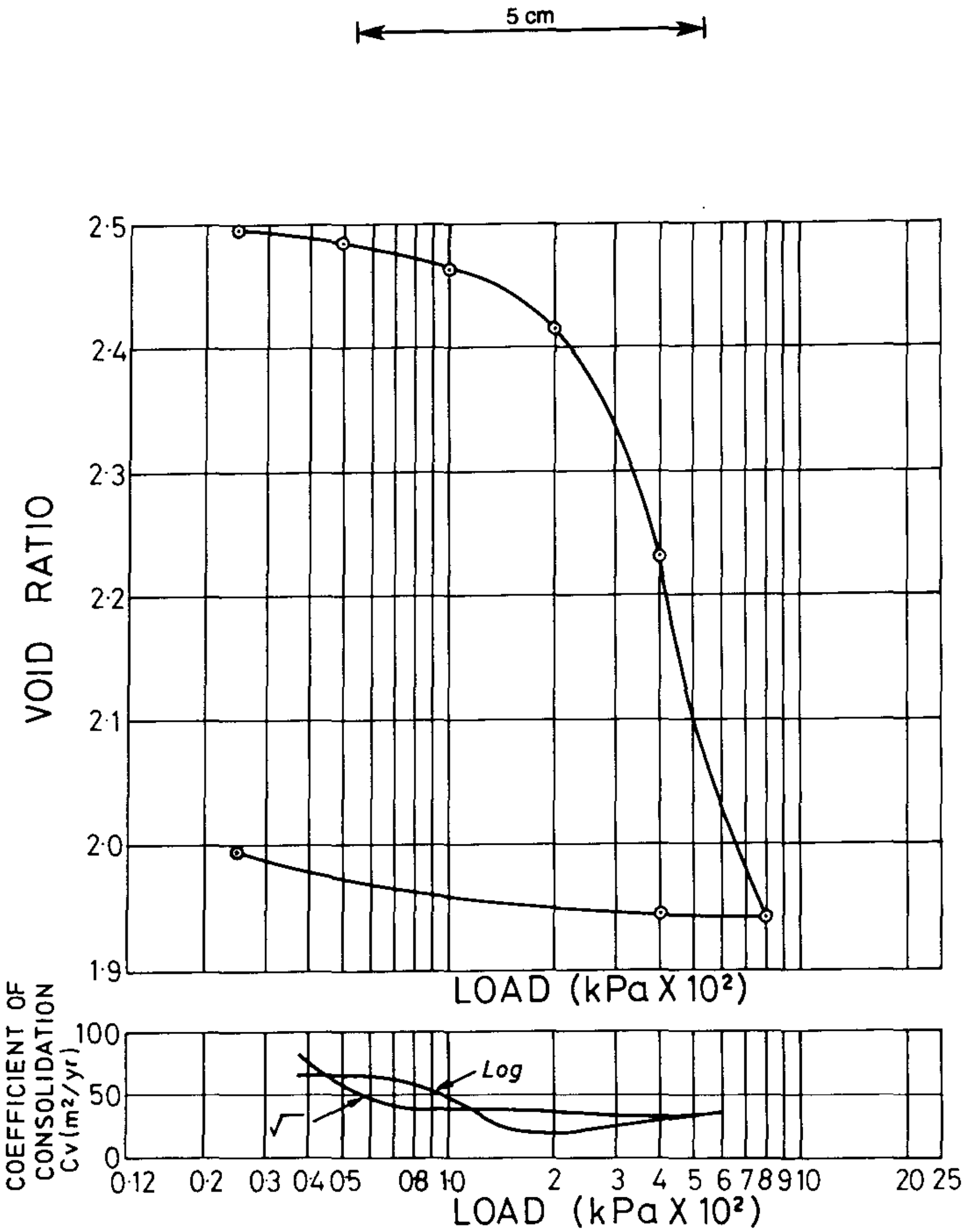


Figure 11. *Consolidation test on deeply weathered basalt, Guide River*

APPENDIX 1

Logs of test pits

Test Pit 1

Depth (m)	*Description*
0 - 0.3	Brown soil and basalt boulders.
0.3 - 0.9	Brown plastic clay (two strong localised seepages at one metre)
0.9 - 1.5	Zones of light brown and red mottled clay (weathered basalt)
1.5 - 4.6	Red and brown mottled clay - deeply weathered vesicular basalt (vesicles up to 15 mm). Very occasional unweathered centres of basalt up to 150 mm across of dark olivine basalt. Clay is friable-plastic.

Some seepage showing on pit surface up to 1.5 m from base after being open for 15 minutes.

Test Pit 2

0 - 0.3	Brown basalt-derived soil.
0.3 - 1.2	Brown friable-plastic clay.
1.2 - 3.1	Dark red and brown mottled clay with weathered vesicle fillings - deeply weathered basalt. Occasional zones of unweathered basalt.

No seepages occurred in the hole although the whole section was damp.

Test Pit 3

0 - 0.6	Brown soil and clay
0.6 - 2.7	Bouldery and pebbly clayey silt. Zones rich in rounded quartz pebbles, usually up to 15 mm across, although one quartz vein fragment was 50 mm across. Slate fragments up to 150 mm across. Basalt fragments, usually weathered, are also included.
2.7 - 4.9	Deeply weathered vesicular basalt. Some slightly harder bands but still deeply weathered, friable clayey material throughout. Some slate fragments at the base of the pit, but these may have been derived from further up the hole.

Water seepages occur in less weathered fractured zones. Rate of seepage is low.

Test Pit 4

0 - 0.3	Brown soil
0.3 - 2.3	Large basalt boulders up to 0.5 m across, relatively unweathered, in clay. Does not appear to be very permeable material.
2.3 - 3.1	Gravelly clay - rounded quartz fragments in a clay and silty clay matrix.

Test Pit 4 (continued)

3.1 - 4.9	Red, purple and brown mottled deeply weathered and very vesicular basalt, friable to plastic.

Hole was completely free of seepages although the weathered basalt was moist.

Test Pit 5

0 - 0.3	Brown soil.
0.3 - 1.2	Brown fairly plastic clay.
1.2 - 4.0	Purple and red-brown mottled clay - vesicular deeply weathered basalt with weathered vesicle fillings up to 5 mm across.
4.0 - 4.9	Weathered basalt with some harder zones. Some small unweathered kernels of basalt.

The hole was damp throughout but with no free seepages.

Test Pit 6

0 - 0.3	Brown soil.
0.3 - 0.5	Light brown plastic clay.
0.5 - 1.8	Mainly vesicular weathered basalt, small zones of less weathered material.
1.8 - 3.1	Less weathered very fine grained basalt - contact basalt? Centres of unweathered basalt make up about 50% of mass in more weathered material.
3.1 - 4.6	Brown and dark grey-brown mottled weathered scoriaceous basalt - tuff or agglomerate? Some planar slip surfaces extend over at least 150 mm.
4.6 - 4.9	Sediments - micaceous clayey sand followed by black sandy silty clay.

Seepage enters the hole from a level of about 4.0 m from the surface to the base. Water entered the hole at a fairly slow rate.

Test Pit 7

0 - 0.3	Brown soil.
0.3 - 1.2	Brown plastic and fragmental clay, some unweathered basalt boulders.
1.2 - 2.6	Clay - mainly derived from vesicular basalt but sometimes the texture is not visible and the material is a plastic clay without an obvious igneous texture.
2.6 - 3.1	Less weathered vesicular basalt.
3.1 - 4.9	Mainly weathered brown-red silty clay with limonite veins through it. Derived from the weathering of Precambrian rocks. Near contact with overlying basalt there are pockets of pebbly clay up to 0.3 m thick. Contact (basalt/Precambrian) slopes towards the north.
4.9 - 5.2	Hard green-brown siltstone - Precambrian.

Test Pit 7 (continued)

Seepage entered pit from less weathered basalt near the contact with the weathered Precambrian material. Water entered all around the pit, but only one zone had running water.

Test Pit 8

0 - 0.3	Brown soil.
0.3 - 2.6	Light brown plastic clay with basalt boulders scattered throughout. The clay is almost certainly derived from weathered basalt.
2.6 - 3.7	Green deeply weathered basalt.
At 3.7	Very hard iron-stained material - probably basalt but due to fairly rapid seepage in base it was not possible to examine it closely.

Water seepages came into the hole slowly from plastic clay and boulder zones but the main seepage is towards the base of the hole.

The hole was open for one hour and made an average of 0.20 m of water over an area of 2.1 x 0.9 m.

Level of base of hole is about the same as river level or about 0.3 m below.

Test Pit 9

0 - 0.3	Brown soil.
0.3 - 0.9	Fairly homogenous brown fragmental, slightly plastic clay (probably basalt-derived).
0.9 - 2.1	Brown, slightly friable weathered basalt-derived clay, vesicles (filled and weathered) only moderately common.
2.1 - 5.2	Vesicular very weathered brown and purplish mottled basalt. Vesicles biscuit like.

Small seepage entering at 4.3 m from the base.

Test Pit 10

0 - 0.6	Brown soil and plastic clay.
0.6 - 1.5	Plastic grey clay, no definite basalt texture.
1.5 - 4.0	Weathered basalt. Hard zone between 1.8 m - 2.4 m from surface. Some unweathered kernels of basalt.

Strong seepages entering the hole at about 2.6 m. Base of hole about 0.9 m below river level.

APPENDIX 2

Logs of auger holes

AH 1

Depth (m)	*Description*
0 - 0.9	Brown soil with occasional unweathered basalt boulders followed by brown fragmentary clayey material showing remnants of igneous texture.
0.9 - 2.7	Brown fragmentary clay with igneous texture. Water struck in this interval at about 1.8 m.
2.7 - 7.3	Heavily sedimented water, mainly clayey material, some weathered zeolite-like material.
7.3 - 8.2	Purple-red clay with obvious igneous texture, some weathered vesicle fillings (weathered basalt).
8.2 - 9.1	Brown weathered clay (basalt), igneous texture.

Hole open to 8.2 m on completion, 7.3 m next day. Water level at 1.3 m after 30 minutes, 1.3 m after 24 hours.

AH 2

0 - 0.9	Red-brown soil and clay.
0.9 - 1.8	Light brown clay.
1.8 - 2.7	Light brown clay with weathered vesicular material (basalt).
2.7 - 4.6	Grey-brown weathered basalt.
4.6 - 7.3	Heavily sedimented water with some weathered zeolite fragments (weathered basalt).
7.3 - 9.1	Becoming slightly harder weathered basalt, light brown iron oxide staining.

Hole open to 7.9 m after drilling, 6.4 next day.
Water level at 3.6 m after drilling, 3.3 m after 24 hours.

AH 3

0 - 0.3	Brown soil.
0.3 - 2.7	Red silty clay, no obvious basalt texture. Some pieces are light brown and are perhaps weathered Precambrian fragments.
2.7 - 3.7?	Red clayey silt changing to brown clayey silt with rounded quartz fragments up to 10 mm across.
3.7?- 7.3	Mid-brown rather soft clay with igneous texture (weathered basalt).
7.3 - 9.1	Light green-brown clay (weathered basalt) igneous texture visible but drilling is soft.

Hole open to 8.5 m after drilling, 7.9 m next day.
Water level at 6.2 m after drilling, 5.9 m after 24 hours.

AH 4

0 - 0.3	Brown soil and boulders.
0.3 - 0.9	Silty clay becoming pinkish in colour.
0.9 - 2.7	Pinkish brown silty clay with rounded pebbles up to 25 mm across.
2.7 - 3.7	Becoming brownish, some silty material but mainly basalt-derived clay.
3.7 - 6.4	Darker brown basalt-derived clay, some pebbles in upper section and some zones are pinkish silt which may have been derived from higher levels.
6.4 - 9.1	Light brown clay with igneous texture (weathered basalt).

Hole open to 7.9 m after drilling, 7.4 m next day.
Water level at 5.5 m after drilling, 4.1 m after 24 hours.

AH 5

0 - 0.3	Brown soil.
0.3 - 1.8	Brown silty clay with occasional unweathered basalt fragments.
1.8 - 2.7	Slightly lighter brown clay showing vesicular fragments up to 3 mm across.
2.7 - 3.7	Lighter brown clay with weathered vesicular fillings.
3.7 - 6.4?	Reddish clay mixed with water. Some solid pieces with definite basalt texture.
6.4 - 9.1	Grey weathered clay, definite basalt texture.

Hole open to 8.4 m on completion, 8.0 m next day.
Water level at 3.8 m on completion, 3.7 m after 24 hours.

AH 6

0 - 0.5	Brown soil and basalt boulders.
0.5 - 1.8	Reddish brown silty clay (some weathered Precambrian fragments?)
1.8 - 3.7	Reddish brown clay, basalt-derived with vesicular fillings common.
3.7 - 5.5	Light brown clay (basalt).
5.5 - 6.9	Weathered basalt (clay) becoming less weathered and harder with depth, grey with some areas rich in iron oxide staining.

Hole open to 6.1 m on completion, 5.8 m after 5 hours.
Water level at 3.7 m on completion, 3.6 m after 5 hours.

AH 7

0 - 0.6	Brown soil and boulders.
0.6 - 1.8	Reddish brown silty clay (no quartz fragments visible).
1.8 - 3.7	Brown clay, soft, basalt-derived. Undisturbed sample taken at this level.
3.7 - 4.6	Some zones of less weathered basalt, some fragments completely weathered.
4.6 - 7.3	Brown, fairly soft clay (weathered basalt).
7.3 - 9.1	Slightly harder clay (weathered basalt).

Hole open to 8.8 m after drilling.
Water level at 7.5 m after drilling.

AH 8

0 - 0.9	Fine grained reddish silty clay and basalt-derived clay, occasional unweathered basalt boulders.
0.9 - 1.8	Dark red-brown silty and sandy clay, basalt-derived. A little red silty clay, occasional basalt boulders.
1.8 - 3.6	Dark red-brown sandy and silty clay, dominantly basalt-derived.
3.6 - 3.7	Lighter brown clay (weathered basalt), fairly plastic when wet.
3.7 - 6.4	Darker brown clay, basalt-derived with a small proportion of rounded grit size fragments, some larger iron oxide fragments. At 6.4 m a large quartz vein fragment 50 mm across.
6.4 - 6.6	Blue hard rock, almost certainly Precambrian.

Water level next day at 2.6 m.

AH 9

0 - 0.6	Mainly basalt boulders and brown soil derived from basalt.
0.6 - 1.8	Brown and red silty clay, some quartz fragments up to 12 mm across.
1.8 - 2.7	Dark grey-brown sandy silty clay, weathered basalt-derived material.
2.7 - 3.7	Soft light brown weathered basalt.
3.7 - 4.0	Undisturbed sample, tube sample 4 (weathered basalt).
4.0 - 4.6	Soft brown weathered basalt, some unweathered pieces.
4.6 - 4.9	As above, but struck unweathered zones of basalt which could not be drilled.

Hole open to 4.6 m next day but dry.

AH 10

0 - 0.9	Light brown basalt-derived clay.
0.9 - 1.8	Light grey-brown basalt-derived clay with vesicle fillings of weathered zeolite.
1.8 - 4.6	Grey basalt-derived clay, sandy and silty texture.
4.6 - 9.1	No return on augers but 4.6 - 6.1 m was very soft drilling, no sedimentary material seen in samples. From 6.1 m possibly (and certainly from 7.3 m) dark grey-brown weathered basalt becoming harder with depth.

Next day water level at 4 m.

A hole was later tube sampled nearby to determine whether sedimentary material occurs in the area surrounding AH10.

0 - 0.9	Weathered basalt with some unweathered pieces of basalt.
0.9 - 2.7 (augered to 2.7 m)	Grey-brown weathered basalt.
2.7 - 5.2	Grey and brown weathered basalt with large weathered vesicle fillings.
5.2 - 5.6	Tube sample fell out.
5.2 - 7.3 (augered)	Deeply weathered basalt, some areas harder and less weathered.

AH 11

0 - 0.9	Brown deeply weathered basalt.
0.9 - 2.7	Dark, mid grey-brown soft weathered basalt.
2.7 - 3.2	Tube sample - top is soft but lower is harder vesicular basalt.
3.2 - 5.0	Drilling becoming gradually harder in weathered basalt, some fragmentary pieces of weathered basalt. Drill was just able to penetrate slowly at the base.

Water level at 2.7 m 2 hours after drilling.

AH 12

0 - 0.9	Brown basalt-derived clay with some pebbles of unweathered basalt.
0.9 - 2.7	Dark to medium grey-brown soft, weathered basalt, one hard zone at 2.6 m. Tube sample at 2.7 m.
2.7 - 5.8	Weathered basalt, becoming successively harder with depth.

Water level one hour after drilling 3.3 m.

AUGER HOLES IN AREA FOR POSSIBLE CONSTRUCTION MATERIAL

AH M1 (on southern seismic spread)

Depth (m)	*Description*
0 - 0.9	Mid-brown slightly moist fragmentary clay.
0.9 - 3.2	Brown fragmental moist clay (weathered basalt).
3.2 - 7.6	Lighter brown wet fragmental clay, soft till 6.7 m when it became harder to drill (weathered basalt).
7.6 - 8.2	Slightly darker greenish brown weathered basalt.
8.2 - 9.1	Greenish brown and greenish grey weathered basalt followed by pebbly clay with rounded quartz fragments and a schist fragment 15 mm in diameter.
9.1 - 9.3	Weathered mudstone, probably Precambrian.

AH M2 (100 m south of M1)

0 - 1.8	Dark brownish grey fragmental clay (weathered basalt), a few unweathered pieces of basalt.
1.8 - 5.8	Light brown fragmental clay, basalt-derived.
5.8 - 5.9	Dark grey harder weathered basalt (crystalline material in vesicles, probably calcite).

AH M3

0 - 0.9	Dark grey-brown basalt soil and fragmental clay.
0.9 - 4.6	Mid brown clay, basalt-derived.
4.6 - 4.9	Basalt, becoming less weathered, some unweathered pieces.

APPENDIX 3

Logs of diamond drill holes

Note. *Deeply weathered basalt* is mainly clay with an igneous texture. *Weathered basalt* shows some sign of weathering, but the material is a firm, fairly hard rock.

Location of holes shown on Figure 1.

DDH 1

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
0 - 2.0	0.77	38.5	Basalt, broken, (pieces up to 200 mm long) medium to fine grained, mainly unweathered, some weathered material around joints.
2.0 - 2.6	0.4	66.7	Basalt, fine grained, dark, olivine rich, jointed-dip at 60-70°, largest piece 180 mm, weathering up to 20 mm wide on joints.
2.6 - 3.8	0.33	27.5	Basalt as above, largest piece 160 mm long.
3.8 - 5.3	0.2	13.3	Basalt, deeply weathered, vesicular.
5.3 - 6.8	0.4	26.6	Basalt, deeply weathered, vesicular, 20 mm zone of clayey sand made up of angular quartz fragments up to 1 mm across.
6.8 - 7.3	0.2	40.0	Basalt, mainly deeply weathered, vesicular. One largely unweathered 30 mm zone. 20 mm gritty clay, quartz fragments, one chert fragment 15 mm across.
7.3 - 8.8	0.68	45.3	Slate fragments, rounded for first 100 mm, followed by basalt, deeply weathered.
8.8 -10.3	1.5	100	Basalt, alternations of deeply weathered vesicular and zones of broken, largely unweathered material.
10.3 -11.8	0.7	46.6	Basalt as above.
11.8 -12.2	0.4	100	Basalt, largely unweathered, very broken, fine grained, dark, a few vesicles, iron oxide staining on joints.
12.2 -13.3	0.7	63.6	Basalt, mainly deeply weathered. 100 mm broken unweathered at beginning, 50 mm less weathered at end.
13.3 -14.8	0.8	53.3	Basalt, a little weathered for 20 mm at beginning then about 600 mm of dark blue-grey mudstone followed by 200 mm of weathered vesicular basalt.
14.8 -16.3	1.25	83.3	Basalt, weathered, vesicular, vesicles filled and weathered.
16.3 -17.8	0.2	13.3	Basalt, weathered, vesicular.
17.8 -19.3	1.6	106.7	Basalt, deeply weathered, purplish for 460 mm then grey-brown and light brown. Becoming slightly less weathered, fewer vesicles.

DDH 1 (continued)

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
19.3-20.8	0.82	54.7	Basalt, deeply weathered, vesicular.
20.8-22.3	1.47	98.0	Basalt, becoming less weathered with depth, vesicular, 60 mm vein fine hard clay (weathered zeolite or glass?) at 21.1 m. Vesicles often unfilled.
22.3-23.8	1.45	96.7	Vesicular basalt, and sandy and clayey grit intermixed for first 550 mm, then vesicular basalt to end. Vesicles mainly unfilled, less weathered at end.
23.8-25.2	1.70	113.3	Basalt, weathered brown and grey for 440 mm followed by 200 mm clayey even-grained quartz, sand and weathered basalt boulders intermixed, followed by cream to white hard clay.

DDH 2

0 - 1.0	1.0	100	Soil, brown with basalt fragments for 0.4 m, followed by 0.6 m weathered basalt.
1.0- 2.0	1.0	100	Basalt, broken, largely unweathered for 0.5 m then 0.5 m of weathered basalt.
2.0- 2.5	0.02	4	Basalt, one fragment, largely unweathered.
2.5- 4.0	0.75	50.0	Basalt, deeply weathered, grey-brown with some vesicles, passing into purple vesicular basalt.
4.0- 5.5	1.5	100	Basalt, deeply weathered, light grey-brown, vesicles filled, fillings weathered.
5.5- 7.0	0.94	62.7	Basalt, as above.
7.0- 8.5	1.5	100	Basalt as above with 0.13 m light brown sandy clay with mica at 7.05 m.
8.5-10.0	1.2	80.0	Basalt, deeply weathered, vesicular - only a few for first 0.7 m (first 0.3 m weathered tuff?). Final 0.5 m is purple with open vesicles and brown with filled vesicles.
10.0-11.5	0.6	40.0	Basalt, weathered purplish and grey-green, vesicles mainly unfilled.
11.5-13.0	1.6	106.7	Basalt, deeply weathered, light brown, a few large vesicles.
13.0-14.5	0.72	48.0	Basalt, weathered vesicular, grey-brown, vesicles mainly open.
14.5-16.0	0.57	38.0	Basalt, deeply weathered, light brown.
16.0-17.5	0.7	46.7	Basalt, weathered, small filled vesicles, becoming less weathered towards end.
17.5-19.0	0.9	60.0	Basalt, less weathered, broken, a few vesicles. 150 mm of fine grained dark unweathered basalt at 0.4 m (on core).

DDH 2 (continued)

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
19.0-20.5	1.5	100	Basalt, weathered (less than much of above), broken.
20.5-22.0	1.55	103.3	Basalt, less weathered, 80 mm unweathered section at 20.63 m. Final 0.45 m is unweathered fine grained dark basalt with some calcite filled vesicles.
22.0-23.5	1.55	103.3	Basalt, unweathered fine grained dark basalt, few vesicles. Vertical joint in final part (0.9 m from end) gives broken appearance.
23.5-25.0	1.53	102	Basalt, unweathered, fine gràined, few vesicles. Broken by vertical joint for first 0.6 m - filling of fine dark material (weathered zeolite?), three broken joints in next 0.9 m. Occasional calcite filled vesicles. Final 80 mm is weathered grey-green vesicular basalt.
25.0-26.5	0.62	41.3	Whitish siltstone/claystone, very broken. Precambrian.
26.5-28.0	1.0	66.7	As above.

DDH 3

0 - 3.2	0	0	
3.2- 4.0	0.13	16.3	Clay with basalt fragments.
4.0- 5.5	0.36	24	Basalt fragments up to 50 mm long, a little brown clay.
5.5- 7.0	0.95	63.3	Basalt, 0.4 m broken basalt, largely unweathered followed by deeply weathered vesicle rich (filled), brown basalt.
7.0- 8.5	1.24	82.7	Basalt deeply weathered grey and brown, vesicular. Decreases with depth, at 0.1-0.2 m (on core) weathered zeolite or glass?
8.5-10.0	0.75	50	Basalt, deeply weathered vesicular for 0.2 m, then 0.3 m silty micaceous clay, sandy clay, quartz sand followed by weathered vesicular basalt, pinkish brown.
10.0-11.5	0.95	63.3	Basalt and sediments intermixed - 70 mm pinkish brown weathered basalt, 0.1 m brown clayey sand, 0.16 m dark grey sandy silty clay, then vesicular (open) basalt with seams of quartz grit along and across core.
11.5-13.0	1.45	96.7	Sand and basalt as above for 0.3 m, then blue-grey vesicular basalt, becoming less weathered, pieces about 120 mm long.

DDH 3 (continued)

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
13.0-14.5	1.55	103.3	Basalt, variably weathered, vesicular - unfilled at beginning, filled at end. Less weathered at end.
14.5-16.0	1.6	106.7	Basalt, weathered, fairly coarse grained, greenish, a few vesicles. Seam of dark weathered zeolite? dipping at 60°.
16.0-17.5	0.9	60.0	Clayey, very fragmentary for 0.1 m, 0.1 m probable weathered basalt, 0.12 m cream hard clay, then very fractured cream siltstone with slip surface on contact.
17.5-19.0	0.63	42	Siltstone, light grey, fractured.
19.0-20.5	1.24	82.7	Mudstone, slaty fractured, possible graphite.
20.5-22.0	1.45	96.7	Mudstone, soft, grey slaty.
22.0-23.5	1.55	103.3	Mudstone, grey, slaty mainly soft, very fractured, becomes darker grey and pyritic with depth. Final 0.27 m quartz sandstone, micaceous, hard with some cleavage.
23.5-25.0	1.62	108	Sandstone micaceous and clayey? Quartz vein at 0.27 m from end. Final 0.13 m soft cream clayey material.

DDH 4

0 - 2.0	0.7	35	Basalt, largely unweathered, broken, up to 140 mm long, dark medium to coarse grained.
2.0- 2.5	0.4	80	Basalt, jointed, weathering on joints, some vesicles.
2.5- 4.0	0.1	6.6	Basalt - four pieces, largely unweathered.
4.0- 5.5	0.5	33.3	Basalt, weathered, vesicular - open at beginning.
5.5- 7.0	1.5	100	Basalt, 0.06 m deeply weathered, vesicular, 1.26 m slightly weathered basalt, 0.18 m weathered vesicular. Calcite filled vesicles.
7.0- 8.5	1.57	104.7	Basalt, weathered, very vesicular at beginning, rarer at end. Vesicles often open and calcite lined and up to 20 mm across.
8.5-10.0	1.53	102	Basalt, weathered, very vesicular after first 0.1 m most vesicles unfilled, some filled with calcite.
10.0-11.5	1.5	100	Basalt, weathered, variable vesicularity calcite and zeolite filled, 30 mm clayey sediment? at 0.27 m, 0.2 m micaceous clay with some basalt at 0.42 m, irregular contact.

DDH 4 (continued)

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
11.5-13.0	1.42	94.7	Grit and basalt intermixed for 0.08 m, 0.5 m vesicular basalt, some filled, most unfilled. Final 0.84 m is weathered basalt with filled and weathered vesicles.
13.0-14.5	1.6	106.7	Basalt, weathered, vesicular mainly filled, some unfilled.
14.5-16.0	1.55	103.3	Basalt, becoming less weathered, vesicular, some filled - fillings weathered. Final one metre is largely unweathered basalt, fairly coarse grained, a few 1 mm wide calcite veins.

DDH 5

0 - 2.0	1.8	90	Clay, speckled brown for 1.15 m, then grey with igneous texture.
2.0- 3.0	0.6	60	Basalt, deeply weathered, vesicular.
3.0- 4.0	0.14	14	Basalt, much less weathered, few vesicles.
4.0- 5.5	0.8	53.3	Basalt, 0.4 m broken some weathering, more weathering on joints, then coarse basalt, some weathering. Vesicularity variable, some zeolite fillings.
5.5- 7.0	1.57	104.7	Basalt weathered, vesicular, mainly zeolite fillings, nine breaks in core. Weathered zone from 0.2-0.35 m on core.
7.0- 8.5	1.45	96.7	Basalt, variably weathered, vesicular, zones of zeolite. At 0.7-0.8 m (on core) hard blue clay - maybe intercalation or xenolith.
8.5-10.0	1.6	106.7	Basalt, some weathering, vesicular, mainly zeolite-filled.
10.0-11.5	1.3	86.7	Basalt, many vesicles, filled and partially filled mainly zeolite, only two breaks.
11.5-13.0	1.6	106.7	Basalt, some weathering, 0.3 m section on each end fairly vesicular, fillings weathered.
13.0-14.5	1.5	100	Basalt, some weathering, vesicular - often weathered fillings, some calcite some zeolite. 50 mm weathered zeolite?
14.5-16.0	1.84	122.7	Basalt, weathered, more broken, vesicle fillings mainly weathered, a few calcite fillings.
16.0-19.0	2.36	78.7	Basalt some weathering, fairly coarse grained, variable vesicularity.

DDH 6

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
0 - 2.0	1.75	87.5	Clay, dark brown, some small basalt fragments.
2.0- 3.0	0.82	82	Basalt deeply weathered, light brown - grey-brown.
3.0- 4.0	0.35	35.0	Basalt, deeply weathered grey-brown vesicular, fillings weathered.
4.0- 5.5	0.68	45.3	Basalt, lighter brown deeply weathered, broken.
5.5- 7.0	1.13	75.3	Basalt, 0.5 m as above, then broken (up to 50 mm pieces) largely unweathered basalt.
7.0- 8.5	1.14	76.0	Basalt, deeply weathered, light brown to grey.
8.5-10.0	1.1	73.3	Basalt, light brown, deeply weathered, vesicular to 0.8 m, then largely unweathered broken (up to 50 mm), few vesicles.
10.0-11.5	0.34	22.7	Basalt, weathered variably, vesicular, filled.
11.5-13.0	1.5	100	Basalt, weathered, coarse grained, vesicles rare first 12 m, occasional 1 mm wide calcite seams, final 0.3 m vesicular, calcite and zeolite filled.
13.0-14.5	1.6	106.7	Basalt, some weathering, vesicular, partially or wholly zeolite filled, six breaks in core, mainly near beginning.
14.5-16.0	1.55	103.3	Basalt, some weathering, vesicular, some filled and weathered, some partially or wholly filled with zeolite and unweathered - X-ray determination - chabazite.
16.0-17.5	1.45	96.7	Basalt as above, mostly zeolite vesicle fillings, some calcite. Weathered zeolite? seams at 0.25 m and 1.07 m (0.1 m thick).
17.5-19.0	1.58	105.3	Basalt, partially weathered, vesicular, calcite and zeolite fillings. Three breaks in core.
19.0-20.5	1.4	93.3	Basalt, partially weathered, vesicular, calcite and zeolite filling.
20.5-22.0	1.58	105.3	Basalt, partially weathered, vesicles very common in centre of run, zeolite and calcite fillings (some partially filled).
22.0-23.5	1.36	90.7	Basalt as above, very vesicular to 0.85 m, then coarse grained basalt with few vesicles. Few breaks.

DDH 6 (continued)

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
23.5-25.0	1.34	89.3	Basalt, partially weathered, coarse grained, vesicles, two breaks.

DDH 7

Depth (m)	*Recovery* (m)	*Recovery* (%)	*Description*
0 - 2.0	2.2	110	Clay, chocolate brown to lighter brown, some quartz, grit fragments, basalt fragments (up to 30 mm across).
2.0- 2.8	0.75	93.8	Basalt, deeply weathered, light brown.
2.8- 4.0	1.0	83.3	As above.
4.0- 5.5	0.42	28.0	As above.
5.5- 7.0	1.15	76.7	Basalt, fragmented unweathered pieces in weathered for 0.5 m, then deeply weathered, brown.
7.0- 8.5	1.30	86.7	Basalt, deeply weathered, brown, filled vesicles, a little less weathered towards end.
8.5-10.0	1.52	101.3	Basalt with seams of iron oxide for first 0.4 m, then 0.4 m cream silty clay, then 0.4 m speckled clay with quartz vein - probably Precambrian sediments.
10.0-11.5	1.27	84.7	Siltstone, light grey.
11.5-13.0	1.70	113.3	Clay, silty, light grey siltstone to 0.65 m, then sandstone with foliations dip 60°. Two quartz veins at 1.0 m.
13.0-14.5	1.55	103.3	Siltstone, sandy, slightly harder, rare quartz veins, some foliations at about 45°.
14.5-16.0	1.6	106.7	Siltstone, light grey, sandy. All above section a little like deeply weathered basalt. Quartz veins.

APPENDIX 4

Results of water pressure tests of diamond drill holes

Hole	Depth (m)	Pressure kPa*	Pressure ft	Pressure corrected	Water Loss galls/ 5 min*	Water Loss galls/ min	Water Loss min^{-1} ft^{-1}	Water Loss K (m/yr)	Water Loss Av. K	Water Loss Lugeons (approx.)
DDH 1	3.8- 6.8	40	13.4	30.5	2	0.4	0.04	23.5		
	2 m casing	100	33.5	50.6	9	1.8	0.18	63.8		
	W.L. 5.2 m	80	26.8	43.9	9½	1.9	0.19	77.6	53.0	15.3
	(17.1')	40	13.4	30.5	4	0.8	0.08	46.9		
	13.3-16.3	70	23.6	51.5	6½	1.3	0.13	45.2		
	12 m casing	140	33.5	61.4	12½	2.5	0.25	59.9		
	W.L. 8.5 m	210	70.2	98.1	14	2.8	0.28	51.1	49.1	14.1
	(27.9')	300	100.5	128.4	17	3.4	0.34	47.5		
		70	23.6	51.5	6	1.2	0.12	41.8		
	16.3-19.3	70	23.6	51.5	2½	0.5	0.05	17.4		
	12 m casing	140	33.5	61.4	7½	1.5	0.15	36.0		
	W.L. 8.5 m	210	70.2	98.1	10	2	0.2	36.6		
	(27.9')	300	100.5	128.4	15½	3.1	0.31	43.2	27.9	8.0
		140	33.5	61.4	4½	0.9	0.09	21.6		
		70	23.6	51.5	2	0.4	0.04	14.0		
		160	53.6	81.5	6	1.2	0.12	26.4		
	19.3-22.3	70	23.6	51.5	1	0.2	0.02	6.9		
	12 m casing	140	33.5	61.4	2	0.4	0.04	9.6		
	W.L. 8.5 m	160	53.6	81.5	3	0.6	0.06	13.2		
	(27.9')	210	70.2	98.1	3	0.6	0.06	10.9	9.6	2.8
		300	100.5	128.4	3½	0.7	0.07	9.8		
		140	33.5	61.4	1½	0.3	0.03	7.2		
	20.8-25.3	70	23.6	51.5	1	0.2	0.014	6.9		
	12 m casing	140	33.5	61.4	3½	0.7	0.047	16.8		
	W.L. 8.5 m	160	53.6	81.5	3	0.6	0.041	13.2	12.2	3.5
	(27.9')	210	70.2	98.1	2½	0.5	0.034	9.1		
		300	100.5	128.5	4½	0.9	0.061	12.5		
		140	33.5	61.4	3	0.6	0.041	14.4		
DDH 2	4.0- 7.0	40	13.4	31.4	½	0.1	0.01	5.8		
	2 m casing	80	26.8	44.8	3	0.6	0.06	24.0		
	(+ 18')	120	40.2	58.2	12	2.4	0.24	73.9	32.3	9.3
		80	26.8	44.8	7½	1.3	0.13	52.0		
		40	13.4	31.4	½	0.1	0.01	5.8		
	7.0-10.0	40	13.4	31.4	½	0.1	0.01	5.8		
	(+ 18')	80	26.8	44.8	2	0.4	0.04	16.0		
		120	40.2	58.2	6½	1.3	0.13	40.0		
		160	53.6	71.6	12	2.4	0.24	60.0	33.6	9.7
		120	40.2	58.2	9½	1.5	0.15	46.1		
		80	26.8	44.8	5½	1.1	0.11	44.1		
		40	13.4	31.4	2	0.4	0.04	22.9		
	10.0-13.0	40	13.4	26.5	½	0.1	0.01	6.8		
	2 m casing	80	26.8	39.9	2½	0.5	0.05	22.5		
	W.L. 4 m	120	40.2	53.3	6	1.1	0.11	37.0		
	(+ 13.1')	160	53.6	66.7	8	1.6	0.16	43.1	22.8	6.6
		120	40.2	53.3	4½	0.9	0.09	30.2		
		80	26.8	39.9	1½	0.3	0.03	13.4		
		40	13.4	26.5	½	0.1	0.01	6.8		

* Field data

DDH 2 (continued)

Hole	Depth (m)	Pressure kPa*	Pressure ft	Pressure corrected	Water Loss galls/ 5 min*	Water Loss galls/ min	Water Loss min^{-1} ft^{-1}	Water Loss K (m/yr)	Av. K	Lugeons (approx.
	13.0-16.0	40	13.4	26.5	1	0.2	0.02	13.5		
	(13.1')	80	26.8	39.9	3½	0.7	0.07	31.4		
		120	40.2	53.3	7½	1.5	0.15	50.4		
		160	53.6	66.7	10	2.0	0.2	53.7	30.9	8.9
		120	40.2	53.3	7	1.4	0.14	47.1		
		80	26.8	39.9	1½	0.3	0.03	13.5		
		40	13.4	26.5	½	0.1	0.01	6.8		
	16.0-19.0	No seal possible								
	19.0-22.0	40	13.4	26.5	½	0.1	0.01	6.8		
	2 m casing	80	26.8	39.9	3	0.6	0.06	26.9		
	W.L. 4 m	120	40.2	53.3	4	0.8	0.08	26.9		
	(13.1')	160	53.6	66.7	5½	1.1	0.11	29.5		
		200	67.0	80.1	15	3.0	0.03	67.1	33.3	9.6
		160	53.6	66.7	8½	1.7	0.17	45.6		
		120	40.2	53.3	6	1.2	0.12	40.3		
		80	26.8	39.9	4	0.8	0.08	36.0		
		40	13.4	26.5	1½	0.3	0.03	20.3		
	22.0-25.0	40	13.4	26.5	nil	-				
	(13.1')	80	26.8	39.9	½	0.1	0.01	4.5		
		120	40.2	53.3	1	0.2	0.02	6.8		
		160	53.6	66.7	1½	0.3	0.03	8.1	5.9	1.7
		200	67.0	80.1	1½	0.3	0.03	6.8		
		120	40.2	53.3	½	0.1	0.01	3.3		
	25.0-28.0	40	13.4	26.5	½	0.1	0.01	6.8		
	2 m casing	80	26.8	39.9	1½	0.3	0.03	13.4		
	W.L. 4 m	120	40.2	53.3	1½	0.3	0.03	10.1		
	(13.1')	160	53.6	66.7	2	0.4	0.04	10.8		
		200	67.0	80.1	4½	0.9	0.09	20.2	13.5	3.9
		300	100.5	113.6	7	1.4	0.14	22.2		
		200	67.0	80.1	4½	0.9	0.09	20.2		
		160	53.6	66.7	2	0.4	0.04	10.8		
		140	46.9	60.0	2	0.4	0.04	12.0		
		80	26.8	39.0	1	0.2	0.02	8.9		
		40	13.4	26.5	nil	-	-			
DDH 3	4.0- 7.0	40	13.4	31.4	nil	-	-	-		
	2 m casing	80	26.8	44.8	4	0.9	0.09	36.0		
	(+ 18')	120	40.2	58.2	7	1.4	0.14	43.2		
		160	53.6	71.6	8	1.6	0.16	40.0	29.8	8.6
		120	40.2	58.2	5½	1.1	0.11	33.8		
		80	26.8	44.8	2½	0.5	0.05	20.0		
		40	13.4	31.4	½	0.1	0.01	5.8		
	7.0-10.0	40	13.4	41.3	7	1.4	0.14	60.8		
	Lost water	80	26.8	54.7	17	3.4	0.34	111.5		
	return at	120	40.2	67.9	41	8.2	0.82	216.4	166.0	47.8
	9 m while	80	26.8	54.7	30	6.0	0.6	196.6		
	drilling	40	13.4	41.3	23	4.6	0.46	199.6		
	(+ 27.9')	120	40.2	67.9	40	8.0	0.8	211.1		

DDH 3 (continued)

Hole	Depth (m)	Pressure kPa*	Pressure ft	Pressure corrected	Water Loss galls/ 5 min*	galls/ min	min^{-1} ft^{-1}	K (m/yr)	Av. K	Lugeons (approx.)
	10.0-13.0	40	13.4	39.7	7	1.4	0.14	63.2		
	2 m casing	80	26.8	53.1	11	2.2	0.22	74.3		
	W.L. 8 m	120	40.2	66.5	14	2.8	0.28	75.5	80.8	23.3
	(+ 26.3')	160	53.6	79.9	20	4.0	0.4	89.7		
		80	26.8	53.1	15	3.0	0.3	101.2		
	13.0-16.0	40	13.4	39.7	5	1.0	0.1	45.1		
	(+ 26.3')	80	26.8	53.1	8	1.6	0.16	54.0		
		120	40.2	66.5	12	2.4	0.24	64.7		
		200	67.0	93.3	29	5.8	0.58	111.5	83.7	24.1
		150	50.1	76.4	23	4.6	0.46	107.9		
		80	26.8	53.1	14	2.8	0.28	94.5		
		40	13.4	39.7	12	2.4	0.24	108.3		
	19.0-22.0	Could not fit seal								
	22.0-25.0	40	13.4	39.7	5½	1.1	0.11	49.7		
	(+ 26.3')	80	26.8	53.1	12	2.4	0.24	81.1		
		120	40.2	66.5	16½	3.3	0.32	89.0		
		200	67.0	93.3	14	2.8	0.28	53.9		
		160	53.6	79.9	14	2.8	0.28	62.8	70.2	20.2
		200	67.0	93.3	15½	3.1	0.31	59.6		
		120	40.2	66.5	12	2.4	0.24	64.7		
		80	26.8	53.1	12	2.4	0.24	81.1		
		40	13.4	39.7	10	2.0	0.2	90.3		
	16.0-25.0	40	13.4	39.7	1	0.2	0.007	9.1		
	W.L. 8 m	80	26.8	53.1	1½	0.3	0.01	10.1		
	(+ 26.3')	120	40.2	66.5	1½	0.3	0.01	8.1	7.5	2.2
		160	53.6	79.9	1½	0.3	0.01	6.8		
		200	67.0	93.3	1½	0.3	0.01	5.8		
		300	100.5	126.8	2	0.4	0.014	5.0		
DDH 4	2.5- 5.5	40	13.4	26.5	11	2.2	0.22	148.8		
	4.5 m casing	80	26.8	39.9	18½	3.7	0.37	166.2	157.5	45.3
	(+ 13.1')									
	4.0- 7.0	50	16.6	26.6	15	3.0	0.3	202.2		
	W.L. 3 m?	100	33.5	43.5	20	4.0	0.4	164.9	189.9	54.7
	(+ 10.1')	50	16.6	26.6	15	3.0	0.3	202.2		
	7.0-10.0	40	13.4	23.4	10	2.0	0.2	153.2		
	4.5 m casing	80	26.8	36.8	13	2.6	0.26	126.6	131.3	37.8
	W.L. 3 m	120	40.2	50.2	17	3.4	0.34	121.4		
	(+ 10.1')	160	53.6	63.6	22	4.4	0.44	124.0		
	10.0-13.0	40	13.4	23.4	nil	-				
	(+ 10.1')	80	26.8	36.8	½	0.1	0.01	4.9		
		120	40.2	50.2	½	0.1	0.01	3.6	6.5	1.9
		160	53.6	63.6	1	0.2	0.02	5.6		
		200	67.0	77	2½	0.5	0.05	11.7		
	13.0-16.0	40	13.4	23.4	½	0.1	0.01	7.6		
	(+ 10.1')	80	26.8	36.8	2	0.4	0.04	19.4		
		120	40.2	50.2	3	0.6	0.06	21.5	19.4	5.9
		160	53.6	63.6	4	0.8	0.08	22.6		
		200	67.0	77.0	5½	0.9	0.09	25.6		
		120	40.2	50.2	2½	0.5	0.05	17.9		

Hole	Depth (m)	Pressure kPa*	Pressure ft	Pressure corrected	Water Loss galls/ 5 min*	Water Loss galls/ min	Water Loss min^{-1} ft^{-1}	Water Loss K (m/yr)	Water Loss Av. K	Water Loss Lugeons (approx)
DDH 5	2.5 - 5.5	40	13.4	25.5	6	1.2	0.12	84.4		
	W.L. 3.7	80	26.8	38.9	10	2.0	0.2	92.2	84.6	24.3
	(+ 12.1')	40	13.4	25.5	5½	1.1	0.11	77.3		
	7.0 -10.0	40	13.4	25.5	3½	0.7	0.07	49.2		
		80	26.8	38.9	10½	2.1	0.21	96.8		
	W.L. 3.7 m	120	40.2	52.3	12½	2.5	0.25	85.7	79.7	22.9
	(+ 12.1')	160	53.6	65.7	19½	3.9	0.39	106.4		
		80	26.8	38.9	5	1.0	0.1	46.1		
	10.0-13.0	40	13.4	25.5	nil	-				
	(+ 12.1')	80	26.8	38.9	½	0.1	0.01	4.6		
		120	40.2	52.3	½	0.1	0.01	3.5		
		160	53.6	65.7	1	0.2	0.02	5.5	5.5	1.6
		200	67.0	79.1	2	0.4	0.04	9.1		
		80	26.8	38.9	½	0.1	0.01	4.6		
	13.0-16.0	40	13.4	25.5	nil	-				
	(+ 12.1')	80	26.8	38.9	2	0.4	0.04	18.4		
		120	40.2	52.3	2	0.4	0.04	13.7	16.7	4.8
		160	53.6	65.7	3	0.6	0.06	16.4		
		200	67.0	79.1	4	0.8	0.08	18.1		
		80	26.8	38.8	nil	-				
	16.0-19.0	40	13.4	25.5	2	0.4	0.04	28.1		
	(+ 12.1')	80	26.8	38.9	3	0.6	0.06	27.6		
		120	40.2	52.3	4	0.8	0.08	27.5		
		160	53.6	65.7	3	0.6	0.06	16.4	18.5	5.3
		200	67.0	79.1	3	0.6	0.06	13.7		
		120	40.2	52.3	1	0.2	0.02	6.8		
		80	26.8	38.9	1	0.2	0.02	9.2		
DDH 6	2.5- 5.5	40	13.4	24.2	15	3.0	0.3	222.2		
	(+ 10.8')	80	26.8	37.6	32	6.4	0.64	305.0	274.5	79.0
		40	13.4	24.2	20	4.0	0.4	296.2		
	4.0- 7.0	40	13.4	31.4	8	1.6	0.16	91.3	91.3	26.3
	(+ 18')	Lost seal								
	5.5- 8.5	40	13.4	36.4	15	3.0	0.3	147.7		
	W.L. 7 m	80	26.8	49.8	20	4.0	0.4	144.0		
	(+ 23')	120	40.2	63.2	27	5.4	0.54	153.2	136.0	39.1
		80	26.8	49.8	19	3.8	0.38	136.8		
		40	13.4	36.4	10	2.0	0.2	98.5		
	7.0-10.0	40	13.4	36.4	5	1.0	0.1	49.2		
	(+ 23')	80	26.8	49.8	16	3.2	0.32	115.2	82.2	23.7
		Lost seal								
	10.0-13.0	Could not get seal								
	13.0-16.0	40	13.4	37.0	nil					
	W.L. 7.2 m	80	26.8	50.4	2	0.4	0.04	14.3		
	(+ 23.6')	120	40.2	63.8	2	0.4	0.04	11.2		
		160	53.6	77.2	1	0.2	0.02	4.6	8.7	2.5
		200	67.0	90.6	2	0.4	0.04	7.9		
		120	40.2	63.8	1	0.2	0.02	5.6		

DDH 6 (continued)

Hole	Depth (m)	Pressure kPa*	Pressure ft	Pressure corrected	Water Loss galls/ 5 min*	galls/ min	Min^{-1} ft^{-1}	K (m/yr)	Av. K	Lugeons (approx)
	16.0-19.0	40	13.4	37.0	nil	0				
	W.L. 7.2 m	80	28.8	50.4	1	0.2	0.02	7.1		
	(+ 23.6')	120	40.2	63.8	2	0.4	0.04	11.2	6.8	2.0
		160	53.6	77.2	1	0.2	0.02	4.6		
		200	67.0	90.6	1	0.2	0.02	3.9		
		120	40.2	63.8	nil	-				
	19.0-22.0	40	13.4	37.0	-					
	(+ 23.6')	80	26.8	50.4	1	0.2	0.02	7.1		
		120	40.2	63.8	1	0.2	0.02	5.6		
		200	67.0	90.6	1	0.2	0.02	3.9	4.9	1.4
		120	40.2	63.8	½	0.1	0.01	2.9		
	22.0-25.0	80	26.8	50.4	½	0.1	0.01	3.6		
	(+ 23.6')	120	40.2	63.8	1	0.2	0.02	5.6		
		160	53.6	77.2	½	0.1	0.01	2.3	3.7	1.1
		200	67.0	90.6	1	0.2	0.02	3.9		
		120	40.2	63.8	½	0.1	0.01	2.9		
DDH 7	2.5- 5.5	40	13.4	26.5	7	1.4	0.14	94.8		
	2 m casing	80	26.8	39.9	18	3.6	0.36	161.4	117.0	33.7
	(+ 13.1')	40	13.4	26.5	7	1.4	0.14	94.8		
	4.0- 7.0	40	13.4	32.4	1½	0.3	0.03	16.6		
	2 m casing	80	26.8	45.8	7½	1.5	0.15	58.8		
	W.L. 5.8 m	100	33.5	52.5	17	3.4	0.34	116.1	56.2	16.2
	(+ 19')	40	13.4	32.4	3	0.6	0.06	33.1		
	5.5- 8.5	40	13.4	32.4	7	1.4	0.14	77.5		
		80	26.8	45.8	16	3.2	0.32	125.3		
	W.L. 5.8 m	120	39.7	58.7	30	6.0	0.6	183.2	117.1	33.7
	(+ 19')	80	26.8	45.8	17	3.4	0.34	123.1		
		40	13.4	32.4	6	1.2	0.12	66.4		
	10.0-13.0	40	13.4	32.4	3	0.6	0.06	33.0		
		80	26.8	45.8	8	1.6	0.16	62.6		
	W.L. 5.8 m	120	39.7	58.7	15	3.0	0.3	91.6	75.6	21.8
	(+ 19')	160	53.6	72.6	26	5.2	0.52	128.4		
		80	26.8	45.8	8	1.6	0.16	62.6		
	13.0-16.0	40	13.4	32.4	3	0.6	0.06	33.1		
	W.L. 5.8 m	80	26.8	45.8	9	1.8	0.18	70.4	54.9	15.8
	(+ 19')	120	39.7	58.7	10	2.0	0.2	61.1		
		160	53.6	72.6	lost seal					

APPENDIX 5

Further shear box testing

Some values of soil strength functions from shear box tests are given in this report. These values were determined using the method adopted by the Department of Mines over the last 2-3 years for the occasional stability analyses undertaken. They are neither peak nor residual strength values, but are almost certainly much closer to the former than the latter.

Further tests have been undertaken on some of the samples, together with tests on samples containing slip surfaces. The results given below are probably near "residual" values, but must be regarded as approximate. They were obtained by repeatedly shearing the samples at various loads.

Hole No.	*Depth* (m)	*Sample state*	"ϕ'_r"	"C'_r" (kPa)	*Sample description*
AH4	1.8-2.7	disturbed	15°-17.5°	3-11	Deeply weathered basalt
AHM2	1.8-3.7	disturbed	12.5°-17°	0?	Deeply weathered basalt
AH7	3-3.7	disturbed	12°-15°	3-16	Deeply weathered basalt
TP D1	5	partially disturbed	12.5°-17°	?	Deeply weathered Pre-cambrian sediment
TP D2	4	undisturbed	10°-12°	14	Deeply weathered basalt with shear surface
TP D2	4	undisturbed	11°-12.5°	3-16	Deeply weathered basalt with shear surface
TP D3	4.6	disturbed	10°	4	Deeply weathered basalt, two sheared surfaces fitted together

It is uncertain in the first two samples containing shear surfaces whether movement in the shear box took place along an existing shear surface, there being several such surfaces in the samples. Consolidation and compaction within the box itself are difficult to estimate when the sample is being prepared. The test (TP D3) with a shear surface resulted from two separated pieces of deeply weathered undisturbed basalt, each showing a slickensided surface, being fitted together. The two pieces were from the same area of the test pit but they may have been slightly separated when in their original position. The movement in the shear box took place along the join between the two pieces.

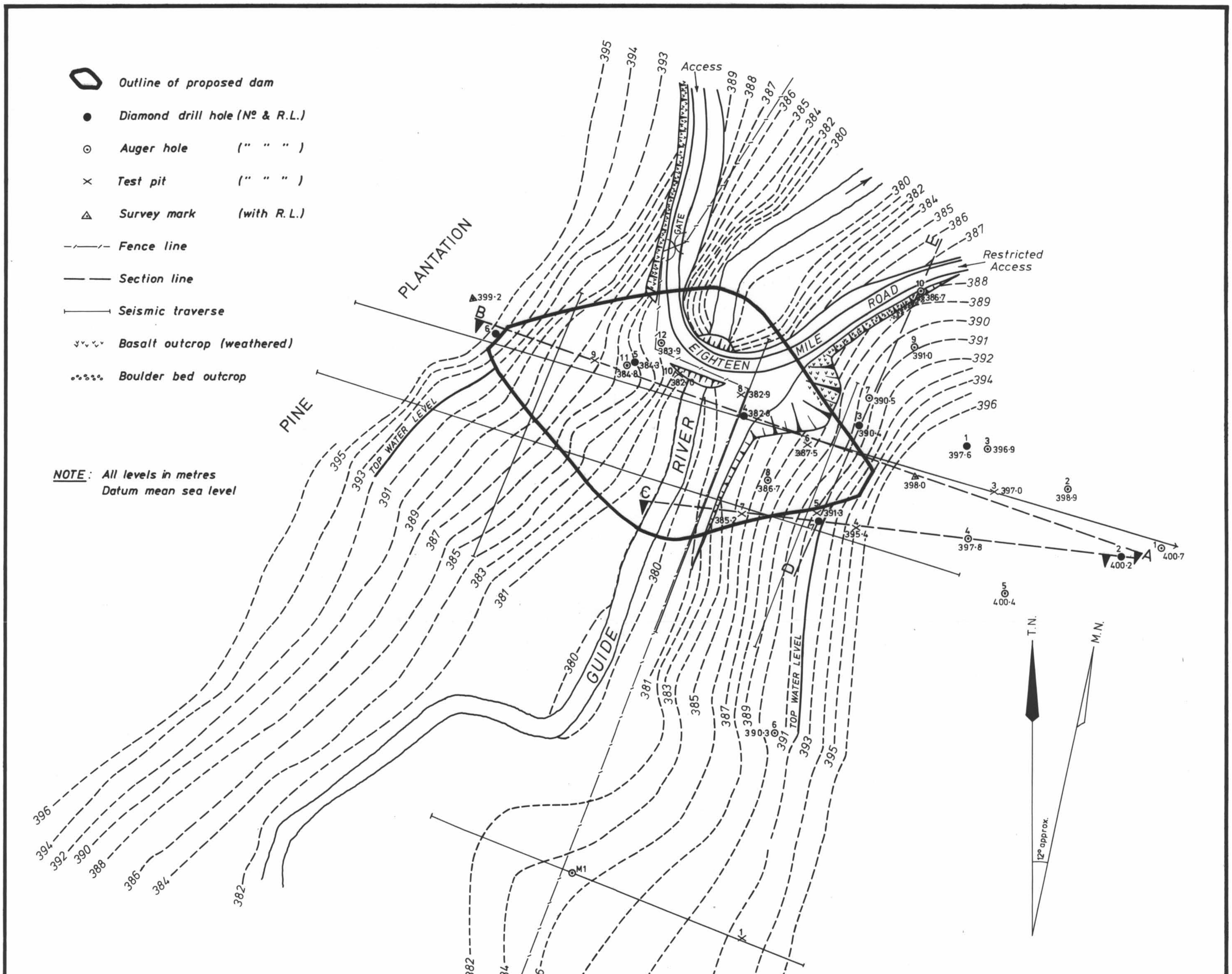
Peak or near peak strength factors may be more appropriate for stability analyses in deeply weathered basalt on unfailed slopes, particularly if the weathered material is not very plastic. Where there is a failure or an existing slip surface, use of residual values may be the more correct procedure (Knights, 1975).

Because of the low "ϕ'_r" angles shown above, particularly for the samples with an existing shear surface, note should be taken in all excavations associated with the dam of any such persistent surface. The extent and attitude of any such surface should be noted. If they dip at angles of say 8°-30° with unfavourable dip directions and extend over considerable distances, procedures to ensure continued stability may be necessary. Steep dips on these surfaces or almost horizontal attitudes are not expected, in most cases, to be particularly dangerous.

REFERENCE

KNIGHTS, C.J. 1975. Strength parameters and the progressive failure of hill slopes. *Tech.Rep.Dep.Mines Tasm.* 19:93-99.

5 cm



SKETCH MAP

GUIDE RIVER PROPOSED DAMSITE

LOCATION OF INVESTIGATIONS

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4666

Figure 1

5 cm

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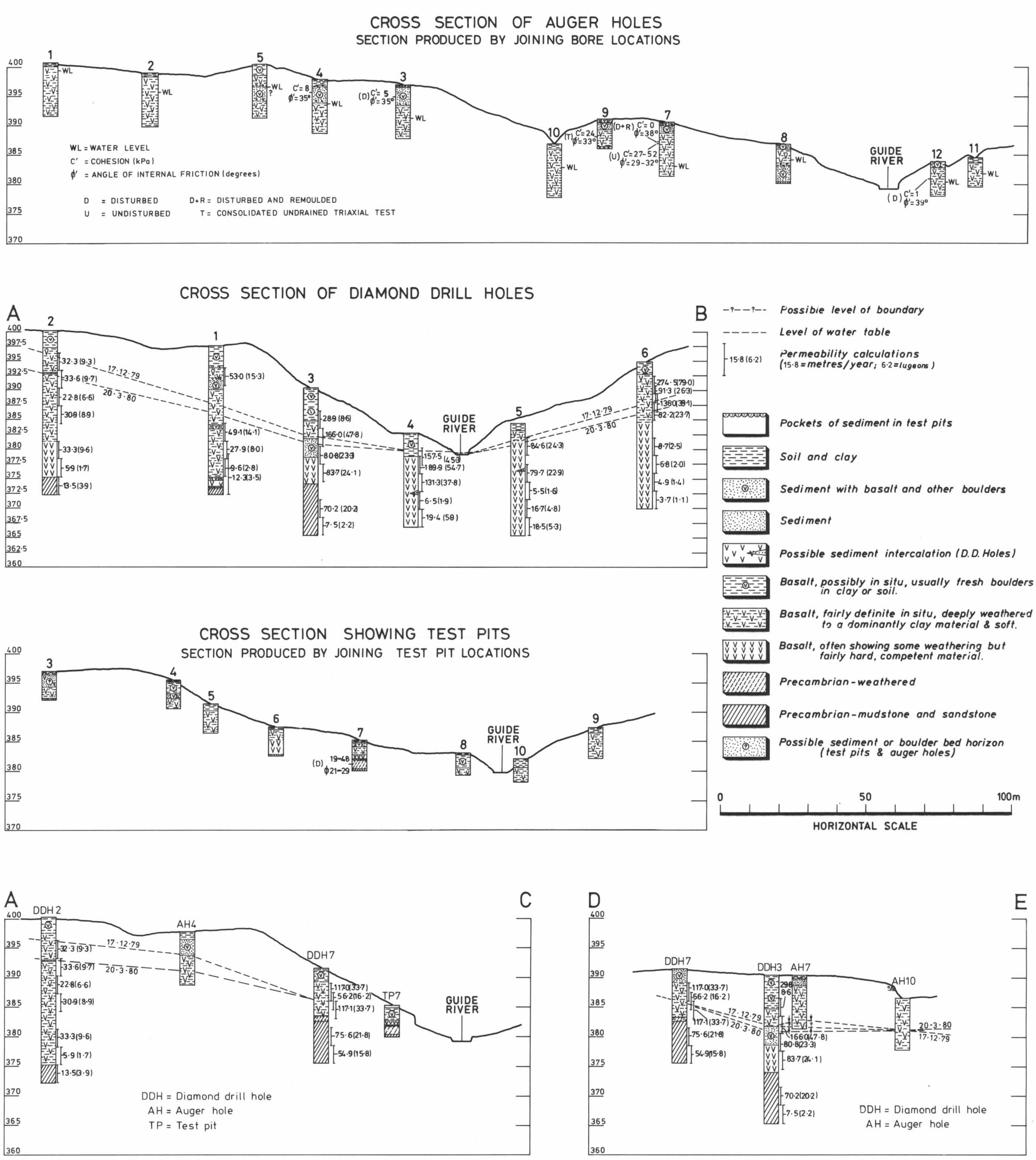

GUIDE RIVER DAMSITE CROSS SECTIONS

(FOR LOCATION OF SECTIONS SEE FIGURE 1)

5 cm

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