# OMOKOROA POINT

# LAND STABILITY INVESTIGATION

REF: 4487/2
MAY, 1980

PREPARED FOR:

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# REPORT

## 1.0 INTRODUCTION

### 1.1 GENERAL

This report summarises the results of an investigation of land stability at Omokoroa Point, Tauranga, undertaken for the Tauranga County Council.

The study was initiated after a number of landslips along the western coastline of Omokoroa in early August, 1979, immediately following a period of heavy rainfall. The largest of these landslips was at Bramley Drive where a 34 metre high cliff failed catastrophically along a 60 metre length of cliff top causing the cliff edge to recede over 20 metres. Five houses endangered by the slip were evacuated and subsequently removed.

Initial inspection of the coastal landslip damage was made by Tonkin & Taylor and the New Zealand Geological Survey, D.S.I.R., Rotorua. From subsequent discussion with Mr. I.D. McKenzie, County Engineer, Tauranga County Council, it was agreed that a comprehensive investigation of coastal stability was warranted for the whole Omokoroa Peninsula, primarily to guide the planning of new and proposed residential subdivisions on the peninsula and to assess coastal stability risk in already developed residential areas.

A preliminary report on the Bramley Drive landslip, dated 15th August,1979, was prepared by Tonkin & Taylor and a more detailed interim report, dated 23rd August, 1979, was prepared by B.F. Houghton, New Zealand Geological Survey, Rotorua. Meetings were held subsequently with the Tauranga County Council and proposals for a stability investigation were established which involved co-operation between Tonkin & Taylor and the New Zealand Geological Survey, D.S.I.R., together with assistance of staff of the Tauranga County Council. The proposal was outlined in a letter to the Tauranga County Council dated 11th September, 1979 and approval to proceed with the investigation was received in a letter dated 4th October, 1979 from Mr. I.D. McKenzie, County Engineer.

It was agreed that the investigation should include consideration of a portion of an approved subdivision on the southeast coast of Omokoroa Peninsula in the vicinity of Margaret Place. Building permit approval for a number of lots was withheld pending the results of stability investigation. Consequently, priority was given to assessment of this area. The results of this stability investigation were presented separately in Tonkin & Taylor Report Ref: 4487/1 dated 12th February,1980.

## 1.2 OBJECTIVES OF THE STUDY

The study objectives as agreed with the Tauranga County Council were as follows:-

(a) To review all existing data with bearing on coastal stability, together with compilation of a history of land-slides and subdivision development on the peninsula.

(b) To study the existing subdivisional drainage and disposal system and consider scope for improvement.

(c) To study the hydrology (rainfall and natural drainage) and shallow groundwater conditions on the peninsula.

(d) To study the geology of the peninsula including the stratigraphy and structure, and in particular the geology of the Bramley Drive slip area.

(e) To study the soil properties by means of subsurface investigations.

(f) To analyse the slip mechanism at Bramley Drive and define any other high risk areas along the coastline.

(g) To produce proposals for remedial work, possible additional investigations and long term monitoring as well as guidelines for future subdivision planning on the peninsula.

## 1.3 AREA OF THE STUDY

The area defined for the investigation is in general the whole of the existing Omokoroa Beach Community urban area, (refer Drawing 4487-2) but with particular reference to the northwestern coastline from the Crapp Historical Reserve in the north to the proposed O.C. Cooney subdivision in the south, but including only the coastline of the stage of that subdivision beyond Hamurana Road as shown on Murray-North/Partners Ltd., plan No. T.84221, dated October, 1979.

As already mentioned the investigation also included Lots 47 to 53 on Stage I of the O.C. Cooney's subdivision situated on the seaward side of Margaret Place. This area has been reported separately and will not be discussed in any detail in this present report.

## 1.4 METHODOLOGY

To achieve the investigation objectives the study was divided into four parts. Duties for each of the three parties involved in the investigation were defined at the outset. The contents of each part of the investigation are briefly outlined below:-

### Part 1: Data Collection, Collation and Review

Main items included were:-

- Compilation of an inventory of all relevent plans and cross-sections held by the Tauranga County Council or others, such as; subdivision, drainage, contour, coastal survey and engineering plans.
- Aerial photograph collection and examination.
- Compilation of data on residential water use and disposal systems including septic tank disposals.
- Collection and analysis of rainfall records.
- Existing information on the geology of the region.
- Historical records of landslides and subdivision development.

### Part 2: Survey and Reconnaissance

This work consisted of:-

- Resurvey of the northwestern Omokoroa coastline.
- Cross-section surveys of selected slip areas.
- Mapping of all landslip areas together with observations of geology and natural drainage.
- Detailed study of the Bramley Drive slip.

### Part 3: Exploration and Testing

This work included:-

- Drilling of nine deep cored boreholes along the coastline and installation of standpipes for groundwater monitoring.
- Testing of soil samples recovered mainly from drilling to establish engineering properties.
- Mineralogical analysis of soil samples.

## Part 4: Analysis and Reporting

To be included was:-

- Stability analysis of Bramley Drive and earlier landslips.
- Recommendations for long term coastal management.
- Recommendations on remedial possibilities.

# 2.0 PHYSIOGRAPHY

## 2.1 LOCALITY

Omokoroa Point is an elongate tapering peninsula extending 5 km northwestward into Tauranga Harbour (refer Drawing 4487-2). The peninsula is 0.75 km wide at its widest point and 21 km by road from the Tauranga Post Office. Omokoroa township lies on the northern end of the peninsula and was the subject of a survey by the local community council in 1979. There were 871 residential sections in existence, in July 1979, with two further subdivisions in progress. The population at this time was 711 and when development is complete the population is estimated to reach 2100.

## 2.2 GEOMORPHOLOGY

A high seacliff rises abruptly from the modern beach on the northern and western coastline. The cliff ranges in height from 9 to 35 metres. At the northern end of the peninsula the seacliff ends in a high level Pleistocene terrace. The land slopes gently from the terrace to the flat crest of the peninsula at 38 - 42 m elevation. A triangular remnant of a 2.5 m post glacial terrace lies between the extension of the seacliff and the shoreline on part of the eastern coast. This terrace remnant forms the region known as Omokoroa Beach. A small terrace remnant also occurs farther south on the eastern coast below Margaret Place.

There are four major gullies on the northern peninsula namely; in the southwestern corner of the Crapp Reserve, along the northern limb of Omokoroa Road, along Beach Road, and north of Kaharoa Avenue in the vicinity of the local purpose reserve. None of these gullies are occupied by permanent streams.

## 2.3 CLIMATE

The Tauranga Basin has an equable climate with very warm summers and mild moderately wet winters. The nearest climatological station to Omokoroa is Tauranga Aerodrome. This station has a normal yearly rainfall of 1348 mm with the highest yearly total up to 1973 being 2049 mm (N.Z. Meteorological Service Miscellaneous Publication 143). The mean daily maximum temperature is 18.8°C with a mean daily range of 9.4°C.

## 3.0 GENERAL GEOLOGY

### 3.1 STRATIGRAPHY

The strata forming Omokoroa Peninsula can be subdivided for the purpose of this report into a cover sequence of units which take part in shallow and deep-seated mass failures and the underlying basement which is not exposed or involved in mass failure on the peninsula.

The basement consists of several units of ignimbrite, a volcanic rock type consisting of welded pumice blocks and ash. The flat, sheet-like ignimbrite deposits formed during violent explosive volcanic eruptions between 0.7 and 1.0 million years ago. The ignimbrites are not exposed on the peninsula but have been detected in deep drillholes at between 150 and 170 m depth. The ignimbrite sheets form the eastern flanks of the Kaimai Range and dip gently eastward under Tauranga Harbour to define a basin partly infilled by the younger cover sequence.

The cover sequence has a threefold subdivision. The oldest beds constitute the Tauranga Beds or Formation, an assemblage of terrestrial and estuarine sediments and interbedded ashes. The second unit is a sequence of weathered rhyolitic ashes now largely altered to clay and referred to in this report as the older ashes. The Rotoehu ash and other young unweathered rhyolitic ashes constitute the youngest unit. All three units are involved in a variety of forms of mass failure in the peninsula but deep-seated failures as typified by Bramley Drive appear to have commenced low in the sequence of older ashes. Each of the units is discussed below.

#### Tauranga Formation

The formation consists of a diverse range of rock types formed in an ancient river/estuary system affected by an influx of volcanic detritus following each explosive eruption in the neighbouring Rotorua-Taupo region. The sedimentary rocks consist of well-sorted gravel and sand units formed in the major river channel and beach environments, carbonaceous silts and muds formed in estuaries and river flats, and peat horizons. Many of these units are lensoid in form and interfinger with volcanic breccias and ashes formed during Rotorua-Taupo volcanism. The rapid change in lithology over short distances is a characteristic of the entire Tauranga Formation. Physical properties of the units, noticeably permeability and strength, also vary greatly as a consequence.

The total thickness of the Tauranga Formation reaches 200 m in some areas, extending well below modern sea level. The early history of the basin is therefore one of continued subsidence over a long time period, during which numerous river channels were established and in turn were abandoned or migrated. The normal pattern of Quaternary sea level changes, in response to glaciation, was superimposed on the trend of continued subsidence, resulting in the formation of a number of poorly preserved terraces at various heights along the coastline.

### Older Ashes

This unit consists of a sequence of partly eroded and deeply weathered air fall volcanic ash horizons from a source or sources outside the Tauranga Basin. A complex history of weathering and partial redistribution by erosion accompanied their formation, so that at many sites a large proportion of the original sequence is missing. The thickness of the sequence varies from 4 to 25 m and the number of strongly developed soil horizons (paleosols) within the sequence,varies between sites. One of the most complete sequences in the entire Tauranga Basin occurs beneath Bramley Drive. The ashes here may be separated into three sets, each possessing a prominent paleosol. The ashes were probably originally rhyolitic and had grainsizes of silt to coarse sand size. Extended weathering has now reduced the majority of the particles to clay size.

### Rotoehu and Younger Ashes

A sequence of young rhyolitic air fall ashes, between two and four metres thick, occurs over the entire peninsula mantling an earlier topography cut into the underlying older ashes. These ashes originated in violent explosions in the Rotorua District and became well sorted during their lengthy transportation. The young ash sequence is therefore highly permeable.

## 3.2 GEOLOGICAL HISTORY

The geological history of Omokoroa can be conveniently subdivided into four periods.

### 1.0 - 0.7 Million Years Ago

Large volcanic eruptions from sources west and south of Tauranga deposited flat lying sheets of ignimbrite (welded tuff-breccia). These rock units form a basement to the sequence infilling the Tauranga Basin.

## 0.7 - Approximately 0.2 Million Years Ago

Subsidence of coastal Bay of Plenty relative to the Kaimai Range and Papamoa Hills formed Tauranga Basin in this time interval. A major river and estuary system was established in the vicinity of modern Tauranga Harbour, in which the sedimentary and pyroclastic rocks of the Tauranga Formation accumulated. A wide range of depositional environments are represented in the formation; major and small river channels, river flat, swamp, beach and estuary. Rapid variation in lithology was produced both by the migration of river channels across the basin and by glacial fluctuations of sea level superimposed on the trend of continued subsidence.

The modern topographic pattern was broadly established during this period with elongate promontories like Omokoroa forming ridges between adjacent river channels.

## Approximately 0.2 - 0.042 Million Years Ago

The sequence of older ashes accumulated during this period and was modified by subaerial erosion during intervals of little volcanic activity.

Lengthy periods of weathering and erosion are marked by well-preserved paleosols within the sequence of older ashes. In some areas much of the sequence was stripped during the intervals of erosion and the thickness in some former valleys considerably increased by redeposition of material from the adjacent slopes. The Bramley Drive landslip took place in one former gully or valley of this type. The final form of the modern topography was established during this period of alternating volcanism and subaerial weathering. Glacial fluctuations of sea level continued during this period. The high level terrace present at the northern tip of Omokoroa was cut into the older ash sequence prior to the deposition of the younger ashes presumably during a Pleistocene high stand of sea level.

## 0.042 Million Years Ago To Present Day

Little modification of Omokoroa has occurred in this period. Continued minor volcanism in the Rotorua District has contributed a thin layer of ash blanketing the relief cut into the underlying rock units. Minor modifications to the coastline have occurred by coastal processes and by processes of mass failure. The 2.5m terrace referred to in section 1.2 is the product of a post glacial sea level maximum.

## 4.0 DEVELOPMENT OF THE PENINSULA

### 4.1 SUBDIVISIONAL DEVELOPMENT

Subdivision of the northern portion of Omokoroa Peninsula commenced in 1943 and continues to the present day. A period of extensive subdivision which included most of the present township, took place between 1952 and 1974 involving most of the northern end of the peninsula. Work on two additional major subdivisions, the Crapp subdivision and the Cooney subdivision, north and south of the present township respectively, commenced in 1979. The dates of approval of individual subdivisions and their boundaries are shown on Drawing 4487 - 2.

The Bramley Drive subdivision was approved in October 1967. Much of this subdivision was covered by mature pine trees which were felled in 1967 and pushed over the seacliff. Fill was used to raise the level of a narrow bench 1 m below the cliff-top and remmants of this fill material are visible on the walls of the recent Bramley Drive landslip. The majority of the dwellings in Bramley Drive were completed between 1974 and 1979.

### 4.2 HISTORY OF INSTABILITY AND EROSION

An examination of the coastline makes it clear that landslip erosion has been occurring at Omokoroa for a long period of time. The positions of all features inferred from geomorphology to be landslip scars are shown on Drawings 4487 - 3, sheets 1 to 8.

The ages of these features prior to 1979 have been obtained either from adjoining property owners, aerial photograph records, or by the state of revegation of the landslips.

Definite records of prior failures date back only to the last decade. Major landslips followed heavy rainfall in late 1962. A major failure occurred at lots 30 and 31 Hamurana Road adjacent to two houses built in October, 1962 (4487-3, sheet 8). This failure removed a 60 m wide and 20 m deep section of the seacliff and produced a flat-lying tongue of debris similar to the Bramley Drive failure. No provision for storm water disposal existed at this time and during heavy rainfall water is reported to have ponded in the area between Omokoroa school and the road, draining away over the area affected by the slip.

A second landslip occurred at the same time in 1962 below lots 15 and 17 Kaharoa Avenue (4487-3, sheet 7). This slip again closely resembled the one at Bramley Drive and 150 mm of rain was recorded during the night preceding failure (O.C Cooney, pers. comm.).

A flat-lying debris deposit was left by the slide and a large quantity of seepage following failure produced a temporary stream which issued from the face.

A third major failure occurred on lot 36 Harbour View Road at this time depositing over a metre of highly plastic mud across the road. These 1962 failures are clearly visible on aerial photographs taken in 1964.

Another period of slipping took place in December 1968, again following heavy rainfall. A second smaller mass failed from the previous Hamurana Road landslip site. Other failures took place on farmland adjacent to the subdivided areas.

Memories of residents of the precise time of events do not extend back earlier than the 1962 landslips. However, long-established residents have memories of the old coastal road being closed by landslips on several occasions in the 1950's and 1960's.

Marine erosion appears to have had little long term effect on retreat of the seacliff in the last 60 years. Surveys made in 1920 and then in 1967 - 71 show little change in mean high water level except where landslips have occurred. However, examination of the coastline showed that localised undercutting of the seacliff, in the order of one to two metres, is occurring in some areas.

## 5.0 SITE INVESTIGATIONS

### 5.1 SCOPE OF INVESTIGATIONS

Initial inspections of the Bramley Drive landslip and other areas of coastal instability were made by the writers soon after the failures occurred in August, 1979. Further field reconnaissance's were made between August 1979 and February 1980 to examine and record in detail features of surface geology and to examine and plot all areas of recent and past instability.

A ground control survey was carried out along the western coastline together with selected cross-sections to provide profiles for stability analyses.

A drilling programme was undertaken to provide information on the geological structure, soil properties and groundwater conditions, as well as to provide samples for testing. Permanent standpipes were installed in the boreholes to allow continued monitoring of ground water levels.

Laboratory soil testing was carried out to obtain engineering parameters for use in stability calculations and tests were also undertaken to determine mineralogy of problem soils.

### 5.2 GROUND SURVEYS

A ground survey of the western Omokoroa coastline was undertaken for the Tauranga County Council by Hubbard and Company, consulting surveyors and engineers, Tauranga. The coast was surveyed between the Omokoroa Beach domain and that part of the Cooney subdivision included within the area of investigation. The survey accurately defined, at a scale of 1:500, the mean high water mark and location of the present cliff edge, together with cliff top levels. The boundaries of residential lots were also defined. This work provided the base maps on which landslip locations and all other relevent information was plotted. (Refer drawings 4487 - 3, sheets 1 to 8).

Five cross-sections in old major slip areas were also surveyed by Hubbard and Company and a cross-section and contour plan of the Bramley Drive slip were prepared by the Tauranga County Council.

## 5.3 GEOLOGICAL RECONNAISSANCE

The whole length of the Omokoroa coastline was inspected and all old slip locations were identified and observations made of geology and hydrology. Aerial photograph examination was used although only a limited number of photos were available.

A detailed examination was made of the Bramley Drive landslip. Detailed stratigraphy of the face of the landslip was logged using a tape and extending ladder. The shape of the slip face meant that it was necessary to log adjoining sections to obtain a complete profile and since the beds varied slightly in thickness and dip angle only an approximate estimation of the vertical depth could be obtained.

Other stratigraphic sections along the coast were also logged at:-

1) a site 50 m north of the Bramley Drive landslip,
2) on the active landslip adjacent to Gerald Place,
3) at the northern extremity of the peninsula.

The locations of these sections are shown on drawings 4487 - 3.

## 5.4 DRILLING INVESTIGATIONS

Drilling investigations were carried out between the 4th and 18th of December, 1979, by Brown Brothers (N.Z.) Ltd., using a rotary drilling rig operated under the full-time supervision of one of Tonkin and Taylor's staff.

A total of nine, 100 mm diameter boreholes were drilled to depths up to 37 metres. Borehole 1 was drilled above the cliffs at Margaret Place and boreholes 2 to 9 were drilled in selected locations along the western coastline. The location of borehole 1 is shown on the attached Drawing 4487-1A (location revised from that shown in our report 4487/1 as a result of final survey information). The remaining borehole locations are shown on drawings 4487-3, sheets 1 to 8.

The relatively weak nature of the soils enabled all core to be recovered by means of the open barrel technique. Undisturbed soil samples for special testing were obtained in short brass tubes taken either in the borehole as drilling progressed or in a subsiduary wash drilled borehole alongside the cored borehole.

As core was recovered it was logged and placed in boxes for storage. Samples were selected for testing and carefully packaged. The highly sensitive nature of much of the core meant that great care was necessary in sample handling and transportation to avoid sample disturbance.

At the conclusion of drilling borehole 1 was grouted, but in the remaining boreholes, P.V.C. standpipes with porous piezometer tips were installed to a depth below the water table, to allow long term monitoring of groundwater levels.

All borelogs (including the log of borehole 1) are appended to this report.

## 5.5 SOIL TESTING

To obtain engineering parameters, selected samples recovered from drilling were tested in our Auckland laboratory. Several block samples from the face of the Bramley Drive landslip were also tested. Tests were carried out to obtain natural water contents, bulk densities, Atterberg limits, and both remoulded and unremoulded vane shear strengths. In addition, a set of consolidated undrained triaxial tests with pore pressure measurement were carried out on the highly sensitive ashes, to obtain effective stress shear strength parameters. Axial loadings during the tests were continued up to strains well beyond initial failure to investigate soil behaviour immediately after failure. A set of consolidated quick undrained tests were also undertaken to obtain total stress shear strength values.

To investigate mineralogy a sample of older ashes from borehole 4 was analysed by I. Smalley, Soil Bureau, D.S.I.R., using Differential Thermal Analysis (D.T.A.) and X-Ray Diffraction techniques. The sample was also subjected to analysis by scanning electron microscope. An additional ten samples were X-Rayed by N.Z. Geological Survey, D.S.I.R.

Soil test results are summarised on the borelogs and on plates 1 and 2, table 1 and figures 1 to 4.

## 6.0 INVESTIGATION RESULTS

### 6.1 BOREHOLE PROFILES

The three main units described in section 3.1 were encountered in all boreholes. The main variations between boreholes occurred in the thickness of the older ashes and in the lithologies within the Tauranga Formation. Soil properties within the units were generally consistent from hole to hole.

Two different nomenclatures are required when describing deeply weathered strata as encountered at Omokoroa, one to describe the present grainsize which is, in part, a function of the extent of weathering and one to characterise the original grainsize of the rocks. In the bore logs appended to this report the present grainsize is described and an inferred original grainsize given in brackets where applicable.

A summary of the stratigraphy of the eight boreholes along the western coast is given in Drawing 4487-5.

Each of the main geologic units as found in the boreholes is described below.

#### Rotoehu and Younger Ashes

The young, relatively unaltered rhyolitic ashes which mantle the topography cut in the under-lying ashes vary in thickness between 2.0 and 4.0 m. They consist of yellow brown to pale yellow rhyolitic silts and sands with some clay rich horizons. In general their permeability is high.

#### Older Ashes

A thick paleosol underlies the Rotoehu Ash and was formed during intense weathering of the top of the older ash sequence prior to deposition of the younger ashes. This paleosol unit, typically about metre thick, is dark brown in colour and consists of firm to stiff clays and silts and is locally referred to as 'the chocolate layer'. The paleosol is considerably less permeable than the overlying younger ashes. The sequences of older ashes can be subdivided into two types:

1) thick sequences containing numerous ash layers and three paleosols (boreholes 4, 5).
2) thin sequences with only the upper paleosol described above (all remaining boreholes).

The total thickness of older ashes varies from 4 metres in borehole 3 to over 20 metres in boreholes 4 and 5. Much of the relative topographic relief at Omokoroa is due to thickness variations in the older ashes. The older ash sequence consists mainly of brown and yellow clays and silts with undisturbed strengths varying from medium to stiff. The sequence consisted orignally of numerous (up to fifteen) thin rhyolitic ash layers and relict textures are still preserved in some of these.

A large proportion of these older ashes exhibit the property of 'sensitivity' (i.e. strength loss on remoulding) to varying extents. The ashes in the upper part of the sequence tend to be less sensitive than those lower in the sequence, or contain only thin highly sensitive layers. A zone of highly sensitive ashes occurs near the base of the sequence in all boreholes excluding borehole 1. This zone varies in thickness from about 2 metres in borehole 8 up to 8 metres in borehole 4 and it is the presence of this thick, highly sensitive zone which is seen as the main cause of stability problems on the pensinsula.

## Tauranga Formation

The upper surface of the Tauranga Formation, as defined in the boreholes, appears to undulate gently along the western coastline and lies at between about 2.5 and 11.5 metres above sea level. At Margaret Place on the eastern coast, the surface of the Tauranga Formation appears to be considerably higher (about 15 metres above sea level in borehole 1.)

However, the boundary between the older ash unit and the Tauranga Formation was not always well defined in view of the variability of materials composing the upper part of the Tauranga Formation. The upper-most part of the sequence in boreholes 3, 4, 5 and 8 consists of thin beds of mainly clayey and sandy silts. In borehole 2 a well sorted sand unit is present. In each of these sequences there is a sharp transition at approximately 0.5 m below the top of the formation to a highly weathered pumiceous tuff breccia which also occurs at the top of the sequences in boreholes 6,7 and 9. This pumiceous tuff breccia is well exposed in coastal sections and is the principal unit within the Tauranga Formation in each of the boreholes, where it forms thick, relatively homogeneous beds of light coloured quartz-rich clayey and sandy silts and silty sands. Quartz, plagioclase and coarse hexagonal columns of a secondary clay species (probably halloysite) are present. The breccia is now extremely weathered but originally contained white rhyolite pumice fragments up to several centimetres in diameter, set in a sand - and silt-sized matrix. The relict texture is generally clearly visible with the outline of pumiceous and grey lithic rhyolite fragments present in the matrix. Within the breccia a few thin layers of white or pinkish highly sensitive clays also occur.

Most of the materials of the Tauranga Formation are firm or compact in strength, but sensitivity is also a feature of the more weathered upper portion of the unit, although to a noticeably lesser extent than the overlying older ashes.

The levels and thicknesses of the various significant units encountered in the boreholes are summarised in the following table:-

| | | Borehole Nos. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Margaret Place | (North East) | | Western Coastline | | | (South West) | | |
| | 1 | 2 | 3 | 4 | 5 | 9 | 6 | 7 | 8 |
| Ground Reduced Level | 23.5 | 13.8 | 11.6 | 33.4 | 35.4 | 20.1 | 19.1 | 26.1 | 20.9 |
| Thickness of Rotoehu ash (m) | (2.0) | (2.3) | (4.0) | (2.0) | (3.2) | (3.0) | (3.5) | (2.3) | 3.0 |
| R.L. Top of older ashes | 21.5 | 11.5 | 7.6 | 31.4 | 32.2 | 17.1 | 15.6 | 23.8 | 17.9 |
| Total thickness of older ashes (m) | (6.9) | (9.1) | (4.1) | (21.5) | (20.8) | (10.5) | (8.9) | (13.6) | (7.0) |
| R.L. Top of main very sensitive ash zone | - | 9.6 | 6.5 | 18.1 | 18.9 | 12.8 | 13.4 | 17.6 | 12.9 |
| Thickness of very sensitive ash zone (m) | - | (4.7) | (2.7) | (7.7) | (6.6) | (6.2) | (6.7) | (7.4) | (2.0) |
| R.L. Top of Tauranga Formation | 14.8 | 2.4 | 3.5 | 9.9 | 11.4 | 6.6 | 6.7 | 10.2 | 10.9 |
| R.L. Water Table at time of drilling | 10.1 | 7.8 | 6.8 | 18.6 | 21.1 | 10.0 | 4.4 | 11.2 | 6.8 |
| Depth of Borehole (m) | 23.0 | 14.0 | 10.6 | 37.0 | 34.5 | 25.2 | 29.0 | 25.6 | 21.2 |

## 6.2 OBSERVATIONS OF COASTAL GEOLOGY

Observations were made of exposures along the western sea cliff and detailed stratigraphic measurements were carried out at four sections. The locations of the stratigraphic sections are shown on drawings 4487-3, sheets 2 to 4 and summary logs of the sections are appended to this report.

The Rotoehu and younger ashes are appreciably thicker in sections 1 and 2 at the northern end of the peninsula (2.5 and 3.05 m) by comparison to sections 3 and 4 close to Bramley Drive. This suggests there has been some erosion of these younger ashes from the higher ground in the centre of the study area. The older ashes, in contrast, are much thinner in sections 1 and 2 by comparison with 3 and 4.

Sections three and four are only 50 m apart but section 3 is on the southern edge of the high level terrace in the northern part of the Peninsula and the cliff height is 12 m less than in section 4. Comparison of the two sections shows the Tauranga Formation occurs at similar elevation but that the older ashes are much thicker in section 4. The second and third paleosols present in section 4 are absent in section 3 and the number of units in the Bramley Drive section is far greater. It is clear that a substantial portion of the older ash sequence was eroded from section 3 before deposition of the Rotoehu ash and that the high level terrace is a degradational not an aggradational feature.

A more diverse range of lithologies is present in the Tauranga Formation along the northern (i.e. between sections 1 and 2) and eastern coastlines relative to the western coastline. This includes a thick (+ 2 m) peat horizon close to high tide mark and overlying well sorted crosslaminated sands and gravels.

Distinctive zones of seepage are present in coastal exposures after heavy rainfall both in the lower older ashes and in the top 2 metres of the Tauranga Formation. The seepage is marked by local undercutting or tunnelling. Several incised erosion channels running up the face of the slip 50 m north of Bramley Drive (section 3) terminate abruptly at a line of seepage approximately 1 m below the top of the Tauranga Formation. The seepage phenomenon are discussed in more detail in section 6.5.

## 6.3 GEOLOGICAL INTERPRETATION

The investigations indicate the top of the Tauranga Formation remains at a fairly consistent altitude along the western coastline. Most of the relative relief at Omokoroa is due to thickness variation in the older ashes. As mentioned earlier the older ash sequences are of two types (1) thick sequences with three paleosols and numerous discrete ash layers and (2) thin sequences with a single paleosol at the top of the sequence.

To interpret this disparity it is necessary to discuss processes of deposition of the ashes and processes acting after deposition. Fine-grained ashes of this type remote from the source of volcanism, form during slow settling of ash particles under gravity from high eruption clouds produced during eruption and subsequently dispersed by wind. The final result is a 'blanket' of unconsolidated particles of remarkably constant thickness covering the entire land area. Thus if for example a total thickness of 21 m of ash was originally present at McDonnell Street it is reasonable to expect that a similar thickness once existed at all other parts of Omokoroa. The soft, unconsolidated ashes however are highly susceptible to weathering and erosion and it is extremely unlikely that the total thickness would be preserved at any site without some modification by erosion. The ash units were deposited on a landscape of some relief and the effects of such erosion have been to remove some ash from former ridges and hills and redeposit it in adjacent gullies.

It appears that the older ashes were subject to at least three periods of weathering and erosion during their formation (creating the three paleosols) and that at some sites (e.g. Bramley Drive) this took the form of chemical weathering to produce strongly developed soils, whereas in other areas severe erosion removed a large portion of the original sequence. Much of the erosion may have occurred after deposition of the sequence during a period of higher sea level than present day when the high level degradational terrace formed at the northern end of Omokoroa.

Since, as will be seen, most landslips are controlled by failures within the lower part of the older ash sequences, the largest deep-seated landslips are likely to occur in the area where the thickest ash sequences are preserved.

## 6.4 RAINFALL ANALYSIS

Daily rainfall records on the Omokoroa Peninsula have been kept since January 1976 by Mr. A.W.Grant of 66 Hamurana Road. This data is presented in Table A3 of Appendix I. A significant fact is that the total rainfall for the seven month period, January-July 1979, immediately prior to the Omokoroa landslips was already close to the average annual rainfall for the preceding three years. A heavy fall of 91 mm was recorded on July 31/ August 1 and the first slipping took place on August 1. With the exception of this period, very little rainfall was recorded in the five weeks between July 2 and August 9. The very high total rainfall in the first half of 1979 was largely due to exceptionally heavy rainfall in February and March. In fact, at other stations in the Tauranga basin, March 1979 had the second highest monthly rainfall recorded since 1898. The return period for the maximum July 1979 rainfalls recorded at Tauranga Airport Meteorological Station, where records have been collected over a long period, is less than two years. This suggests that while the rainstorm of July 31/August 1 may have triggered the Omokoroa landslips, other factors must have been the major contributing causes.

From the analysis of long term rainfall records given in Appendix 1, it seems that a major factor contributing to landslipping was exceptionally high rainfall over an extended period, of the order of six months.

Examination of records from Tauranga Airport over the period 1910-1979 shows that three of the ten highest 6 monthly rainfalls occurred in the period 1960-1979 and that each of these preceded major slipping. The period 1.2.79 - 31.7.79 was in fact the second highest total recorded in the seventy year period. The periods corresponding to the remaining seven of the ten highest totals occurred prior to 1960 when no records of landslips were kept.

## 6.5 SHALLOW GROUNDWATER HYDROLOGY

The presence of the highly permeable younger ashes dominates the surface hydrology of Omokoroa. A high rate of infiltration of rainfall into these ashes and the limited catchment provided by the narrow peninsula, means there are no permanent water courses at Omokoroa. Little runoff occurs during light to moderate rainfall. Some ponding of rainfall and sheet runoff formerly occurred in limited areas e.g. Hamurana Road but this is now largely averted by the county stormwater drainage system.

The hydrology of shallow groundwater is probably complicated by the variable subsurface geology. The clay-rich older ashes are relatively impermeable but portions of the equally clay-rich but more competent Tauranga Formation have appreciable fracture permeability. Local observations suggest heavy seepage outflow often discoloured by clay, occurs from close to the top of the Tauranga Formation one to two days after rainstorms implying this is the time required for water to infiltrate through the older ashes. Semi-permanent seepage from near the base of the older ashes occurs at many sites in winter suggesting this zone is a relative aquiclude.

Data on groundwater tables is limited to water levels recorded in the bore holes several days after the completion of drilling and installation of standpipes. Borehole water levels are summarised in the table of Section 6.1 The water tables recorded are an average for any particular borehole, but it is possible that local perched water tables within the older ashes could exist in some areas in the same way that the paleosol at the top of the sequence is known to form an impermeable barrier. Perched water tables if they exist however, remained undetected in the present investigation. To monitor such water tables it would be necessary to install several piezometers at various levels. The fact that the upper portion of the older ashes at Bramley Drive (above the zone at the rear of the bench where strong seepage was apparent) was remarkably dry immediately after failure suggests that, at least in this area, perched water tables are absent.

Definite conclusions from the water table data can only be made after a lengthy period of monitoring. However, the water table at the time of drilling does show a close relationship to topography and is seen to rise considerably in the higher part of the coastline. The water table along the lower part of the coast, from Ruamoana Drive north (BH's 2 and 3), appeared to be within 5 to 6 metres of the surface; from Bramley Drive south (BH's 4 to 8), between 14 to 15 metres of the surface, apart from Borehole 9 where it was about 10 metres deep; and in Borehole 1 at Margaret Place, the water table was recorded as 13.4 metres deep.

The general uniformity of depth to water table along the higher portions of the coastal area, i.e. indicating that groundwater levels reflect the topography and do not conform to a flat horizon, suggest the soil layers are only moderately permeable and that the water table level may be quite responsive to variations in infiltration rates. However, until further water table monitoring is carried out over an extended period the seasonal groundwater variations and water table responsiveness remains uncertain. The piezometric gradient between inland and coastal areas is also known and may be quite significant in assessing coastal groundwater fluctuations and piezometric pressures.

The variation in the recorded water levels along the coast means that the water table lies within the older ashes at the northern end of the coastline (holes 2 to 5 and 9) and within, or close to the Tauranga Formation at the southern end of the coast (holes 6 to 8). The water content of the highly sensitive lower older ashes is probably critical to formation of deep-seated slips of the Bramley Drive type. The water levels recorded during the investigation represents an approach to equilibrium under summer conditions and suggests a possible broad subdivision of the western coastline into three regions:

1) Historical reserve - Ruamoana Place, where the summer water table lies within the older ashes and so the lower older ashes are likely to be saturated most of the year. Small variations in the water table could lead to landslips but cliff heights are relatively low which would limit the magnitude of such failures.
2) Bramley Drive - McDonnell Street, where the lower older ashes lie below the water table and cliffs are high. Small water table variations could thus cause landslips of large magnitude.
3) Hamurana Road - Cooney Subdivision, where the older ashes lie mainly above the summer water table and therefore a correspondingly greater variation in water table (i.e. from high intensity rainfall) is required to saturate the older ashes and induce failures.

Such a subdivision as above can only be substantiated after a considerable period of water level monitoring.

One aspect of groundwater movement worthy of mention, is the possible existence of underground erosion pipes which concentrate water flow. In view of the layered nature of the ashes erosion 'pipes or 'tunnels' could readily be formed by concentrated water seepage (possibly in some cases under pressure) in weak ash layers between more competent or less permeable layers, or at interfaces between soils of differing competence. Such 'pipes' have been observed by the writers in other landslip areas in Tauranga. A large failure observed at Mangatapu in the heavy March 1979 rainstorm appears to have been related to formation of such a 'pipe', as a jet of discoloured water from the cliff-face was observed during the failure.

In some areas of cliff face at Omokoroa, distinct 'cavities' were noted associated with discrete seepage exits at soil interfaces. This is particularly evident in the cliffs immediately north of the Bramley Drive slip where erosion cavities and gullies occur in soils near the interface of the older ashes and the Tauranga Formation. Evidence for underground 'pipes' is also supported by the reports of several residents of hearing 'rushing water' below ground after heavy rain.

The presence of such 'pipes' could have significant influence on cliff stability as the water concentrations could lead to progressive 'erosion' and ultimately sudden failure of the overlying mass. There is obvious difficulty in detecting these pipes which may develop suddenly, but where they are known to exist, seepage exit control measures could be beneficial in reducing erosion. The sudden appearance of piping erosion in a cliff face could conceivably give warning of an impending landslip.

## 6.6 EFFECTS OF SUBDIVISION ON GROUNDWATER HYDROLOGY

Subdivision has had a number of effects on the hydrology of the northern end of Omokoroa Peninsula. Domestic waste water is discharged by soak hole seepage from septic tanks. Standard procedure over the last seven years has been to construct a 1 m diameter soakage hole to a depth of 12 m. Procedures were more variable prior to this, but the general approach was to penetrate the dark brown paleosol horizon immediately below the Rotoehu Ash.

The effect of domestic water usage is therefore to increase the total amount of water entering the groundwater regime and to concentrate it below the permeable younger ashes. Deep soak holes could also provide points of localised 'high head' which would increase groundwater pressures.

Data for water usage in Omokoroa township for two four year periods (1966-1970, 1975-1979) and one five year period (1970-1975) has been supplied by Tauranga County Council. Some statistics are summarised below.

Table of water use data May 1966 - May 1979

| | 1966-1970 (4 years) | 1970-1975 (5 years) | 1975-1979 (4 years) |
|---|---|---|---|
| Total use ($m^3$) | 79,900 | 154,000 | 211,800 |
| Number of users | 236 | 316 | 366 |
| av.domestic use over period ($m^3$) | 338 | 488 | 579 |
| average annual use ($m^3$) | 85 | 98 | 145 |

The data show a substantial increase in domestic water usage over the period. Both the number of properties connected to the country supply and the average volume per property have increased dramatically. Total water use for the four years ending May 1979 is equivalent to 6.0% of average annual rainfall for Omokoroa. While this amount is not a major contribution to the groundwater regime individual usage varied greatly from less than 4 $m^3$ to greater than 7000 $m^3$. Variation in individual usage has meant that in some localised areas domestic waste water represents a substantial portion of the total volume of water entering the groundwater regime. The usage for the five dwellings in Bramley Drive evacuated after the August 1979 landslips for example was 3500 $m^2$ or equivalent to 23% of average annual rainfall, for the five properties. An examination of Table A1 indicates that the difference in rainfall between the six month periods followed by landslipping and many six months periods which were not followed by landslipping is less than this percentage.

Another illustration is water use at Omokoroa Bowling Club for the year ending May 1979. The volume of 44,892 $m^3$ is approximately equivalent to 6.5 times the rainfall in that period. The location of the club adjacent to a relatively low portion of the seacliff was fortuitous because similar water usage further north in the McDonnell Street - Bramley Drive area would have almost certainly produced landslipping.

Data for other areas adjacent to the western coastline indicate consumption is generally lower than in the areas already mentioned, but high domestic usage (greater than five times the average value) adjacent to the western seacliff was recorded for 1975 - 1979, at a number of individual properties,notably lot 12 Walnut Grove, lot 24 Ruamoana Place, lots 1 and 18 McDonnell Street, lots 13 and 17 Kahroa Avenue, and lot 23 Hamurana Road. The data suggests the desirability of restraints on water use during periods of high water table.

Stormwater from houses and private paved areas is also disposed of by additional soak holes which leads to a rapid concentration of water at and within the relatively impermeable older ashes. Stormwater from the country roads is discharged at beach level which has the beneficial effect of effectively removing a substantial amount of water which would otherwise enter the groundwater.

A less obvious effect of subdivision results from the removal of the thick tree cover from parts of the peninsula. Many of the trees in the area were mature pines. A substantial amount of rainfall in areas of forest vegetation is believed to be lost by processes of evaporation and transpiration associated with plants. However, few measurements have been made of evaporation/transpiration rates. An estimate of the loss in an area at Tairua (annual rainfall 160 mm) made by staff of the Forest Research Institute was 500 - 600 mm, approximately a third of the annual rainfall. Losses from garden or lawn, with much less foliage per unit area of land, will be much less.

## 6.7 SOIL PROPERTIES

### (a) Engineering Properties

In addition to field descriptions a limited amount of testing was undertaken to quantify properties of the more susceptable soil types.

Most of the tests were carried out on the highly sensitive ashes within the older ash layers. A few tests were also done on materials from the uppermost parts of the Tauranga Formation . A more extensive test programme to determine the properties of the wide range of soil types encountered in the boreholes was outside the scope of the present investigation.

Tests on 25 soil samples showed these soils to have in the main, by comparison with more 'normal' soils, low bulk densities, high natural moisture contents, high liquid limits (but low plasticity indices) and extremely high sensitivities. These properties appear to be typical of many of the weathered volcanic ash layers found in the Tauranga region.

Bulk densities obtained on nine samples proved to be low, varying between about 1.5 and 1.6 $t/m^3$. A single sample of clay from a paleosol layer in borehole 5 had a higher bulk density of 1.71 $t/m^3$. This sample also had the lowest water content of any recorded. Natural water contents of the sensitive older ashes (twenty samples tested) were exceptionally high, commonly in the region of 60 to 100%, and for the Tauranga Formation soils (four samples tested), between about 45 and 60%.

Atterberg limit tests carried out on five samples show the highly sensitive ashes to have high liquid limits but relatively low plasticity indices.

Natural water contents were often *above* the liquid limits. When plotted on the Casagrande Plasticity Chart for soil classification (refer fig.1) the samples all plotted well below, but parallel to the 'A' line, in the region of highly compressible inorganic silts (MH). Such soils can be expected to show high shrinkage characteristics and low dry strengths.

It is interesting to note that although the soils have a clay mineral *composition* (discussed in part (b)), they show engineering *behavioural* characteristics more of silts (as based on the Unified Soil Classification System), having low plasticity and the tendency to undergo volume change on deformation. Hence the soils are defined for soil mechanics purposes generally as 'silts' rather an 'clays'.

The most detrimental property of the soils tested was that of 'sensitivity' which is a measure of the loss in strength which occurs when a soil is disturbed or remoulded. Sensitivity is defined as the ratio of soil strength in the undisturbed state to that in the remoulded state . Most 'normal' soils show sensitivities typically less than 4. The values of sensitivity for the twenty Omokoroa samples tested (using a laboratory shear vane) were commonly found to be well over sixteen and a maximum value of 140 was recorded. Soils of such very high sensitivity are often referred to as 'quick' clays (as defined by Skempton and Northey, 1952.). The soils have been derived from decomposition of initially porous and loosely deposited rhyoltic volcanic ash. Weathering has produced an unusual 'meta stable' structure in which the water is loosely held in voids within the soil mass. Once disturbed the unstable soil structure collapses causing sudden strength loss and with the very high percentage of water present the soil readily liquifies. The nature of the soil structure causing the sensitivity is described more fully in part (b) below.

Triaxial tests on a set of samples of the sensitive clays from borehole 5 gave effective stress shear strength parameters of $\phi' = 29.5^{\circ}$ and $C' = 0$. Total stress parameters obtained on a set of samples from the slip face at Bramley Drive were $\phi = 10^{\circ}$ and $C = 90$ Kpa.

In the case of the effective stress tests, loading was continued well beyond failure up to axial strains of 20%. Deviator stress and pore pressure plotted against strain are shown on figures 2 to 4. The significant aspect of these graphs is that the deviator stresses reach a peak at fairly small strain, indicating sudden brittle failure, then decreases with further strain, however, the pore pressure continues to increase even after the deviator has reached its maximum. This behaviour reflects the unstable skeleton structure of the sensitive clay. As the clay shears the soil structure collapses and the clay suffers a great decrease in volume. As this occurs large positive pore pressures are induced as load is transferred from the soil skeleton to the water held in the voids, since the sample is sheared undrained. The effect of this is to decrease effective stresses and greatly reduce the overall shear resistance of the soil immediately after failure. These stress curves predict therefore that soil failure is likely to be sudden and that very great strength loss will occur after failure. Because of this unstable nature of the soil, it is difficult to choose realistic average strength parameters for use in practical stability calculations. Shear strength values considerably less than those at peak strength are liable to be more realistic for analysis.

### (b) Mineralogy

The sample of highly sensitive older ash analysed by Soil Bureau, D.S.I.R., proved to contain 85% hydrated halloysite (I. Smalley, pers. comm). The mineralogy of the ten other ash samples analysed by N.Z. Geological Survey using x-ray diffraction, is also dominated by halloysite, as indicated in the table below:

| Sample | Depth (m) | Formation | Mineralogy of Clay Fraction |
|---|---|---|---|
| 4/4 | 5.2 | Older Ashes | Halloysite, cristobalite |
| 4/6 | 8.7 | Older Ashes | Halloysite, cristobalite |
| 4/8 | 11.0 | Older Ashes | Halloysite, cristobalite, quartz |
| 4/9 | 13.3 | Older Ashes | Halloysite, cristobalite, quartz |
| 4/11 | 16.4 | Older Ashes | Halloysite |
| 4/12 | 18.8 | Older Ashes | Halloysite |
| 4/13 | 20.6 | Older Ashes | Halloysite |
| 4/14 | 23.0 | Older Ashes | Halloysite, trace of cristobalite |
| 4/17 | 28.2 | Tauranga Formation | Halloysite, trace of cristobalite |
| 4/18 | 32.7 | Tauranga Formation | Halloysite |

Halloysite is a clay mineral which although has a high liquid limit has a very low Plasticity Index, as well as limited swelling properties on hydration. The analyses suggest that Halloysite is the dominant clay mineral in both the older ashes and the weathered pumice tuff breccia of the Tauranga Formation.

The soil sample supplied to Soil Bureau, D.S.I.R., (sample 4/13), was also subjected to an electron microscopic scan. The results indicate that the Halloysite is of an unusual spherical variety as shown in Fig. 6.1. The soil structure consists essentially of a mass of halloysite spheres with diameters of about 0.2 microns with no evidence of cementation between particles. These particles appear to be single crystalline units and not aggregations of smaller particles. It seems that the sensitivity of the soils results from very low attraction or bonding forces between the loosely packed particles. Thus although clay mineral particles predominate in the soil, long range interparticle forces are essentially absent and structural collapse can readily occur. The studies carried out on this soil by Soil Bureau lends some support to the inactive - particle theory of soil sensitivity (Cabrera & Smalley, 1973).

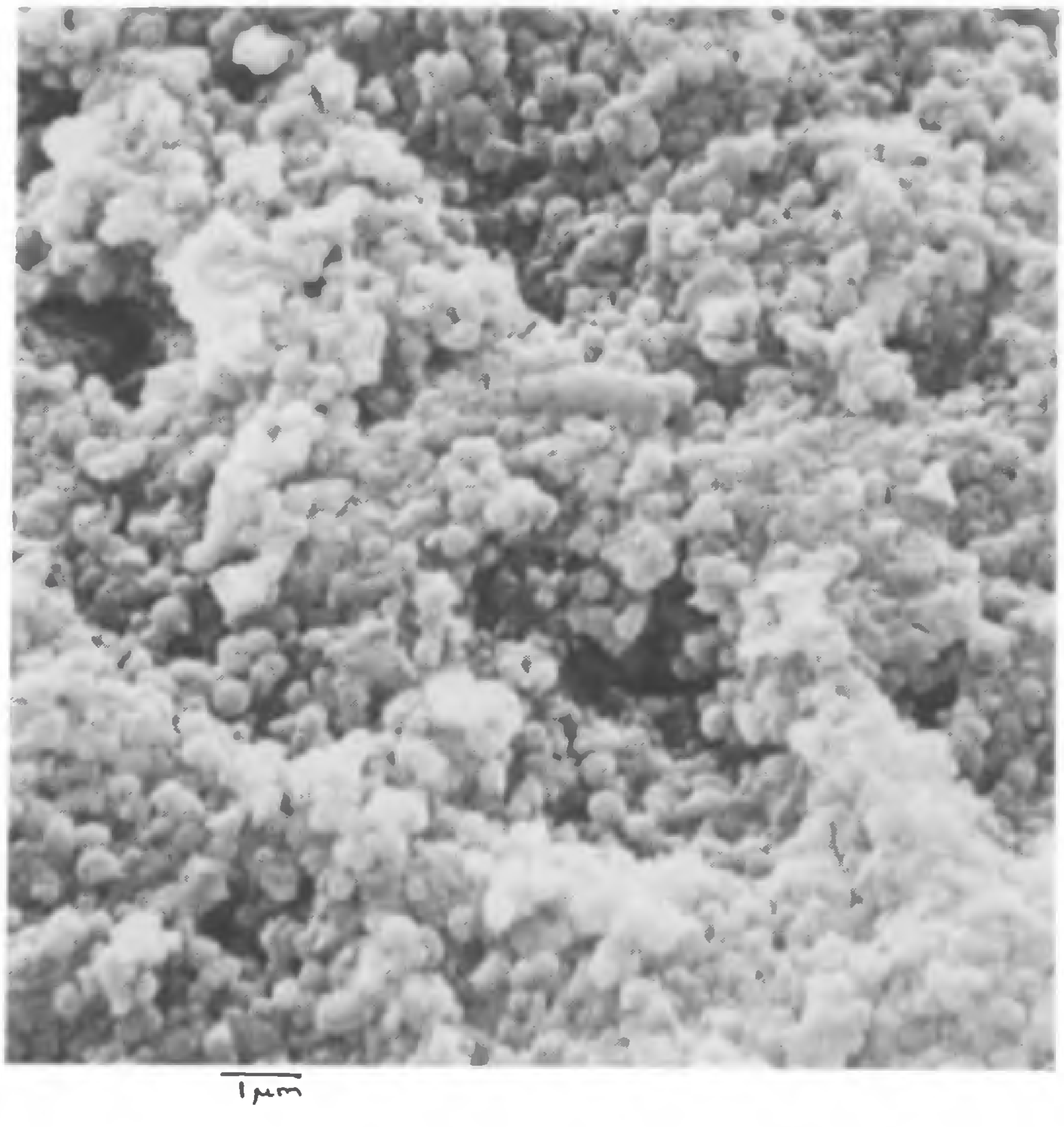

Fig. 6.1 Scanning electron microscope picture of spherical halloysite particles comprising sensitive soil from bore-hole 4, depth 20.6 m. Magnification 7,500 times.

# 7.0 DESCRIPTION OF LAND INSTABILITY

## 7.1 GENERAL

As outlined in Section 4.2 the Omokoroa coastline, particularly along the western portion, has been subjected to a long history of instability. A considerable number of major deep seated failures have occurred from time to time and are likely to continue to occur. Smaller scale failures are also continually active in many coastal areas.

The locations of past and present landslips on the pensinsula which have been identified in this study, are shown on drawings 4487 - 3, sheets 1 to 8. In the following three sections these areas of instability are described in detail, commencing with the recent major failure at Bramley Drive.

## 7.2 THE BRAMLEY DRIVE LANDSLIP

### Events of August 1979

An arcuate segment of seacliff 60 m wide and about 16 m deep, centred on 11 Bramley Drive, failed and collapsed into the sea at 1100 h on 9 August (Figure 7.4). The failure removed much of the Esplanade Reserve fronting 9 and 11 Bramley Drive, and a substantial portion of these properties. There were few precursory indications of the failure. Concentric cracks up to 5 cm in width in the lawns of 9 and 11 Bramley Drive were first observed at approximately 1045 h on 9 August, which prompted two local residents to descend the seacliff and the failure was observed by these residents and a third person at the top of the cliff. Their accounts suggest failure was catastrophic and the failed material slid outwards as a single mass. The mass entered the sea at considerable velocity sweeping a number of large logs over 1 metre in diameter outwards from the base of the cliff for distances up to 150 m. The entry into the sea generated waves of one metre amplitude observed at Pahoia Point five kilometres distant. Arcuate tension cracks were still present after the failure, parallel and adjacent to the cliff edge on 9-13 Bramley Drive and extending into 15 Bramley Drive.

A second failure occurred at 0500 h on 11 August removing a further 9 m deep segment of the cliff-face. This failure extended to a patio immediately adjacent to the dwelling on 11 Bramley Drive. The failure occurred in darkness and was therefore unobserved.

Subsequent failures on 21-22 August removed a further 10 m wide and 4 m deep segment from the cliff between 11 and 13 Bramley Drive leaving the house on 11 Bramley Drive undercut (Figures 7.5 & 7.6). Demolition orders on five dwellings affected by the landslip, were issued on 26 August and all were successfully removed in sections.

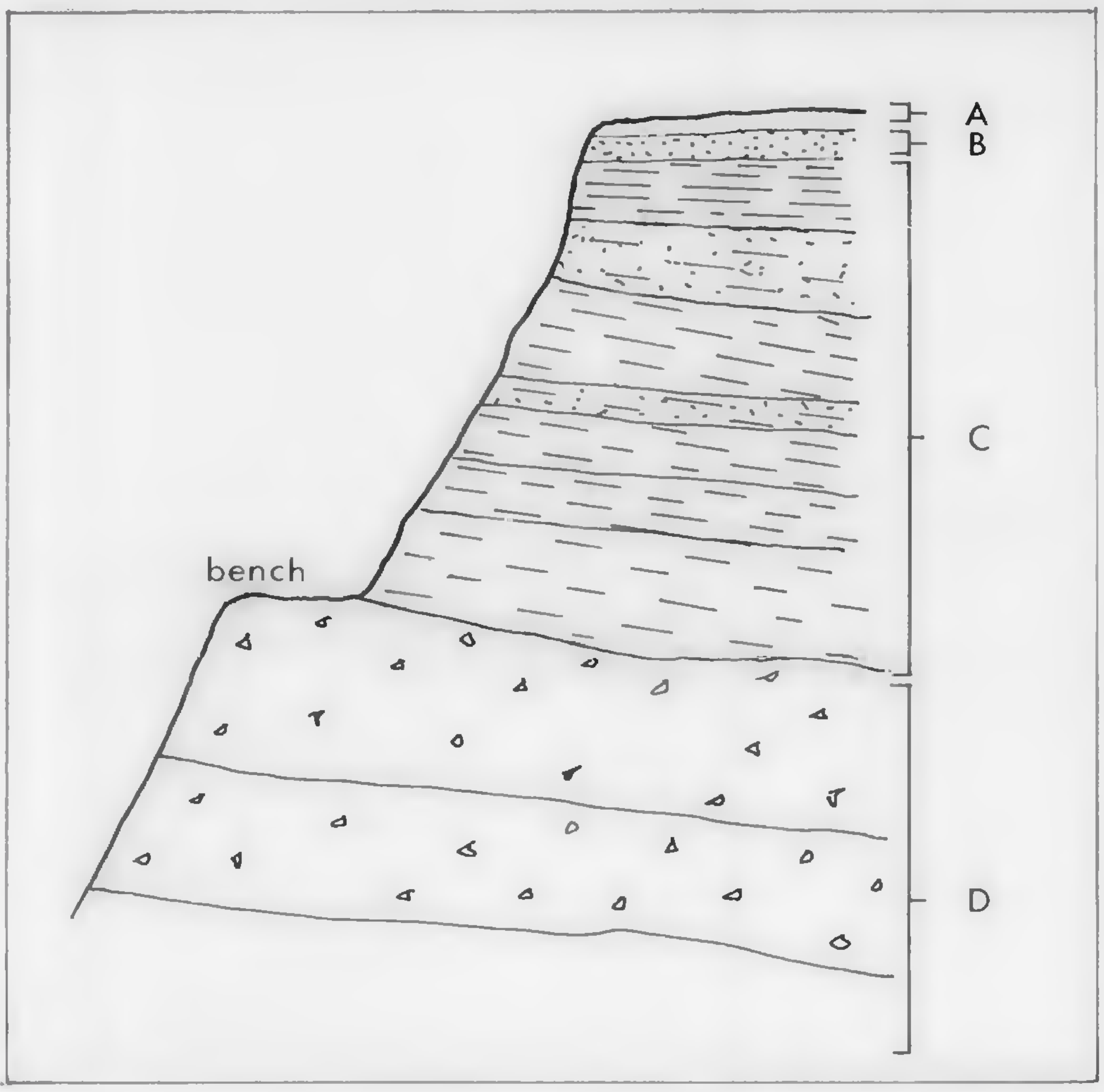

Figure 7.1 Cross section of face of Landslip.

A Earth Fill

B Rotoehu and Younger Ashes

C Older Ashes

D Tauranga Formation

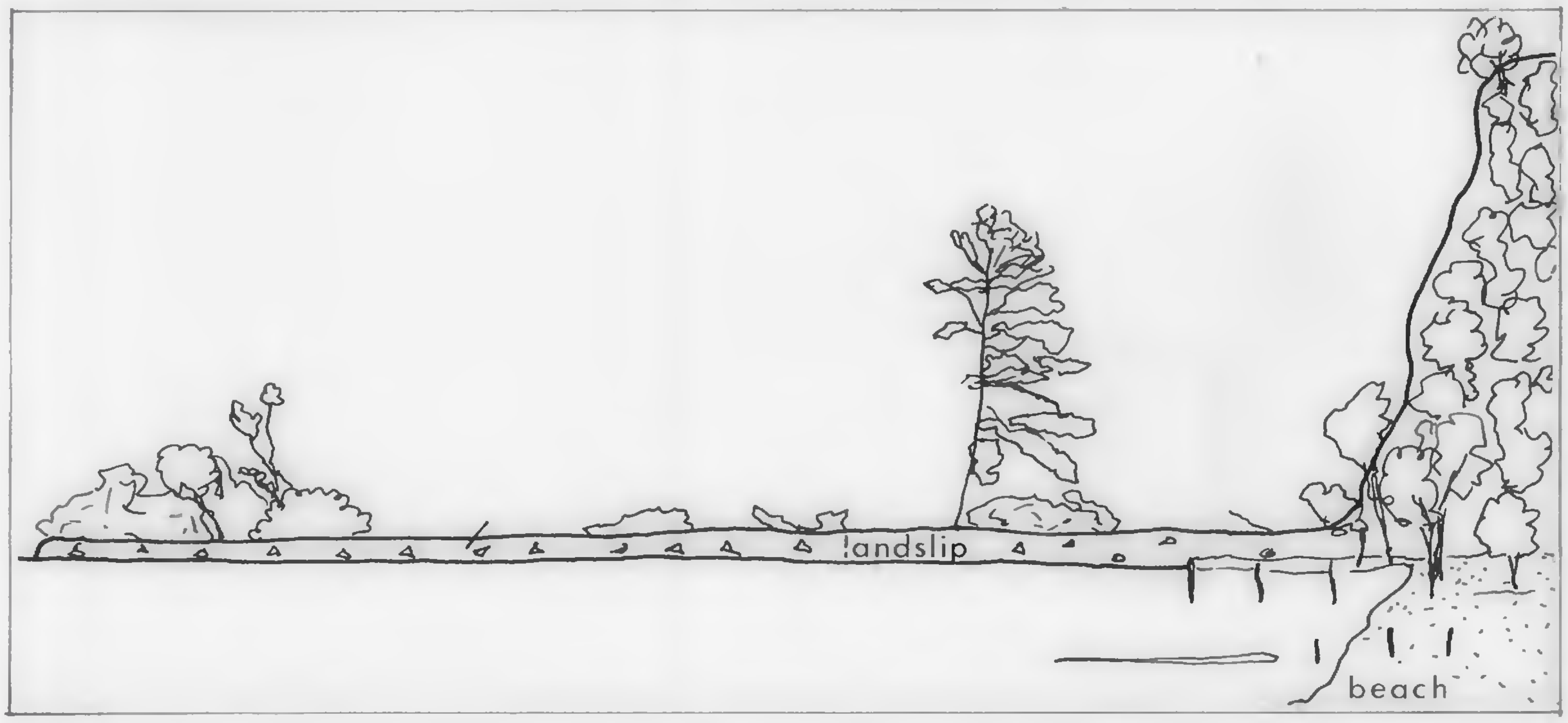

Figure 7.2 Plan view of deposit of 11 Bramley Drive Landslip. Approximate width of box 150 metres.

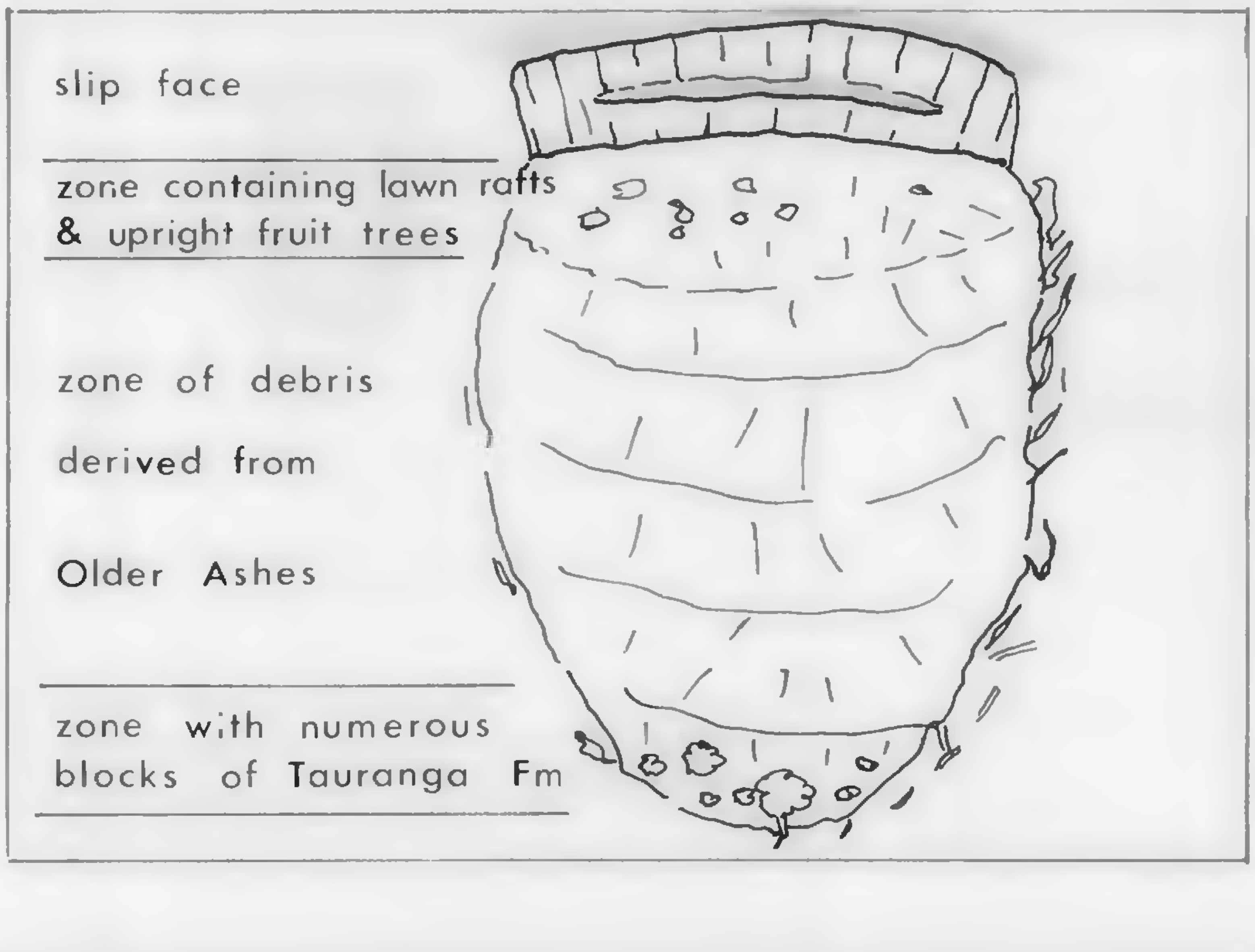

Figure 7.3 Map view of deposit of 11 Bramley Drive Landslip, showing concentric zonation of debris.

Fig. 7.4 The Bramley Drive Landslip taken 10th August 1979.

(photo courtesy Bay of Plenty Times)

## Landslip Face

The face of the landslip was examined by both writers on 13 August and subsequently revisited several times. The trace of the landslip face at the surface is a tight arc. Hairline cracks parallel to the surface trace were present on the Bramley Drive properties on 13 August. Cracks extended across the patio terraces on 9 and 11 Bramley Drive prior to the failures on 21 August and one crack had broken a brick on a terrace at 9 Bramley Drive. There were otherwise few signs of deformation and disturbance adjacent to the landslip.

The face consisted of two steep portions separated by a gently sloping bench. The level of the bench was immediately above the contact between the Tauranga Formation and the older ashes. The lower portion of the slip face, largely within the Tauranga Formation, was a smooth, planed surface. The failure surface was partially buried at the centre of the face but clearly visible at both margins. The upper portion of the face was more irregular with protruberant resistant ridges and blocks.

Prior to the landslips the cliff projected adjacent to 7-11 Bramley Drive between two pre-existing landslip embayments. The older ashes at this point are appreciably thicker than in cliff sections 50 m to the north and south. The greater thickness is largely due to an increase in the height of the cliff and partly due to the fact that the older ashes infill a pre-existing valley cut into the Tauranga Formation. Individual beds within the older ashes slope gently down into this gully from both sides whereas the underlying Tauranga Formation strata dip back into the cliff-face (approximately eastward) at between 5 and $10^{o}$ (Figure 7.1).

The bench on the slip face was partially covered on 13 August by blocks of coherent material derived from the upper older ashes, as well as an irregular deposit of cohesionless mud which readily liquified on disturbance and was derived from the lower highly sensitive older ashes close to the level of the bench. Considerable seepage from the lower ashes occurred during most of August, causing small mobile slurries of debris from the mud deposit on the bench. Outflow pipes related to the septic tank on 9 and 11 Bramley Drive were visible on the slip face 2 m beneath the surface during inspection on 13 August. The edge of the tank on 11 Bramley Drive was exposed during subsequent small failures and the tank was later destroyed during the failures on 21-22 August.

## Nature of the Deposit of the 9 and 11 August Landslips

Debris from the landslides formed a tongue-like sheet extending approximately 150 m from the seacliff. The sheet was flat-lying and of remarkably uniform thickness with an irregular upper surface produced by coherent blocks up to one metre in diameter. Logs originally lining the beachfront had been propelled outwards and now ringed the deposit. Very little debris had over-ridden the logs. High mobility of the failed mass was clear from the distance travelled by the material and its unusually flat profile ( Figures 7.2 & 7.7).

The deposit showed a crude concentric zonation (Figure 7.3). Blocks of the Tauranga Formation derived from the base of the headland had travelled the greatest distance and were concentrated adjacent to the transported logs at the toe of the deposit. The middle portion of the deposit was derived largely from the older ashes and a concentric internal banding was noticed with concentrations of debris from successively higher stratigraphic horizons. The alternation of black and dark brown debris from the paleosols and the lighter less weathered intervening ashes produced a striking colour zonation. Material derived from the soil horizons and Rotoehu Ash was concentrated at the foot of the slip face and had travelled the least distance. This material included intact rafts of lawn up to two metres across and numerous upright fruit trees with fruit, foliage and root systems totally preserved. The grass rafts were never overturned and clearly had been carried gently on the surface of the slide without significant rotation or disturbance.

The subsequent failures of 21-22 August produced a similar but smaller zoned deposit with the axis of the deposit at approximately 30$^{\circ}$ to the axis of the main deposit. Redistribution of material by tidal processes commenced immediately after the failures and the deposit has now been substantially modified.

## 7.3 INSTABILITY ON THE REMAINDER OF THE PENINSULA

Concurrent with the Bramley Drive slip numerous smaller coastal failures occurred both north and south of Bramley Drive. Significant slips occurred (a) along the coastline bordering the Crapp subdivision, where the formation of tension cracks above the cliffs also indicated areas of incipient failures, and (b) below the Cooney subdivision where numerous failures occurred mainly at the toe of cliffs. Shallow failures also occurred on the cliffs immediately north of the Bramley Drive slip.

Previous major slips remembered by residents have been documented in Section 4.2. An examination of the Drawings 4487 - 3, sheets 1 to 8, shows that the slips mentioned above are only the latest in a long history of landslips which have occurred on the pensinsula.

Features presumed to be very old slip scars were noted on the eastern coast of the pensinsula as well as inland. (Refer Key Plan 4487 - 3, sheet 1). The landslips in the Margaret Place area have been documented elsewhere (Report 4487/1 Tonkin & Taylor 1979). Many of the larger slips on the east coast appear to be very old and were probably related to a time when an ancient shore line was farther inland. Small failures have occurred in recent years but on nothing like the same scale as have occurred on the more exposed western coast.

Along the western coastline over 50 sites of significant past landslips have been identified, of which at least 17 can be considered as major deep seated failures. Guesses have been made of the ages of all failures where not definitely known (these ages are based primarily on the state of revegetation) and are indicated on the drawings.

## 7.4 COASTAL ZONES

Based on the topography, ground conditions and type of instability, the western coastline had been divided into four broad zones in which similar conditions appear to prevail. These zones are indicated on Drawing 4487 - 3, sheet 1 and the general features of each zone are described as follows:

Zone 1 Extending from the end of the Crapp Historical Reserve to the southern end of Ruamoana Road.

- Cliff height varies between 9 and 19 metres.
- Significant ground conditions (as represented by boreholes 2 and 3) are;

  the top of the Tauranga Formation between about 2 and 4 metres above sea level;

  the very sensitive ash layer up to about 5 m thick;

  the summer water table about 6 to 8 metres above sea level.

- Instability in this zone includes; active shallow instability (Historical Reserve and from about Lot 25 Ruamoana Road to the southern end), active deep seated slumping (Crapp subdivision to Lot 15 Walnut Grove), and apparently relatively stable coastline (Lot 14 Walnut Grove to Lot 26 Ruamoana Road).

  Most of the slips within this zone are assumed to have occurred in relatively recent years, although historic records are not available.

Zone 2 Extending from the southern end of Ruamoana Road nearly to Kowhai Grove.

- Cliff height varies between 20 and 34 metres.
- Significant ground conditions (boreholes 4 and 5) are;

  the top of the Tauranga Formation between about 10 and 12 metres above sea level;

  the very sensitive ash layer between about 6 and 8 metres thick;

  the summer water table about 18 to 22 metres above sea level.

- Instability consists mainly of deep seated major slumping similar to the Bramley Drive landslip. South of Bramley Drive a number of these features appear to be very old (i.e. in excess of 50 years).

Zone 3 Extending from Kowahi Grove to the end of Kaharoa Avenue.

- Cliff height varies from 12 to 22 metres.
- Significant ground conditions (boreholes 6 and 9) are;

  the top of the Tauranga Formation between about 6 and 7 metres above sea level;

  the thickness of the very sensitive ashes between about 6 and 7 metres;

  summer water-table 4 to 10 metres above sea level.
- Instability consists mainly of major deep seated slumping ranging from very old to relatively recent.
  A rather curious land feature once existed in the area now occupied by the Bowling Club and Recreation Reserve. The 1964 aerial photos reveal a large depression in this area with a wide elongated gully extending northeast. These features have since been filled and extensively modified by earthworks, but were probably caused by ancient stream erosion (perhaps accompanied by slumping). Strong seepage occurs from this area. Two streams appear from small pools a short distance above the beach which suggests they may be spring fed. Concentrated seepage in this area close to sea level, is consistent with the low water table found in borehole 6 and may reflect a generally lower water table in this region of coastline.

Zone 4 Extending from the end of Kaharoa Avenue to the end of the investigation area in the Cooney subdivision.

- Cliff heights vary from 19 to 27 metres.
- Significant ground conditions (boreholes 7 and 8) are;

  top of the Tauranga Formation between 10 and 11 metres above sea level;

  Thickness of the very sensitive ash layer between 2 and 8 metres thick;

  Ground water table between about 7 and 12 metres above sea level.
- Instability consists of mainly relatively recent major deep seated slumping. Recent reactivation within areas of older deep seated slumping has occurred along the coast of the Cooney subdivision.

While the above divisions of coastline can be made on the basis of similar conditions, differences between the zones, with the exception perhaps of Zone 1, do not appear to be great enough to cause much variation in the mode of coastal failures along the whole length of coastline. In all the zones a high risk of coastal instability must be assumed to exist. In Section 8.0 the nature of this instability is analysed leading to the concept of a landslip risk zone.

# 8.0 LANDSLIP ANALYSIS

## 8.1 APPROACH TO ANALYSIS

The most appropriate approach to the analysis of stability at Omokoroa was to look at the characteristics of previous major landslips along the coast and compare these with the Bramley Drive slip to try and establish similarities between the modes of failure. Once a model for failure was established, theoretical calculations could be carried out on typical slip profiles using parameters derived from soil testing and drilling investigations.

Theoretical stability calculations are highly sensitive to the choice of parameters, many of which have to be assumed and there are also a large number of possible variations of ground condition. Selection of strength parameters for the highly sensitive soils, to be used in practical calculations, present a particular problem because of the unstable nature of these materials. At best, the theoretical calculations are seen as a means of confirming the probable stability mechanism decided after study of a number of examples of failure, rather than as a means of establishing the primary slip mechanism from a wide variety of ground variables.

Inferred limits of potential cliff failure therefore, as presented in this report, have been based on precedent rather than on the results of theoretical stability analyses.

## 8.2 CHARACTERISTICS OF THE BRAMLEY DRIVE LANDSLIP

The failure which occurred at Bramley Drive has the characteristics of both a translational slide and a flow slide. A translational slide is one which is controlled by a relatively weak layer on which a large soil block moves as a 'raft'. A flow slide on the other hand, results from the sudden failure of a soil mass at relatively small shear strains, accompanied by a great decrease in soil strength and volume. This results in the general disintegration of the soil mass and the highly mobile slide debris spreads out rapidly over a large area.

In the Bramley Drive slip there was very little prior deformation and total failure occurred within a few minutes. The debris mass spread over a wide area and had a flat profile with very little in the way of large intact soil blocks remaining. These are all typical characteristics of a flow slide. The failure appears to have been controlled by the layer of highly sensitive soils at the base of the older ashes and seems to have been caused by a rise of pore pressure within these materials. As the unstable structure of the ashes collapsed, liquifaction readily occurred since, as shown by soil tests, natural water content of the soil is often close to or in excess of liquid limit. (i.e. the moisture content at which the consistency of soil changes from a solid to a liquid).

The ordered, stratified nature of the slip debris however, as described in Section 7.2, is inconsistent with a completely flow type mechanism, as are the undisturbed fruit trees and rafts of grass at the head of the deposit. This suggests that 'flow' was confined to a layer within the ashes and that the overlying materials were somewhat more rigid.

Within the debris deposit the sequence from the toe to head, of concentrations of debris from progressively younger strata, suggests failure commenced at approximately the level of the bench and extended progressively upwards. The displacement without burial of large logs, which originally lined the foreshore, to the margins of the slip debris, serve to demonstrate the high velocity of the landslip.

## 8.3 GENERAL LANDSLIP CHARACTERISTICS

The type of failure mechanism described in the preceding section for Bramley Drive appears to be fairly typical of many of the previous landslips along the coastline, as might be expected from the similar geological conditions encountered in the boreholes to those existing at Bramley Drive. Similarities in the mode of past failures is also confirmed by eye witness accounts of these events. The type of failure produces a rather distinctive slip profile shown in Figure 8.1.

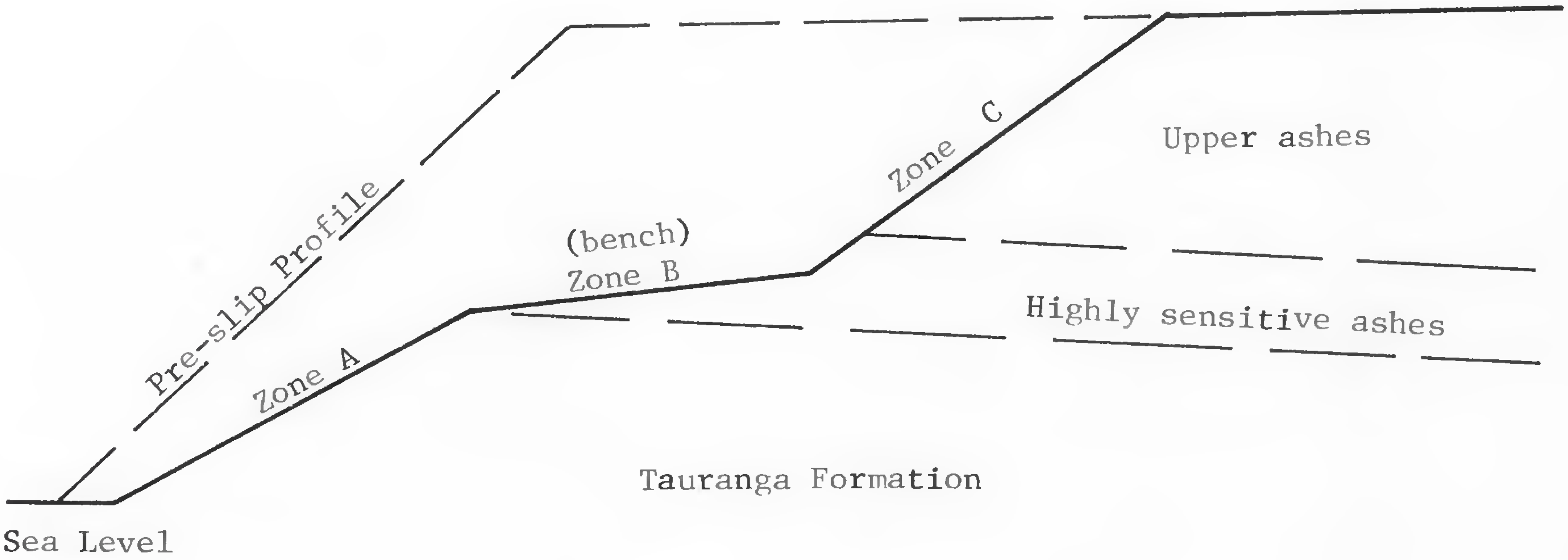

Fig. 8.1 Typical Landslip Profile

A fairly well defined low angle 'bench' is produced by failure through the zone of weak, highly sensitive ashes. Steeper overall failure slopes occur in both the underlying Tauranga Formation and the overlying more rigid ash layers.

This general profile is shown in the six surveyed cross-sections (which include Bramley Drive) at sites of major landslips presented on Drawings 4487 - 4 and 5. On these cross-sections the profiles of nearby boreholes have been projected and assumed boundaries between the significant layers have been indicated. The inferred ground profiles prior to landslip are also shown, determined from the adjacent non-failed sections of the cliff as well as old survey information.

In the table below, the average slopes of zones A, B and C are shown for each of the surveyed cross-sections. In addition are shown the ratios of vertical height to horizontal depth for the overall landslips as well as height to depth ratios for just that portion of the failure which occurred above the Tauranga Formation (i.e. zones B and C).

| Section | Average Slope of Zones | | | Vertical Height : Horizontal Depth | |
|---|---|---|---|---|---|
| | A | B | C | Slip shape in Zones B & C | Overall slip shape (zones A,B, & C) |
| 1 | - | 11° | 33° | 1:2 | 1:1.8 |
| 2 | 28° | 12° | 34° | 1:1.7 | 1:1.8 |
| 3 | 25° | 16° | 39° | 1:2 | 1:2.1 |
| 4 | 30° | 7° | 39° | 1:2.5 | 1:2.0 |
| 5 | 23° | 13° | 49° | 1:2 | 1:2.1 |
| 6 (Bramley Drive) | 22° | 15° | 50° | 1:1.5 | 1:1.8 |

This simple geometrical analysis shows the similarities in the profiles of these slips and points to the uniformity in the overall slip shapes and to lesser extent in the shapes of the upper portions of the slips. It should be noted that in many cases the final slip profiles are probably the result of several retrogressive failures which occur at intervals, particularly in Zone C where an initial steep slip scarp will tend to regress to a flatter, more stable angle. The upper portions of the slips in Section 5 and 6 (Bramley Drive) may thus in time regress further.

In those areas of the coastline where landslips have not occurred, average natural slopes of up to 50° were measured. However, typical average slopes for these non-failed areas are in the order of 36° to 45° (i.e. between 1:1.4 and 1:1).

The similarity shown by the cross-sections of the overall slip shapes, led to the measurement of the overall height to depth ratios for all the major localities along the western coastline. These are shown in the table below, the slips being numbered from the Crapp subdivision southwards. The landslip depths have been measured from the base of the cliffs corrected for the effects of debris or erosion since failure.

| | Slip No. | Overall Slip Shape - Vertical Height: Horizontal Depth | Remarks |
|---|---|---|---|
| Crapp Subdivision | 1 | 1:2.1 | |
| | 2 | 1:1.8 | Section 1 |
| | 3 | 1:1.8 | Section 6, (Bramley Drive) |
| | 4 | 1:1.6 | |
| | 5 | 1:1.5 | |
| | 6 | 1:1.8 | Section 2 |
| | 7 | 1:1.6 | |
| | 8 | 1:1.7 | |
| | 9 | 1:1.9 | |
| | 10 | 1:2.2 | |
| | 11 | 1:2.1 | Section 3 |
| | 12 | 1:1.4 | |
| | 13 | 1:2.0 | Section 4 |
| | 14 | 1:1.6 | |
| | 15 | 1:1.6 | |
| Cooney Subdivision | 16 | 1:2.1 | Section 5 |
| | 17 | 1:2.0 | |

The ages of the slips span a long period, probably at least a few hundred years and it can be seen that there is considerable uniformity in the overall proportions of the major slips, sixty percent of them having height to depth ratios between 1:1.8 and 1:2.2. This uniformity between landslip shapes is seen as reflecting similar failure mechanisms as a result of the basic similarities of conditions which exist along the coastline, mentioned in section 7.4.

It is considered therefore, that a valid approach to the assessment of stability risk and the limits of possible future failures, is to assume that future landslips will continue to have the same general modes of failure and produce the same failure shapes as in the past. This approach has been used as a basis for risk zoning along the coastline as discussed in Section 8.6.

## 8.4 MODEL FOR FAILURE

From the foregoing, a model for the failure mechanism has been established.

The initial failure at Bramley Drive removed an estimated 16 m of cliff edge which retreated further in subsequent failures to its present position (compare Figures 7.4 & 7.5) This initial failure line, occurring through the upper ashes, is indicated on the cross-section of the Bramley Drive slip (Drawing 4487 - 5) and it can be seen that this initial failure occurred at a very steep angle indeed (approx. $80^{o}$).

As mentioned in Section 8.2 the slip has characteristics of both translational and flow slides and does not conform to the more typical rotational slide mechanism. The profile of the failure plane is also inconsistent with the type of failure plane that would be expected in a rotational failure.

The model for failure that has been inferred and which appears to fit observations, is shown in Figure 8.2.

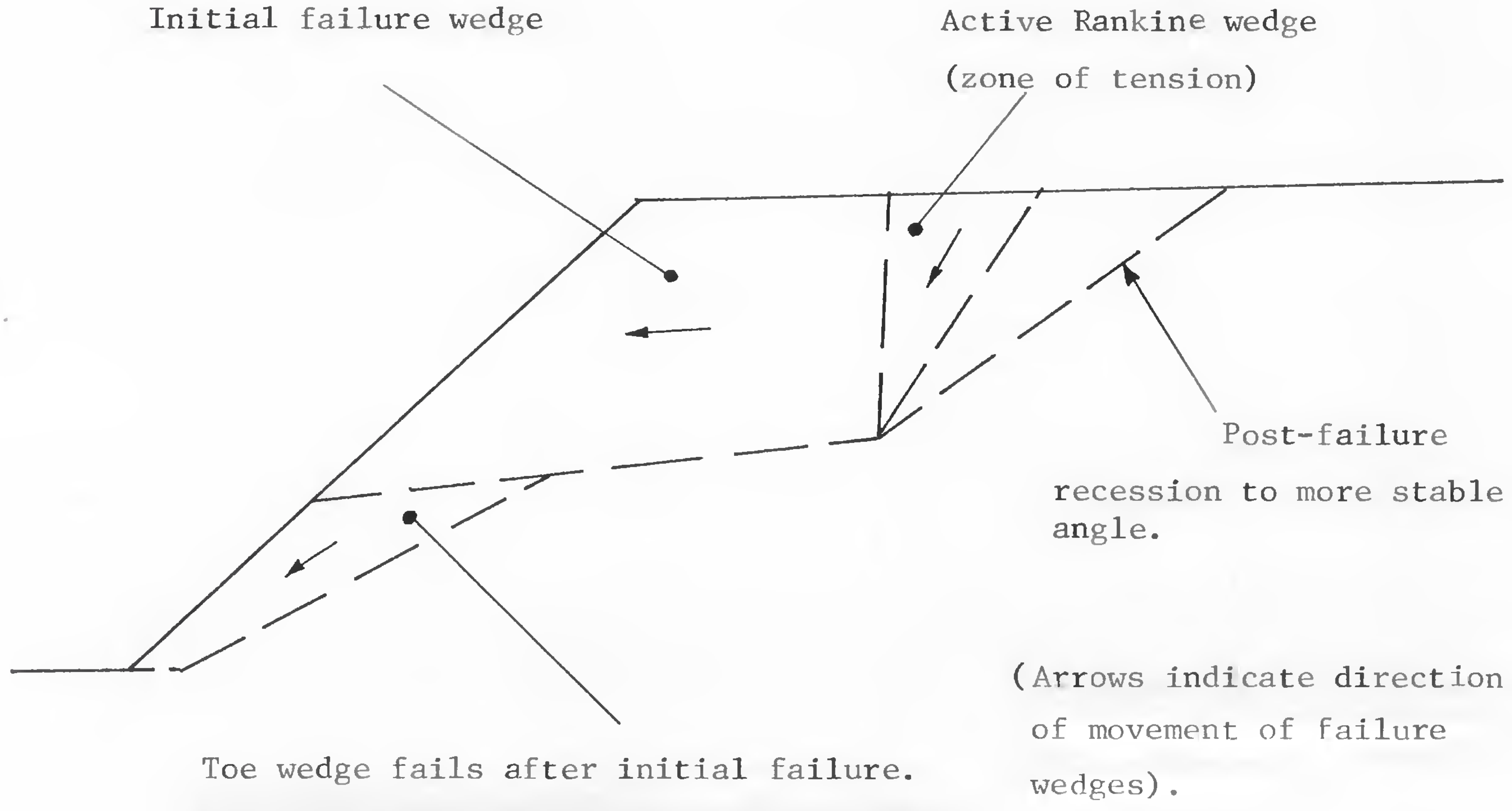

Fig. 8.2 Two-dimensional model for wedge failure.

Translational sliding of a large soil block seems to have occurred initially as a consequence of failure and liquification within the highly sensitive soil layer. Movement of this block could then have promoted failure of a toe wedge in the more competent Tauranga Formation. An 'active wedge' developed behind the main soil block would produce a zone of tension and post-failure recession of the soils within this wedge zone would be likely to occur, possibly extending beyond the limits of the active wedge.

The above failure model is consistent with the known sequence of failures and the shape of the initial and final failure surfaces.

## 8.5 STABILITY ANALYSIS

Stability calculations were carried out using the model for failure described in Section 8.4. Analyses were tried in terms of both total stress and effective stress parameters. However, factors of safety using total stress methods proved to be over-conservative and are therefore considered inappropriate.

Effective stress analyses gave reasonable confirmation of the failure mode. This method has the advantage of enabling variations in pore pressures to be included in the calculations and since increase in pore pressures is thought to trigger failure, this method of analysis seems the most appropriate.

The slips shown in cross-section 4 (a 1962 slip) and 6 (the Bramley Drive Slip) Drawings 4487 - 4 and 5 ,were analysed in detail by the method of 'back analysis' . In this method, a stability calculation is performed using the known failure surface and assumed ground water conditions at the time of failure. The strength parameters of the soils required for failure may then be calculated (i.e. for a safety factor of unity). These calculated parameters can then be compared to those obtained from laboratory testing. It should be noted the calculation of safety factor is very sensitive to the choice of the friction angle $\phi'$.

Using assumed ground water conditions at the time of failure, analysis of Section 4 gave a safety factor close to unity for $\phi'$ close to $18^o$, and analysis of the Bramley Drive slip gave a safety factor of unity for $\phi' = 23^o$ assuming a water table about 2 metres higher than the summer water table measured in borehole 4.

The value of peak friction angle obtained from soil tests was $\phi' = 29.5^o$ which is considerably higher than the value suggested by calculation to exist at the time of failure. The difference between calculated and tested values of $\phi'$ could be due to:

a) Incorrect choice of groundwater conditions and hence pore pressures, which are unknown at the time of failure.

b) Over estimation of $\phi'$ by the laboratory method of testing extremely sensitive soils, or use of 'peak' rather than residual friction angle. However, it was found that even at a strain of 20% there was no significant reduction in the residual friction angle from that measured at the peak (although shear strength falls off rapidly). The only 'residual' measurements possibly more relevant would be the direct measurement of undrained residual shear strength such as could be obtained by shear box testing. In view of the constraints of the present report shear box tests were not attempted and there is scope for further investigations in this direction. However, the use of residual strength in stability calculations may be inappropriate in view of the lack of a pre-existing failure surface and the inability of the soil to tolerate much deformation, as demonstrated by the sudden brittle nature of the failures.

c) The general difficulty of selecting an 'average' parameter for use in calculations when soils may vary in properties throughout the failure zone. There is also the possibility that 'progress ive' failure may have occurred causing overstressing and failure in one portion of the soil mass before another. Analysis of such a case does not lend itself to easy theoretical calculation.

The analyses serves to demonstrate the difficulty of choosing realistic parameters for practical calculation in the case of these extremely sensitive soils. Without the benefit of more accurate information on groundwater conditions at the time of failure (such as could be obtained only by monitoring) theoretical calculations such as those performed can only serve to indicate the likely order of magnitude of strength parameters at the time of failure and cannot provide unique values. For this reason, and uncertainties about the actual mode of failure, we consider that assessment of stability risk cannot be based with any certainty on theoretical stability analyses.

## 8.6 LANDSLIP RISK ZONING

Based on the measurement of all previous major landslips as detailed in Section 8.3, a coastal zone of landslip risk has been defined as shown on Drawing 4487 - 3, sheets 1 to 8. The boundary of this zone is the inferred maximum limit beyond which we would not expect landslips to occur. This failure limit has been obtained by assuming that the ratio of vertical cliff height to horizontal depth from base of cliff, for all landslip failures will be within the ratio of 1:2.25 (1:2¼) (or an average slope from MHWM to top of cliff of $24^{\circ}$).

As mentioned in Section 8.3, 60% of all the major failures to date have height to depth ratios between 1:1.8 and 1:2.2. None have yet exceeded the upper limit of 1:2.2.

In applying the ratio 1:2.25 to define the failure limit, cliff heights used were those assumed to exist after possible failure (e.g. in the case of land sloping towards the cliff edge). The horizontal depth chosen was measured from the toe of the cliff, with allowance for any debris or marine erosion since slipping occurred. Since the ratio has been derived from measurements of landslips which span a long period of time it is felt that there is some built-in allowance for the effects of marine erosion. The level of risk that exists within the landslip risk zone for various parts of the coastline is not easy to define. The level of risk will be greater closer to the cliff edge since slips of smaller dimensions will probably occur more frequently, e.g. from the table of shapes of 17 major slips (section 8.3) only 4 of these have height to depth ratios greater than 1:2.0 (or about 25% of the major slips). One could therefore argue a somewhat higher level of risk within the overall risk zone, for land within the height to depth ratio of 1:2.0 than between 1:2.0 and 1:2.25. The level of risk will also vary along the coast. Groundwater condition is likely to be a major factor influencing this variation of risk. Comments have been made in section 6.5 on groundwater level variations, which if they can be substantiated after a period of monitoring may lead to the recognition of some sections of coast having higher levels of risk than others.

However, we do not feel that on the data so far available, we are able to delineate areas with different degrees of risk within the overall risk zone.

Periods of major landslips appear to correlate reasonably well with those years which have high cumulative monthly rainfall. Over the last 70 years at least ten 6 monthly periods of high rainfall have occurred with magnitudes equal to or greater than those which caused the periods of known landsliding in 1962, 1968 and 1979. We conclude therefore, that there is a fairly high risk that further major failures will occur along the coast somewhere within the landslip zone and that the maximum limits to which these failures could occur are likely to be the boundary of the risk zone.

# 9.0 FACTORS INFLUENCING INSTABILITY

## 9.1 GENERAL

As is generally the case with land instability problems it is the combination of a number of factors which, acting together to a greater or lesser degree, result in eventual failure of a portion of land.

At Omokoroa the main contributing factors which influence instability are seen as:-

(a) The nature of the geology and soil conditions.

(b) Rainfall frequency.

(c) Marine erosion.

(d) Subdivisional development.

(e) Drainage and waste water disposal systems.

The significance of each of these factors is discussed in the following sections.

## 9.2 GEOLOGY AND SOIL CONDITIONS

The nature of the geology and soils at Omokoroa is seen as the prime factor influencing instability.

As described in other sections of this report, the peninsula is composed of a thick sequence of relatively flat lying deposits of weak volcanic ashes, for the most part deeply weathered. Owing to the particular nature of the ash deposits, weathering has caused within the sequence, the formation of soils with the very undesirable property of extreme sensitivity. The delicate structure of these soils means that they are susceptible to sudden catastrophic strength losses. Such soils are present as layers throughout the ash sequence but a particularly thick zone of them exists well down in the sequence and it is the failure of the soil within this zone that appears to be the controlling influence on nearly all of the major deep seated coastal landslips at Omokoroa. The minority of major failures not specifically controlled by the zone of sensitive ash are, nonetheless the result of failure within the thick sequence of low strength ashes which compose the cliffs.

Given these particular ground conditions the various other influencing factors will tend to promote slope failures in a number of ways.

## 9.3 RAINFALL

The high permeability of the covering layer of Rotoehu ashes means that there is little surface drainage on the peninsula and rainfall rapidly infiltrates this surface layer of younger ash. The deeper older ashes contain appreciable amounts of clay and are significantly less permeable. However, there is an alternation of clay-rich and coarser units, particularly in the upper part of the ash sequence, and hence there is likely to be a wide difference in permeabilities and overall permeability of the upper older ash layers may be moderately high.

Rainfall infiltrating from above, and aided by man-made soak pits, will percolate through the upper ash layers down to the level of the water table. As mentioned in Section 6.5 the water table could well be fairly responsive to infiltration. Increased piezometric pressures associated with a rising water table and possibly localised high heads in confining layers and from soak pits, together with the effect of loss of soil strength from water softening, plus the possible development of seepage erosion, will lead to the reduction of those factors maintaining stability.

If ground water tables are already high, for instance, as a result of a long period of wet weather, a small additional influx of infiltration could be sufficient to initiate slope failure.

An analysis of the rainfall record given in detail in Appendix 1, suggests that such a triggering action as outlined above probably caused the Bramley Drive landslip. The significant feature of the rainfall analysis was the exceptionally high amount of rainfall in the months preceeding the August failures (e.g. 6 months) and not the short term rainfall duration which although high, was not exceptionally uncommon.

This interpretation points to the relevance of recording rainfall and groundwater levels on a continued long term basis. From these records it may be possible to predict periods in which there is a likelihood that slope failure will occur, as well as confirm groundwater levels influencing the variation of risk along the coastline.

## 9.4 MARINE EROSION

Marine erosion does not appear to have had much effect on the retreat of the cliffs over the last 60 years. On Drawing 4487 - 3, sheets 1 to 8, older surveys of MHWM along sections of the coast are indicated. The earliest surveys were those of 1920 and later surveys were carried out in 1967, 1968, 1970 and 1971. Comparison of the recent coastline survey with these older surveys shows that there has generally been little change in the horizontal position of the mean high water mark.(MHWM) Where changes have occurred they are often the result of landslip.

Unfortunately the older surveys do not extend along the complete coastline. From the records that are available marine erosion does appear to have contributed to retreat of the coastline in localised areas, such as below Lot 15 Walnut Grove where pine tree roots have preserved a small promontory. Other areas where significant erosion has occurred are below Lots 12 to 25 Ruamoana Road and Lots 31 and 34 Hamurana Road.

It is of note that surveys taken in 1920 and again in 1970 show that below Bramley Drive very little change in MHWM has occurred. Even though along most of the coastline marine erosion appears to be fairly small, it probably still has the effect of keeping the instability active. Localised undercutting of the cliffs will cause small failures which could contribute to larger failures and continued removal of the slip debris by the sea will tend to keep sites of landslips active, particularly where relatively shallow failures have occurred.

We conclude therefore, that while marine erosion does not appear to be a prime cause of the coastal instability it has a definite long term effect of maintaining the level of landslip activity.

## 9.5 SUBDIVISION DEVELOPMENT

The effect on coastal instability resulting from subdivision of the Omokoroa Peninsula is difficult to quantify. Subdivision has been carried out mainly within the last 30 years. Major landslips have been occurring for a period much longer than this and hence subdivisional development cannot be considered as a prime cause of the instability. However, subdivision has no doubt changed the pattern of natural water flow both at the surface and below ground. Rainfall run off has been much increased by construction of roading and housing, and water use and thus disposal problems have increased markedly. Large areas of tree cover have been removed, for instance, in Bramley Drive area and more recently along the coastline in the Crapp subdivision. Many of the trees in the area were mature pines and their deep root systems must have contributed substantially to soil strength. Only now will the root masses of trees cleared in the 1960s have decayed to a point where they no longer contribute to the strength of the regolith. During development slight modification to topography have been made by filling. All the above factors, which taken separately are probably insufficient to cause much change in stability, taken collectively tend to upset the balance of equilibrium of those forces maintaining stability.

The effects of subdivisional development therefore, are seen as causing the peninsula to become more prone to coastal instability.

## 9.6 DRAINAGE AND DISPOSAL SYSTEMS

Of all the effects of subdivision, methods of disposal of stormwater and domestic waste water have probably had the greatest effect on stability by altering the groundwater regime.

We may subdivide the disposal of water on the peninsula into the following main categories:

(i) Rainfall falling on pasture or gardens together with domestic water used for hosing gardens. This water infiltrates the soil and younger ashes,

(ii) Rainfall falling on pathways, drives and roofs discharged mainly into soakholes,

(iii) Domestic waste water discharged via septic tanks to soakhole seepage,

(iv) Rainfall falling on roads discharged via culverts and easements to high tide level,

(v) Rainfall lost by evaporation and transpiration.

Water in categories (iv) and (v) does not enter the groundwater regime and therefore cannot affect land stability. Water in category (i) cannot for the most part be controlled. It is the water in categories (ii) and (iii) that could be controlled.

The standard methods of soakpit disposal and quantities of water involved are discussed in Section 6.6 and it can be seen that these quantities are significant. The effect on the groundwater regime of discharging a volume of domestic waste and stormwater to soakage is greater and takes place more rapidly than the effect of a comparable volume of rainwater.

Waste effluents may also change the pH of the groundwater over a long period and there is overseas evidence to suggest that a reduction in pH can cause a loss of shear strength in sensitive soils (Yong,et.al.,1979)

It is not only the soakage from coastal sections which may effect the groundwater regime since water discharged inland on the peninsula may increase piezometric gradients towards the coast.

The use of deep soakhole disposal therefore, by providing a significant contribution to the natural groundwater system is clearly detrimental to the maintenance of stability.

## 10.0 GENERAL CONCLUSIONS

### 10.1 THE BRAMLEY DRIVE LANDSLIP

We conclude from this investigation that the Bramley Drive landslip was primarily caused by the build up of pore water pressures within a deep layer of extremely sensitive, weathered volcanic ashes. The delicate structure of these soils means that when they become over-stressed they are susceptible to sudden catastrophic failure.

The build up of water pressure within the ground is seen as resulting from a period of exceptionally high rainfall in the months prior to the August failure, the final 'trigger' for the landslip being provided by the high rainfall on July 31st immediately preceeding failure.

Contributing factors to the Bramley Drive landslip which have tended to make the area prone to failure are:

a) the high seacliffs at this location, and consequent great thickness of older ash layers,

b) a high natural ground water table,

c) the results of subdivisional development such as the removal of trees and minor earthworks.

d) the standard use of soakpits for disposal of property stormwater and domestic waste water,

e) the long term effect of marine erosion.

### 10.2 THE OMOKOROA COASTLINE

Ground conditions found at Bramley Drive were found to be fairly typical of those existing along most of the western Omokoroa coastline, particularly in regard to the continuity of the extremely sensitive volcanic ash layers.

Major deep failures similar to the one at Bramley Drive, have occurred over a long period along the entire length of coastline bounded by high cliffs. Periodic major failures seem likely to continue, the magnitude of which, based on the evidence of past failures, will be governed by the height of the cliffs. This investigation points to no area of coast which can be said with any certainty to be free from the risk of major instability in proportion to height above sea level.

The prime cause of failure seems to be increased groundwater levels, resulting from periods of high rainfall, acting in conjunction with the particular geological and soil conditions which exist in the area. The tendency for failures to occur has been aggravated by the effects of subdivisional development, in particular the standard method of soakpits used for disposal of property stormwater and domestic waste water, as well as the long term effect of marine erosion.

Recommendations for the lessening or avoidance of these stability problems in the future are discussed in the following section.

# 11.0 RECOMMENDATIONS

## 11.1 BUILDING RESTRICTIONS

From what has been said in section 10.2 it is clear that the prime causes of instability i.e. geology and rainfall are beyond the control of man and hence the most prudent measure is to provide, by means of building restrictions, a clear buffer zone, in which natural processes can proceed with less expensive and dangerous consequences.

In section 8.6 a coastal zone has been defined in which land is considered to be vulnerable to long term landslip risk. The boundary of this risk zone shown on drawings 4487-3, sheets 1 to 8, defines the limit beyond which we would not expect landslips to extend.

We recommend that in all new areas of subdivision or on those lots not yet built upon, that no dwelling should be allowed within an arbitary set back distance from the defined risk zone. We suggest as a general rule that a 6 metre set back from the risk zone boundary should be allowed.

The purpose of such a set back behind the risk zone boundary is to:

(a) allow for the inevitable uncertainty in defining such a line and

(b) in the event of failure, to allow some reasonable distance between any building and the edge of a landslip.

## 11.2 IMPROVEMENT OF DRAINAGE AND DISPOSAL SYSTEMS

A considerable number of houses south of Bramely Drive lie either on the limit of, or within the zone considered to have landslip risk. Every effort should be made to lessen the risk in these areas. Any measures which control or reduce groundwater pressures will help achieve this objective.

The present use of soakpit disposal systems is highly undesirable. We recommend that for all coastal lots the use of soakpits for stormwater discharge is discontinued. It should be a requirement that all stormwater is discharged to high tide level either by drainage to roadways, and thence by the existing piped system if its capacity is sufficient (this will need to be assessed by the Tauranga County Council), or by piped discharge down the seacliffs.

A number of residents have already provided pipes or wooden flumes extending down the seacliffs; this practice should be encouraged by the development of some standard design details.

A more difficult problem exists in dealing with the disposal of domestic waste water. At present this water is discharged via deep soakpits so that water is concentrated deep down at specific sites and the influence on groundwater is rapid. The most effective improvement would be to provide a reticulated sewerage system for the peninsula and this should be planned for in the long term. In the interim, some improvement could be obtained by conversion to surface irrigation fields or domestic evapo-transpiration systems. In this way water would be less concentrated at depth and the quantity reduced. Coastal residents with particularly high water usage should be encouraged to restrain consumption where possible.

It is difficult to estimate what effect soakpit disposal over the remainder of the peninsula has on the groundwater regime, and therefore the stability, of the coastal areas. Undoubtedly there is a flow of groundwater towards the coast line.

In the long term, conversion from soakpit disposals to a reticulated system over the whole peninsula can only be beneficial to the improvement of stability. Examination by the writers of several other August 1979 failures in different parts of Tauranga made it clear that this general reliance in the Tauranga region on soakpit disposals for both domestic, and in many cases public property, can have very serious effect on land stability in certain areas.

## 11.3 REMEDIAL WORKS

Major remedial works to stabilise the cliff within the coastal risk zone appear to be neither economically feasible nor practicable in view of the potential depth and size of the failures and the length of coastline involved.

It might be possible to achieve some localised improvement in the properties of the sensitive ashes by the use of a chemical grout such as AM-9, but the use of this material over a large area is likely to be prohibitively expensive and considerable experimentation would be required before deciding on the effectiveness of such treatment.

More positive remedial measures which could be considered would be aimed at lowering or controlling groundwater levels. Horizontal drilled-in relief drains could be installed from part way up the seacliffs. These drains would need to be installed at close spacing and would need to penetrate some 20 to 30 metres to be effective.

Here again use of this method, other than in a localised area is likely to be very costly. We recommend that a decision on the use of this method be deferred until more knowledge on groundwater levels is obtained from an extended period of monitoring.

Some superficial success seems to have been achieved by Mr K.D. Grant of 66 Hamurana Road, in stabilising the face of a 1962 slip below his property. Mr Grant has installed a system of 4" diameter perforated P.V.C. pipes several metres into the slip face at the rear of the upper bench. These pipes appear to have been effective in keeping the slip face dry and controlling seepage erosion.

As a trial measure it is recommended that in those areas of recent slipping along the coast where significant water seepage is apparent, short P.V.C. pipes are installed in the cliff face to control further possible erosion at the exits of these seepages. The pipes should be installed as deeply as is possible by hand excavation. It is realised that this is only a very superficial measure, but may help to control localised undermining by concentrated seepages.

In view of the lesser role of marine erosion as a factor in coastal instability we do not consider that any major shore protection works are justified beyond those discussed in the following section.

## 11.4 RESERVE MANAGEMENT

We recommend the establishment of a plan for the management of coastal reserves acting as protection zones for the seacliff. Marine erosion has an effect on the lanslip erosion by undermining the cliff face and removing landslip debris. Retreat of the seacliff by marine erosion alone is significant at a few points.

The following measures are recommended:

(a) Periodic inspection along the length of the coast line and after periods of very heavy rainfall, to record new slips, seepage sources, tension cracks and any other features which could indicate a deterioration of the cliff stability and which may require treatment.

(b) Check the existing system of seawalls and barrages and improve or extend these in areas of obvious distress or excessive erosion.

(c) Establish a planting programme within areas of recent or active slipping. Planting will increase surface soil strength through root development, control surface erosion and remove some water by transpiration. The stabilising effect of tree roots can be seen on the headland below lot 15 Walnut Grove.

Here a narrow strip of trees remain forming a promontory flanked by two deep actively eroding faces. The 1920 M.H.W.M. survey shows a gently rounded, tree covered headland in this area.

d) In areas of established vegetation, prunning should be undertaken to prevent the weakening of the ground where the weights of trees are becoming too great. Indiscriminate removal of established trees in both existing and new subdivision areas should be discouraged.

e) Immediate attention should be given to planting the Bramley Drive slip face and controlling erosion at the seepage exists from the rear of bench by means of short pipes as suggested in section 11.3. If significant seepage continues, and after a period of groundwater monitoring, consideration could be given to the installation of long horizontal relief drains, particularly on the southern flank of the slip where buildings close to the cliff are well within the landslip risk zone.

## 11.5 MONITORING

We recommend the establishment of a plan for coastal monitoring. Such a plan would have two objectives:

a) To obtain information on groundwater levels and movement.

b) To give prior warning of possible failures.

Information on groundwater can be obtained by regular recordings of the borehole standpipe water levels installed during the course of this investigation. In addition to regular long term measurements (carried out say monthly) water levels should be recorded for a few days immediately following heavy rain, to provide information on the reaction of the water table.

Recording of monthly rainfalls on the peninsula should also be carried out possibly from a rain gauge monitored by a local resident (such as Mr. A.D. Grant whose previous recordings have been of considerable value in this investigation.)

From these recordings, coupled with observations of seepage along the coast, it should be possible to identify periods and those areas in which, the likelihood of landslips is increased.

Information will also be obtained to allow a greater refinement of stability calculations (discussed in section 8.5).

Regular coastal inspections as outlined in Section 11.4 may help identify areas of potential failure. It is possible that local residents would be willing to assist with regular observations under the guidance of an officer of the Tauranga County Council. Weekly and even at times daily observations of coastal changes could be made by residents and reported. Ground movements, surface cracking, erosion and variations in, or the appearance of seepage flows could thus be carefully monitored.

## 11.6 FURTHER INVESTIGATIONS

It is felt that sufficient information has been gained from the present investigation to demonstrate the general uniformity of ground conditions over the Omokoroa Peninsula and hence the similarity in the type of failures which have occurred. Further drilling would seem unlikely to change the basis of landslip analysis, although the possibility is not discounted that localised variations in geology may make conditions in limited areas appear more favourable for stability (such as the lack of very sensitive soil layers). We do not consider therefore, that additional deep drilling is necessary at this stage.

Further information does need to be obtained on groundwater and analysed after a period of observation. The areas of coast line at greater risk (e.g. where natural groundwater levels are high) may then become more evident. It may become desirable in the longer term to install further groundwater monitoring pipes, either along the coast or inland, once the effectiveness or otherwise of the existing monitoring system is established. There is an obvious danger in drawing definite conclusions about groundwater conditions or in making recommendations for specific lots on the basis of a few widely spaced monitoring points.

Greater knowledge of groundwater conditions may also allow stability calculations to be refined. Further costly soil testing, which has been beyond the budgetary constraints of this investigation, could also be carried out in an attempt to better define soil strength parameters for use in calculations. However, we feel that while refined stability calculations could be instructive in understanding more precisely the landslip mechanisms, it seems unlikely that theoretical calculations could ever be refined to the extent that would justify significant alteration to the landslip risk zone defined in this report.

Finally we suggest that inspection and if necessary investigation, of new subdivisions which are not covered by this report, or of individual lots, within the investigation area should be carried out by an experienced engineering geologist or soils engineer where potential stability problems have been identified.

## 12.0 ACKNOWLEDGEMENTS

In compiling this report the authors gratefully acknowledge the assistance of the staff of the Tauranga County Council, in particular Mr. I.G. McKenzie, County Engineer, for his helpful liaison and prompt attention to our requests. We also acknowledge the valuable services of the New Zealand Geological Survey,D.S.I.R., for field assistance, comments and mineralogical analyses. We especially thank Dr. I.J. Smalley, Soil Bureau, D.S.I.R., and his colleagues, for useful contributions and for carrying out sample analyses and mineralogical interpretation. We also thank Mr. A.W. Grant of Omokoroa for supplying rainfall data.

Finally we extend our thanks to the residents of Omokoroa for their co-operative attitude through all phases of the investigation and to those residents who willingly provided assistance and information.

D.K. TAYLOR
(Partner)

This report has been jointly prepared by:-

C.P. GULLIVER, Engineering Geologist, Tonkin & Taylor

and B.F. HOUGHTON, N.Z.Geological Survey, D.S.I.R., Rotorua.

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# APPENDIX 1

# RAINFALL EVALUATION

# APPENDIX 1

## OMOKOROA POINT STABILITY INVESTIGATION
## RAINFALL EVALUATION

An attempt has been made to assess the significance of rainfall prior to the major landslides which occurred on the Omokoroa Peninsula over the period 1 - 11th August, 1979.

### Source of Data

The Ministry of Works and Development (M.W.D.) have an automatic rainfall recording station "Mangawai' which has been in operation since August, 1971. Daily rainfall was obtained for the period 8/71 to 9/1979, and more recently a tabulation of hourly rainfall (5/79 to 7/79) was received.

The N.Z. Meteorological Service has rainfall stations at Tauranga and Tauranga Airport. Owing to the length of the Airport record (from 1910) and the fact that it is the only rainfall station in the area for which 'depth-duration-frequency' data is available the following data from this station was obtained from the N.Z. Meteorological Service:

- daily rainfall data, 1910 to 10/1979
- daily rainfall charts covering days of 'significant' rain for the period 8th May to 1st August, 1979. Also copies of significant charts for March 1979 since rainfall was exceptional during this month.
- 'depth-duration-frequency' data based on records over the period 1943-78.

Rainfall data from a private rainfall station (Mr. K.D. Grant of 66 Hamurana Road, Omokoroa) is presented in Table A3. This data includes monthly rainfall from 1/1976 to 7/1979 and daily rainfall from 1st July to 19th August, 1979. Although this would be the most relevent rainfall station in terms of proximity, the record is only short and does not permit comparison with historic events. However, as cumulative monthly rainfall data for both this station and the Tauranga Airport show a similar trend from January 1976 to July, 1979, evaluation of the more comprehensive N.Z. Meteorological Service rainfall information available for Tauranga Airport would seem to be appropriate.

The location of the rainfall stations mentioned above are shown on the accompanying map.

## Evaluation of Tauranga Airport Rainfall Record

Although rainfall for July 1979 was nearly twice the rainfall 'normal' for this month a departure from the normal of this magnitude is not at all uncommon. The return period of maximum rainfalls recorded during July for durations of 10,20, 30, 60 minutes and 2, 6, 12, 24, 48 and 72 hours is less than 2 years for all these durations. During the first half of August, at which time landslips occurred, the rainfall is even less significant than that occurring in July. The most important thing to note about rainfall in the early months of 1979 was the exceptional rainfall recorded in March. This was the second highest monthly rainfall recorded since 1898 and the highest 48 hours and 72 hour rainfalls recorded in this month. The rainfall recorded at the M.W.D. rainfall station between March - August 1979 is of a similar magnitude and frequency to that recorded at the Airport station.

The cumulative monthly rainfall from 1960-79 was plotted to help identify periods of excessive rainfall. This was used together with tabulations of monthly rainfall for the earlier part of the record (1910 - 59) to identify the maximum 6 monthly rainfalls. (Table A1). The period 2/79 to 7/79 inclusive was the second wettest 6 monthly period recorded over the past 70 years with a total of 1,160 mm. The wettest 6 monthly period occurred during 8/1916 to 1/1917 inclusive, with a total of 1,250 mm.

Two other periods of major landsliding occurred in November - December, 1962 and December, 1968. The maximum 6 monthly rainfall for both 1962 and 1968 are 1,070 mm (12/61 to 5/62; also 1,000 mm from 7/62 to 12/62) and 1,040 mm (4/68 to 9/68 respectively. These 6 monthly totals would be about the 6th and 10th most severe since 1910. The wettest year on record is 1962 with 2,050 mm. Monthly rainfalls exceeding 300 mm have been extracted (Table A2). As already mentioned, March 1979 (504 mm) was the second wettest month since 1898 (532 mm) but the wettest since 1910, and December 1962 was the third most severe (447 mm) since 1898. In 1968 April was the wettest month with 243 mm.

The above facts would tend to indicate that the occurrence of slips are influenced by exceptional rainfall over a long period (say 6 - 12 months) and are merely triggered by some shorter duration event; possibly a rainstorm, which in itself may not be of exceptional magnitude or intensity.

## TABLE A1

## MAXIMUM 6 MONTHLY RAINFALLS FOR TAURANGA AIRPORT (1910 - 1979 INCLUSIVE, 70 YEARS)

| Period | | Rainfall - mm | Ranking |
|---|---|---|---|
| 1/ 8/16 to 31/ 1/17 | = | 1250 | 1 |
| 1/ 4/17 to 30/ 9/17 | = | 1120 | 4 |
| 1/ 1/20 to 30/ 6/20 | = | 1124 | 3 |
| 1/ 4/23 to 30/ 9/23 | = | 1013 | |
| 1/ 3/27 to 31/8/27 | = | 1069 | 7 |
| 1/ 3/35 to 31/ 8/35 | = | 1065 | 8 |
| 1/ 2/38 to 31/ 7/38 | = | 1092 | 5 |
| 1/ 5/56 to 31/10/56 | = | 1061 | 9 |
| 1/ 2/60 to 31/ 7/60 | = | 900 | |
| 1/ 4/61 to 30/ 9/61 | = | 950 | |
| 1/ 12/61 to 31/ 5/62 | = | 1070 | 6 |
| 1/ 7/62 to 31/12/62 | = | 1000 | |
| 1/ 4/63 to 30/ 9/63 | = | 850 | |
| 1/ 5/64 to 31/10/64 | = | 770 | |
| 1/ 1/65 to 31/ 5/65 | = | 810 | |
| 1/ 7/67 to 31/12/67 | = | 890 | |
| 1/ 4/68 to 30/ 9/68 | = | 1040 | 10 |
| 1/ 3/70 to 31/ 8/70 | = | 870 | |
| 1/ 4/71 to 30/ 9/71 | = | 1030 | |
| 1/ 7/71 to 31/12/71 | = | 890 | |
| 1/ 2/74 to 31/ 7/74 | = | 990 | |
| 1/ 5/74 to 31/10/74 | = | 910 | |
| 1/ 2/79 to 31/ 7/79 | = | 1160 | 2 |

NOTE: (i) There are some 6 monthly totals which may be greater than some of those listed above but these would overlap with the period for which a value is already noted. Certainly the worst independent 6 monthly periods are identified above.

(ii) The ten most severe 6 monthly totals between 1910-79 have been 'ranked'.

(iii) The derivation of the 6 monthly maximums is only approximate and could be verified by a more accurate manual analysis or computer processing.

## TABLE A2

## MAXIMUM MONTHLY RAINFALL FOR TAURANGA AIRPORT
## (1910 to 1979)

Summary of monthly rainfalls $\geq$ 300 mm (1910 - 1979)

| Month/Year | Rainfall - mm | Ranking |
|---|---|---|
| 4/1911 | 383 | 4 |
| 10/1916 | 357 | |
| 6/1920 | 309 | |
| 4/1923 | 318 | |
| 6/1925 | 381 | 5 |
| 2/1936 | 343 | |
| 4/1948 | 331 | |
| 5/1950 | 312 | |
| 7/1951 | 348 | |
| 12/1962 | 447 | 3 |
| 3/1972 | 319 | |
| 3/1979 | 504 | 2 |
| (Maximum Monthly 1898 - 1910 ) | 532 | 1 |

Note: (i) The maximum monthly rainfall (1910 - 1979) was 504 mm recorded in March, 1979.

(ii) Between 1898 - 1910 a maximum monthly value of 532 mm was recorded in January. This was not recorded at Tauranga Airport but assumed to somewhere in the area.

(iii) The five wettest months have been 'ranked'.

## TABLE A3

## RAINFALL RECORDS FOR 66 HAMURANA ROAD, OMOKOROA
## (DATA FROM MR. A.W. GRANT)

All recordings in millimetres.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 108 | 49 | 82 | 154 | 78 | 94 | 114 | 228 | 97 | 69 | 83 | 114 | 1270 |
| 1977 | 41 | 21 | 108 | 76 | 153 | 232 | 190 | 95 | 100 | 111 | 49 | 66 | 1277 |
| 1978 | 18 | 82 | 49 | 178 | 33 | 176 | 210 | 98 | 118 | 114 | 101 | 77 | 1187 |
| 1979 | 6 | 221 | 355 | 42 | 127 | 127 | 283 | 1161 | (to July 31) | | | | |

### Daily Records 1 July - 19 August, 1979

| Date | July 1979 | August 1979 | Date | July 1979 |
|---|---|---|---|---|
| 1 | 63 | 13 | 25 | 37 |
| 2 | - | 1 | 26 | - |
| 3 | 1 | - | 27 | - |
| 4 | - | 2 | 28 | 22 |
| 5 | 7 | - | 29 | 3 |
| 6 | - | - | 30 | - |
| 7 | - | 1 | 31 | 78 |
| 8 | - | 4 | | 283 |
| 9 | - | 1 | | |
| 10 | - | 1 | | |
| 11 | 30 | 2 | | |
| 12 | 11 | 3 | | |
| 13 | 1 | 1 | | |
| 14 | 6 | 29 | | |
| 15 | 1 | 1 | | |
| 16 | - | - | | |
| 17 | - | - | | |
| 18 | - | - | | |
| 19 | - | 5 | | |
| 20 | 1 | | | |
| 21 | - | 63 | | |
| 22 | 5 | | | |
| 23 | 3 | | | |
| 24 | 14 | | | |

SITE: MARGARET PLACE, OMOKOROA

# BOREHOLE No. 1

JOB No: 4487 DATE DRILLED: 4/12/79 RL GROUND: 23.48

SHEET 1 OF 4

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|
| ROTOEHU ASH | SILT, sandy, slightly clayey, firm, dark yellow-brown | | | | | |
| | CLAY, silty, firm to stiff, light yellow-brown | | 1 | | | |
| | SAND(m), silty, sl. cemented, lt. grey-yellow, pumiceous | | 2 | | | |
| PALEOSOL | CLAY, peaty, silty, firm, dark brown with lt. brown mottle, friable.<br>becomes yellow brown | | | | | |
| OLDER ASH LAYERS | SILT, clayey, firm to stiff, friable, sensitive, yellow-brown with white specks (medium ash)<br>slightly sandy<br>2cm black sand | | 3<br>4 | | | |
| | CLAY, silty, firm, sl. sensitive, lt. brown (fine ash) | | 5 | | | |
| | SILT, clayey, sl. sandy, friable, lt. brown to yellow/brown: (coarse ash) | | | | | |
| | SAND, silty, clayey, sl. cemented, red/brown - yellow/brown mottle | | | | | |
| | CLAY, sl. silty, stiff, yellow brown with lt. grey and red mottle (fine ash) | | 6 | | | |

DRILL METHOD: Rotary rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

NZ Met Service Rainfall Stn.
Tauranga Airport, B76621

Rainfall Data to hand (at 8/1/80)
- Computer listing daily rainfall 190 - 22/10/79
- Daily charts from Auto.Gauge covering dwgs. of significant rain 8May to 1/8/79 also March1979
- Depth-Duration-Frequency (based on 1943 to 1978)

Rainfall by K.D. Grant of 66 Hamurane Rd.

Data to hand (8/1/80)
- Monthly totals 1/76 to 8/79
- Daily Rainfall 1/7 to 19/8/79

M.W.D. Rainfall Stn. – Mangawhai

Data to hand (at 8/1/80)
- Daily Rainfall (24-2400 hrs) from computer listing 4/3/74 to 9/1/79. From Auto.Gauge.
- Daily Rainfall (24-2400hrs) from manual processing and tabulation of Auto. Records 8/71 to 12/74

# OMOKOROA STABILITY INVESTIGATION

## Location of Rainfall Stations

Scale 1:63 360

## DESCRIPTIVE TERMS

In addition to the "appendix of terms" for soil descriptions, the following terms have been used for field description in these borelogs.

(a) For silts and sands with low cohesion, strength has been indicated by use of:

'compact' - dense soil but disintegrates readily.

'slightly cemented' - soil breaks into lumps which can be crushed with light finger pressure.

'moderately cemented' - broken or crumbled with strong finger pressure, abrades with thumb.

In Addition:

'friable' is used to denote a soil which is particularly crumbly.

(b) 'sensitivity' (St.) denoted by:-

'sensitive' $St = 4 - 8$

'very sensitive' $St > 8$

$$\text{where St.} = \frac{\text{unremolded vane strength}}{\text{remolded vane strength}}$$

SITE: MARGARET PLACE, OMOKOROA

**BOREHOLE No.** 1

JOB No: 4487 DATE DRILLED: 4/12/79 RL GROUND: 23.48

SHEET 2 OF 4

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|---|
| Older ash | becomes yellow/ brown | | 7<br>8 | | | | |
| Tauranga Formation | SILT, clayey, firm, friable, sensitive, lt. grey and red mottle, mica flakes, dark brown. Mn patches, (coarse ash)<br>(core crumbles easily) | | 9<br>10 | | | | |
| | Core lost | | 11 | | | | |
| | SILT, sl. clayey, sl. sandy ($qt_3$), friable, sensitive, white with lt. red mottle and black Mn flecks (coarse ash) | | 12<br>13 | | 5/12/79 ▼ | | |

DRILL METHOD: Rotary rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: MARGARET PLACE, OMOKOROA

**BOREHOLE No.** 1

JOB No: 4487 DATE DRILLED: 4/12/79 RL GROUND: 23.48

SHEET 3 OF 4

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH KPa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|
| Poor recovery (core water softened from drilling) | | 14 | | | | |
| | | 15 | | | | |
| SILT, clayey, sandy ($qt_3$), firm, friable, sl. sensitive, yellow white with black Mn flecks. (weathered coarse pumice ash) | | 16 | | | | |
| 1cm bands pink-white sensitive clay | | 17 | | | | |
| Pale grey with yellow weathered micas and black flecks | | 18 | | | | |
| | | 19 | | | | |
| | | 20 | | | | |

TAURANGA FORMATION

DRILL METHOD: Rotary rig

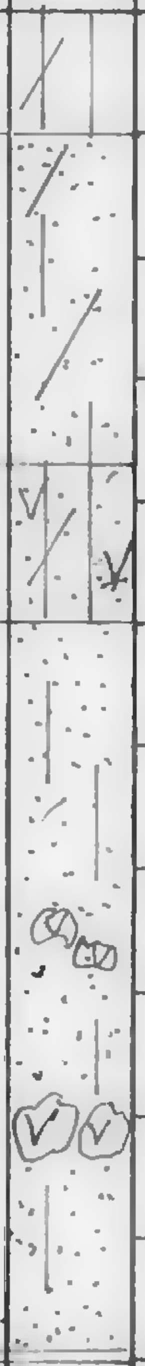
**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: MARGARET PLACE, OMOKOROA

# BOREHOLE No. 1

JOB No: 4487 DATE DRILLED: 4/12/79 RL GROUND: 23.48

SHEET 4 OF 4



| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) $W_P$ W $W_L$ |
|---|---|---|---|---|---|---|---|
| TAURANGA FORMATION | | | | | | | |
| | SAND, silty, clayey, compact, lt. grey brown with black flecks.<br>yellow brown | | 21 | | | | |
| | SILT, sandy, clayey, firm, lt. grey, lenticular pumice fragments | | | | | | |
| | SAND, pumice gravel (to 5cm), silty, compact, lt. grey with some brown stains.<br>becomes grey brown with some yellow-green stains | | 22 | | | | |
| | END OF BOREHOLE 23.0m | | 23 | | | | |

DRILL METHOD: Rotary rig

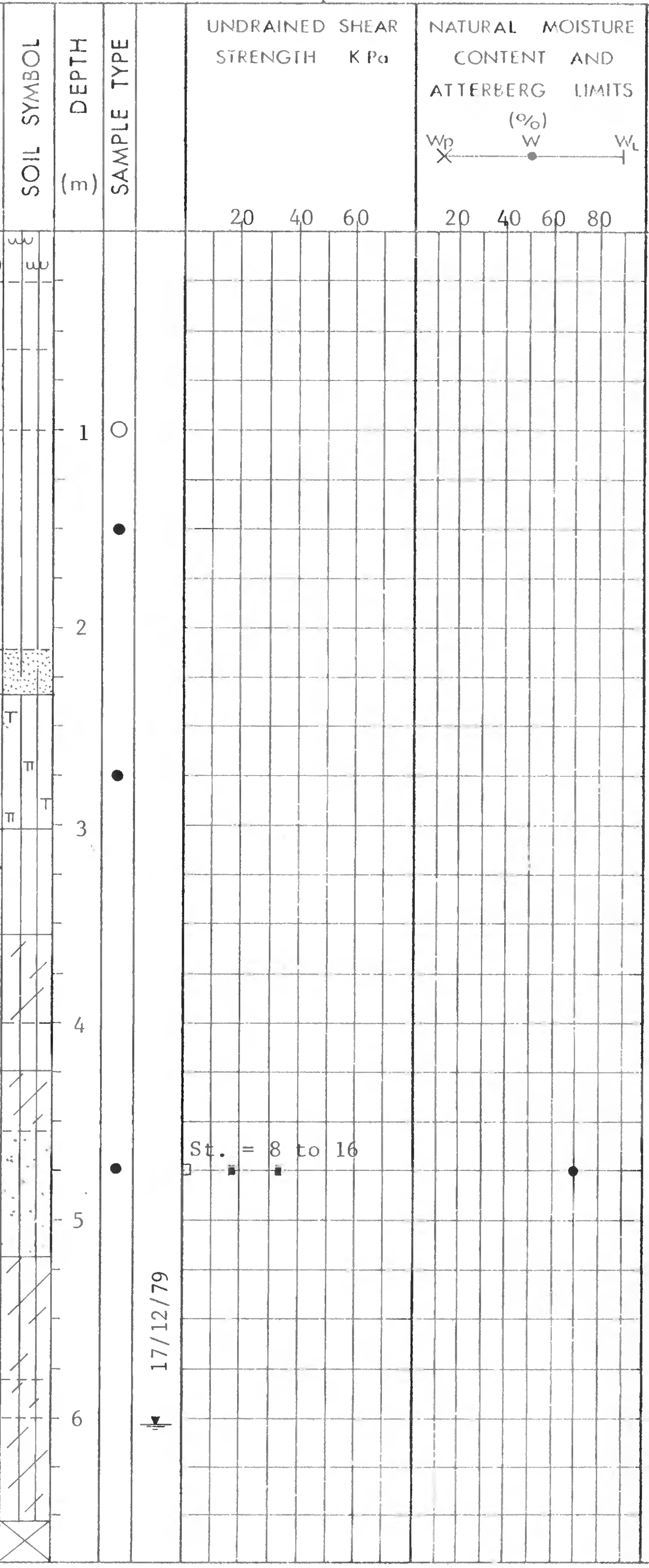
SITE: GERALD PLACE, OMOKOROA

# BOREHOLE No. 2

JOB No: 4487 DATE DRILLED: 5/12/79 RL GROUND: 13.78

SHEET 1 OF 2

| | DESCRIPTION OF SOIL |
|---|---|
| ROTOEHU ASH | SILT, organic, firm, dk.bn(topsoil) |
| | SILT, firm, dk.yellow/brown, lt.yellow grains<br>lt.brown/grey, brown patches |
| | SILT, compact, yellow/brown, brown speckling, qtz grains<br>lt.brown<br>lighter |
| | SAND, silty, compact, yellow/brown, limonite bands |
| PALEOSOL | SILT, firm, sl.cemented, friable, dk.brown, black mottles. |
| OLDER ASH LAYERS | SILT, stiff, friable, brown mottled, black speckle |
| | SILT, clayey, stiff, yellow/brown, brown patches, qtz fragments (medium ash)<br>lt.brown<br>brown speckle |
| | SILT, clayey, medium - firm, v. sensitive, reddish/yellow/brown, black speckle, lt.yellow speckle (coarse ash)<br>to sandy, lt.brown |
| | SILT, clayey, firm, v.sensitive, pale brown, brown and yellow speckle, (coarse ash)<br>sl.clayey to lt.yellow/brown, v.lt.grey specks, brown grit, black specks (coarse ash) |
| | Core lost |



DRILL METHOD: Rotary Rig.

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

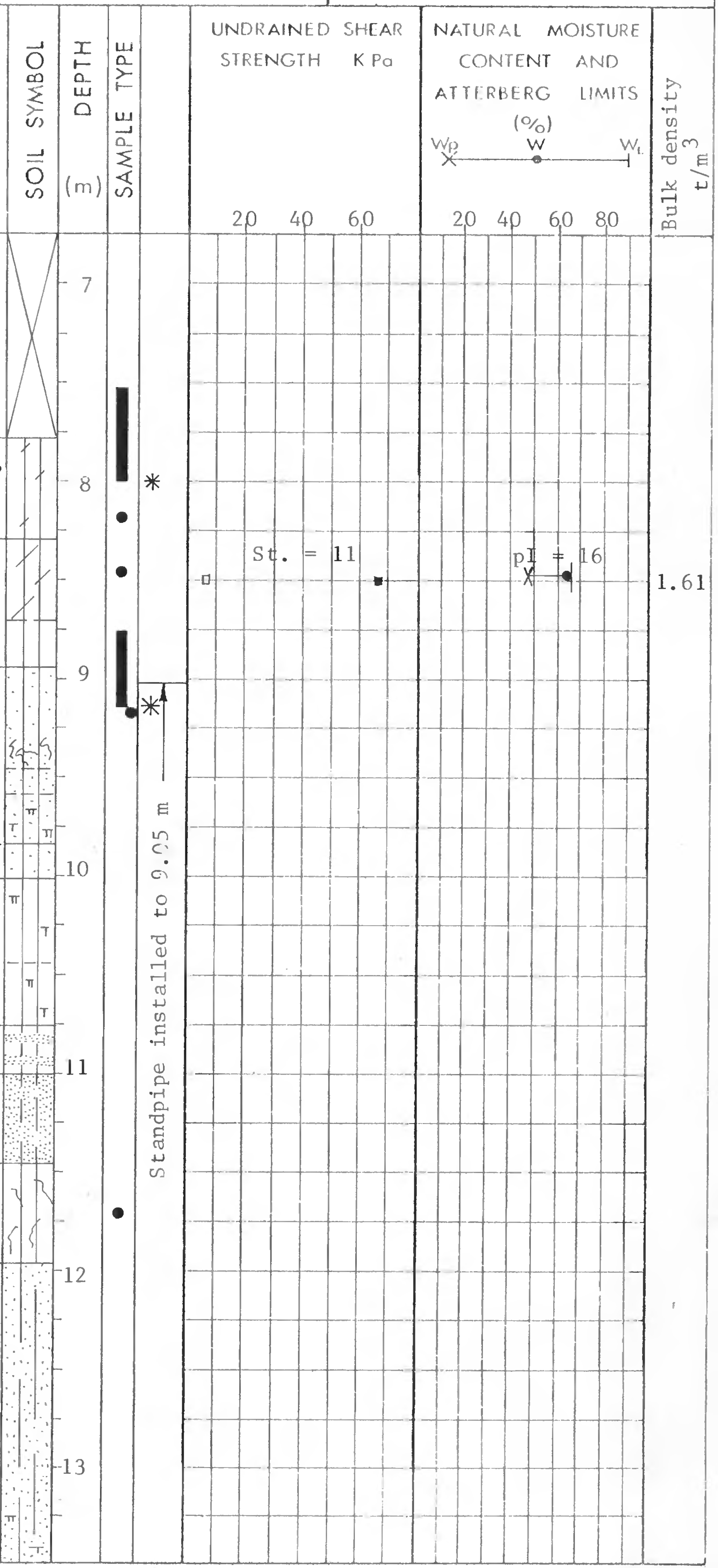
SITE: GERALD PLACE, OMOKOROA

# BOREHOLE No. 2

JOB No: 4487 DATE DRILLED: 5/12/79 RL GROUND: 13.78

SHEET 2 OF 2

| | DESCRIPTION OF SOIL |
|---|---|
| OLDER ASH LAYERS | Core lost |
| | SILT, sl.clayey, firm, v.sensitive, lt.yellow/brown, lt.grey and lt. yellow speckle (coarse ash) |
| | SILT, clayey, firm, v.sensitive, v.lt.brown, grey, speckle (coarse ash)<br>to v.lt.grey, brown speckle |
| | SILT, sandy, compact, lt.brown/grey, brown stain, contains rootlets (coarse ash)<br>Sl.cemented, sl.sandy, brown stains.<br>25 mm cemented black Limonite band →<br>to compact, yellow/brown |
| | SILT, sl.cemented, reddish yellow/brown, lt.grey mottle, brown patches, mica specks, (coarse ash)<br>to lt.grey |
| MARINE SANDS | SILT, stiff, grey brown, sand layers, loose, grey |
| | SAND, (medium), sl.silty, compact, grey mottled, lt.brown/green |
| TAURANGA FORMATION | SILT, stiff, v.sensitive, lt.grey/green, speckled black and white, fine rootlets, (fine ash) |
| | SAND, (fine), silty, compact lt. grey/green, speckled black, qtz grains, green tint (Pumice tuff-breccia).<br>sl.cemented<br>End of borehole 14.0 m |



* Tube in auxillary wash borehole

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: RUAMOANA PLACE, OMOKOROA

# BOREHOLE No. 3

JOB No: 4487 DATE DRILLED: 5/12-6/12/79 RL GROUND: 11.56

SHEET 1 OF 2

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH KPa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|---|
| ROTOEHU ASH | SILT, organic, sl.sandy, firm, dk brown, brown mottles (topsoil) | | | | | | |
| | SILT, sl.sandy, slightly compact, brown, lt.brown mottle<br>lt.brown<br>sl.clayey, grey/brown, occassional black mottles, glassy shards, (fine ash) | | 1<br>2 | | | | |
| | SAND,(med),silty,compact,bn/yellow black grains,qtz grains (med.ash) | | | | | | |
| | Core lost | | 3 | | | | |
| | SILT, sandy, compact lt.brown, black specks (pumiceous)<br>sand, silty | | | | | | |
| OLDER ASH LAYERS | SILT, firm to stiff, grey/brown, friable (medium ash)<br>yellow/brown, dk.brown and yellow specks (fine ash)<br>sl.lighter, lt.yellow specks (medium ash) | | 4 | | 17/12/79 ▼ | | |
| | SILT, firm to stiff, v.sensitive, lt.yellow brown, brown Mn $O_2$ patches, red stains, (fine ash)<br>to yellow brown | | 5 | ○ | | | |
| | Core lost | | 6 | | | | |
| | SILT, sl.clayey, med-firm, v. sensitive, lt.yellow/brown, dk. brown Mn $O_2$ staining,(coarse ash) | | | ○ | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: RUAMOANA PLACE, OMOKOROA

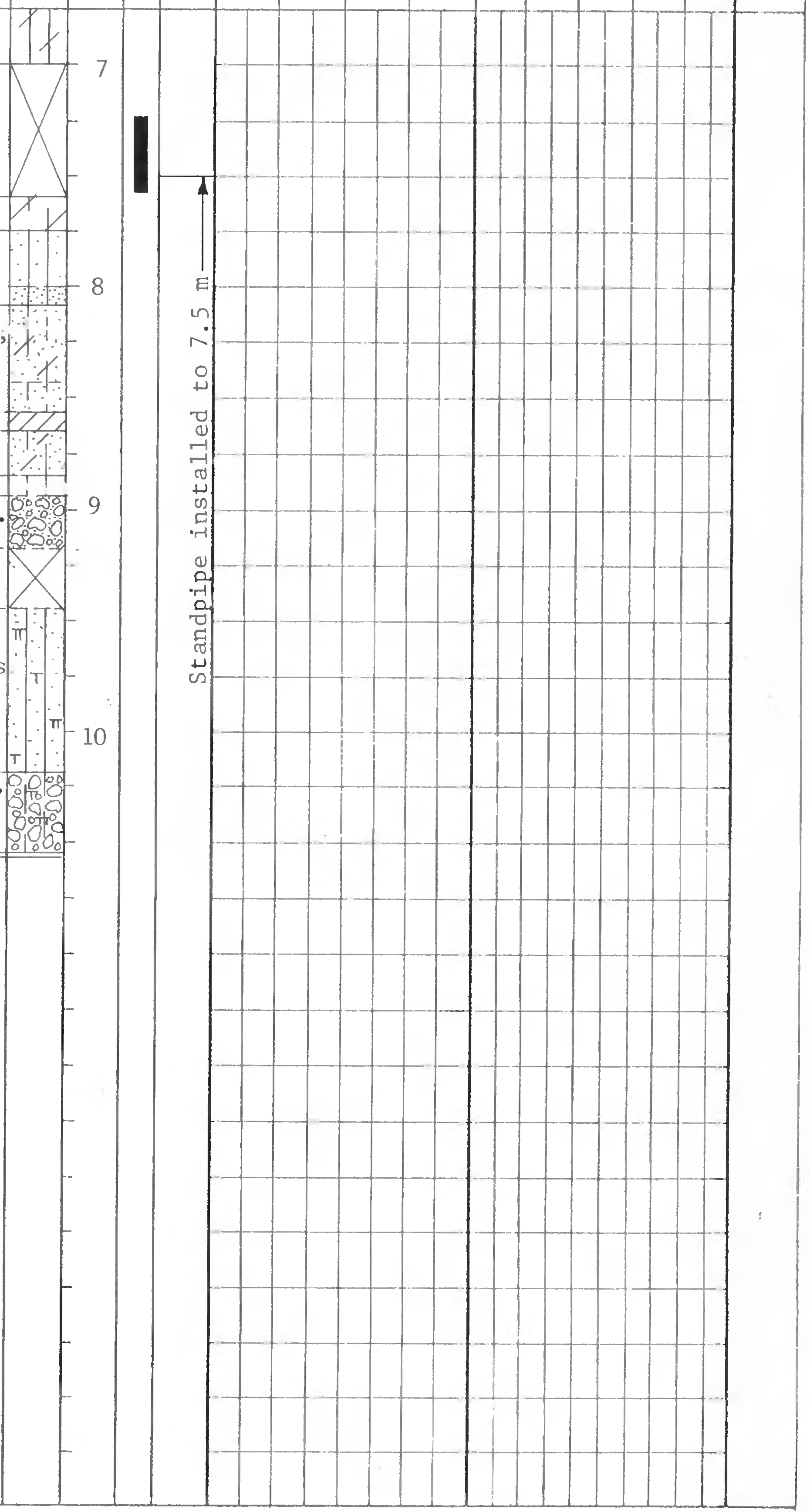
# BOREHOLE No. 3

JOB No: 4487 DATE DRILLED: 5/12-1/12/79 RL GROUND: 11.56

SHEET 2 OF 2

| DESCRIPTION OF SOIL | |
|---|---|
| OLDER ASH LAYERS | Wash & sample |
| | CLAY, silty, soft to med, v. sensitive, brown/white |
| | SILT, sandy, med-firm, sensitive, lt. brown/grey<br>pocket sand, dk.brown |
| TAURANGA FORMATION | SAND, silty, sl.clayey, sl.compact, lt. grey/brown<br>banded dk.brown Mn $O_2$<br>CLAY, firm, v.sensitive, white |
| | SILT, firm, v.sensitive, lt.grey |
| | GRAVEL (fine), sandy, compact, lt. grey, (weathered pumice breccia) |
| | Core lost |
| | SILT, sandy (fine), sl. to moderately cemented, lt.grey, dk.brown stains (pumiceous tuff-breccia) |
| | GRAVEL, (fine), silty, sl.cemented, lt.yellow/brown, rounded pumice clasts, dk.grey chips |
| | End of Borehole 10.6 m |

SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%)



DRILL METHOD: Rotary Rig

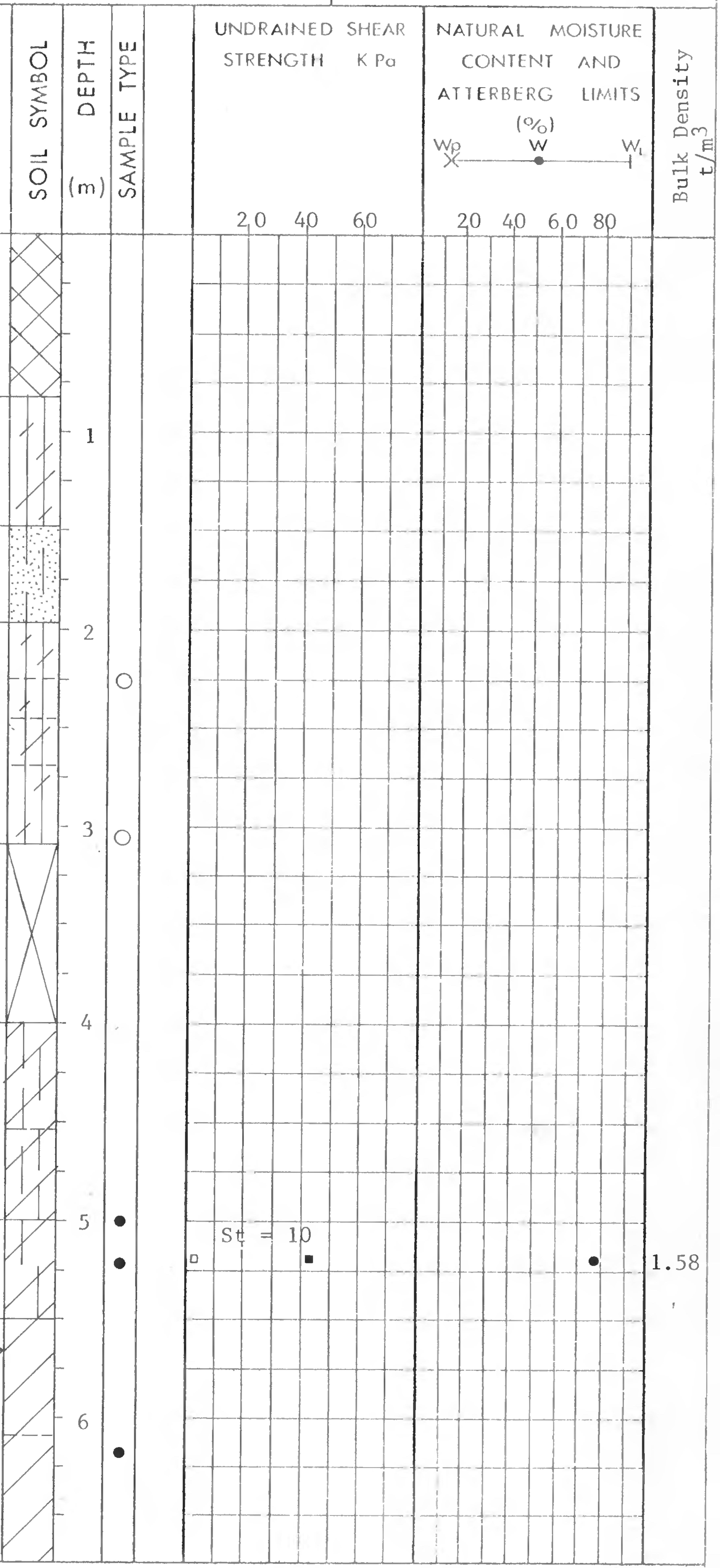
SITE: BRAMLEY DRIVE, OMOKOROA

# BOREHOLE No. 4

JOB No: 4487 DATE DRILLED: 6/12-11/12/79 RL GROUND: 33.43

SHEET 1 OF 6

| | DESCRIPTION OF SOIL |
|---|---|
| ROTOEHU ASH | FILL, silt, gravelly, firm, brown white specks |
| | SILT, clayey, firm to stiff, mottled brown/dk.brown |
| | SAND, silty, compact, lt.brown black speckles (med-coarse ash) brown/grey |
| PALEOSOL | SILT, clayey, firm, dk.brown<br>brown, qtz. grains<br>to dk.yellow/brown<br>to yellow/brown<br>(fine ash) |
| OLDER ASH LAYERS | Core lost |
| | CLAY, silty, firm, lt.brown (fine ash)<br>to v.lt.brown |
| | CLAY, silty, firm, v.sensitive, lt.yellow/brown, dk.grey stains (coarse ash) |
| | CLAY, stiff, sensitive, v.lt.brown, brown and white specks (fine ash)<br>to v.lt.brown |



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

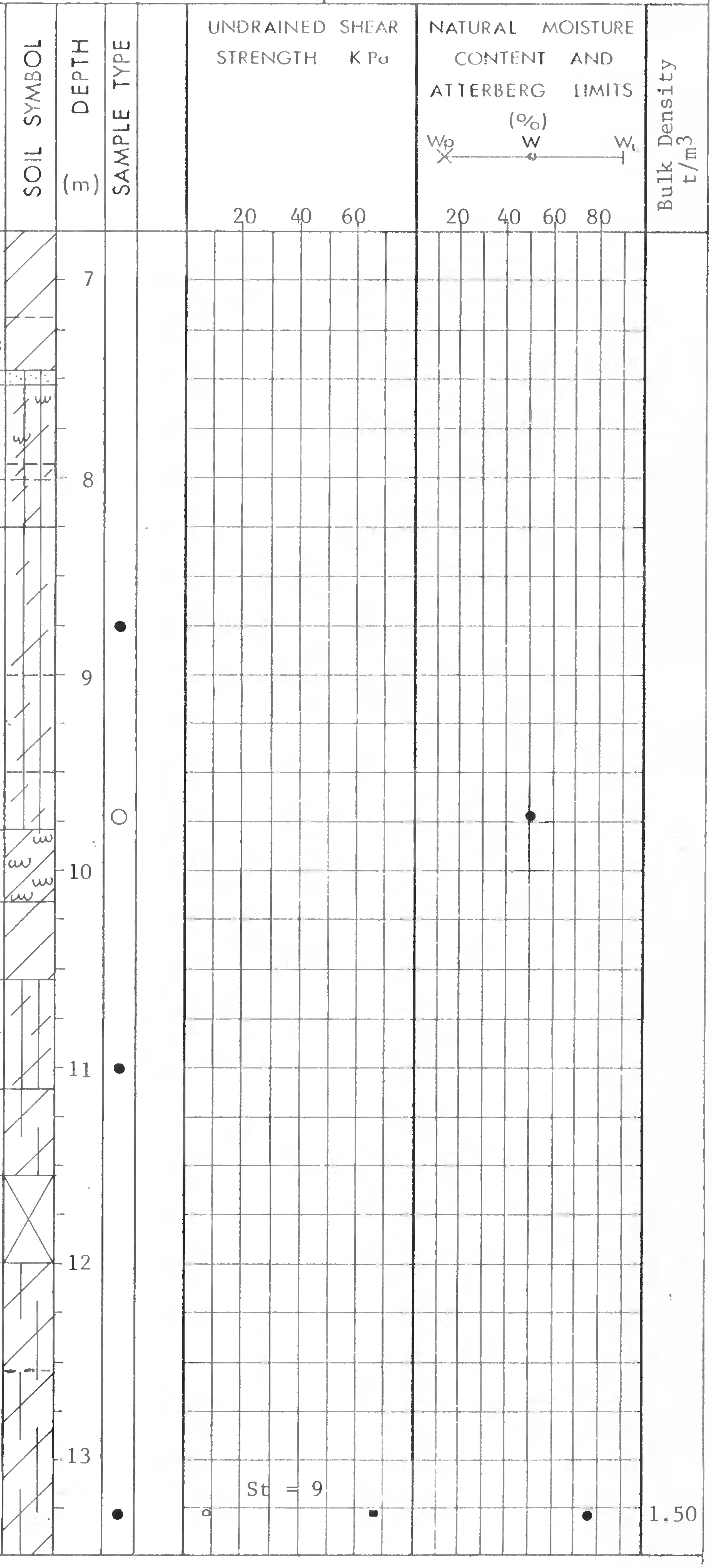
SITE: BRAMLEY DRIVE, ONOKOROA

# BOREHOLE No. 4

JOB No: 4487 DATE DRILLED: 6/12-11/12/79 RL GROUND: 33.43

SHEET 2 OF 6

| | DESCRIPTION OF SOIL |
|---|---|
| | Ditto above.<br>to brown, Mn $O_2$ stains |
| | SILT, sandy, friable, (coarse ash) |
| PALEOSOL | SILT, clayey, firm, sensitive, dk. brown, organic<br>to brown |
| | SILT, clayey, stiff, yellow/brown |
| OLDER ASH | SILT, clayey, firm, v.sensitive, yellow/brown, dk.brown Mn $O_2$ mottles, qtz. grains (medium ash)<br>yellow/brown, lt.yellow speckle<br>black Mn $O_2$ patches, qtz shards |
| PALEO SOL | CLAY, organic, firm, dk.brown, mottled lt.brown, reddish brown |
| OLDER ASH LAYERS | CLAY, silty, stiff, red brown, brown mottle, (medium ash) |
| | SILT, clayey, firm, yellow/brown, qtz.grains (medium ash) some brown mottle |
| | CLAY, silty, firm, sensitive, brown<br>Core lost<br>yellow brown<br>(fine to medium ash layers)<br>to lt.brown with black specks |



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: BRAMLEY DRIVE, OMOKOROA

# BOREHOLE No. 4

JOB No: 4487 DATE DRILLED: 6/12-11/12/79 RL GROUND: 33.43 SHEET 3 OF 6

DESCRIPTION OF SOIL

OLDER ASH LAYERS

SILT, clayey, firm, sensitive, yellow/brown, occ.black patches (Mn $0_2$), red/brown speckles, (med. ash)

SILT, clayey, sl.sandy, firm to stiff, mod.sensitive, yellow/brown, 2mm Ø black Mn $0_2$ patches, (coarse ash)

lt.yellow/lt.brown

SILT, clayey, firm, v.sensitive, lt.brown, black Mn $0_2$ patches, black/dk.brown mottles

lt.yellow/brown

(fine ash) lt.grey speckles

to yellow/brown minor Mn $0_2$ specks

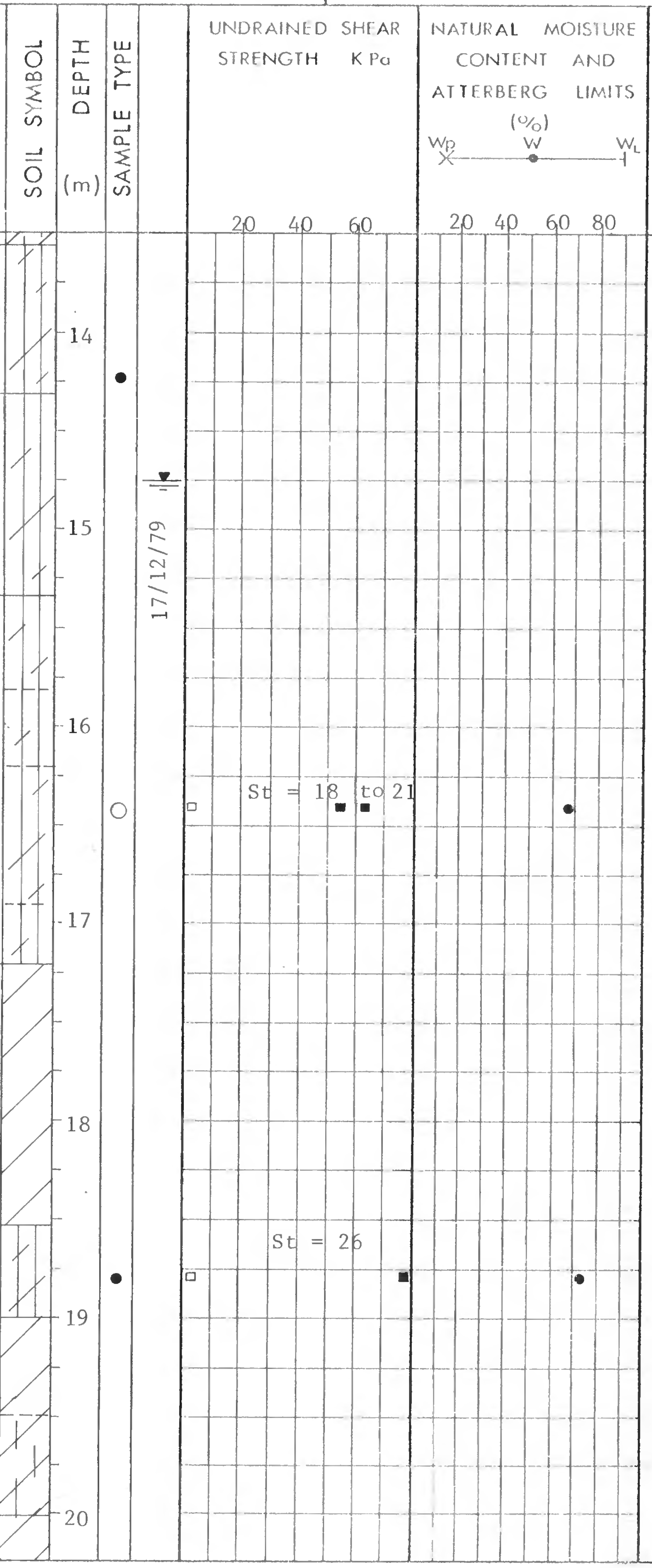
CLAY, firm, v.sensitive, yellow/brown, Mn $0_2$ patches, lt.grey speckling (fine ash)

SILT, clayey, firm, v.sensitive, yellow/brown with black Mn $0_2$ specks (coarse ash)

CLAY, firm, v.sensitive, lt.grey/v.lt.brown, speckled lt.brown, lt.grey, black Mn $0_2$ patches, (coarse ash)

to silty, black & brown patches, (fine - medium ash)

CLAY, stiff, v.senstive, brown, white speckles, black Mn $0_2$ specks (fine ash)



DRILL METHOD: Rotary Rig

TONKIN & TAYLOR CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: BRAMLEY DRIVE, OMOKOROA

# BOREHOLE No. 4

JOB No: 4487 DATE DRILLED: 6/12-11/12/79 RL GROUND: 33.43

SHEET 4 OF 6

DESCRIPTION OF SOIL

**OLDER ASH LAYERS**

SILT, clayey, firm, v. sensitive, lt.yellow/brown, black patches, grey speckles (medium ash)

CLAY, v.silty, firm to stiff, v. sensitive, lt.yellow/brown, black $MnO_2$ patches, v.lt.grey speckles (coarse ash)

CLAY, silty, stiff, v.sensitive, lt.brown, black $MnO_2$ specks, white specks (medium ash)

Wash

SILT, sl.clayey, sl.sandy, firm, sensitive, yellow/brown, black patches, (coarse ash)

**TAURANGA FORMATION**

SILT, clayey, firm, sensitive, pinkish/white, black patches (med ash)

SILT, sl.clayey, sl.sandy, firm, sensitive, lt.pinkish grey, mica specks, black patches, yellow/brown patches, lt.grey lenses

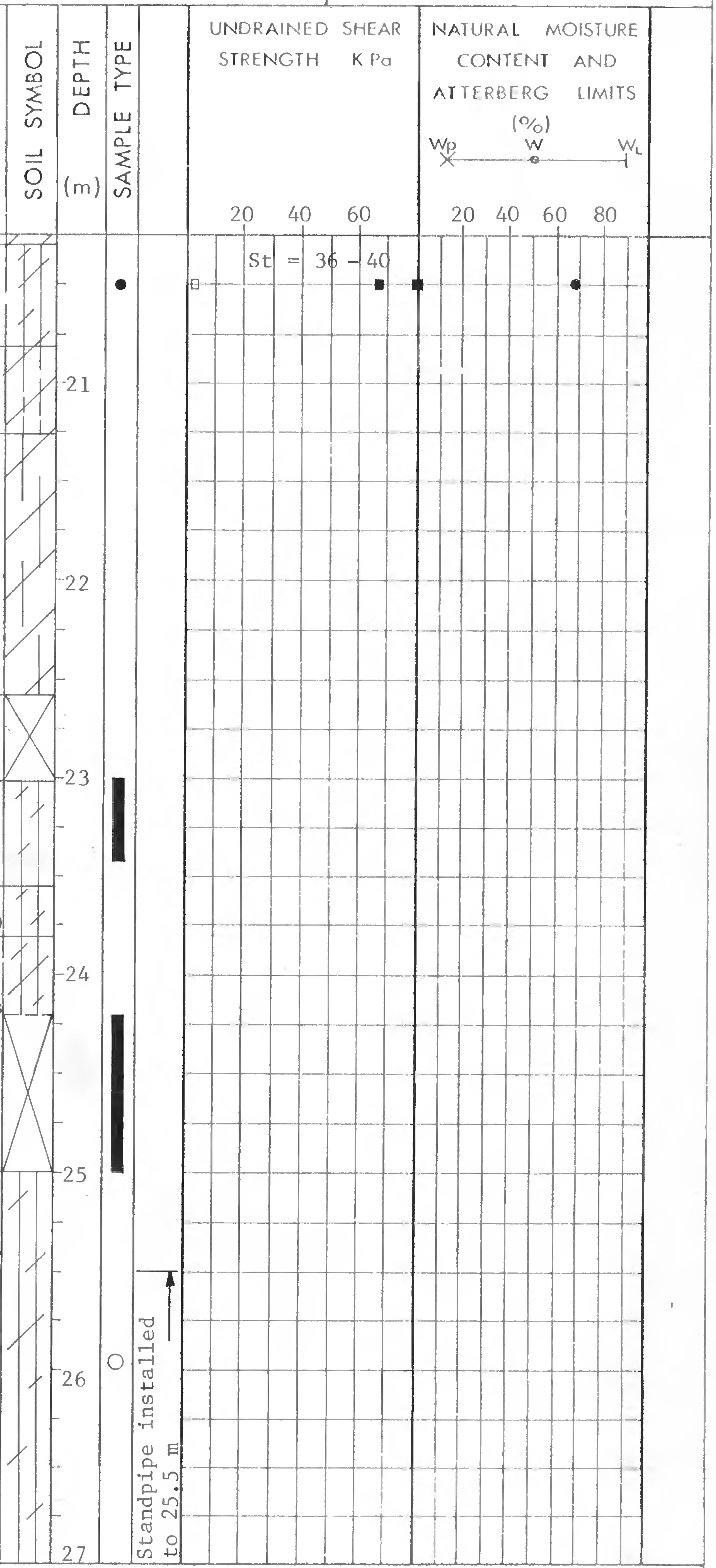
(pumice tuff-breccia)

wash & sampled

SILT, clayey, sl.sandy, firm, sensitive, lt.yellow/brown, black patches, grey grains and lt.grey lenses, mica specks.

(pumice tuff-breccia)

lt.grey relict texture 2 cm Ø pumice frags.



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: BRAMLEY DRIVE, OMOKOROA

**BOREHOLE No.** 4

JOB No: 4487 DATE DRILLED: 6/12- 11/12/79 RL GROUND: 33.43

SHEET 5 OF 6

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|---|
| TAURANGA FORMATION | Ditto above.<br>yellow/brown staining | | 27 | | | | |
| | SILT, sl.sandy, firm, lt.grey, white pumice clasts, mica specks, black Mn $0_2$ patches, yellow/brown mottle<br>(pumice tuff-breccia) | | 28<br>29<br>30<br>31<br>32 | ● | | | |
| | SILT, sandy, compact, dk.yellow/brown, black patches, lt.yellow to black mottles (tuff-breccia)<br>to clayey, lt.yellow and lt.grey mottles (med.ash) | | | | | | |
| | SILT, sandy, compact, lt.yellow/brown, lt.grey patches, black specks (tuff-breccia) | | 33 | ● | | | |
| | CLAY, firm, sensitive, creamy white, yellow/brown speckles, black patches (coarse ash) | | | | | | |
| | SAND, silty, clayey, compact, yellow/brown, lt.grey, black and grey speckles (tuff-breccia) | | | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: BRAMLEY DRIVE, OMOKOROA

# BOREHOLE No. 4

JOB No: 4487 DATE DRILLED: 6/12-11/12/79 RL GROUND: 33.43

SHEET 6 OF 6

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|---|
| TAURANGA FORMATION | Ditto Above.<br>to yellow/brown<br>to lt.yellow/brown | | 34 | | | | |
| | SILT, sl.clayey, firm, lt.grey/ black | | | | | | |
| | SAND, silty, compact, purple grey, black speckles (fine ash) | | | | | | |
| | Core lost; but disturbed sample recovered | | 35 | | | | |
| | | | 36 | | | | |
| | SAND, silty, compact, lt.grey, green tint, black speckle (highly weathered pumice breccia)<br>to lt.grey, black speckle<br>to yellow/brown stain | | | | | | |
| | End of Borehole 37.0 m | | 37 | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: McDONNELL STREET, OMOKOROA

# BOREHOLE No. 5

JOB No: 4487 DATE DRILLED: 11/12-12/12/79 RL GROUND: 35.40

SHEET 1 OF 6

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp × W ● WL |
|---|---|---|---|---|---|---|
| ROTOEHU ASH | SILT, clayey, firm, brown, lt. yellow specks, occasional brown mottles | | | | | |
| | SILT, compact, v.dk.brown-black, peaty (old soil layer)<br>Lost | | 1 | | | |
| | SILT, clayey, firm, red/brown, lt. yellow speckle, dk.brown mottle<br>to brown, lt.yellow speckle<br>to yellow/brown | | 2 | ● | | |
| | SAND, silty, slightly compact, lt. yellow/brown, black-dk.grey speckles, qtz. grains<br>to v.silty, lt.grey/brown<br>Lost | | 3 | | | |
| PALEOSOL LAYERS | SILT, clayey, firm, brown, dk. brown mottle, occasional lt.yellow speckle<br>to red/brown, dk.brown mottles | | 4 | | | |
| | SILT, clayey, firm, sensitive, dk. brown<br>to lt.brown | | | | | |
| | CLAY, silty, firm, yellow/brown<br>to lt.yellow/brown | | 5 | | | |
| OLDER ASH LAYERS | SILT, clayey, firm, sensitive, v. lt.yellow/brown, dk.grey grains (fine ash) | | 6 | | | |
| | SILT, sl.clayey, stiff, v.sensitive, lt.grey/brown, occ.black and yellow speckle (fine ash) | | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

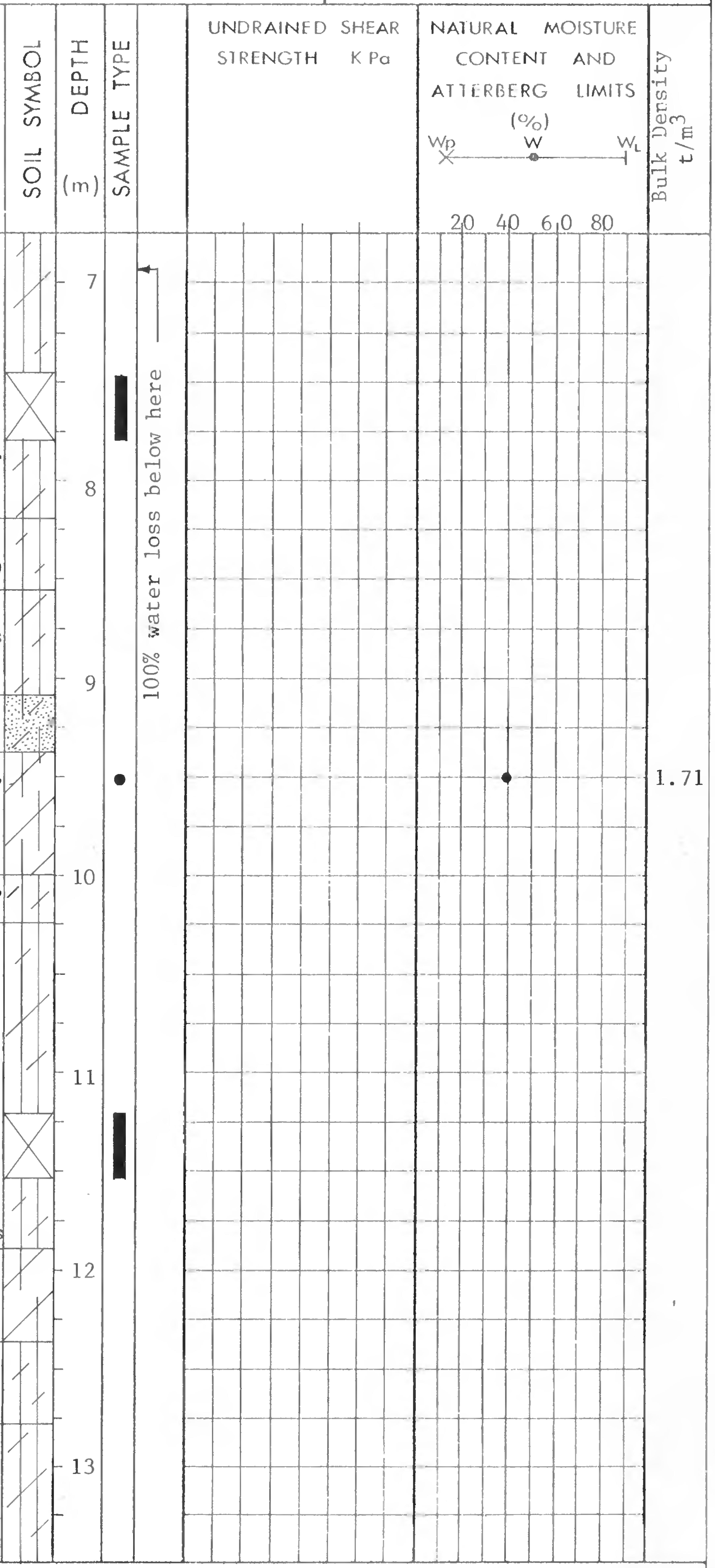
SITE: McDONNELL STREET, OMOKOROA

# BOREHOLE No. 5

JOB No: 4487 DATE DRILLED: 11/12-12/12/79 RL GROUND: 35.40

SHEET 2 OF 6

| | DESCRIPTION OF SOIL |
|---|---|
| LAYERS | ditto above |
| | SILT, clayey, firm, v.sensitive, lt. yellow/brown, yellow mottles, black patches (med. ash) |
| | SILT, sl.clayey, firm, sensitive, red/brown, black speckles(med.ash) |
| | SILT, clayey. sl.sandy, firm, yellow/brown-red/brown, qtz.grains black and lt.grey speckles (fine to med.ash) |
| | SAND, silty, clayey, compact, lt. yellow/brown, black patches, qtz. grains, grey grains(fine-med.ash) |
| PALEOSOL | CLAY, silty, med., sensitive, brown, black mottles |
| | SILT, sl.clayey, stiff, sensitive, red/brown |
| ASH | SILT, clayey, firm, v.sensitive, lt.yellow/brown, occ.black mottle (Mn $O_2$) (fine ash)<br>to sensitive, lt.yellow/brown, mica and qtz grains |
| PALEOSOL | CLAY, sl.silty, firm, red/brown, to yellow/brown |
| OLDER | SILT, sl.clayey, sensitive, firm, yellow/brown, black mottle |
| | SILT, clayey, v.sensitive, firm, lt.yellow/brown (fine ash) |



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: McDONNELL STREET, OMOKOROA

# BOREHOLE No. 5

JOB No: 4487 DATE DRILLED: 11/12-12/12/79 RL GROUND: 35.40

SHEET 3 OF 6

DESCRIPTION OF SOIL

OLDER ASH LAYERS

ditto above.

SILT, clayey, stiff, friable, lt. yellow/brown, dk.bn mottles (fine ash)

CLAY, silty, firm, sensitive, lt. yellow/brown, lt.grey & brown mottle (fine ash)

SILT, clayey, firm, sensitive, yellow/brown, (fine ash)

sampled

SILT, sl.sandy, firm to stiff, v. sensitive, yellow/brown, dk.brown mottle

reddish/brown mottle

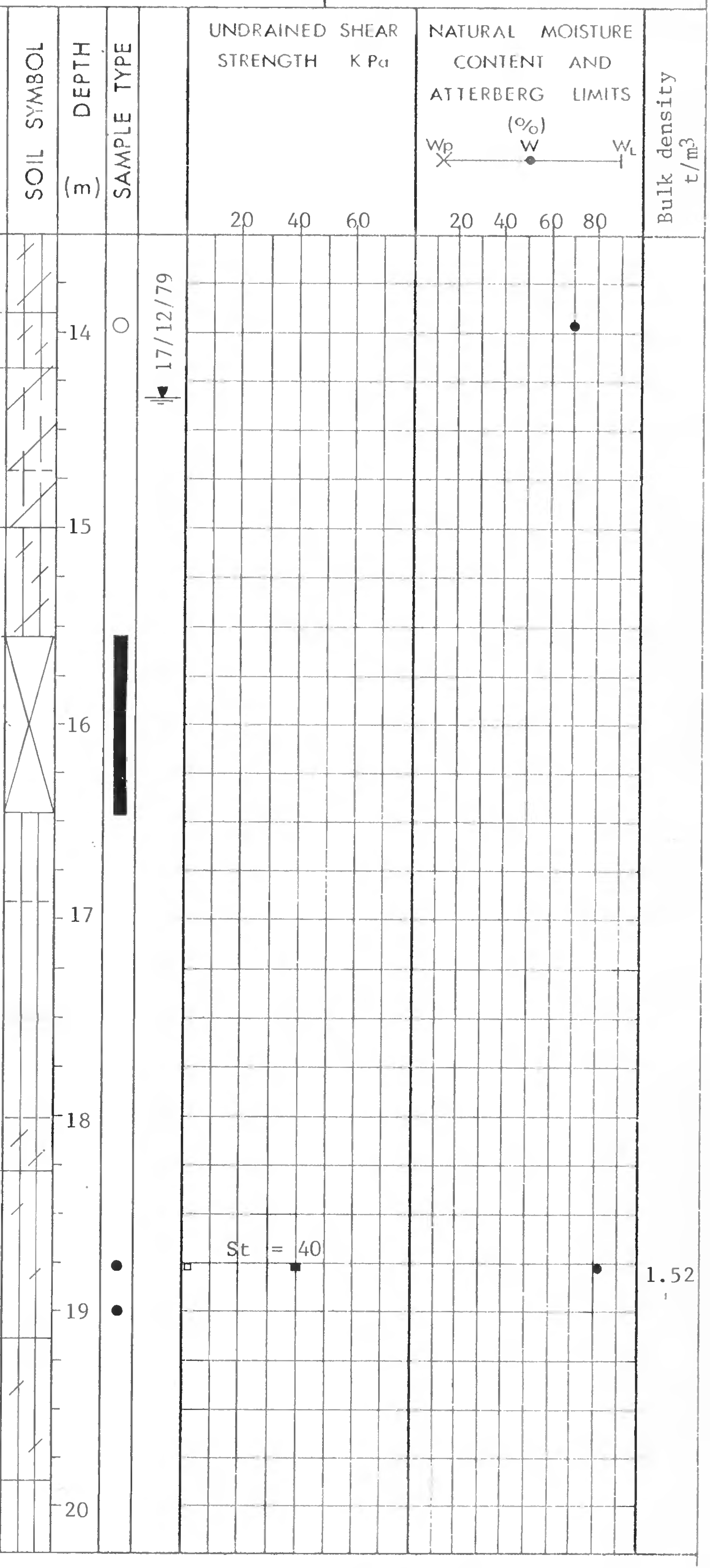
to clayey

SILT, sl.clayey, med-firm, v. sensitive, yellow/brown, occ.black and reddish mottles (fine ash)

white patches

SILT, sl.clayey, firm to stiff, v. sensitive, yellow/brown, lt.grey and red/brown speckles (med-coarse ash)

SILT, firm, v.sensitive, yellow/brown, lt.grey specks, black mottle, (med.ash)



DRILL METHOD: Rotary Rig

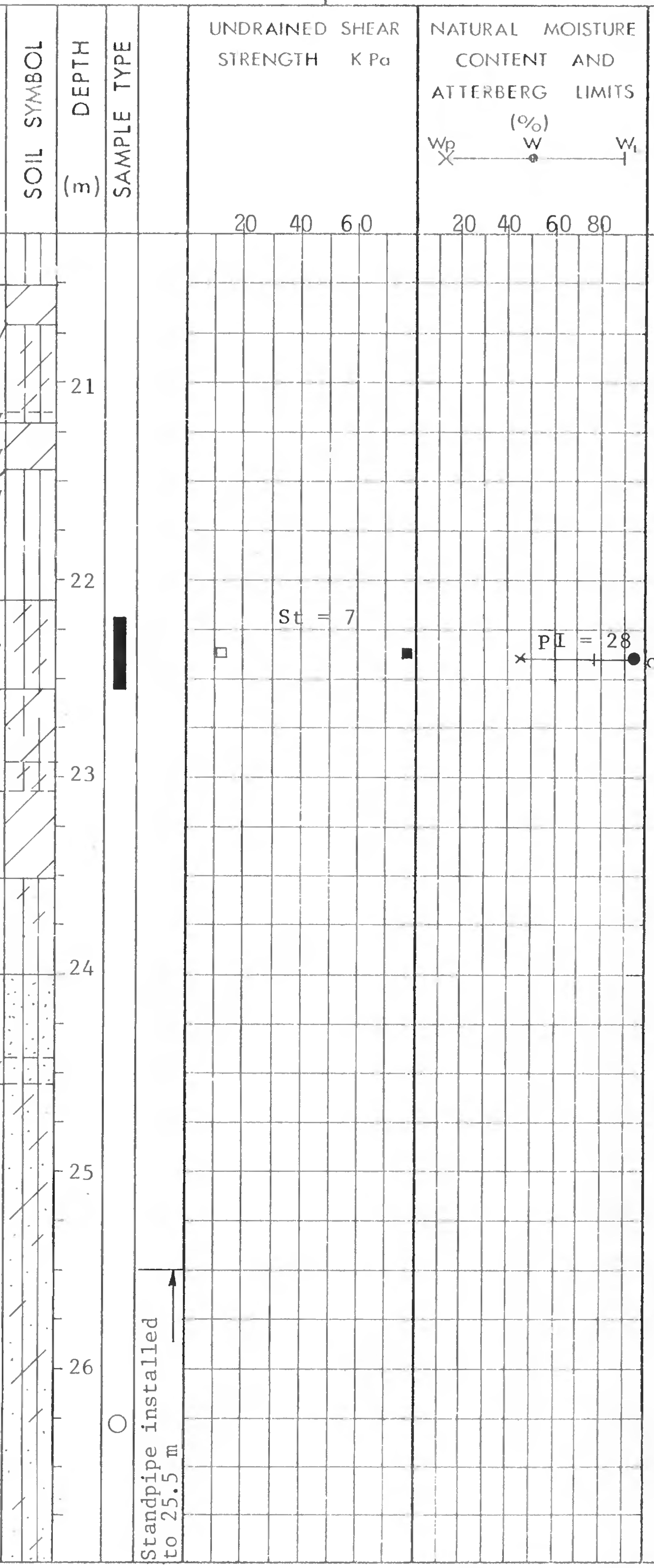
SITE: McDONNELL STREET, OMOKOROA

# BOREHOLE No. 5

JOB No: 4487 DATE DRILLED: 11/12-12/12/79 RL GROUND: 35.40

SHEET 4 OF 6

| | DESCRIPTION OF SOIL |
|---|---|
| OLDER ASH LAYERS | Ditto. reddish mottle (med.ash) |
| | CLAY, firm, v.sensitive, lt.grey/brown, occ. red stain, black patches, (fine ash) |
| | SILT, clayey, firm, v.sensitive, brown, black patches, white streaks (med-fine ash)<br>to lt.grey |
| | CLAY, firm, v.sensitive, pink/bn, black patches, grey grains, lt.grey mottle. (med-coarse ash) |
| | SILT, firm, v.sensitive, lt.yellow /brown, black patches (med.ash) |
| | SILT, clayey, sl.sandy, firm, sensitive, v.lt.grey-creamy white, red/brown speckle, grey grains, black patches (med.ash) |
| | CLAY, sl.silty, firm, v.sensitive, lt.reddish/brown, lt.grey specks, black specks (med.ash)<br>to SILT, sl.clayey (coarse ash) |
| | CLAY, sl.sandy, firm, sensitive, pinkish/grey, black patches, grey grains (med.ash) |
| | SILT, sl.clayey, firm, friable, yellow/brown, lt.grey speckle, black patches, mica specks (med.ash) |
| TAURANGA FORMATION | SILT, sandy, compact, lt.grey to cream white, black patches<br>to sl.sandy |
| | SILT, clayey, sl.sandy, firm, sensitive, lt.grey/brown, brown patches, reddish/brown speckle (pumice tuff-breccia) |



Other tests

$c^1$, $ø^1$,

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: McDONNELL STREET, OMOKOROA

JOB No: 4487 DATE DRILLED: 11/12-12/12/79 RL GROUND: 35.40

# BOREHOLE No. 5

SHEET 5 OF 6

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|
| Ditto above. | | 27 | | | | |
| (Pumice tuff-breccia) | | | | | | |
| | | 28 | | | | |
| SILT, sl.sandy, clayey, firm, sensitive, lt.grey/brown, black patches, lt.grey mottles, reddish speckle and staining, mica flakes | | | | | | |
| | | 29 | | | | |
| | | 30 | | | | |
| SILT, sandy, sl.clayey, compact, lt. grey/brown, mottled, v.lt.grey and brown, black grains & patches, lenticular highly weathered pumice fragments. | | | | | | |
| | | 31 | | | | |
| to sl.sandy | | | | | | |
| | | 32 | | | | |
| reddish/brown staining | | 33 | | | | |
| SILT, sl.sandy, compact, sensitive, red/brown staining, lt.grey lenticular pumice fragments. | | | | | | |

TAURANGA FORMATION

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: McDONNELL STREET, OMOKOROA

# BOREHOLE No. 5

JOB No: 4487 DATE DRILLED: 11/12-12/12/79 RL GROUND: 35.40

SHEET 6 OF 6

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W Wl |
|---|---|---|---|---|---|---|
| SAND, (fine) silty, compact, green /grey, lt.grey lenticular pumice, grey grains, black nodules.<br>red/brown stained | | 34 | | | | |
| End of Borehole 34.5 m | | | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

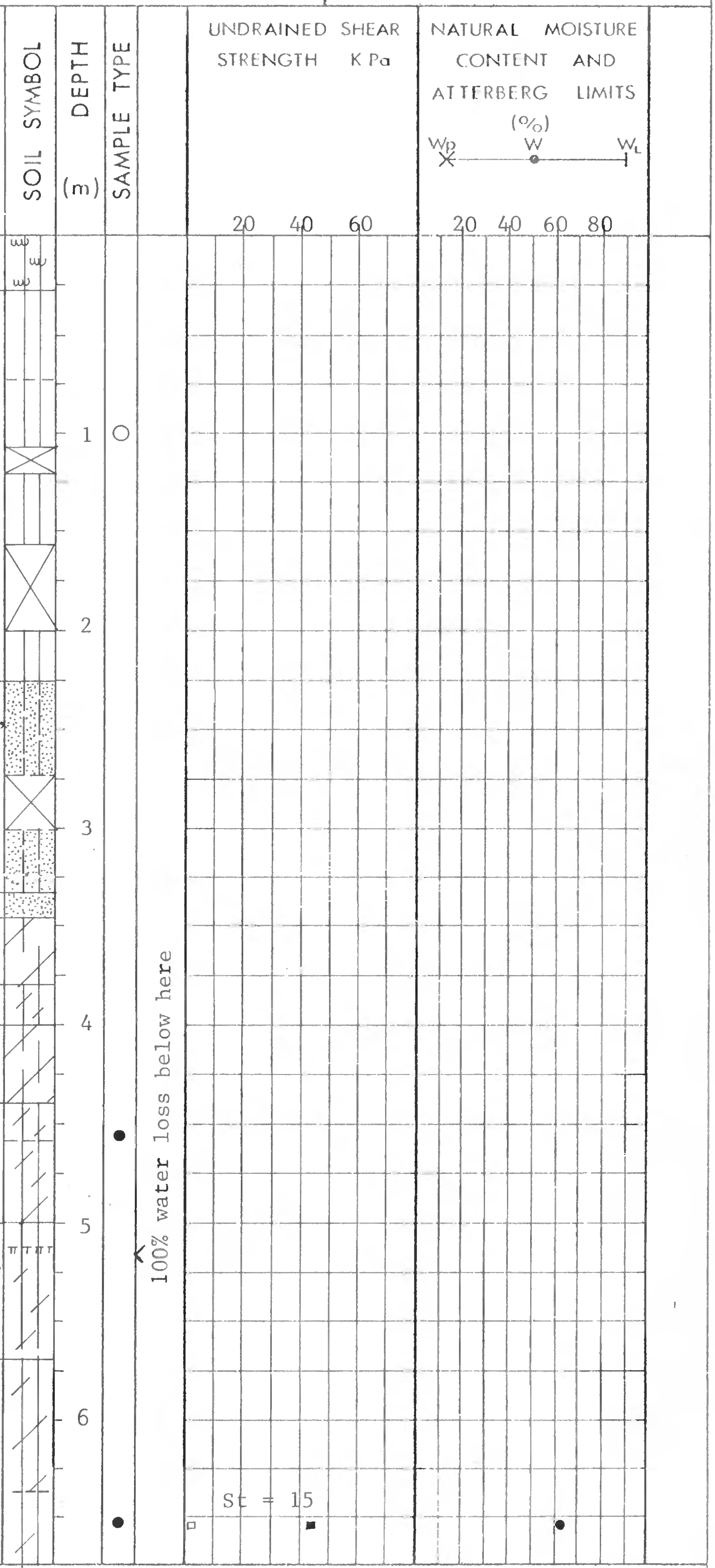
SITE: KAHAROA AVENUE, OMOKOROA

# BOREHOLE No. 6

JOB No: 4487 DATE DRILLED: 12/12-13/12/79 RL GROUND: 19.06

SHEET 1 OF 5

| | DESCRIPTION OF SOIL |
|---|---|
| ROTOEHU ASH | SILT, organic, firm, dk.brown, yellow streaks (topsoil) |
| | SILT, compact, friable, brown, yellow/brown speckles, fine qtz grains (med.ash)<br>lt.brown, occ.dk.brown mottle<br>lost<br>reddish/brown,qtz.<br>lost |
| | SAND, (medium) v.silty, slightly compact, yellow/brown, qtz grains, grey grains, (med.ash)<br>lost |
| | SAND, (med.) loose, greyish/brown, speckled blue |
| PALEOSOL | CLAY, silty, firm, sl.sensitive, lt.grey/brown, dk.brown mottle |
| | SILT, clayey, stiff, brown, brown patches |
| | CLAY, silty, firm to stiff, v. sensitive, brown, dk.brown mottles |
| OLDER ASH LAYERS | SILT, clayey, firm to stiff, sensitive, yellow/brown. (med.ash)<br>brown and lt.yellow speckle |
| | SILT, sl.clayey, firm, yellow/ brown, yellow and black specks (Coarse ash)<br>1cm cemented band |
| | SILT, clayey, firm, v.sensitive, lt.yellow/brown, lt.yellow mottle, brown layers (med.ash)<br>to pinkish/white, black patches and speckling (fine ash) |



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

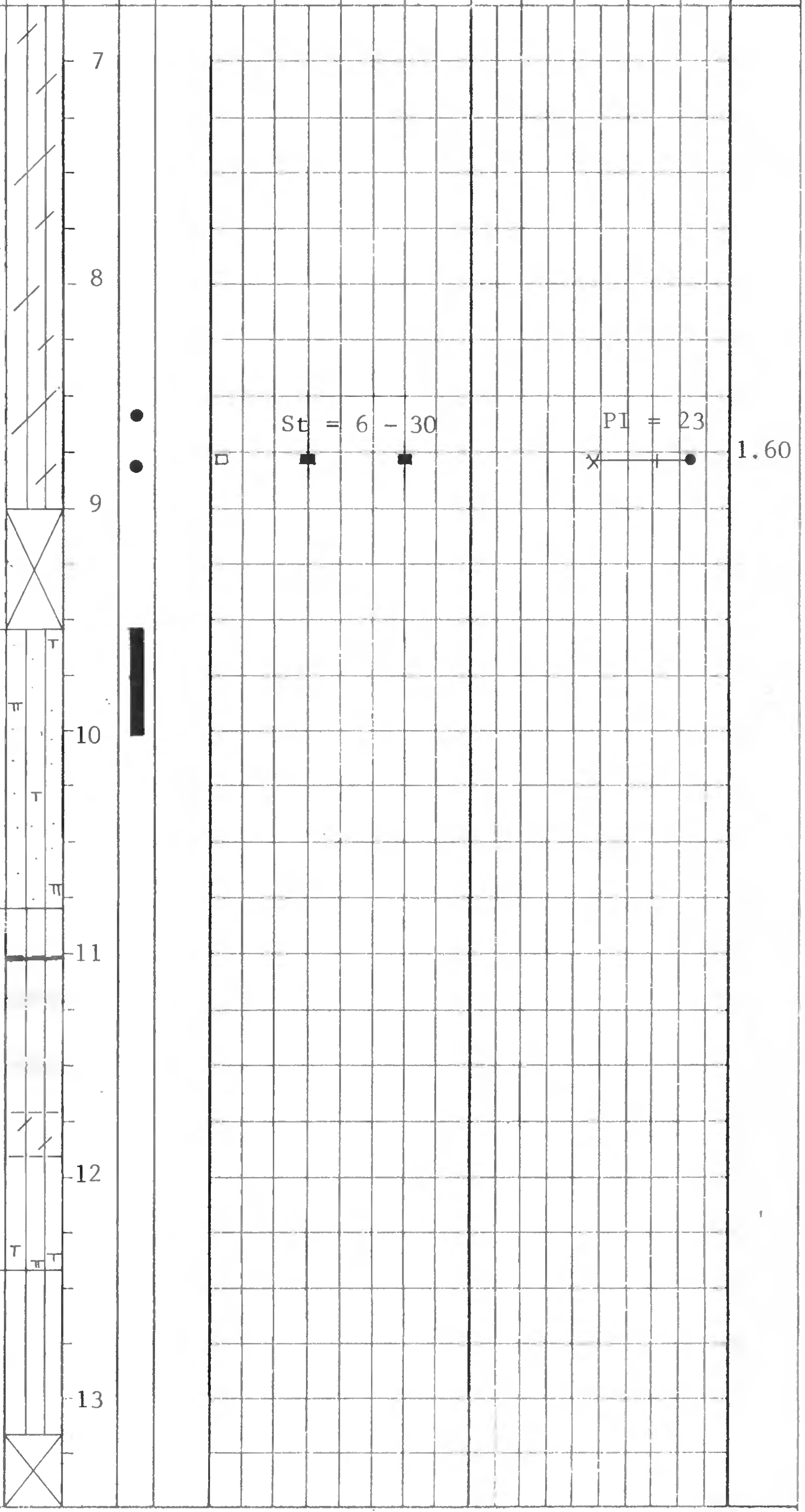
SITE: KAHAROA AVENUE, OMOKOROA

# BOREHOLE No. 6

JOB No: 4487 DATE DRILLED: 12/12-13/12/79 RL GROUND: 19.06

SHEET 2 OF 5

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W Wl | Bulk density $t/m^3$ |
|---|---|---|---|---|---|---|---|



**OLDER ASH LAYERS**

SILT, clayey, firm, v.sensitive, yellow/brown, lt.grey speckle, black grains,

(fine ash containing burnt plant frags.)

to yellow/brown

med-firm

(Wash)

SILT, sl.sandy, compact, mod. cemented zones, v.sensitive, friable, lt.yellow, some yellow/brown layers, black nodules, mica specks (coarse ash)

SILT, stiff, v.sensitive, v.lt. grey, laminated v.lt.red and greenish tint

carbonaceous layer

to sl.clayey, v.lt.brown

red/brown staining

to sl.cemented, mica specks

**TAURANGA FORMATION**

SILT, firm, v.sensitive, lt.grey, red stains, black modules, mica flakes

lenticular highly weathered pumice, white.

lost

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: KAHAROA AVENUE, OMOKOROA

# BOREHOLE No. 6

JOB No: 4487 DATE DRILLED: 12/12-13/12/79 RL GROUND: 19.06

SHEET 3 OF 5

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|

TAURANGA FORMATION

lost

SILT, sl.sandy, med-firm, sensitive, lt.grey, black speckle, mica flakes, some white lenticular pumice

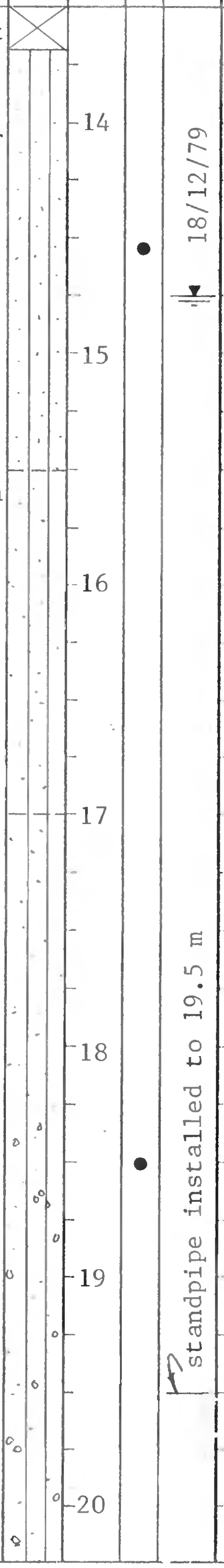
(pumice tuff-breccia)

to v.lt.yellow/brown

to yellow/brown stains

some red/brown stains

white pumice gravel



DRILL METHOD: Rotary Rig

TONKIN & TAYLOR CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE : KAHAROA AVENUE, OMOKOROA

# BOREHOLE No. 6

JOB No: 4487 DATE DRILLED: 12/12 - 13/12/79 RL GROUND: 19.06

SHEET 4 OF 5

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|---|
| TAURANGA FORMATION | red/brown stains | | | | | | |
| | SILT, sl.clayey, firm, v. sensitive, lt.grey, red/brown speckles, black speckles (med.ash)<br>red/brown mottled | | 21 | | | | |
| | SAND, silty, compact, lt.grey/ brown, black patches, white patches (pumice), green/brown staining, mica specks<br>(pumice tuff-breccia)<br>wash<br>to sl.cemented | | 22<br>23 | | | | |
| | SAND,(fine),silty, compact, sensitive, lt.grey,red/brown speck and staining, black patches, mica and qtz grains, lenticular white highly weathered pumice<br>(pumice tuff-breccia) | | 24<br>25<br>26 | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: KAHAROA AVENUE, OMOKOROA

# BOREHOLE No. 6

JOB No: 4487 DATE DRILLED: 12/12 - 13/12/79 RL GROUND: 19.06

SHEET 5 OF 5

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|---|
| TAURANGA FORMATION | Ditto above. | | 27 | | | | |
| | | | 28 | | | | |
| | lt.yellow, lt.grey speckle | | | | | | |
| | | | 29 | | | | |
| | End of Borehole 29.0 m | | | | | | |

DRILL METHOD:

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: 58 HAMURANA ROAD, OMOKOROA

# BOREHOLE No. 7

JOB No: 4487 DATE DRILLED: 13/12 - 14/12/79 RL GROUND: 26.06

SHEET 1 OF 4

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL 20 40 60 80 |
|---|---|---|---|---|---|---|---|
| ROTOEHU ASH | SILT, organic, firm, dk.brown, rootlets | | | | | | |
| | SILT, firm, brown/grey, to lt. brown, black and brown specks | | 1 | | | | |
| | SAND, (med), silty, compact, lt.bn | | | | | | |
| | SILT, compact, lt.brown, brown speckle<br>lost | | | | | | |
| | SAND, (med), silty, compact, lt. yellow/brown, qtz. grains | | 2 | | | | |
| PALEOSOL LAYERS | CLAY, firm, brown, dk.brown mottles | | | | | | |
| | core lost | | 3 | | 100% water loss below here | | |
| | SILT, clayey, stiff, brown, dk. brown mottles<br>to lt.brown | | 4 | | | | |
| | SILT, compact, brown/grey, dk.brown mottles<br>lost<br>to stiff, brown, black tubes, | | | | | | |
| OLDER ASH LAYERS | SILT, stiff, red/brown (fine ash)<br>to lt.brown, lt.yellow speckle | | 5 | ● | | | ● |
| | SILT, firm, sensitive, lt.yellow/ brown, black mottles, sl.red stain, lt.grey clasts<br>lost<br>to sl.clayey | | 6 | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: 58 HAMURANA ROAD, OMOKOROA

# BOREHOLE No. 7

JOB No: 4487  DATE DRILLED: 13/12-14/12/79  RL GROUND: 26.06  SHEET 2 OF 4

DESCRIPTION OF SOIL

OLDER ASH LAYERS

core lost

CLAY, silty, med-firm, sensitive, yellow/brown

SILT, firm-med, v.sensitive, yellow, extensive black mottling, white patches

black tubes

to mottled black, sl.lighter colour (fine ash)

wash and sample

SILT, sl.clayey, firm, v.sensitive, yellow brown, black patches, grey grains (med to coarse ash)

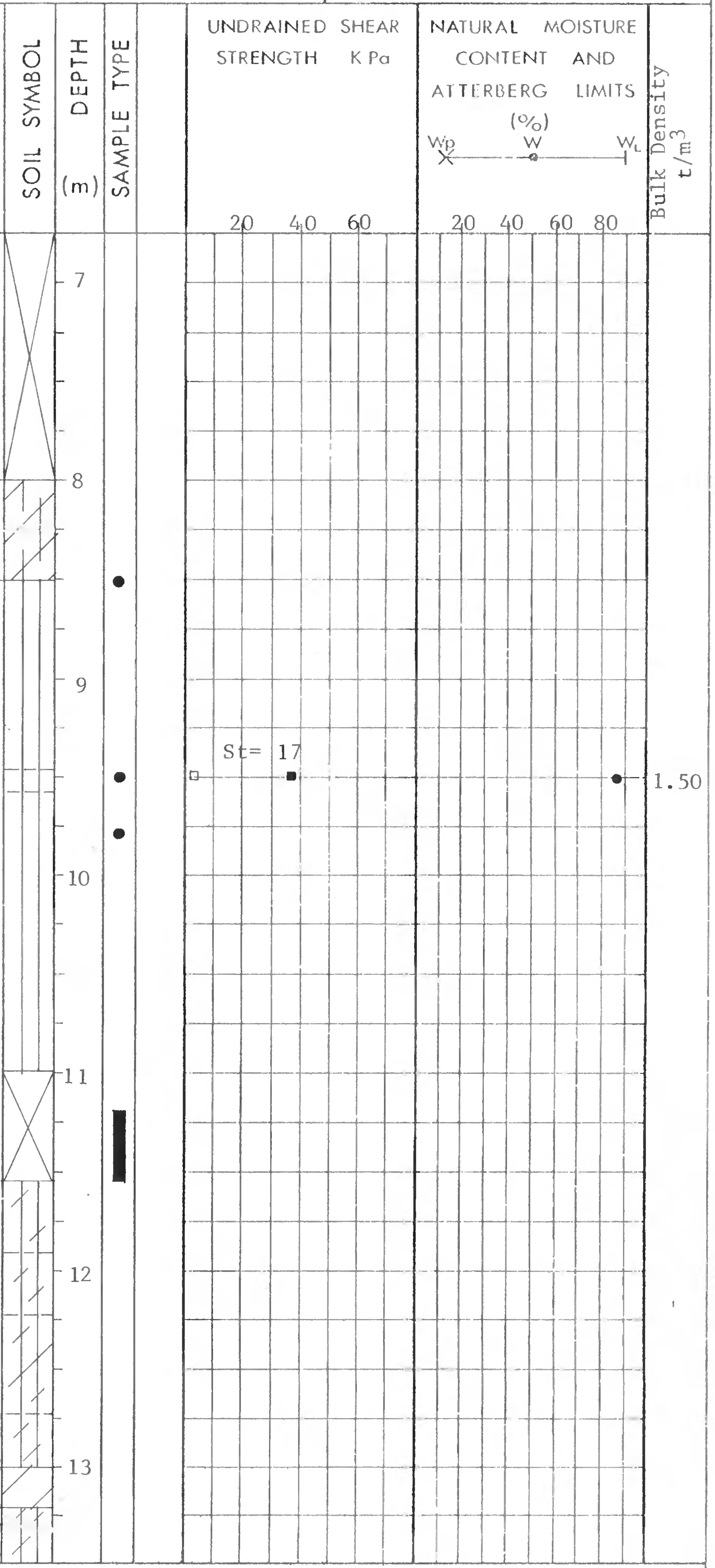
to clayey, sensitive, lt. yellow/brown, speckled grey red and white

to lt.grey, speckled black, occ.brown stain

very sensitive, speckled lt.grey

CLAY, firm, sensitive, grey, reddish stains

SILT, sl.clayey, firm, v.sensitive, bn, black patches, lt.yellow speckle (med ash)



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

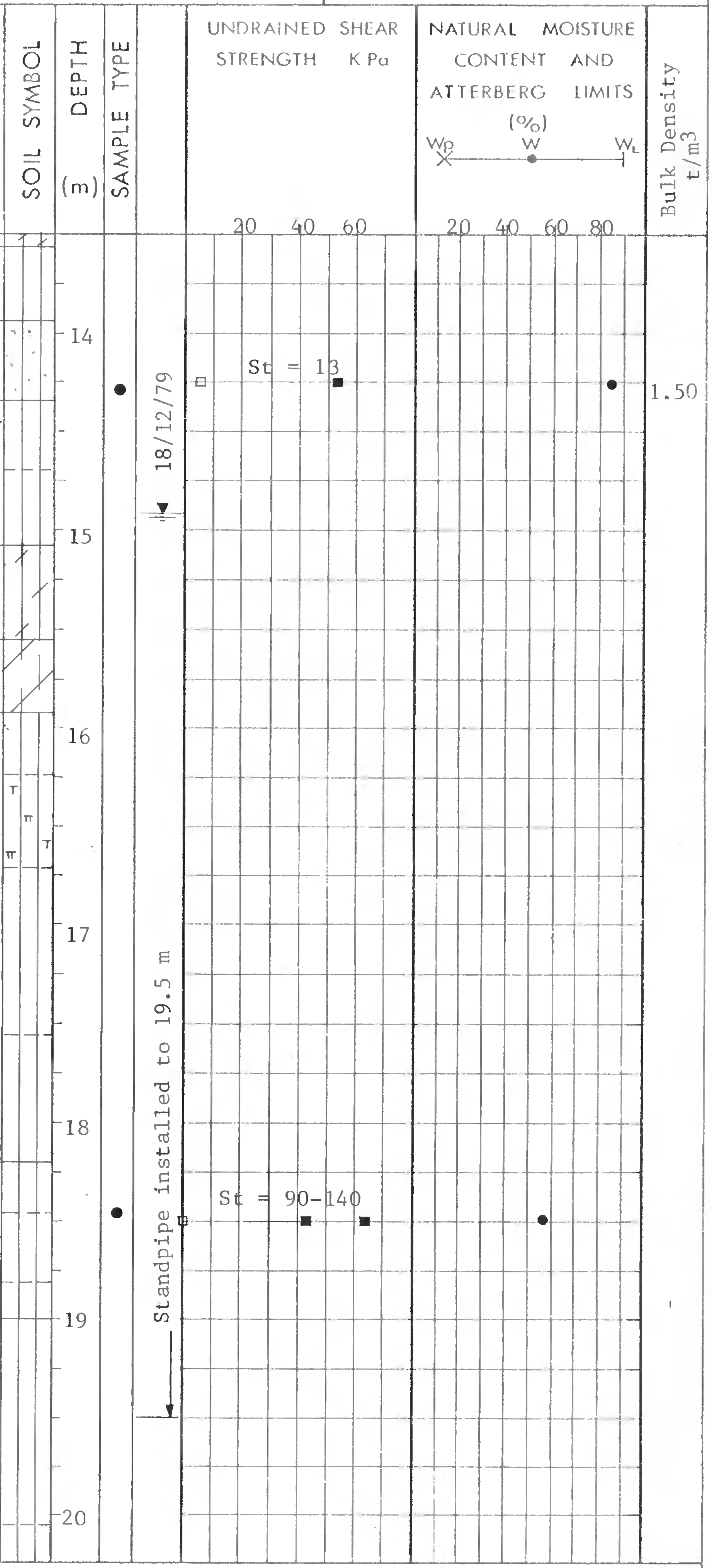
SITE: 58 HAMURANA ROAD, OMOKOROA

# BOREHOLE No. 7

JOB No: 4487 DATE DRILLED: 13/12 - 14/12/79 RL GROUND: 26.06

SHEET 3 OF 4

| | DESCRIPTION OF SOIL |
|---|---|
| OLDER ASH LAYERS | SILT, firm,v.sensitive, yellow/ brown, black patches, occ.grey speckle (fine ash) |
| | SILT, firm, sl.sandy, v.sensitive, lt.yellow/brown, black and white speckling (med-coarse ash) |
| | SILT,firm, v.sensitive, brown,black patches, lt.yellow speckle(med.ash)<br>lighter in colour |
| | SILT, sl.clayey, firm, v.sensitive, lt.yellow, black patches,brown stains (med.ash) |
| | CLAY, silty, firm, sensitive, lt. yellow/brown, black and lt.grey speckle, black patches |
| TAURANGA FORMATION | SILT, stiff, sensitive, friable, red/brown, lt.yellow mottles, black patches, white specks<br>to sl.cemented, mica specks<br>(pumice tuff-breccia)<br>to pale brown<br>to lt.grey, pale red tint |
| | SILT, firm,v.sensitive, pale red/ brown, occ.reddish spotting,black patches<br>to red/brown speckle, mica specks<br>to pale brown, black speckle |
| | SILT, compact, v.sensitive, lt. grey/brown speckle, black patches, mica specks, lenticular highly weathered pumice<br>(pumice tuff-breccia)<br>occ.brown stain |



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: 58 HAMURANA ROAD, OMOKOROA

**BOREHOLE No.** 7

JOB No: 4487 DATE DRILLED: 13/12 - 14/12/79 RL GROUND: 26.06

SHEET 4 OF 4

DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL

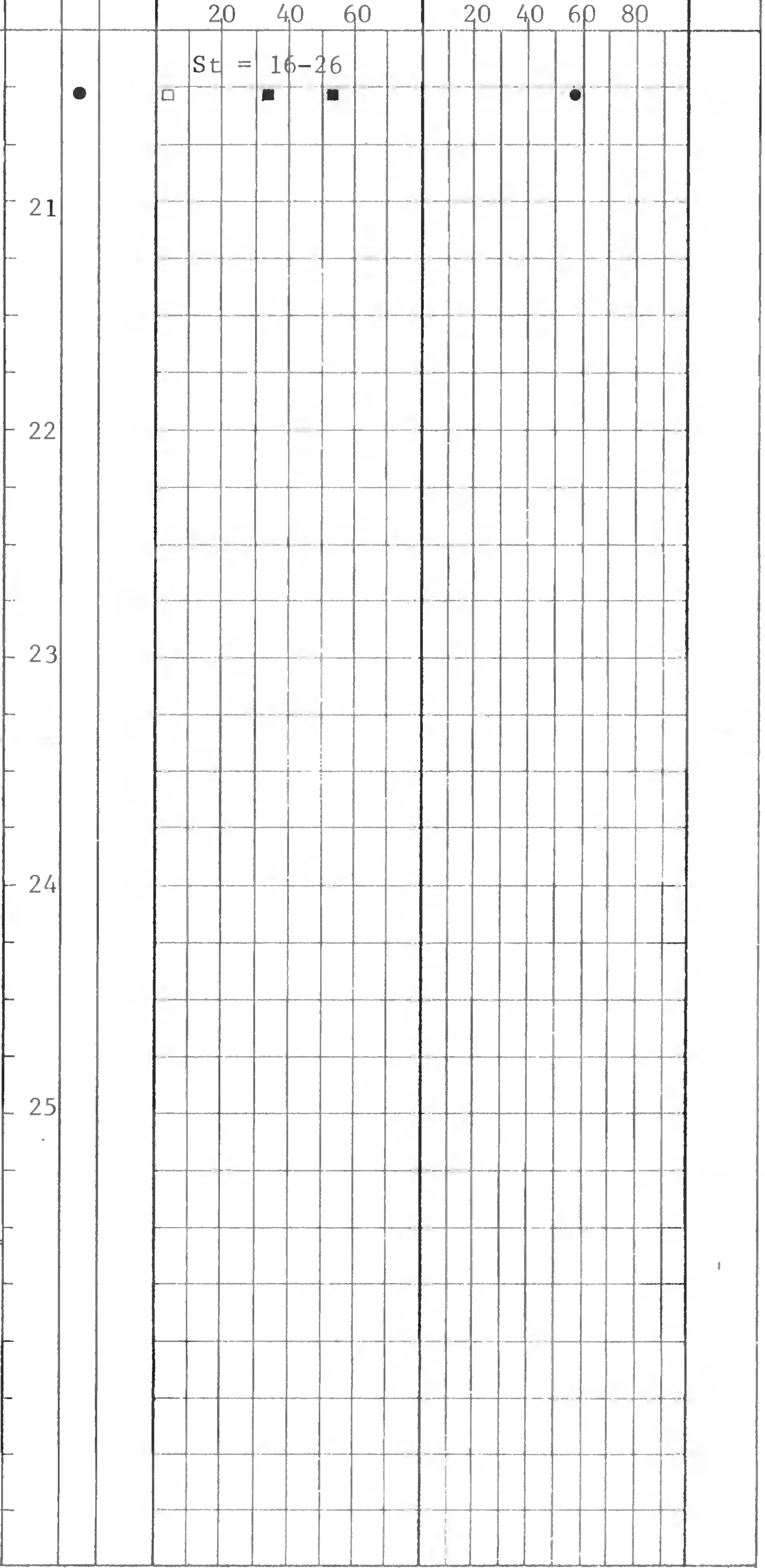
TAURANGA FORMATION

Ditto above

sl.sandy

sandy, occ.brown stain

END OF BOREHOLE 25.6 m



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: COONEY SUBDIVISION, HAMURANA ROAD, OMOKOROA

# BOREHOLE No. 8

JOB No: 4487 DATE DRILLED: 17/12/79 RL GROUND: 20.90

SHEET 1 OF 4

| | DESCRIPTION OF SOIL | DEPTH (m) | SAMPLE TYPE | |
|---|---|---|---|---|
| ROTOEHU ASH | SILT, organic, firm, friable, dk. brown, rootlets (topsoil) | | | |
| | SILT, firm, friable, brown | | | |
| | SILT, firm to stiff, friable, brown, qtz.grains | 1 | | 100% water loss |
| | to yellow/brown | | | |
| | to sandy, sl.cemented | 2 | | |
| | core lost | | | |
| PALEO-SOL | SILT, sl.clayey, firm, brown (limonitic) | 3 | | |
| OLDER ASH LAYERS | CLAY, silty, stiff, lt. reddish/brown, reddish stains, qtz.grains (med.ash) | 4 | ● | |
| | lost | | | |
| | SILT, sl.clayey, firm, v.sensitive, yellow/brown, reddish mottle, white patches, mica specks, (coarse ash) | 5 | | |
| | to clayey, non.sensitive | 6 | | |

UNDRAINED SHEAR STRENGTH K Pa

NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%)
Wp × — W ● — WL ┤

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: COONEY SUBDIVISION, HAMURANA ROAD, OMOKOROA

# BOREHOLE No. 8

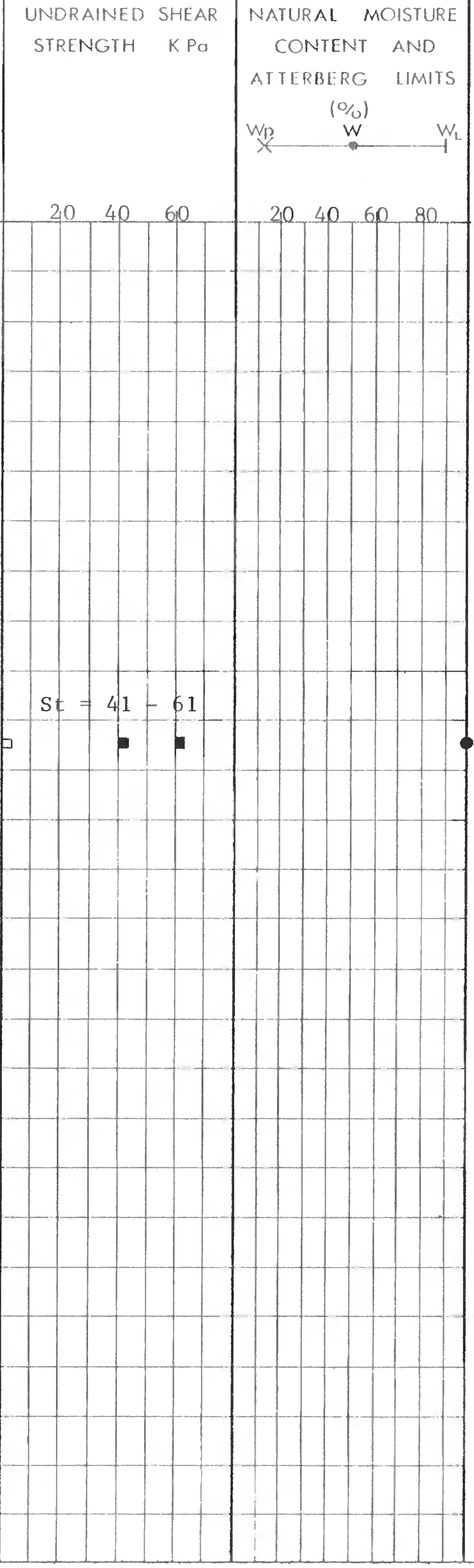
JOB No: 4487 DATE DRILLED: x 17/12/79 RL GROUND: 20.90

SHEET 2 OF 4

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE |
|---|---|---|---|---|
| OLDER ASH LAYERS | Ditto above. | | 7 | ● |
| | SILT, sl.clayey, firm, friable, brown, lt.yellow/brown mottle, lt.grey speckling, dk.brown patches, (coarse ash) | | 8 | |
| | SILT, firm, v.sensitive, lt.yellow, black patches (med.ash)<br>occ.yellow/brown mottles to brown,<br>to yellow/brown, lt.grey speckle | | 9 | ▮ |
| TAURANGA FORMATION | SILT, compact, friable, yellow/brown, lt.yellow/brown mottles, black patches, mica specks | | 10 | |
| | SILT, firm to stiff, v.sensitive, lt.grey, red mottles, black specks, mica specks<br>(pumice tuff-breccia)<br>white laminae<br>to sl.clayey, white streaks, lt.grey/brown | | 11 | |
| | SILT, compact, grey/brown, yellowish stain, lt.grey streaks, mica specks | | 12 | |
| | core lost | | 13 | |

UNDRAINED SHEAR STRENGTH K Pa

NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%)



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: COONEY SUBDIVISION, HAMURANA ROAD, OMOKOROA

# BOREHOLE No. 8

JOB No: 4487 DATE DRILLED: 17/12/79 RL GROUND: 20.90

SHEET 3 OF 4

DESCRIPTION OF SOIL

SOIL SYMBOL

DEPTH (m)

SAMPLE TYPE

UNDRAINED SHEAR STRENGTH K Pa

20 40 60

NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%)

Wp W WL

20 40 60 80

lost

SILT, sl.clayey, firm, sensitive, lt.grey/brown, red/brown stains, mica specks, lenticular grey highly weathered pumice .

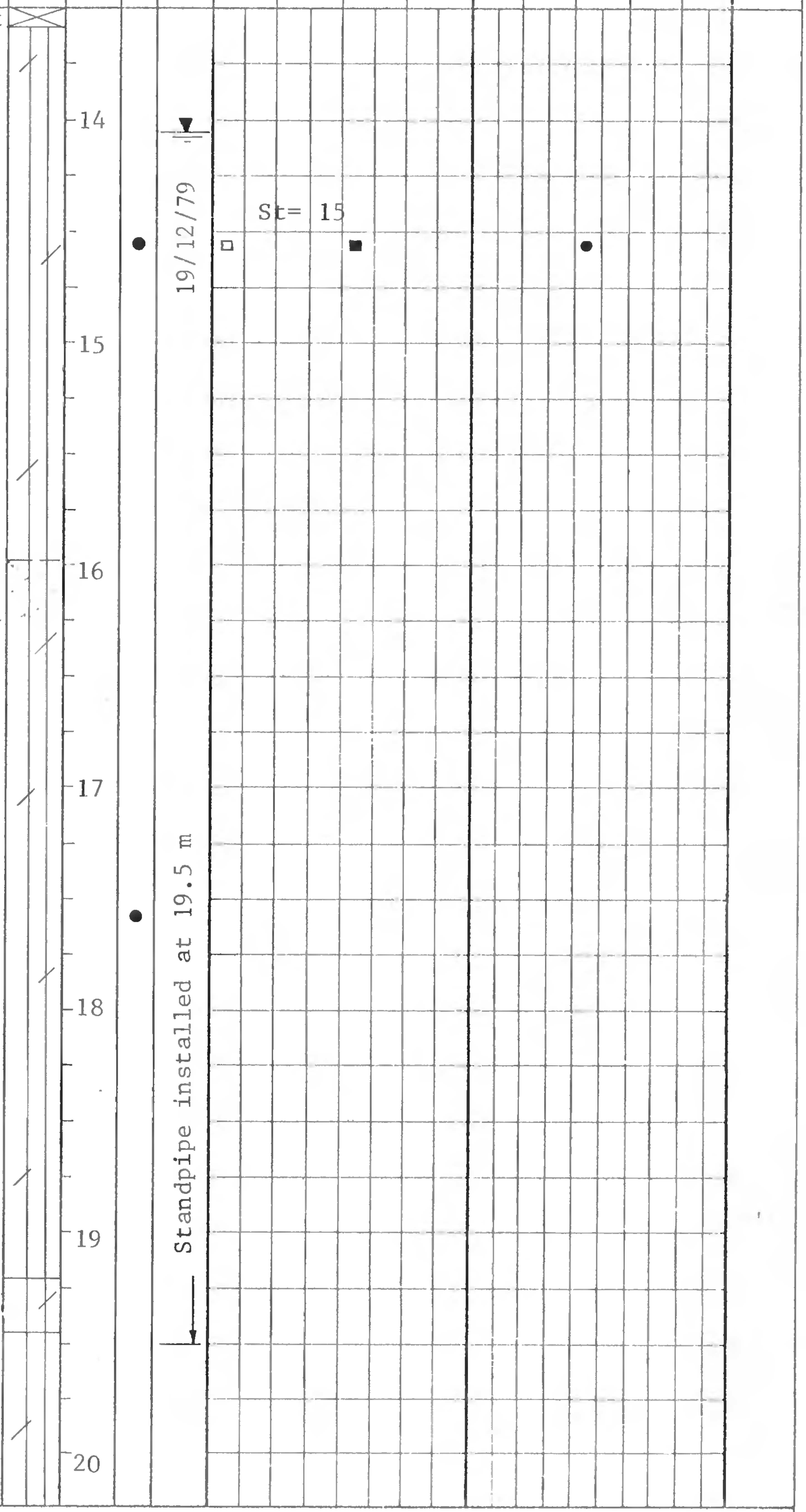
(pumice tuff-breccia)

sl.sandy

to lt.grey, reddish mottled, black patches, v.lt.grey, pumice fragments, mica specks

v.sensitive, lt.grey band

TAURANGA FORMATION



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: COONEY SUBDIVISION, HAMURANA ROAD, OMOKOROA

# BOREHOLE No. 8

JOB No: 4487 DATE DRILLED: 17/12/79 RL GROUND: 20.90

SHEET 4 OF 4

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|
| Ditto above. | | 21 | ▮ | | | |
| END OF BOREHOLE 21.2 m | | | | | | |

DRILL METHOD:

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: KOWHAI DRIVE, OMOKOROA

# BOREHOLE No. 9

JOB No: 4487 DATE DRILLED: 18/12/79 RL GROUND: 20.11

SHEET 1 OF 4

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|---|---|
| ROTOEHU ASH | FILL | | | | | | |
| | SILT, compact, grey/brown, speckled lt.grey and lt.yellow<br>to brown, yellow lumps, roots | | | | | | |
| | SILT, firm, friable, lt.brown (med.ash)<br>black speckling | | 1 | | | | |
| | SAND, silty, compact, lt.yellow/brown, black specks, qtz.grains (med.ash)<br>to greyish/brown | | 2 | ● | 100% water loss | | |
| | lost | | | | | | |
| PALEOSOL | CLAY, peaty, sl.silty, firm, dk. brown, black mottles, lt.brown mottles<br>to brown | | 3 | | | | |
| OLDER ASH LAYERS | CLAY, silty, firm, lt.brown | | 4 | ● | | | |
| | lost | | | | | | |
| | SILT, clayey, firm, sensitive, lt. grey, red mottles, brown stained, occ.brown patches, (coarse ash) | | 5<br>6 | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: KOWHAI DRIVE, OMOKOROA

# BOREHOLE No. 9

JOB No: 4487 DATE DRILLED: 18/12/79 RL GROUND: 20.11

SHEET 2 OF 4

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|

OLDER ASH LAYERS

Ditto above

mod.sensitive

SILT, firm, v.sensitive, brown speckled, lt.grey and black (coarse ash)

SILT, compact, friable, pale brown, black patches (med.ash)

SILT, sl.clayey, med,very sensitive, pale brown, black patches (med.ash)

to yellow/brown mottle

SILT, firm, v.sensitive, lt.grey /brown, black specks,brown stains

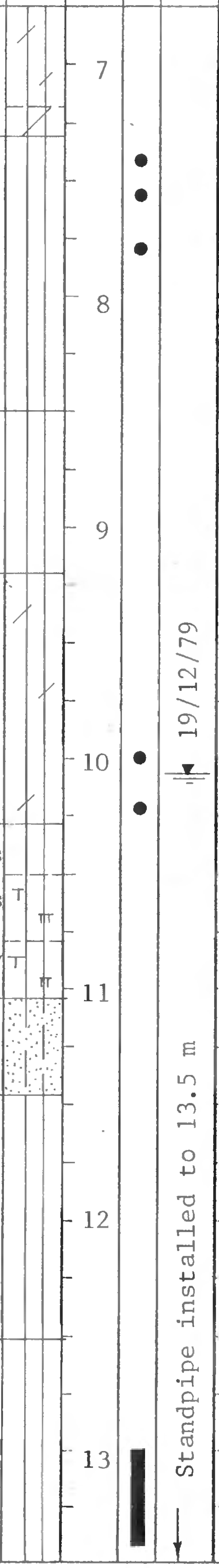
to sl.cemented, mica specks

to pinkish/grey

SAND, silty, compact, lt.grey/ brown, brown stains, mica specks, black patches

SILT, firm to stiff, sensitive, lt.grey, red mottles, black specks and patches

SILT, firm. v.sensitive, lt.grey /brown, fine black and mica speckle (fine ash)



DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: KOWHAI DRIVE, OMOKOROA

# BOREHOLE No. 9

JOB No: 4487 DATE DRILLED: 18/12/79 RL GROUND: 20.11

SHEET 3 OF 4

| | DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%)<br>Wp W WL |
|---|---|---|---|---|---|---|---|
| TAURANGA FORMATION | SILT, sandy, firm, sensitive, lt. brown mica speckle, black patches | | | | | | |
| | occ. lt.brown | | 14 | | | | |
| | | | 15 | | | | |
| | | | 16 | | | | |
| | to lt.grey, occ.reddish speckle, black speck and patches, mica specks | | | ● | | | |
| | (pumice tuff-breccia) | | | | | | |
| | | | 17 | | | | |
| | | | 18 | | | | |
| | brown stained | | | | | | |
| | brown stained, white streaks | | | | | | |
| | core lost | | 19 | | | | |
| | | | 20 | | | | |

DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

SITE: KOWHAI DRIVE, OMOKOROA

# BOREHOLE No. 9

JOB No: 4487 DATE DRILLED: 18/12/79 RL GROUND: 20.11

SHEET 4 OF 4

| DESCRIPTION OF SOIL | SOIL SYMBOL | DEPTH (m) | SAMPLE TYPE | UNDRAINED SHEAR STRENGTH K Pa | NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS (%) Wp W WL |
|---|---|---|---|---|---|

TAURANGA FORMATION

Ditto above.
(pumice tuff-breccia)

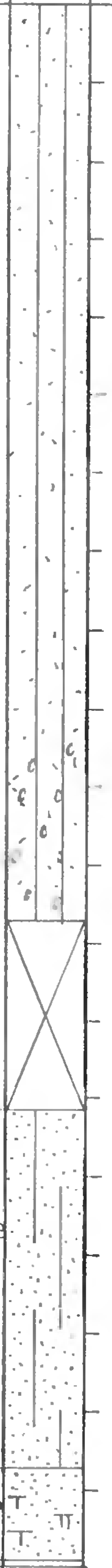
greenish/brown stain, some gravel, black

core lost

SAND, silty, compact, lt.brownish /grey, white streaks, black specks, occ.red/brown stain(pumice tuff-breccia)

SAND, fine, mod.cemented, lt.grey, black speckle

END OF BOREHOLE 25.2 m



21

22

23

24

25

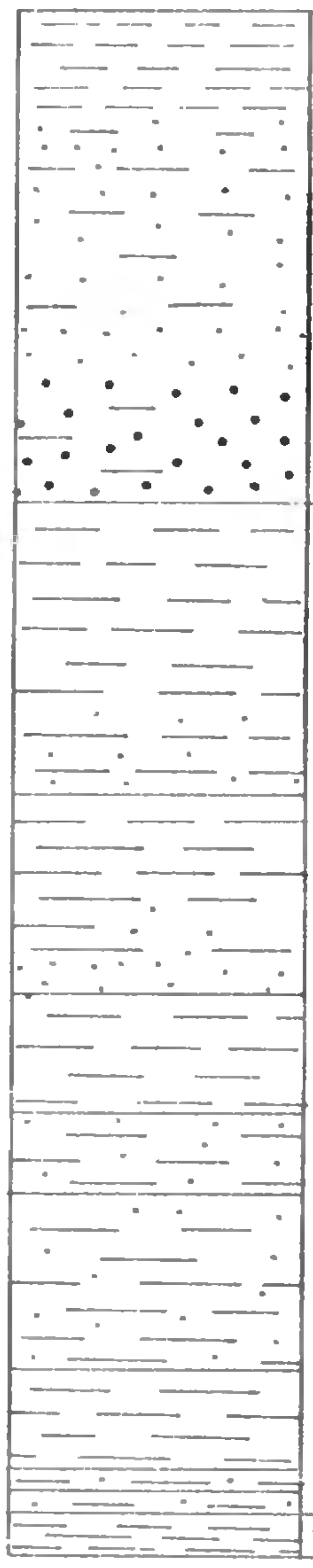
DRILL METHOD: Rotary Rig

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

## STRATIGRAPHIC SECTION 1

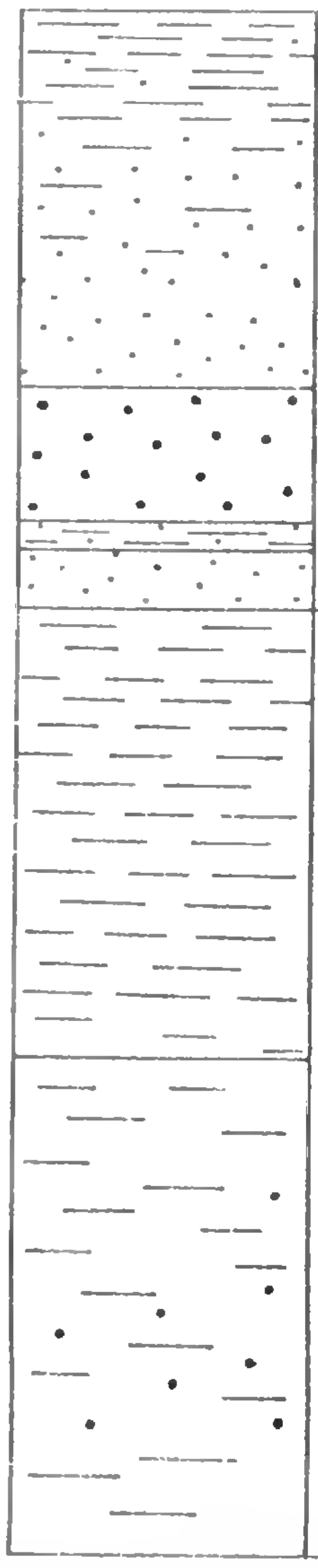
Cliff-Face below Crapp Historical Reserve

cliff elevation

| m | Section | Colour | | Rock Type | Notes |
|---|---|---|---|---|---|
| 0 |  | dark brown<br>yellow-brown | Rotoehu & Younger Ashes | humus layer and modern soil A horizon | sandy silt penetrated by roots. |
| | | | | rhyolitic ash weakly weathered | weathered at top becoming progressively less weathered with depth. |
| | | pale yellow<br>white | | fresh rhyolitic ash | reverse graded with increasing percentage of silt-sized material at base, iron oxide cementation at base predominantly mud sized material with some relict sand grains, Mn $0_2$ mottling. Slightly fresher at base. |
| 2.5 | | dark brown<br>yellow | Older Ashes | paleosol<br>strongly weathered rhyolitic ash | |
| 4.0 | | light brown<br>orange | | paleosol<br>strongly weathered rhyolitic ash | predominantly mud sized, dark at top becoming rapidly lighter below 4.6 m and Mn $0_2$ stained relict sand sized grains. |
| 4.95 | | orange-brown<br>pale pink-brown | | strongly weathered rhyolitic ash | highly weathered mud sized ash, weak internal bedding. |
| 5.60 | | | | | ash with relict coarse sand sized texture. Finely bedded. |
| 6.00 | | pale yellow-brown<br>yellow | | | weathered coarse-medium ash, now mud sized. |
| 6.85 | | pinkish white | | | weathered fine ash. |
| 7.4 | | | | | weathered ash, relict coarse ash texture. |
| | | medium brown | | paleosol | thin paleosol developed on Tauranga Formation. |

## STRATIGRAPHIC SECTION 2

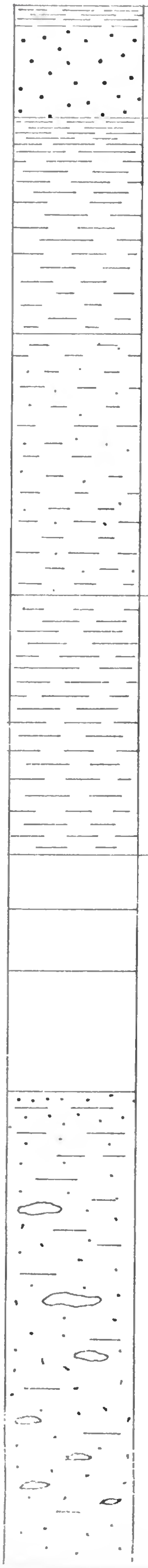
Slip below Walnut Grove

| m | Section | Colour | | Rock Type | Notes |
|---|---|---|---|---|---|
| 0 |  | dark brown<br>yellow | Rotoehu & Younger Ashes | modern soil | friable silt with relict sand grains. |
| | | pale yellow | | weakly weathered rhyolitic ash | sandy and silty slightly weathered ash. Numerous quartz & plagioclase crystals. White rhyolitic pumice, grey lithic rhyolite. |
| 1.9 | | white | | fresh rhyolitic ash | coarse ash, pumice to 12 mm, also crystal fragments and lithic rhyolite. |
| 2.6 | | | | | ~~silt = fine sand sized tephra ash~~<br>medium-coarse sand sized ash. |
| 3.05 | | dark brown<br>yellow brown | Older Ashes | paleosol<br>severely weathered rhyolitic ash | paleosol passing gradationally into strongly weathered ash, relict fine sand sized texture with some crystal and lithic rhyolite fragments preserved. |
| 5.25 | | | | | severely weathered ash now mud-sized, but relict texture of coarse ash, Mn $0_2$ staining. |
| 7.75 | | | | | |

# STRATIGRAPHIC SECTION 3

50 m north of Bramley Drive Landslip

Section



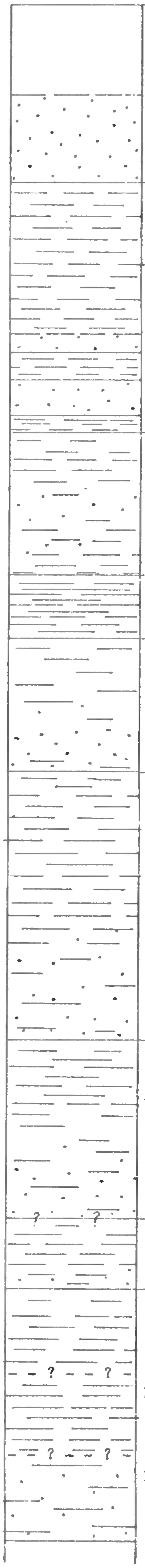
| m | Colour | | Rock Type | Notes |
|---|---|---|---|---|
| 0 | dark brown | Rotoehu & Younger Ashes | modern soil | |
| 0.25 | yellow<br>white | | fresh rhyolitic ash | white rhyolitic pumice, grey lithic rhyolite, abundant quartz and plagioclase. |
| 1.3 | dark brown<br>orange brown | | paleosol<br>severely weathered ash | paleosol zone becoming progressively lighter coloured with depth, in lower 1 m relict sand sized texture apparent. |
| 3.8 | pale brown<br>v. pale brown | Older Ashes | severely weathered ash | dominantly clay and silt sized material with rare relict pumice to 0.5 mm. |
| 6.8 | orange | | severely weathered ash | intensely weathered ash, no trace of relict texture. |
| 9.8 | white | | clay | |
| 10.4 | orange-brown | | clay | relict tuffaceous texture |
| 11.1 | white | | clay | claystone with red and brown laminations. |
| 12.5 | white | Tauranga Formation | <br>weathered tuff breccia | silty sand size material<br>weathered pumiceous tuff breccia, now clayey silt sized but originally containing white rhyolitic pumice to 2 cm. Abundant quartz and lithic rhyolite relict fragments. Secondary hexagonal clay prisms.<br>In lower parts stratification defined by concentrations of large pumice fragments. |

# STRATIGRAPHIC SECTION 4

Composite section Bramley Drive Landslip

Sheet 1 of 2

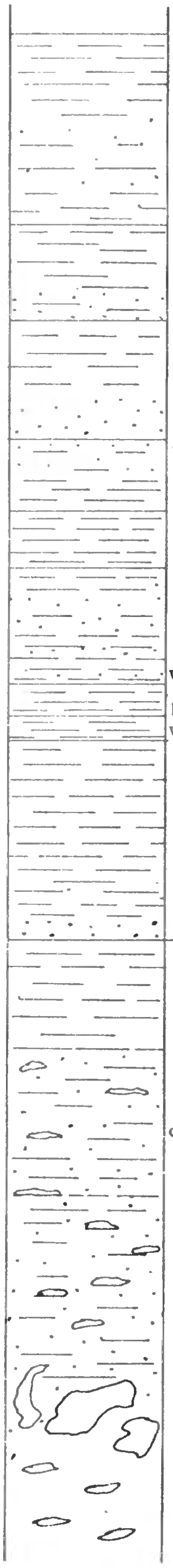
Section



| m | | Colour | Rock Type | Notes |
|---|---|---|---|---|
| 0 | Rotoehu & Younger Ashes | | fill | |
| 1.0 | | cream-white | fresh rhyolitic ash | white, rhyolitic pumice and grey lithic rhyolite, quartz and plagioclase |
| 2.0 | | dark brown<br>light brown<br>light red brown | paleosol | strongly developed paleosol becoming increasingly lighter with depth, at base baked and dry with numerous desiccation cracks. |
| 3.7<br>4.2<br>4.6 | | yellow and white | thinly bedded rhyolitic ashes | relict sand sized grains in some units, but now mud sized. |
| 4.8 | | white<br>pale brown<br>pale brown | strongly weathered rhyolitic ash | clay weathered top containing progressively more relict clasts until 5.7 m where material becomes more weathered. |
| 6.4 | | brown and white | strongly weathered rhyolitic ashes | thinly bedded white and brown clay replacing rhyolitic ash. |
| | | brown<br>pale yellow | weak paleosol<br>weathered ash | thick weakly developed paleosol with heavy Mn $0_2$ staining between 7.1 and 8.3 m passing into 0.3 m weathered ash. |
| | Older Ashes | black<br>red brown<br>pale red brown<br>yellow with white & yellow brown mottles | paleosol<br>weathered ash | dense humus-rich strongly developed paleosol passing into weathered ash with Mn $0_2$ staining.<br>relict quartz and plagioclose crystals of sand size at base. |
| 11.6 | | dark brown<br>brown<br>pale yellow brown | paleosol<br>weathered ash | as above. |
| 13.6 | | pale brown<br>pale yellow | weathered ash | |
| 14.4<br>15.2 | | pale brown<br>pale brown | heavily weathered ashes | Now entirely mud sized. No relict clasts, Mn $0_2$ mottling. |
| 16.3 | | yellow | less weathered ash | relict sand sized texture - originally coarse ash. Internal planar bedding. Mn $0_2$ staining. |
| 17.2 | | | | |

STRATIGRAPHIC SECTION 4/continued..

Sheet 2 of 2



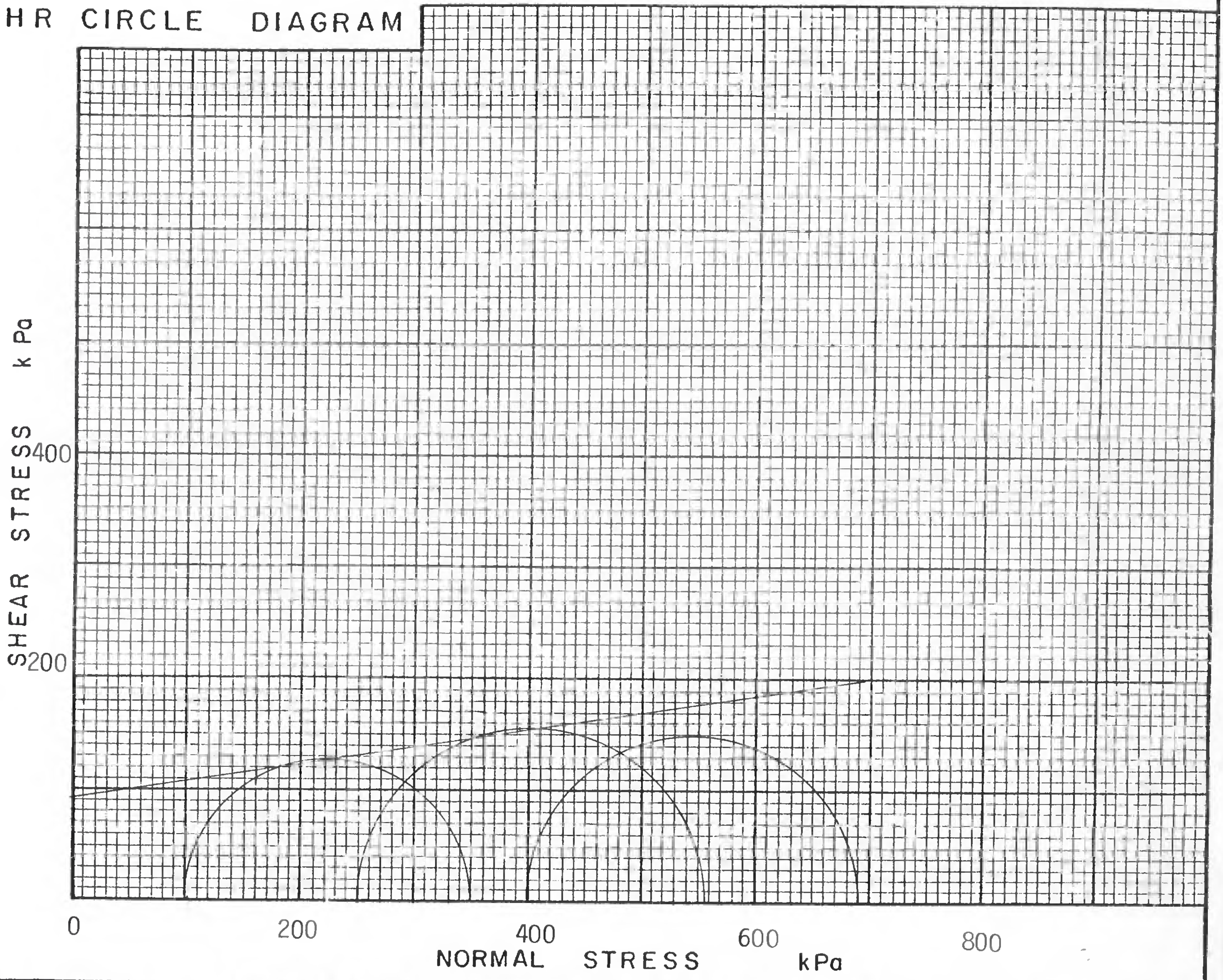
| | | | | |
|---|---|---|---|---|
| 17.2 | yellow brown | Older Ashes | weathered ash | featureless brown mud passing at 18.0 m to less weathered ash with relict sand sized grains and plant fragments. |
| | pink brown | | | |
| 19.0 | pale brown | | | relict sand sized grains at base. |
| | pinkish brown | | weathered ash | |
| 19.9 | pale brown | | | no reliect texture at top, rare sand sized clasts at base. |
| 21.0 | bluish grey | | | very distinctive unit,'vesiculated' texture, dark grey patches indicating relict texture. |
| 21.65 | pale brown | | weathered rhyolitic ashes | originally sand sized ashes, but no mud sized. |
| 22.2 | | | | |
| | white | | | |
| 23.3 | pale brown | | | |
| 23.6 | white | | | |
| | | | | basal 0.5 m relict texture well preserved. |
| 25.7 | | Tauranga Formation | severely weathered tuff breccia | somewhat diffuse contact, strongly weathered to 26.7 m. Few rare large pumice relics. |
| | cream | | weathered tuff-breccia | large pumice relics now altered to clay consisting of up to 2 cm coarse hexagonal prisms of halloysite. |
| | | | | between 30 and 31 m 'rip-up' mudstone clasts. |

# TRIAXIAL TEST

~~BORE/PIT~~ SLIP FACE BRAMELY DR.
SAMPLE 1.
DEPTH

SITE OMOKOROA
JOB No. 4487

## MOHR CIRCLE DIAGRAM



**TEST METHOD** CONSOLIDATED QUICK UNDRAINED (no pore pressure measurements

## DETAILS OF TESTS

| INITIAL SOIL PROPERITES | | CONSOLIDATION STAGE | | | FAILURE VALUES | | | |
|---|---|---|---|---|---|---|---|---|
| BULK DENSITY $\rho$ t / m³ | WATER CONTENT % | CELL PRESSURE k Pa | BACK PRESSURE k Pa | EFFECTIVE CONSOLIDATION PRESSURE $\sigma_3'$ k Pa | DEVIATOR STRESS $\sigma_1 - \sigma_3$ k Pa | PORE PRESSURE CHANGE DURING SHEARING $\Delta u$ k Pa | MINOR PRINCIPAL EFFECTIVE STRESS $\sigma_3'$ k Pa | STRAIN % |
| 1 .46 | 91.7 | 100 | - | 100 | 248 | - | 100 | 2% |
| 1.46 | 93.1 | 250 | - | 250 | 301 | - | 250 | 4% |
| 1.46 | 87.2 | 400 | - | 400 | 288 | - | 400 | 5% |

**TEST RESULTS**

Angle of shearing resistance ~~XX~~ = Ø = 10°
Apparent cohesion ~~XX~~ = C = 90 kPa

**REMARKS** TOTAL STRESS VALUES

**TONKIN & TAYLOR** CONSULTING CIVIL AND FOUNDATION ENGINEERS

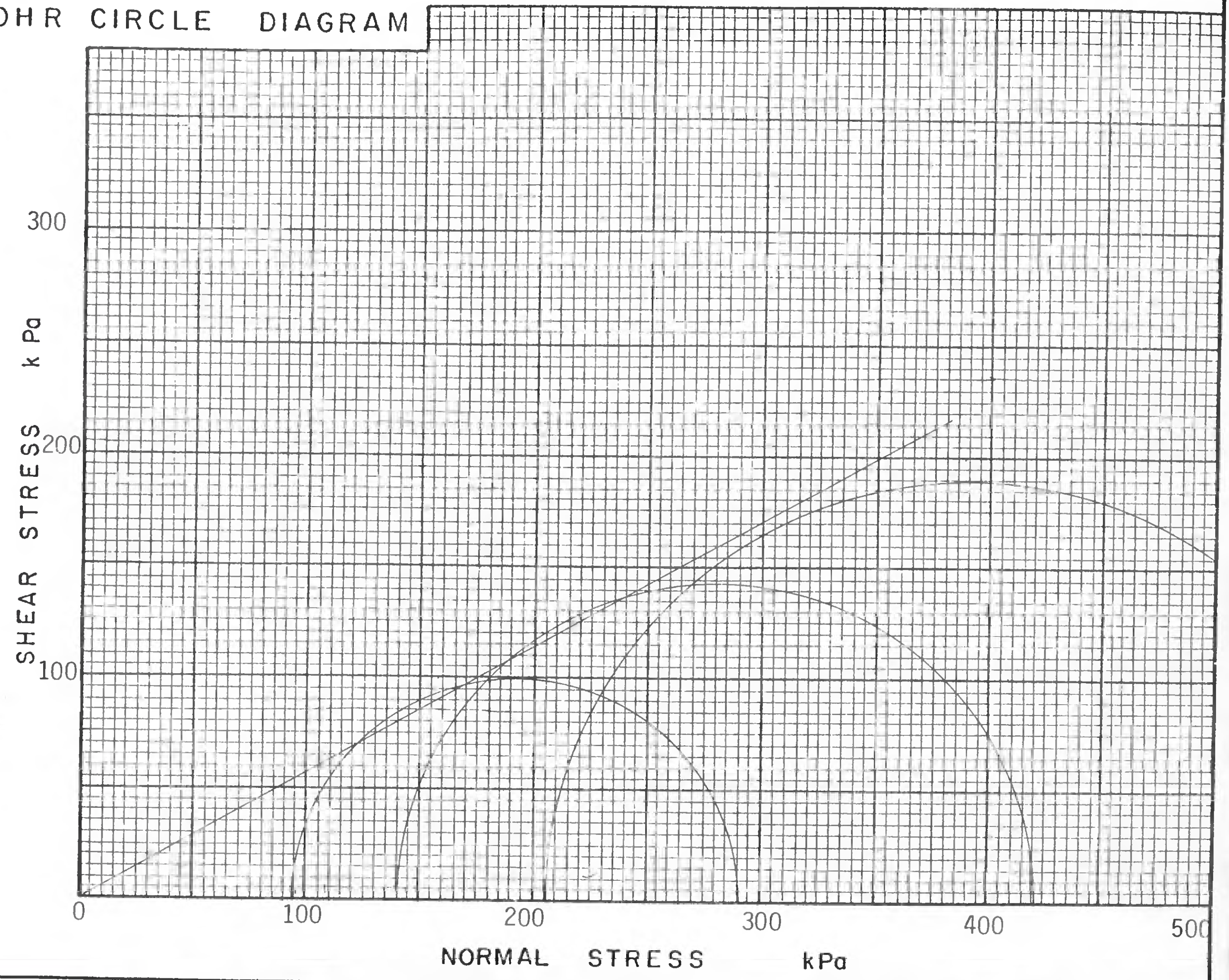
PLATE No. 1.

# TRIAXIAL TEST

BORE/~~PIT~~ 5
SAMPLE 10
DEPTH 22.2 m

SITE OMOKOROA
JOB No. 4487

## MOHR CIRCLE DIAGRAM



**TEST METHOD** CONSOLIDATED UNDRAINED TRIAXIAL TEST WITH PORE PRESSURE MEASUREMENT. BACK PRESSURE USED ON 1 OF 3 SAMPLES

## DETAILS OF TESTS

| INITIAL SOIL PROPERITES | | CONSOLIDATION STAGE | | | FAILURE VALUES | | | |
|---|---|---|---|---|---|---|---|---|
| BULK DENSITY $\rho$ t/m³ | WATER CONTENT % | CELL PRESSURE kPa | BACK PRESSURE kPa | EFFECTIVE CONSOLIDATION PRESSURE $\sigma_3'$ kPa | DEVIATOR STRESS $\sigma_1 - \sigma_3$ kPa | PORE PRESSURE CHANGE DURING SHEARING $\Delta u$ kPa | MINOR PRINCIPAL EFFECTIVE STRESS $\sigma_3'$ kPa | STRAIN % |
| 1.52 | 93.6 | 450 | 300 | 150 | 196 | 55 | 95 | 1 |
| 1.45 | 94.8 | 300 | - | 300 | 282 | 160 | 140 | 3 |
| 1.51 | 94.6 | 450 | - | 450 | 376 | 245 | 205 | 5 |

**TEST RESULTS**

Angle of shearing resistance $\phi'$ = 29.5°
Apparent cohesion c' = 0 kPa

**REMARKS** SIDE DRAIN & MEMBRANE CORRECTION APPLIED TO DEVIATOR STRESS AT RATE OF 1kPa /1% STRAIN (STRESS/STRAIN GRAPHS REFER FIGS ..... to ......)

TONKIN & TAYLOR CONSULTING CIVIL AND FOUNDATION ENGINEERS

PLATE No. 2.

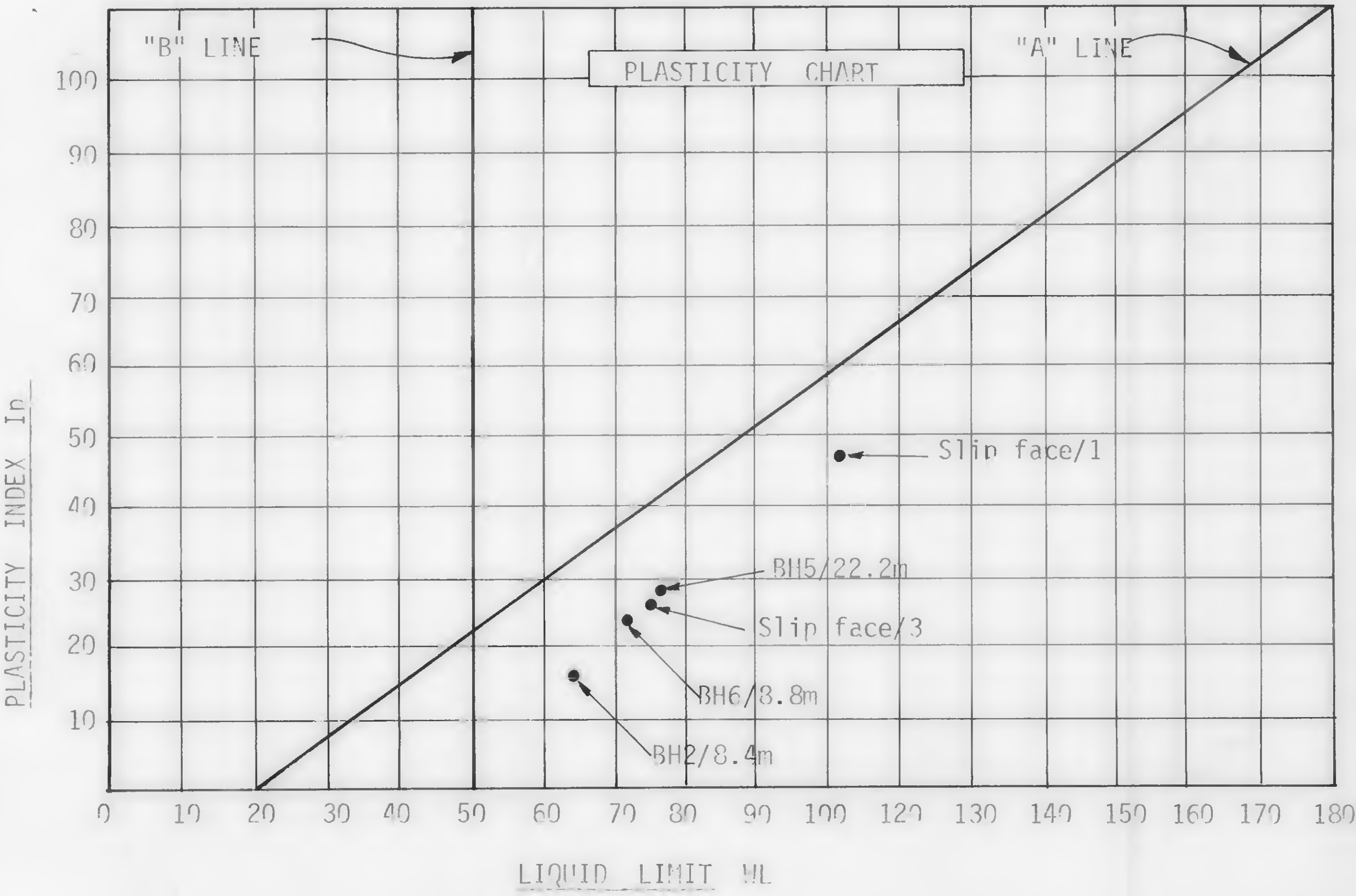
## TABLE 1.

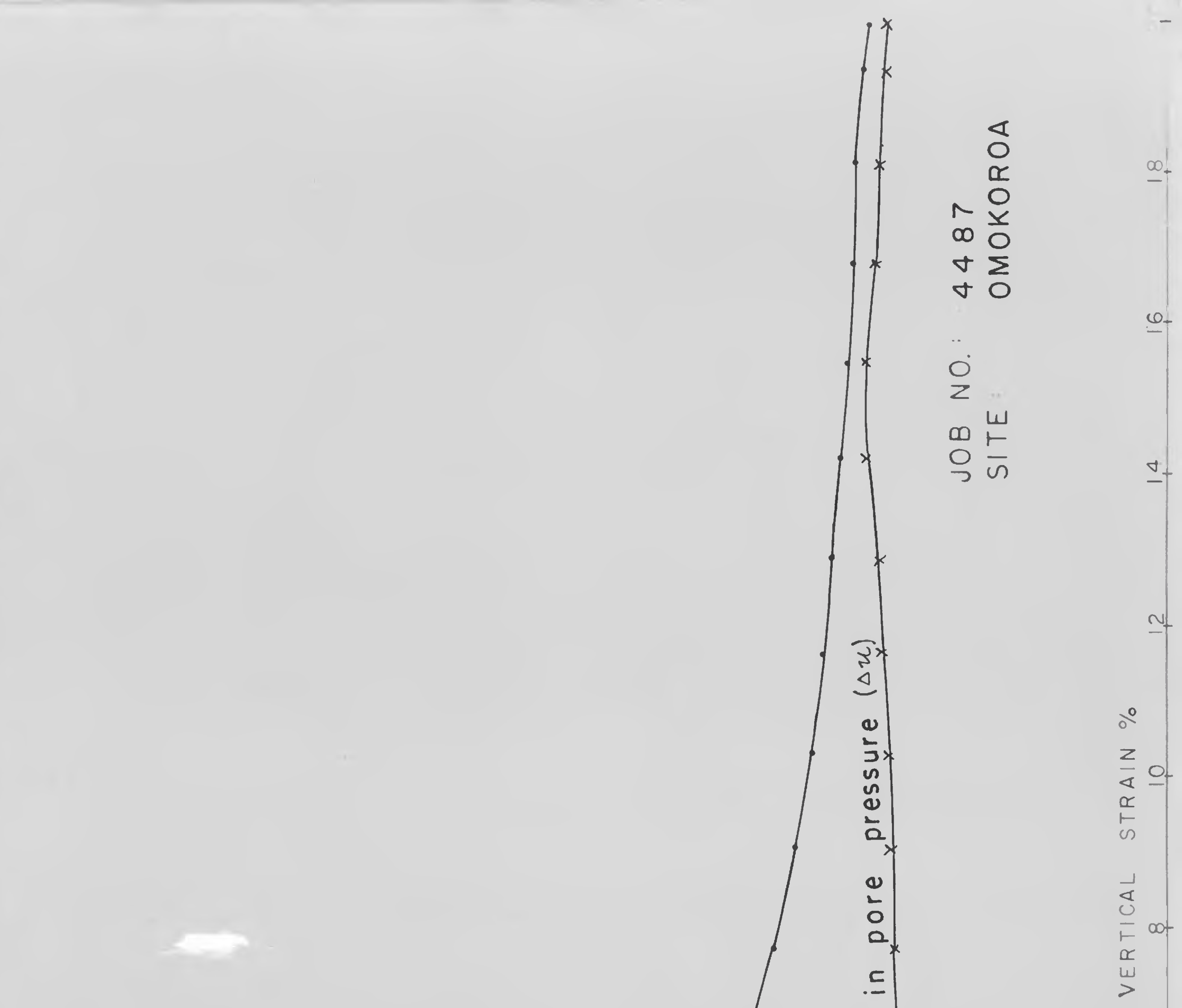
## ADDITIONAL SOIL TEST RESULTS

Samples from Bramely Drive Slip face taken at rear of bench approximately 22-23m below top of cliff.

| SAMPLE NO | NATURAL WATER CONTENT % | UNDRAINED SHEAR STRENGTH kPa | | SENSITIVITY ST. | ATTERBERG LIMITS | | BULK DENSITY t/m$^3$ |
|---|---|---|---|---|---|---|---|
| | | 'as recieved' | remoulded | | L.L | P.L | |
| 1 | 90.7 | 99 | 14 | 7 | 101 | 54 | 1.46 |
| 2 | 85.3 | 109 | 8 | 14 | - | - | - |
| 3 | 75.3 | 77 | < 2 | >39 | 76 | 50 | |

Fig. 1.

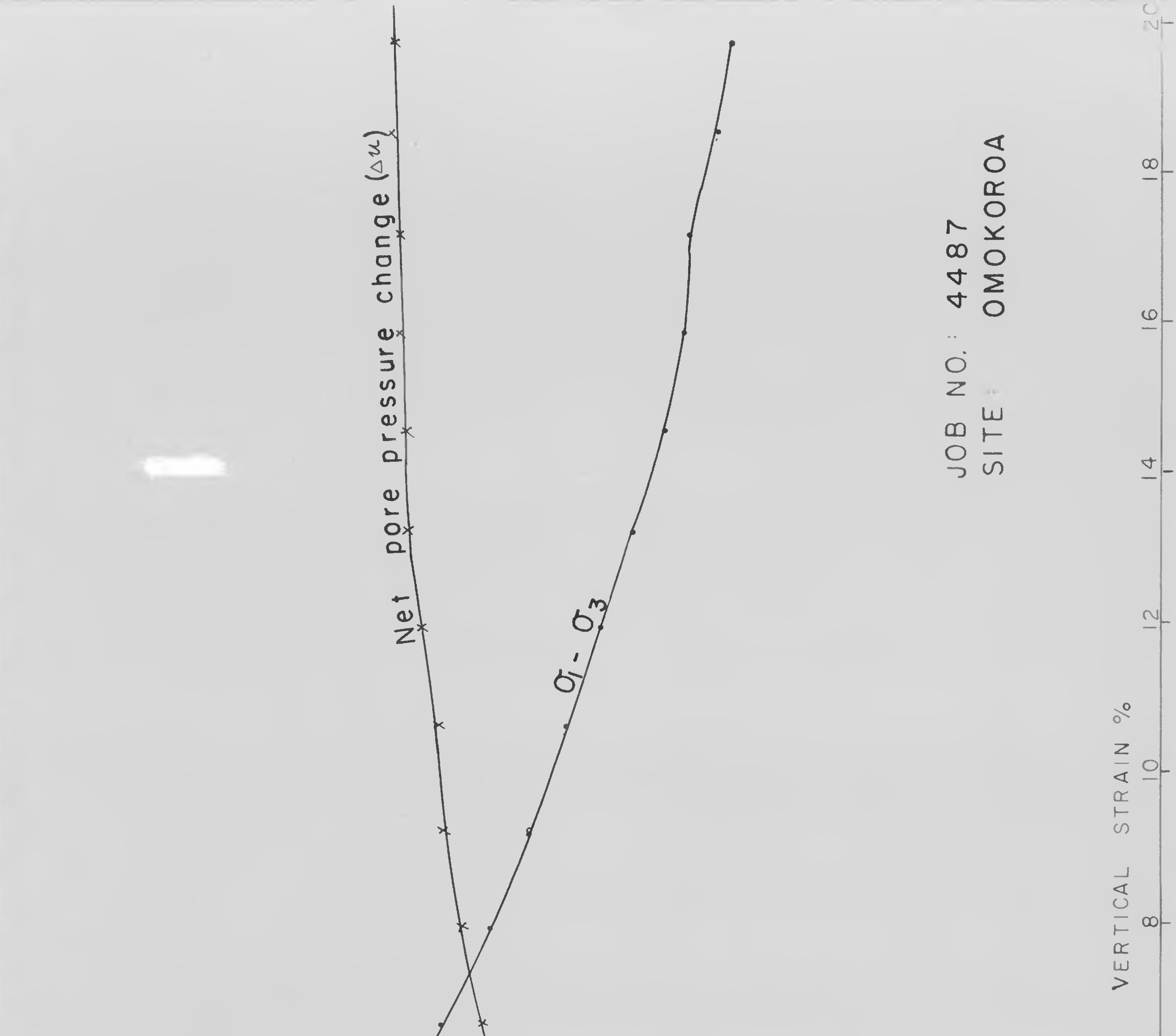




## TRIAXIAL COMPRESSION TEST
## STRESS/STRAIN RELATIONSHIP

BOREHOLE 5 SAMPLE 10 DEPTH 22·2 m
EFFECTIVE CONSOLIDATION PRESSURE 150 kPa

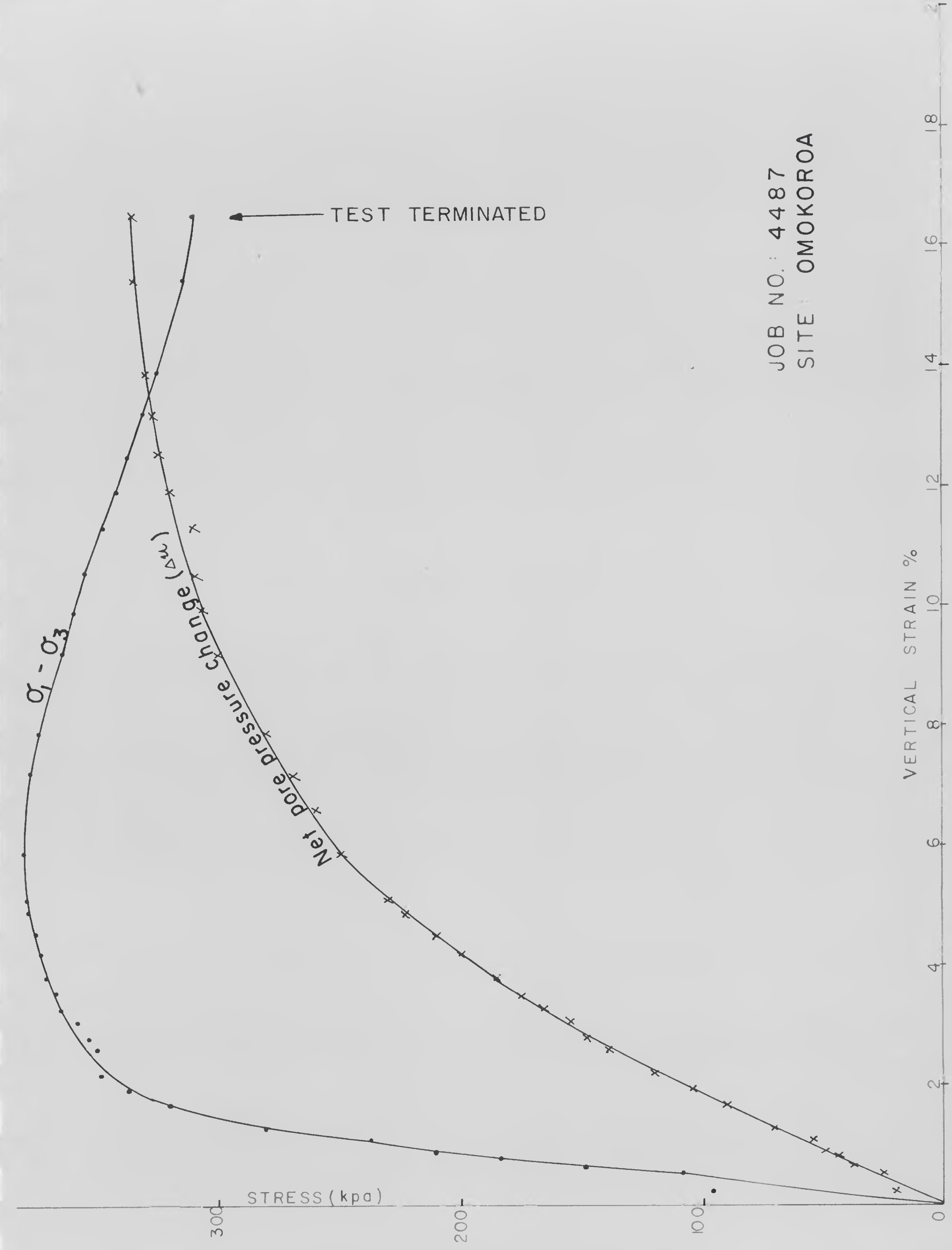
FIG. 2



## TRIAXIAL COMPRESSION TEST
## STRESS/STRAIN RELATIONSHIP

BOREHOLE 5 SAMPLE 10 DEPTH 22·2 m
EFFECTIVE CONSOLIDATION PRESSURE 300 kPa

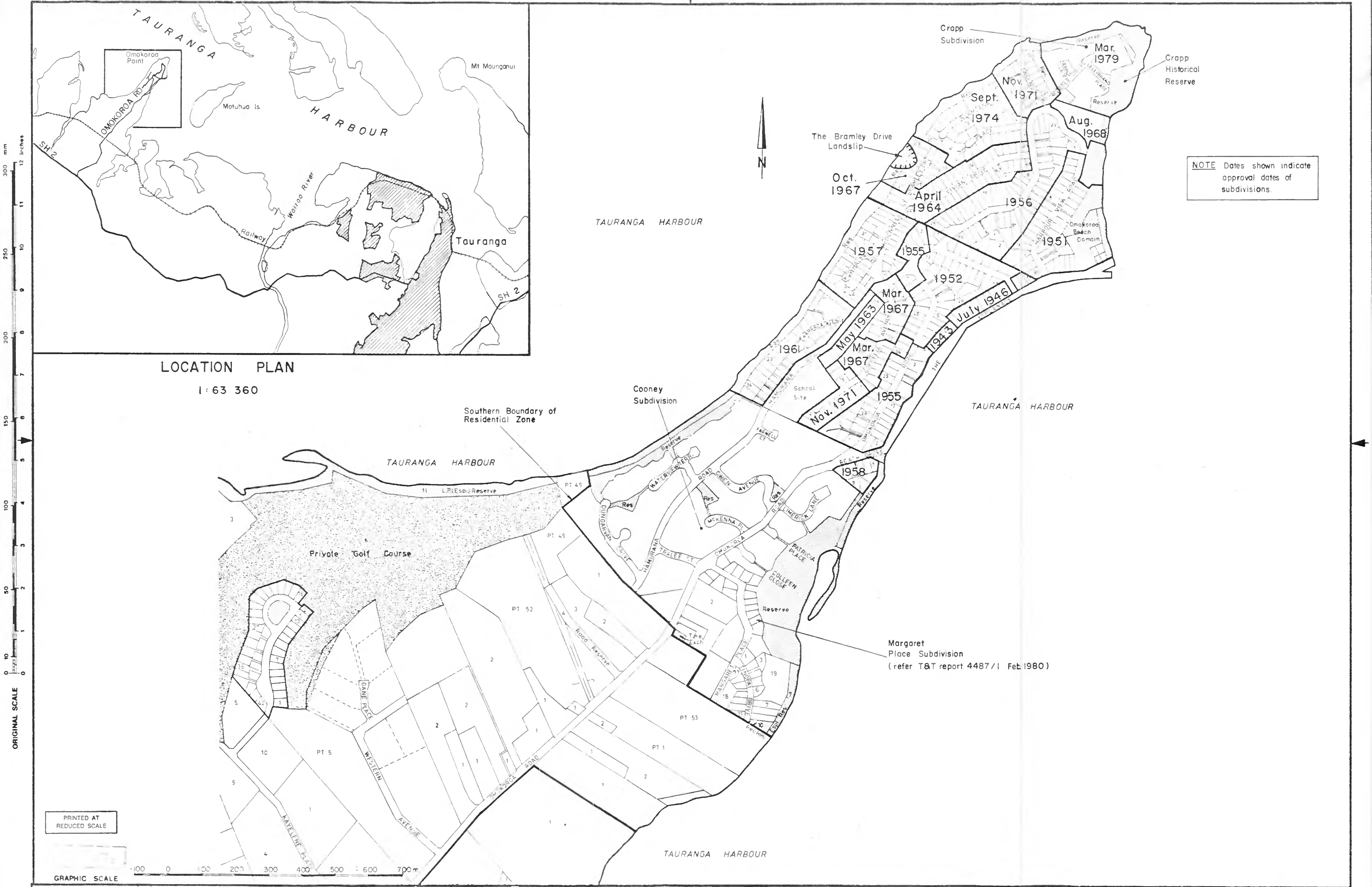
FIG. 3



## TRIAXIAL COMPRESSION TEST
## STRESS/STRAIN RELATIONSHIP

BOREHOLE: 5 SAMPLE: 10 DEPTH: 22·2 m
EFFECTIVE CONSOLIDATION PRESSURE: 450 kPa

FIG. 4



| ORIGINAL SCALE | AMENDMENTS | CKD | DATE | AMENDMENTS | CKD | DATE | REFERENCES |
|---|---|---|---|---|---|---|---|
| 1:5000 | | | | | | | |
| CKD DATE | | | | | | | |

## TAURANGA COUNTY COUNCIL

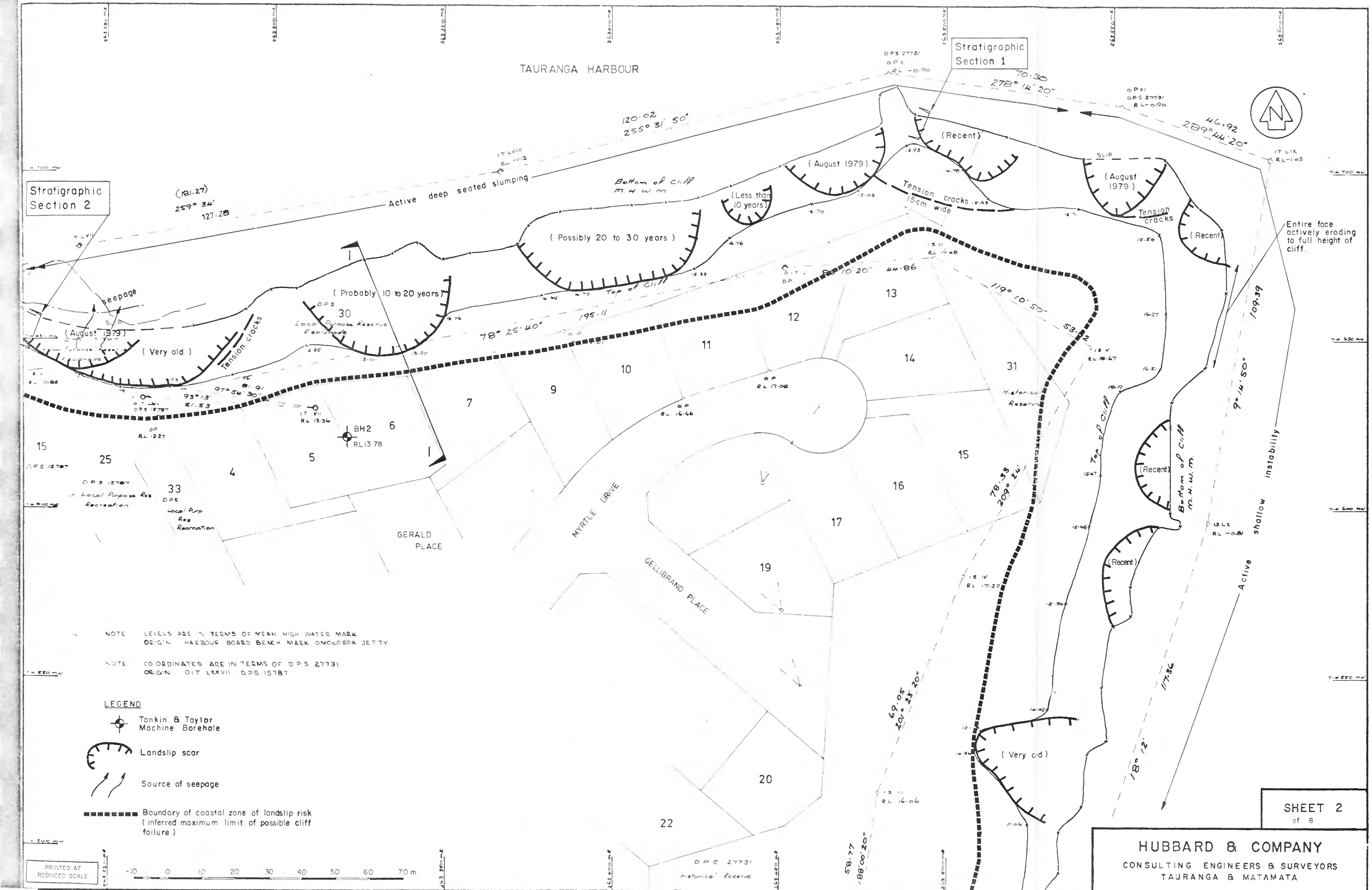
OMOKOROA POINT
LAND STABILITY INVESTIGATION

*Subdivisional and Locality Plans*

metric design

**TONKIN & TAYLOR**
CONSULTING ENGINEERS
& REGISTERED SURVEYORS
47 GEORGE ST., NEWMARKET
AUCKLAND

DRAWING NO.
4487 - 2
0
DATE JAN 1980



NOTE LEVELS ARE IN TERMS OF MEAN HIGH WATER MARK
ORIGIN HARBOUR BOARD BENCH MARK OMOKOROA JETTY

NOTE CO ORDINATES ARE IN TERMS OF D.P.S. 27731
ORIGIN OIT LXXVII DPS 15787

LEGEND

- Tonkin & Taylor Machine Borehole
- Landslip scar
- Source of seepage
- ■■■■■■ Boundary of coastal zone of landslip risk (inferred maximum limit of possible cliff failure)

SHEET 2
of 8

HUBBARD & COMPANY
CONSULTING ENGINEERS & SURVEYORS
TAURANGA & MATAMATA

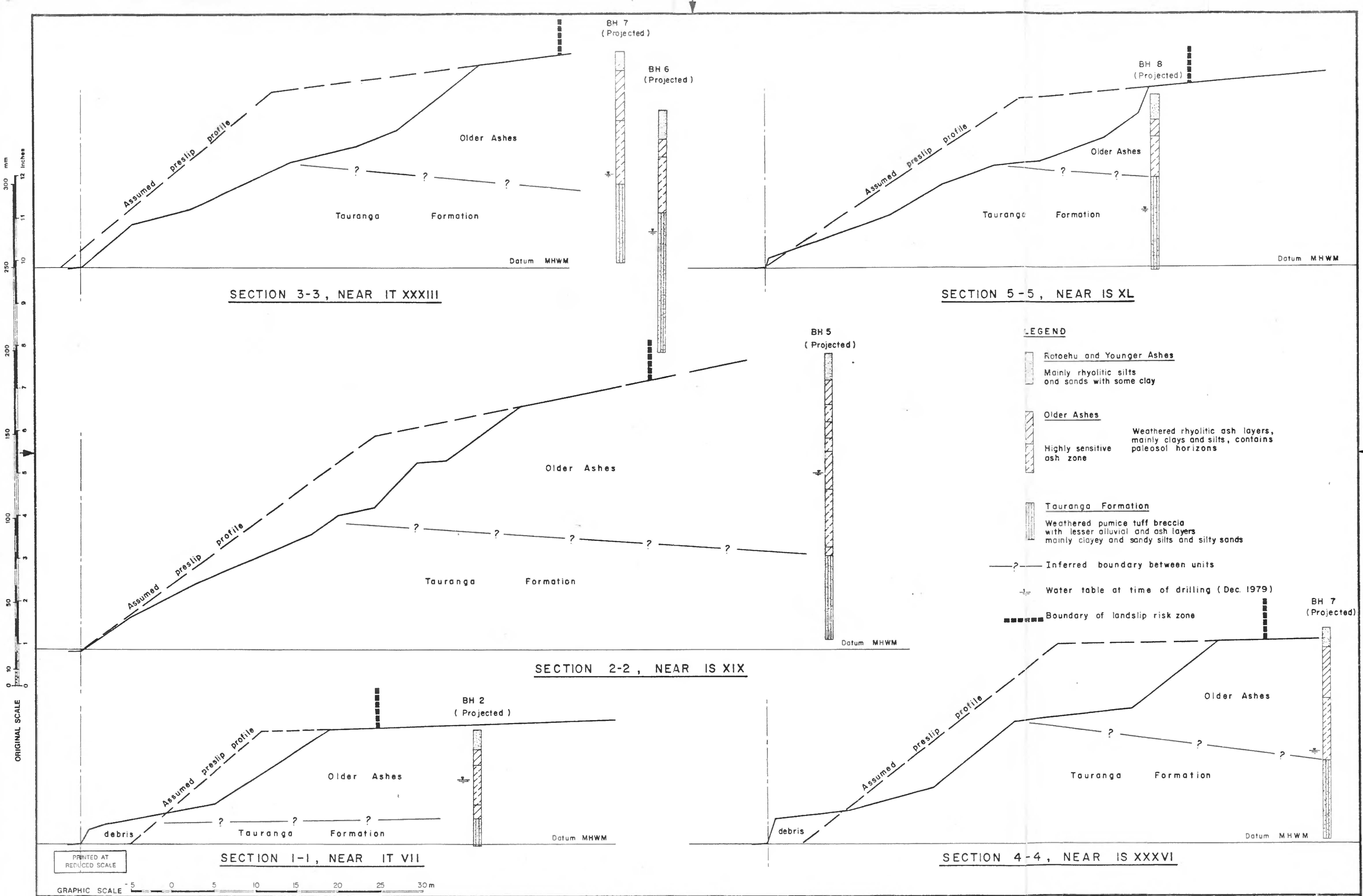
| ORIGINAL SCALE | AMENDMENTS | CKD | DATE | AMENDMENTS | CKD | DATE | REFERENCES |
|---|---|---|---|---|---|---|---|
| 1:500 | | | | | | | Hubbard & Company<br>Ref 80032 1277/2<br>date Nov 1979 |
| CKD / DATE | | | | | | | |

TAURANGA COUNTY COUNCIL
OMOKOROA POINT
LAND STABILITY INVESTIGATION
Coastline Survey - Locations Plan and Risk Zoning

metric design

TONKIN & TAYLOR
CONSULTING ENGINEERS
& REGISTERED SURVEYORS
47 GEORGE ST., NEWMARKET
AUCKLAND

DRAWING NO.
4487 - 3
0
DATE JAN. 1980



SECTION 3-3, NEAR IT XXXIII

SECTION 5-5, NEAR IS XL

SECTION 2-2, NEAR IS XIX

SECTION 1-1, NEAR IT VII

SECTION 4-4, NEAR IS XXXVI

LEGEND

░ Rotoehu and Younger Ashes
Mainly rhyolitic silts and sands with some clay

▨ Older Ashes
Weathered rhyolitic ash layers, mainly clays and silts, contains paleosol horizons
Highly sensitive ash zone

▥ Tauranga Formation
Weathered pumice tuff breccia with lesser alluvial and ash layers mainly clayey and sandy silts and silty sands

—?— Inferred boundary between units

≟ Water table at time of drilling (Dec. 1979)

▪▪▪▪▪ Boundary of landslip risk zone

ORIGINAL SCALE
1:200
CKD DATE

| AMENDMENTS | CKD | DATE | AMENDMENTS | CKD | DATE |
|---|---|---|---|---|---|
| | | | | | |

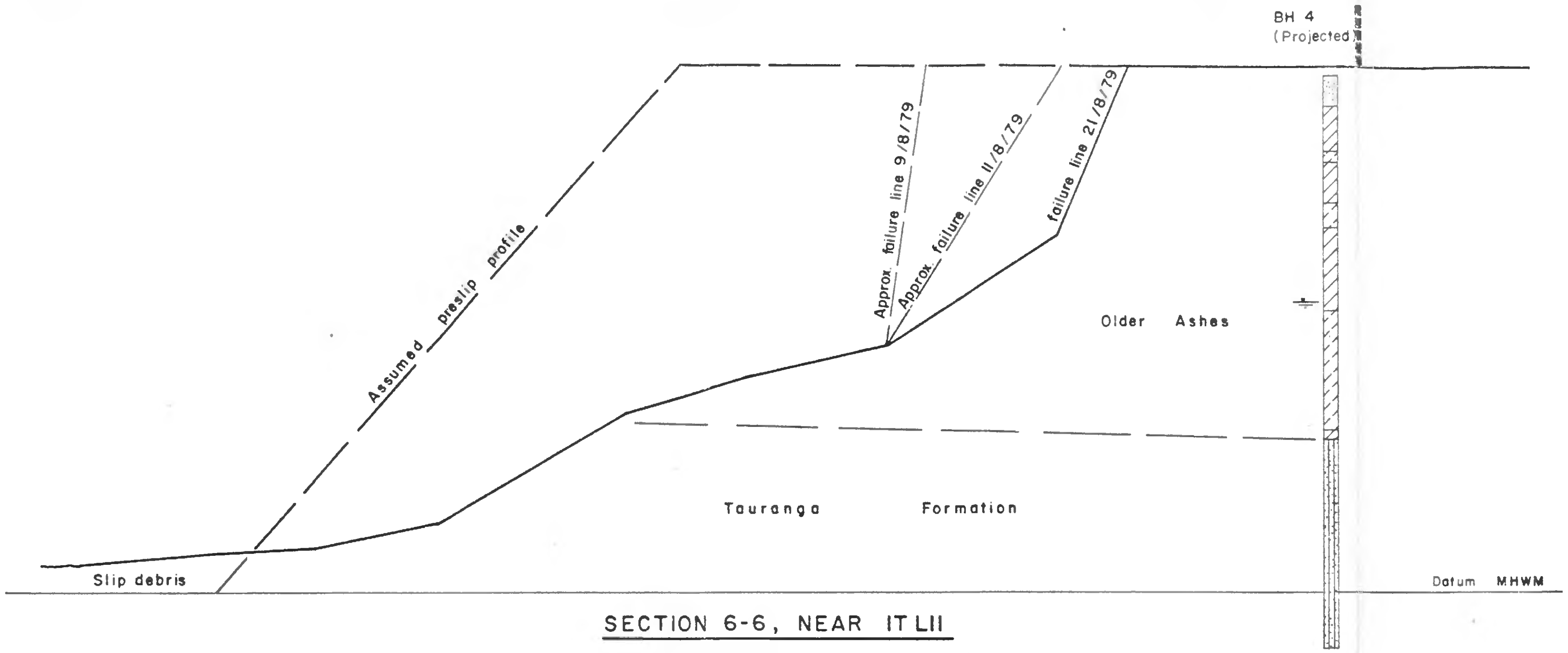
REFERENCES

TAURANGA COUNTY COUNCIL
OMOKOROA POINT
LAND STABILITY INVESTIGATION
*Cross Sections 1-1 to 5-5*

metric design

**TONKIN & TAYLOR**
CONSULTING ENGINEERS
& REGISTERED SURVEYORS
47 GEORGE ST, NEWMARKET
AUCKLAND

DRAWING NO.
4487 - 4
0
DATE JAN 1980

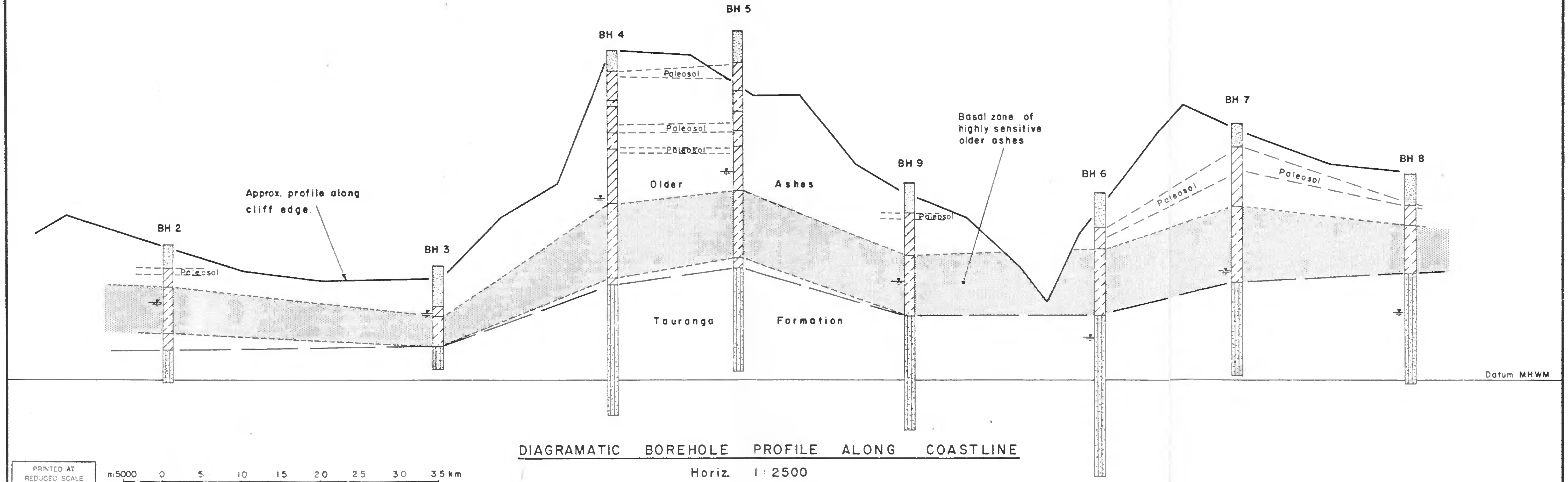


## SECTION 6-6, NEAR IT LII

( Bramley Drive Landslip)

1 : 200

**NOTE** Borehole legend shown on Dwg. No. 4487-4



## DIAGRAMATIC BOREHOLE PROFILE ALONG COASTLINE

Horiz. 1 : 2500
Vert. 1 : 200

PRINTED AT REDUCED SCALE

GRAPHIC SCALE
1:5000 0 5 10 15 20 25 30 35 km
-5 0 5 10 15 20 25 30m

ORIGINAL SCALE
0 1 2 3 4 5 6 7 8 9 10 11 12 inches
0 10 50 100 150 200 250 300 mm

| ORIGINAL SCALE<br>1:200<br>Horiz. 1:2500<br>Vert. 1:200 | AMENDMENTS | CKD | DATE | AMENDMENTS | CKD | DATE | REFERENCES | TAURANGA COUNTY COUNCIL<br>OMOKOROA POINT<br>LAND STABILITY INVESTIGATION<br>*Cross Section 6-6 and Borehole Profile* | metric design | TONKIN & TAYLOR<br>CONSULTING ENGINEERS<br>& REGISTERED SURVEYORS<br>47 GEORGE ST. NEWMARKET<br>AUCKLAND | DRAWING NO.<br>4487 - 5<br>0<br>DATE JAN. 1980 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CKD DATE | | | | | | | | | | | |

**TONKIN & TAYLOR LTD**
CONSULTING ENGINEERS
REGISTERED SURVEYORS
AND TOWN PLANNERS

Auckland — 47 George St, PO Box 5271
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Wellington — Molesworth House
101 Molesworth St, PO Box 12152
Telephone (04) 726-997 ☐

Whangarei — 7 Hunt St, PO Box 1261
Telephone (089) 89-055 ☐

Tauranga — 111 Cameron Rd, PO Box 231
Telephone (075) 88-021, 88-131 ☐

# DOCUMENT TRANSFER RECORD

Date: 5/9/84
Your ref:

To: Mr. B.F. Houghton
Address: c/o N.Z. Geological Survey
Box 499 Rotorua.

Attention:
Contract:
Job No: 4487

Transmitted herewith:- Letters ☐ Photos ☑ Negatives ☐
Prints ☐ Transparencies ☐ Specifications ☐ Schedules ☐ Calculations ☐

| Dwg or Ref No. | Rev | Description | Copies |
|---|---|---|---|
| Original of | | fig 7.5 report 4487 as requested by Chris. Gulliver | 1 |
| | | PLEASE RETURN | |

Remarks:

Sent by ☐ Our messenger
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Signed for
Tonkin & Taylor Ltd.

22/2/82

BEFORE THE PLANNING TRIBUNAL

Judge Sheppard
+ 2 others

IN THE MATTER of the Town and Country Planning Act 1977

-and-

IN THE MATTER of an appeal by J.V. and W.T. Crapp, O.C. Cooney and R.A. Van Heyst and OTHERS

Appellants

A N D: THE TAURANGA COUNTY COUNCIL

Respondent

I, CHRISTOPHER PYM GULLIVER of Auckland, Engineering Geologist state as follows:

1. I am an Engineering Geologist and an associate partner of the firm of Tonkin & Taylor Limited, Consulting Engineers of Auckland. I hold the qualifications BSc, BE (Honours) having graduated in 1970. I am a member of the New Zealand Institution of Engineers and have been a registered engineer since 1976. As an engineering geologist much of my work is involved in land stability issues and I have investigated and advised upon a large number of land slip situations, both following slips and with a view to achieving stability in unstable land.

2. FOLLOWING the land slips along the western coastline at Omokoroa in early August 1979, Tonkin & Taylor Limited were instructed to make a detailed land stability investigation of the Omokoroa Point in conjunction with the New Zealand Geological Survey of the DSIR. The report was provided to

the Tauranga County Council in May 1980 and I now produce a copy of the report to the Tribunal. This report was prepared jointly by myself and Dr B.F. Houghton of the DSIR at Rotorua under the supervision of Mr D.K. Taylor, a principal in the firm of Tonkin & Taylor Limited.

3. FROM the investigations we concluded that the Bramley Drive land slip was primarily caused by the build up of pore water pressures within a deep layer of extremely sensitive weathered volcanic ashes. The delicate structure of those soils meant that when they became overstressed they were susceptible to sudden catastrophic failure. There were a number of contributing factors to the land slip which in our view tended to make the area prone to failure. These were:

(a) The height of the sea cliffs at the location and consequent great thickness of older ash layers.

(b) A high natural ground water table.

(c) The results of subdivisional development such as the removal of trees and minor earth works.

(d) The standard use of soak pits for disposal of property storm water and domestic waste water.

(e) The long term effect of marine erosion.

4. IN the course of the report an analysis was made of the land slip problem, that portion of

the report having been prepared by myself. This is contained in section 8 of the report commencing at page 34. In the course of the study, some 50 land slips in the area were identified, there being 17 major land slips which are listed on page 37 of the report. In order to assess the stability risk and the limits of possible future failures, it was assumed that future land slips would continue to have the same general modes of failure and produce the same failure shapes as in the past. From our analysis a model for the failure mechanism was established. Based on the measurement of all previous major land slips a coastal zone of land slip risk was defined. This zone is shown on the drawings annexed to the report numbers 4487-3 sheets 1 to 8.

5. THE boundary of this zone is the inferred maximum limit beyond which I will not expect land slips to occur, say within the next 100 years. This failure limit has been obtained by assuming that the ratio of vertical cliff height to horizontal depth from base of cliff, for all land slip failures will be within the ratio of 1:2.25. From our measurements 60% of all the major faiures to date have height to depth ratios between 1:1.8 and 1:2.2 as shown in the table on page 37 of our report. None of the major failures have yet exceeded an upper limit of 1:2.2.

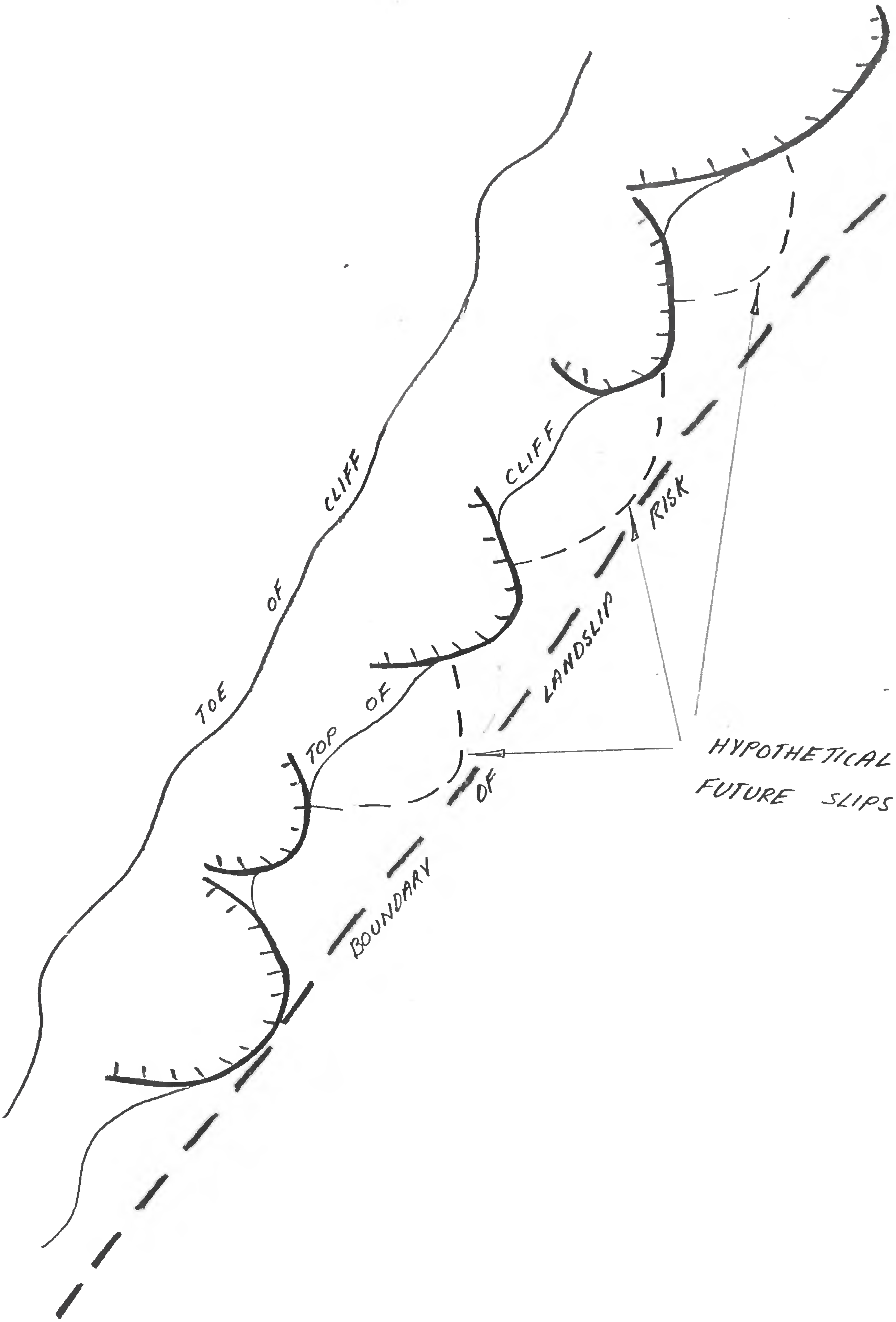
6. MY concern in respect of future land slipping is not so much the likelyhood of the larger old

slips continuing to retreat back to the risk zone boundary, but rather the possibility that new slips could occur within the gaps between, or adjoining the old failures, and that these new slips could conceivably retreat back to the risk zone boundary. Some of the larger slips which have occured are composite slips and include within them the sites of smaller less extensive slips. Annexed to my evidence is a sketch illustrating this potential situation.

7. THE boundary of the coastal zone of land slip risk is consequently not an arbitrarily drawn line, but a calculated limit related to cliff height and based upon the measurement of a large number of previous cliff failures. The line is thus the maximum limit of possible cliff failure inferred from the evidence of past cliff failures and detailed soil investigations.

8. I believe that having regard to the potential land slip risk, building should not generally be permitted within the zone defined by the report.

DATED at this day of February 1982


TOE OF CLIFF
TOP OF CLIFF
BOUNDARY OF LANDSLIP RISK
HYPOTHETICAL FUTURE SLIPS

'B'

## COUNTY OF TAURANGA

## SECOND REVIEW OF THE DISTRICT PLANNING SCHEME

Pursuant to the provisions of Section 47 (2) of the Town and Country Planning Act 1977 the Tauranga County Council proposes the following variations to the Second Review of the District Planning Scheme.

### Proposed Variation No. 1 - Land Stability Omokoroa

A. To add the following clause to the Scheme Statement

### Clause 21.1.9 Land Stability Omokoroa

During August 1979 a number of landslips occurred along the western foreshore of the Omokoroa Peninsula damaging and endangering several properties. To advise what action should be taken in that area the Council engaged a firm of consulting soils engineers to investigate land stability in the affected area. Their report contained a number of recommendations including the siting of future buildings and the disposal of stormwater and septic tank effluent.

A copy of the report "Omokoroa Point Land Stability Investigation" by Tonkin and Taylor, Consulting Engineers, Auckland, is available for perusal at the County Office.

Acting on the report the Council has adopted the following policies:

Areas identified in the report as being "vulnerable to long term landslip risk" have been shown on planning maps 23 and 24. [In these areas buildings or extensions to buildings will not generally be permitted.]

Possible deletion

In these areas identified as such on the planning maps [and in areas in proximity thereto] applications for building permits must be supported by a comprehensive report covering stability aspects, prepared by a registered engineer experienced in Soil Mechanics. The Council shall refuse to issue a building permit unless the provisions of Section 641 (2) of the Local Government Act 1974 are satisfied.

Minor alterations and repairs to existing buildings and the construction of accessory buildings may be permitted provided the County Engineer is satisfied that the probability of any damage from potential landslips, and the likely extent of such damage is not increased by doing so.

Earthworks and development, including significant planting of trees or shrubs will only be permitted subject to the prior approval of the County Engineer and any application for such approval may have to be supported by a report prepared by a registered engineer experienced in Soil Mechanics.

B. To show on planning maps 23 and 24 the areas defined as "vulnerable to long term landslip risk". (See plans attached).

Section 36 (not + Section 36(1)(a))
+ Section 641
District scheme is Public Doc on which public should be able to rely.

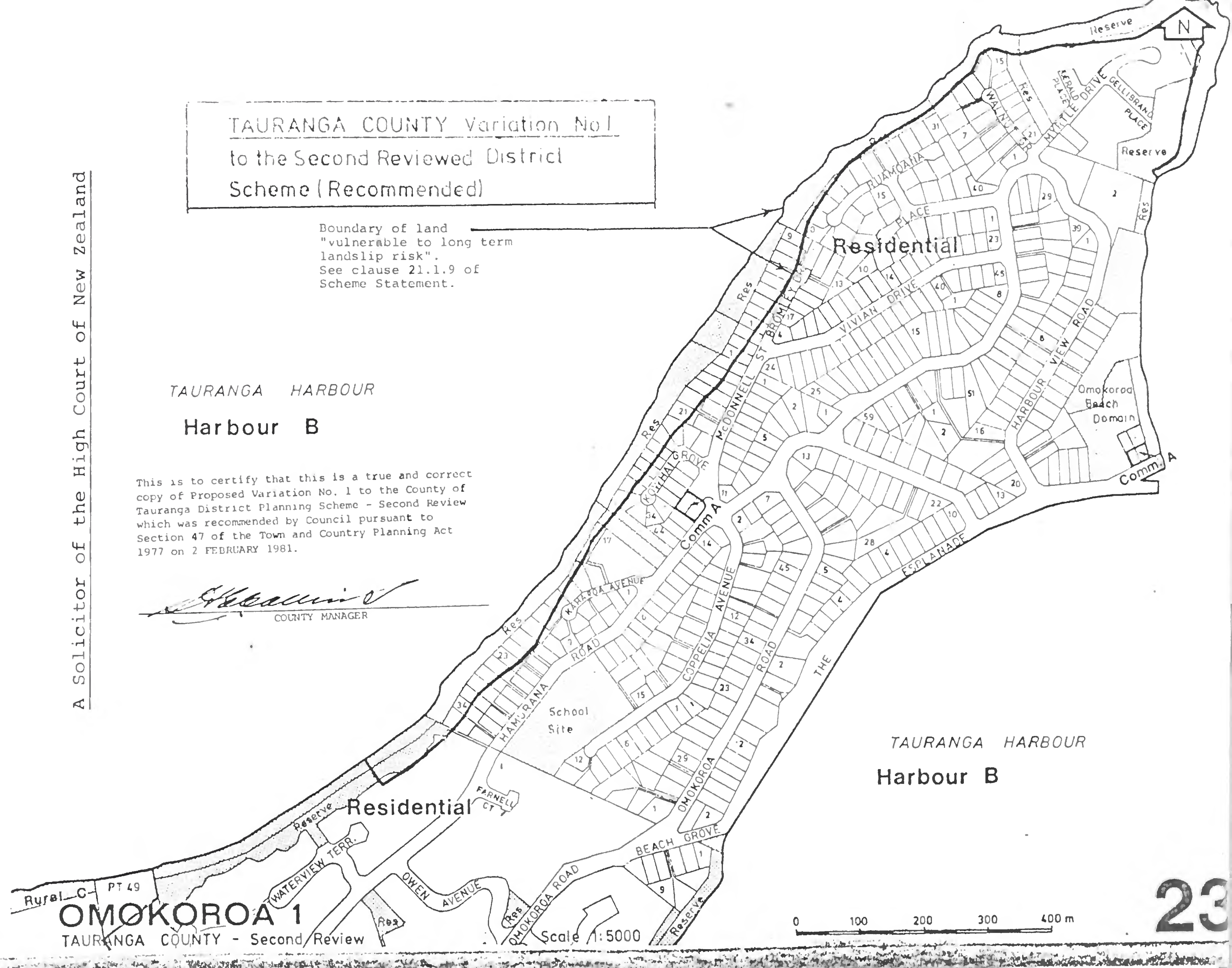
A Solicitor of the High Court of New Zealand

TAURANGA COUNTY Variation No 1
to the Second Reviewed District
Scheme (Recommended)

Boundary of land "vulnerable to long term landslip risk". See clause 21.1.9 of Scheme Statement.

This is to certify that this is a true and correct copy of Proposed Variation No. 1 to the County of Tauranga District Planning Scheme - Second Review which was recommended by Council pursuant to Section 47 of the Town and Country Planning Act 1977 on 2 FEBRUARY 1981.

COUNTY MANAGER



OMOKOROA 1
TAURANGA COUNTY - Second Review
Scale 1:5000

23

*Harrington House,*
*Cnr Willow & Harrington Streets,*
*Tauranga, New Zealand.*
*Phone 82-530 P.O. Box 257*

12 February 1982

FILE REFERENCE
DATE RECEIVED 16 FEB 1982
N
CPG

Messrs Tonkin & Taylor,
Consulting Engineers,
P.O. Box 5271,
AUCKLAND.

Mr Gulliver

Dear Sir,

Omokoroa Land Slip Appeals

I refer to my letter of 5th February. It appears that Mr Mitchell will not be called to give evidence, however the Appellants have required me to have his reports available at the hearing.

I note that in respect of Margaret Place, Omokoroa Mr Mitchell's report was sent to you by Mr McKenzie, the County Engineer and that you commented on it in a letter dated 21st August 1980 under reference number 4487. It would be prudent for you to refresh your memory of the contents of Mr Mitchell's report and your letter of 21st August 1980 which sets out the basis upon which you advised the Council that you cannot endorse Mr Mitchell's revised recommended building limitations.

There has also been some apparent confusion amongst the various Appellants as to just which line it is the Council has imposed on the District Scheme.

The line adopted is the boundary of land slip risk as defined by your report and does not include the further six metre building restriction suggested in the report. Consequently we are in a position where the Council have taken a less conservative attitude than that recommended by your report. This does not adversely affect our position at all and I comment on the matter only to let you know what information I am getting from the other side as to the likely approach they might take.

Yours faithfully,

J.L. Saunders

4487

8 February 1982

Mr J.L. Saunders
Barrister and Solicitor
PO Box 257
TAURANGA

Dear Sir,

**OMOKOROA STABILITY PLANNING APPEAL**

I return the corrected draft of my evidence for the above Appeal, together with a sketch relating to Item 6.

As mentioned to you it is possible that Mr Taylor will want to attend the hearing. He is due to return from overseas on 17 February.

Yours faithfully
TONKIN & TAYLOR LTD

C.P. Gulliver

Encl.

CPG/Gay

*Harrington House,*
*Cnr Willow & Harrington Streets,*
*Tauranga, New Zealand.*
*Phone 82-530 P.O. Box 257*

5 February 1982

Messrs Tonkin & Taylor,
Consulting Engineers,
P.O. Box 5271,
AUCKLAND.

Mr Gulliver

Dear Sir,

## Omokoroa Land Slip Planning Appeals

I have had discussions with Counsel for the Appellants and it now appears clear (and I expect to have it confirmed formally early next week) that the only issue that will be put before the Planning Tribunal will be the question of how the land slip risk problem is to be dealt with in the District Scheme and that the technical aspects of your report will not be in question. Notwithstanding this, it is still necessary for the formal evidence as drafted by me to be presented.

The Appellants have required that Mr McKehnzie, the County Engineer, be available to give evidence if required as he presented certain reports to the Council. You may well be questioned on those and accordingly I enclose them for your perusal.

The Appellants have also obtained advice from Mr M.T. Mitchell, a consulting engineer who has prepared three reports. They have indicated to me that Mr Mitchell will not be called to give evidence. If however he is to be called (and I will know at least a week in advance) I will let you have his reports for perusal in case you have to be questioned on them.

Yours faithfully,

J.L. Saunders

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# TAURANGA COUNTY COUNCIL

## REPORT ON LAND STABILITY INVESTIGATION

## MARGARET PLACE, OMOKOROA

Following the commissioning, by Council, of an investigation into land stability at Omokoroa, discussions were held with Mr O.C. Cooney and his advisers on the likely affect this investigation would have on his subdivision. Because the survey plan of the Margaret Place subdivision had been approved by Council (on 4/12/78) and some agreements for sale and purchase had been entered into for sections bounded by a steep slope on the seaward side, Mr Cooney was most anxious that an early decision be made on whether or not building permits would be issued for these sections.

As a result, an agreement was made to include seven residential allotments on the eastern side of Margaret Place in the overall investigation being undertaken by Tonkin and Taylor, Consulting Engineers of Auckland. It was also agreed that if practicable, an interim report would be prepared on the Margaret Place sections and that the costs incurred in obtaining the necessary information and writing the report would be shared between the County and Mr Cooney.

This special report by Tonkin and Taylor has now been received and is attached herewith.

## COMMENTS ON THE RECOMMENDATIONS CONTAINED IN TONKIN AND TAYLOR'S REPORT

The following comments are offered on the recommendations contained in Tonkin and Taylor's report:

1. I agree that no dwelling should extend beyond the building line shown on 4487-1. Although the building line has been only arbitrarily established 6 m from the assumed limit of potential failure, some reasonable distance must be maintained between any dwelling and the possible future cliff edge; 6 m appears to me to be reasonable.

2. Because I cannot believe that any accessory building situated right on the edge of a failure would retain its usefulness for the purpose it was constructed - such as a private garage or workshop - I would go further and recommend that no building, for which a building permit is required, should extend beyond the building limit line.

3. The Tonkin and Taylor report makes it clear that building within the recommended limit still involves some risk. Probably the only sure way to avoid any possibility of a future claim for damages by an owner of any building affected by landslip, is to refuse building permits altogether.

   However I consider that to refuse building permits in this case would be unwarranted.

   It is generally agreed that an acceptable answer to any allegation of negligence on Council's part - and negligence would have to be established before any claim could succeed - is that the Council acted reasonably and on proper technical advice.

Dispensation from Council's front yard - and possible side yard - requirements will be required for some of the allotments if they are to retain their usefulness for building purposes.

Notwithstanding any dispensations which may be given, it seems certain that Lot 48 will not be suitable for residential purposes and that Lot 47 must, at least, be doubtful.

5. The recommendation that soak pits for the disposal of sewage effluent, should be avoided on all elevated lots, is a sensible precaution although one which could cause some difficulty.

   The only satisfactory and practical way I can see of complying with this recommendation is for Council to allow the construction of a communal soakage trench, in the reserve below, to take effluent from all properties.

   A small diameter effluent pipeline constructed down the western (roadside) boundaries to the north side of Lot 53, and thence down the accessway to the reserve would appear to be the most appropriate way to convey the effluent to the trench.

   Although effluent from individual properties could be separately piped down the bank to soakholes in the reserve, trenching down the steep face could lead to future problems if the ground is not restored satisfactorily and maintained afterwards.

6. There should be no difficulty in getting stormwater from houses, driveways and hardstanding areas, into the street channel.

7. Council cannot really enforce recommendations (c) and (d) of the report because it neither has the power to prevent an owner discharging water over the steep bank, nor has it the power to require the provision of horizontal relief drains at seepage points on the face.

   However it can inspect the area periodically, advise the owners of any changes which could lead to instability and encourage them to undertake any necessary remedial work.

8. The same comment applies to recommendation (e) except that some control can be exercised at the time of issuing building permits.

## REMEDIAL WORK TO IMPROVE STABILITY OF SUBDIVISION

Although not mentioned in the report it may be possible for the subdivider to carry out remedial work to improve the stability of this part of the subdivision, thus obviating the need for a building line limit. The work necessary would probably involve extensive earthworks to flatten steep slopes and some sort of drainage to control seepage.

Any such proposal put forward by the subdivider would need to be backed up by a comprehensive investigation and a thorough technical appraisal before being accepted by Council.

## RECOMMENDATIONS

1. That no building for which a building permit is required, be permitted to extend beyond the building limit shown on drawing 4487-1.

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2. That the Chief Inspector be authorised to grant reasonable dispensations from Council's yard requirements where this is necessary to retain the usefulness of sections for building purposes.

3. That the use of soak pits on elevated lots for the diposal of sewage effluent and stormwater be not allowed and that piped disposal systems be provided to the satisfaction of the County Engineer.

4. That the Council agrees in principle to the use of the adjacent reserve for sewage effluent and stormwater disposal from the subdivision.

5. That no modification of the existing steep hill slope by cutting or filling be allowed without Council's approval.

I.D. McKenzie
COUNTY ENGINEER

21 February 1980

# TAURANGA COUNTY COUNCIL

## OMOKOROA LAND STABILITY INVESTIGATION

The report presented to Council today contains results of an investigation into land stability at Omokoroa carried out by Tonkin and Taylor, Consulting Engineers, in conjunction with the New Zealand Geological Survey, D.S.I.R. The study was commissioned by Council following a series of land slips along the north western coastline of Omokoroa in August 1979. The largest of these landslips was at Bramley Drive where a 34 metre high cliff failed catastrophically endangering five houses which were evacuated and subsequently removed.

Because the report is a fairly lengthy document, contains a substantial amount of technical data and only a limited number of copies are available, I have compiled an abridged version which I think covers the main observations, results, conclusions and recommendations contained therein.

A copy of this summary is attached herewith.

## RESULTS

The report outlines the main factors which influence land instability on the Omokoroa peninsula. These are:

(a) The nature ~~and~~ of the geology and soil conditions.

(b) Rainfall frequency.

(c) Marine erosion.

(d) Subdivisional development.

(e) Drainage and Wastewater Disposal Systems.

By analysing the results of the various investigations carried out and corellating these with observations of existing slip characteristics the failure mechanism has been established.

By demonstrating the uniformity in the overall proportions of major slips that have occurred over the last few hundred years, the Consultants have been able to define a zone of landslip risk. The boundary of this zone is the inferred maximum limit beyond which they would not expect landslips to occur.

No doubt the public's immediate attention will be focused on this aspect of the report especially since the report concludes that: "........ periodic major failures seem likely to continue .........."

However, recommendations for the lessening or avoidance of these stability problems are also made in the report. These can be summarised as follows:

1. That on those lots not yet built upon, no dwelling should be allowed within a 6 metre set back from the risk zone boundary.

2. That the use of soak pits for stormwater discharge from coastal lots be discontinued and that all stormwater be discharged to high tide level by piped systems.

3. That a reticulated sewerage system be provided in the long term, and that in the interim, disposal of wastewater via surface irrigation fields or domestic evapo-transpiration systems be utilised, instead of deep soak holes.

4. That where significant seepage is apparent in those areas of recent slipping, short lengths of perforated pvc pipe should be installed in the cliff face to control further possible erosion at the exits of the seepages.

5. That periodic inspections be carried out along the length of the coastline after periods of very heavy rainfall to record new slips, seepage sources, tension cracks and any other features which could indicate a deterioration of the cliff stability and which may require treatment.

6. That the existing system of seawalls be improved or extended in areas of obvious stress or excessive erosion.

7. That a programme of replanting be established within areas of recent or active slipping.

8. That immediate attention be given to planting the Bramley Drive slip face and controlling erosion and seepage exits from the rear of the bench.

9. That information on ground water levels be obtained by monitoring water levels in borehole stand pipes and recording rainfalls on the peninsula.

ACTION REQUIRED

line of
[illegible]

1. It is suggested that in the meantime no decisions be made on the recommended building line restrictions. Further investigations into the stability of certain areas of Omokoroa are at present being carried out by a privately engaged soils engineer who will be making submissions to Council within a short time. Council will therefore have the opportunity of studying another point of view before deciding on the matter.

2. Immediate action should be taken by Council to plant the Bramley Drive Slip and to control erosion from seepage points on the slip face. A programme of planting should also be commenced along the reserve where active slipping is still occurring.

3. Investigations should be commenced by Council staff as soon as possible into the alternative methods available to each owner for dealing with stormwater discharge from his property.

This will involve checking the capacity of all existing piped stormwater drains, ascertaining which properties can discharge into street channels, investigating the use of communal private drains to discharge stormwater directly down the sea cliffs to high tide level and developing standard designs and techniques for doing so.

Owners should then be encouraged to change their stormwater disposal systems - where these now involve soak pits - for more suitable methods.

4. Investigations should be carried out as required and advice given on alternative sewerage disposal methods presently available. Discussions should also be held with the Community Council on the possibility of providing a reticulated sewerage system for the peninsula in the long term.

5. In those areas where erosion is significant, the provision of protection works should be undertaken as soon as possible; this will involve investigation and design work by Council staff.

6. It is suggested that in co-operation with the Community Council a regular observation programme to record ground water levels, rainfall, seepage sources, ground movement, marine erosion and other significant coastal changes, be established.

I.D. McKenzie
COUNTY ENGINEER

13 May 1980

# TAURANGA COUNTY COUNCIL

## OMOKOROA POINT LAND STABILITY INVESTIGATION

Following a series of landslips along the north western coastline of Omokoroa in August 1979, Council commissioned Tonkin and Taylor, Consulting Engineers of Auckland to investigate and report on the question of land stability. The resulting report was considered by Council at a meeting on 19th May 1980, and the following resolutions adopted:

1. That the report of Tonkin and Taylor be received.
2. That the recommended remedial planting and seepage control works be commenced on the Bramley Drive slip and adjacent areas, subject to the consent of the landowners being obtained, with the cost being apportioned equally between the County and the Omokoroa Community Council.
3. That the County Engineer produce a report and programme for planting other slip areas.
4. That investigations be commenced into recommended alternative methods of stormwater and wastewater disposal from residential properties, and into the provision of protection works where marine erosion is sigificant.
5. That in co-operation with the Omokoroa Beach Community Council, a regular observation programme to record ground water level, rainfall, seepage sources, ground movement, marine erosion and other significant coastal changes be established.
6. That the County Engineer report on steps necessary to identify other areas of potential land instability within the County.

Since that meeting, initial remedial planting has been substantially completed on the Bramley Drive slip and the seepage points controlled. Further planting of larger species will be carried out once the face of the slip has been sufficiently stabilised to enable trees to be safely established.

Mr Brian Smith of the Engineering Division staff is at present investigating the existing stormwater disposal systems at Omokoroa and assessing their potential capacity to accept stormwater, which is at present being discharged into soakpits. Once this information has been determined he will proceed with the design of piped or flumed discharge systems to take the remaining stormwater drainage down the seacliffs to high tide level.

Ground water levels are being monitored regularly by Council's staff and Mr K.D. Grant of Hamurana Road is keeping rainfall records which will be made available to us when required.

Mr Sherring will be reporting on further monitoring of coastal changes and the need to plant other slip areas, in due course.

The question of identifing other areas of potential instability within the County is discussed later in this report.

## RISK ZONE

One of Tonkin and Taylor's recommendations related to the risk of building along the coastline. It is worth repeating the relevant sections of their report on this aspect.

> "Major deep failures similar to the one at Bramley Drive, have occurred over a long period along the entire length of coastline bounded by high cliffs. Periodic major failures seem likely to continue, the magnitude of which, based on the evidence of past failures, will be governed by the height of the cliffs. This investigation points to no area of coast which can be said with any certainity to be free from the risk of major instability in proportion to height above sea level.
>
> The prime cause of failure seems to be increased ground water levels, resulting from periods of high rainfall, acting in conjunction with the particular geological and soil conditions which exist in the area.
>
> Because these are beyond the control of man the most prudent measure is to provide, by means of building restrictions, a clear buffer zone, in which natural processes can proceed with less expensive and dangerous consequences.
>
> In Section 8.6 a coastal zone has been defined in which land is considered to be vulnerable to long term landslip risk. The boundary of this risk zone defines the limit beyond which we would not expect landslips to extend.
>
> We recommend that in all new areas of subdivision or on those lots not yet built upon, that no dwelling should be allowed within an arbitrary setback distance from the defined risk zone. We suggest as a general rule that a six metre setback from the risk zone boundary should be allowed.
>
> The purpose of such a setback behind the risk zone boundary is to:
>
> (a) Allow for the inevitable uncertainity in defining such a line, and,
>
> (b) In event of failure, to allow some reasonable distance between any building and the edge of the landslip."

A similar recommendation had been made by Tonkin and Taylor in an earlier interim report on seven residential allotments in Margaret Place, presented to Council on 3 March 1980. As part of the general investigation it had been agreed that special consideration would be given to the recently approved subdivision of Mr O.C. Cooney's land at Margaret Place.

At that time, at Mr Cooney's request, consideration of the report by Council was deferred pending receipt of a "second opinion" commissioned by Mr Cooney.

Similarly, because the results of this independent investigation - carried out by Mr Mark T. Mitchell, Consulting Geotechnical Engineer of Hamilton - had not been received by the time the main report was presented to Council, Tonkin and Taylor's recommendation concerning the risk zone and the restriction on building along the coastline, was not considered at the May meeting.

## RESULTS OF INDEPENDENT INVESTIGATION

Mr Mitchell's report on his investigation to review the general stability of the Margaret Place site, has been received and is summarised below. He was also retained to investigate and report on the recently approved Crapp subdivision, located at the north eastern end of the Omokoroa Peninsular, and the results of this have also been received.

### (A) MARGARET PLACE

As part of his investigation Mr Mitchell drilled six bore holes ranging in depth from 7.9 metres to 24.4 metres. He encountered similar soil profiles to those found in the Tonkin and Taylor borehole, and also confirmed the uniformity of soil conditions over the subdivision, and general correspondence in the levels of the main geological boundaries.

The main conclusions in his report are as follows:

1. As recommended by Tonkin and Taylor, sewage effluent should not be disposed of into soakpits or drainfields on elevated lots, but should be piped to a lower level, and all concentrated stormwater from roofs and sealed driveways should be collected and discharged into street channels.

2. From the ground profiles it appears that each of the slopes has two distinct parts:

   An upper steeper part lying at a slope of 35 degrees to the horizontal and a lower flatter part lying at a slope of about 20 degrees to the horizontal. It is considered that the lower slopes consist of accumulated debris from the gradual erosion of the steeper slope above. The upper part is believed to be the resultant of a natural parallel retreat on an exposed slope, the retreat being brought about by near-surface ground water movement.

3. The major landsliding took place under a different environment than that existing today and therefore it is unlikely that it will be repeated under present circumstances. Unlike the areas along the north western coastline where tidal action is continually removing landslip debris, the slopefall debris in the Margaret Place area is not removed, but instead remains in the lower slope where it effectively serves as a buttress to prevent large scale or deep seated slope movement.

4. The results of a series of simplified slope stability calculations show that a state of marginal stability would exist within about the outer 0.5 metres of the slope, where ground water flows are high enough to provide buoyancy to the overlying soils. For the slope to be effectively stabilised against this type of slipping, these groundwater flows will have to be diverted away from the critical near-surface location.

5. It is considered that the Margaret Place subdivision could proceed with some adjustment to section boundaries provided due consideration was given to control of the near-surface slipping of the higher slopes. This could be achieved by horizontal drilling of drainholes into the slope, and by suitable planting of the slopes. If control of the near-surface slipping is not attempted, then it is possible that, over a very long period of time, parallel retreat of the slope will occur, until the upper two or three metres stands at about 35 degrees inclination.

6. A further six metre setback from this long term slope profile is suggested as being somewhat conservative. If no remedial slope measures are undertaken, then structures could be built up to the assumed limit of potential cliff failure, provided deepened foundations are used.

7. It is recommended that a series of inclined drains be drilled into the cliff at about 10 metre intervals around the slope face. The drains are to be drilled from about 4 metres below the top of the cliff and all obvious scarps should be planted with suitable shrubs or low trees, and grassed, to prevent further erosion. If this work is satisfactorily carried out, building lines, as shown on the attached plan, could be adopted.

A plan showing the Tonkin and Taylor assumed limit of potential cliff failure (under existing conditions) and the Mitchell estimated limit of new surface slipping after ground water flow has been controlled, is attached herewith as Appendix I.

## (B) CRAPP SUBDIVISION

Five boreholes were drilled and the usual shear strength tests carried out on selected samples recovered from one of them. Soil conditions encountered were similar to those found in the Tonkin and Taylor borehole.

Mr Mitchell's conclusion were as follows:

1. Tonkin and Taylor's method of determining the extent of the landslip risk zone, by observing the existing slope failure patterns rather than on any theoretical or technical analysis of soil strengths and ground water levels, is a reasonable one, since there are several examples of former deep seated failures along the exposed northward facing slope of the Crapp Subdivision.

   However, this method of approach is only considered to be valid providing:

   (a) Soil conditions are essentially similar along the length of the cliff face. That is, soils in the non-slip areas are similar to those in areas which have already slipped.

(b) No improvement in controlling seepage concentrations and groundwater levels is attempted.

(c) No control of wave erosion at the toe of the cliff face is attempted.

(d) Vegetation cover on the steeper slopes remains as at present.

If, however, a satisfactory attempt is made to improve upon existing circumstances, then the basis for the original landslip zoning becomes no longer valid, and new boundaries of landslip risk may be formed.

2. Horizontal drains could be used to control groundwater levels but for these to be effective they should be placed at maximum 10 metre centres along the cliff face and be in the order of 25 metres long.

3. The percentage improvement to slope stability which can be obtained by the installation of the drains, is not able to be calculated with certainity, on account of the many factors involved. If it is decided to proceed with the installation of drains as suggested, the 6 metre setback from the risk zone boundary could be reduced, but not entirely eliminated. Some risk will also remain largely on the account of the soft, clayey, silt layer which lies immediately above the Tauranga formation.

COMMENT ON MITCHELL REPORT

Because Mr Mitchell had had the opportunity of reading and commenting on Tonkin and Taylor's report, a copy of Mr Mitchell's report was forwarded to Tonkin and Taylor for comment. The main points made were as follows:

> "In Mr Mitchell's analysis of stability he seems to have only considered superficial failure of the upper 2 or 3 metres composed of Rotoehu Ash. However, the main concern in our own analysis was the possibility of deeper failures involving the older ashes. As found in the investigation of the western Omokoroa coastline the presence of sensitive ashes in the lower portion of the older ash sequence constitutes a considerable hazard. Mr Mitchell's investigations and testing have clearly demonstrated the existence of these low strength, high sensitivity ashes at Margaret Place (e.g. Boring No. 2 between 5 and 8.5 metres).
>
> While we realise that a more protected and less vulnerable situation exists at Margaret Place compared to the western coastline, we cannot agree that the risk of deeper failure involving the older ashes can be ignored.
>
> In our drawing 4487-1A we have shown the sites of previous slips. The very large failure in the south marked "ancient major landslide" probably is several thousand years old, and conditions under which it occurred no longer exist, however, the slips marked "old" are of indeterminable age but are likely to be much younger since debris fans are well preserved. Some

> of these slips are quite deep and involve both the upper Rotoehu ashes and the older ashes. The "recent" scars are merely those superficial slips which have occurred in the last year or so. We therefore feel that the potential risk of deep failures needs to be considered and it was on this basis that our "assumed limit of potential cliff failure" was derived, possible failures being controlled by the depth to Tauranga Formation ashes. From Mr Mitchell's investigations we see no justification for redefining this limit.
>
> While drilled inclined drainage as shown by Mr Mitchell will undoubtedly improve near surface stability we consider that drainage at deeper levels, near the base of the older ashes, would also be highly desirable.
>
> If such drainage were installed and if after a period of extended water level observation the ground water levels were found to be adequately controlled, then building could probably be considered within the 6 metre arbitrary set back from the failure limit.
>
> In assessing the stability risk in such a situation as this which does not lend itself readily to analytical methods a certain amount of subjective judgement must be used. In view of the unknowns involved therefore, we have preferred to use a conservative approach to stability assessment and hence cannot endorse Mr Mitchell's revised recommended building limitations."

In general I find Tonkin and Taylor's assessment of the situation more convincing - although, as will be seen later in this report I do not agree with the categorical prohibition on building suggested by them.

It appears to me that Tonkin and Taylor are correct when they say:

> "The risk to existing houses within the zone can possibly be lessened by certain measures recommended, but such measures certainly do not invalidate the zoning which is based on a long term record and includes numerous factors. Too many unknowns exist quite apart from what individual property owners may do to improve the situation. In particular, there are unknown variations in the deep ground water regime.
>
> It would be very difficult therefore, to provide a basis on which the landslip risk zone could be revised with confidence, although one may be able to say the level of risk within the zone has been reduced."

## PUBLIC COMMENT

Since the public meeting at Omokoroa in June 1980, where Tonkin and Taylor's report was explained in detail, and discussed with a large group of residents and ratepayers, many people have contacted me in order to study the report more fully, to have various points clarified or to discuss the implications of the recommendations made.

On 24th July 1980, a group of six owners of coastal property in Omokoroa, prepared submissions on the problem and forwarded these to Council for consideration. The main points made were:

1. The building restriction proposed by Tonkin and Taylor would seriously affect property values, saleability, mortgages and insurances and if written into the district scheme would detrimentally affect the whole Community, and,

2. The slips that have occurred have been mainly caused by sea erosion, stormwater drainage problems or are of a comparatively minor nature.

A full copy of this submission is attached herewith as Appendix II.

A further submission was received from the same group of six owners on 23 September 1980 - by which time they had received letters of support from 34 of the remaining 41 owners of coastal property between Walnut Grove and Hamurana Road.

A copy of this submission is also attached herewith as Appendix III.

## USE OF DISTRICT SCHEME

I believe that the only effective and satisfactory method of informing the public of Council's policy with respect to building control along the Omokoroa coastline - in particular - is via the District Scheme. Only then will owners know where they stand and be able to plan future development with confidence, knowing that Council will approve schemes which comply with the criteria set.

The current legislation, under the Town and Country Planning Act 1977 and Regulations 1978, already provides adequately for the administration of stability classifications through the District Scheme. Maps showing the extent of the areas classified and to which the appropriate Ordinances therefore apply, can be included in the District Scheme in terms of Clause 22 (6) of the Regulations, which states:

> "Maps, other than the district planning map or the inset maps, may be included in the district scheme in order to explain ordinances, designations and other particulars of the scheme, and all such maps shall be endorsed to the effect that they are for illustrative purposes only."

The ordinances can provide in terms of Section 36 (6) of the Act, for dispensation from or waiver of the classification of a property on the basis of suitable technical evidence, and can also provide, pursuant to Section 36 (7) of the Act, that application in terms of these matters, may be made without notice.

It should be emphasised that I am not advocating a change in the zoning of any land, but merely using the district scheme to describe the land for what it is.

## COUNCIL'S RESPONSIBILITIES

A local authority's responsibilities with respect to landslip hazards are clearly defined in Sections 274 and 641 of the Local Government Act 1974, the relevant parts of which are set out hereunder.

## Section 274 : Subdivision not to be permitted in certain circumstances

1. The Council shall refuse to approve any scheme plan where it is satisfied that -

   (a) The land on the plan is not suitable for subdivision; or

   ...........................................................

   ...........................................................

   (f) Without limiting the generality of paragraph (a) of this subsection, -

   (i) The land or any part of the land in the subdivision is subject to erosion or subsidence or slippage or inundation by the sea or by a river, stream, or lake or by any other source; or

   (ii) The subdividing of the land is likely to accelerate, worsen, or result in erosion or subsidence or slippage or inundation by the sea or by a river, stream, or lake, or by any other source, of land not forming part of the subdivision:

   Provided that this paragraph shall not apply if provision to the satisfaction of the council has been made or is to be made for the protection of the land (whether part of the subdivision or not) from erosion or subsidence or slippage or inundation; or

   ...........................................................

## Section 641 : Power to refuse building permit

1. ...........................................................

2. Notwithstanding anything in any bylaw made under section 684 of this Act, if in the opinion of the council -

   (a) The land on which a building is proposed to be erected or altered, or any part of the land, is not suitable for the purpose of erecting the building or making the alteration, as the case may be; or

   (b) The land, or any part of it, is subject to erosion or subsidence or slippage, or inunduation by the sea or by a river, stream, or lake or by any other source; or

   (c) The erection or alteration is likely to accelerate, worsen, or result in erosion or subsidence or slippage, or inundation by the sea or by a river, stream, or lake, or by any other source, of other land, -

   the council shall refuse to grant a permit to erect the proposed building or to make the alteration, unless the council is satisfied that provision has been made or is to be made for the protection of the land from erosion or subsidence or slippage or inundation.

3. ...........................................................

4. Section 304 of this Act (relating to the giving of security by a subdividing owner) shall, with the necessary modifications, apply in any case where under subsection (2) of this section the council grants a building permit subject to any condition imposed for the protection of the land from erosion or

subsidence or slippage or inundation, as if it were a condition imposed on the approval of a scheme plan.

5. Sections 299 and 300 of this Act (relating to objections to the council and appeals to the Planning Tribunal) shall apply with respect to any decision of the council refusing a building permit or granting a building permit subject to conditions pursuant to subsection (1) or subsection (2) of this section.

6. Where it comes to the knowledge of the council that a proposed building or alteration of an existing building to be erected to made by or on behalf of the Crown would, if a building permit were required, be such that this section would apply, the council shall notify the appropriate Minister.

## IMPLEMENTATION OF RESULTS OF INVESTIGATION

It is important to recognise that the investigation carried out by Tonkin and Taylor is a "broad brush" coverage of the problem, despite the fairly detailed delineation of the boundary of coastal zone of landslip risk. When examining the plan one should "stand back" to get an overall appreciation of the problem rather than concentrate on any particular aspect of the zone boundary as it affects any one property. Bearing in mind the methods used to determine the position of the boundary I do not believe that it is reasonably possible to categorically state that a particular point on any property is safe but another a few centimetres away - on the other side of the line - is not.

It is therefore recommended that Council should not absolutely prohibit building activity in any area covered by the investigation, however unlikely it is that building would be permitted within the risk zone. All applicants should be given the opportunity of submitting detailed technical evidence that geological conditions on a particular property, or other circumstances, are sufficiently different from the general case to allow building in safety, or that intended remedial work will overcome the problem.

For this reason I would recommend that the land in Omokoroa be classified into three groups as follows.

### ZONE 1

This would cover the area of low risk behind the recommended 6 metre setback from Tonkin and Taylor's risk zone boundary. Tonkin and Taylor in their report on Margaret Place stated:

> "Whilst building within this recommended limit must inevitably still involve some risk by the very nature of the cliff top situation, we consider that the risk of damage to a structure is exceptably low for housing development."

Building and development should be allowed to take place under normal by-law control although yard dispensations should be allowed where this is necessary to retain the usefulness of sections or buildings.

### ZONE 2

The 6 metre wide area behind the risk zone boundary should be I believe a discretionary zone where building under limited circumstances could be allowed.

Tonkin and Taylor recommended that no dwelling should be allowed within this arbitrary setback distance, the purpose of which was to allow for the inevitable uncertainty in defining the risk zone boundary and in the event of failure to allow some reasonable distance between any building and the edge of a landslip. In general I agree with this. However, I can foresee occasions when this restriction could reasonably be relaxed - for accessory buildings for instant, or where re-building is required after fire damage, or where relatively minor alterations are required to an existing structure.

Under normal circumstances any application for a building permit, or any application to carry out earthworks within this zone, would need to be supported by an engineering report on the suitability of the proposal.

### ZONE 3

This classification would cover the areas of actual, potential and suspected instability, that is, the land within Tonkin and Taylor's risk zone.

In a similar way - but probably to a lesser extent - the remarks made above regarding the relaxation of restrictions for accessory buildings or where fire damage is being repaired in existing buildings, could also apply in this zone. Although building should not normally be allowed - and I cannot foresee any circumstances under which a new dwelling would be allowed to encroach on land within this zone - it should not be absolutely prohibited.

Earthworks, subdivision, building or other proposed development works should all be subject to prior approval and any applications for such approval would have to be supported by a comprehensive engineering report defining the extent of possible stability hazards and the proposed measures necessary to overcome those hazards.

## OTHER AREAS OF POTENTIAL LAND INSTABILITY

It is recommended that steps be taken to identify other areas of potential land instability within the County. Although it is not considered necessary to carry out any investigations similar to that completed by Tonkin and Taylor in Omokoroa, some investigation is required.

Although instability problems are not limited to urban areas, it is suggested that any investigation at this stage be confined to those areas zoned for urban use in the District Scheme. A study of aerial photographs - by a person experienced in this field - will reveal the severity and extent of previous landslipping in the area. If this is then followed up by a "walkover" survey, an engineering geologist should be able to assess the likelihood of future landslip problems. The resulting problem areas should be shown on the district scheme as "stability sensitive" (or similar) indicating that special care is needed to ensure stability and that any application for subdivision, building or other development should be supported by an engineering report.

Because of the necessarily broad nature of the study and the limited information available, the areas shown would be indicative only.

After inspecting urban areas within the County I have listed several where there could be some doubt about the stability of some land in those areas. Tonkin and Taylor have been asked to assess the cost of carrying out an investigation as described above, in those areas.

## RECOMMENDATIONS

1. That the report be adopted.

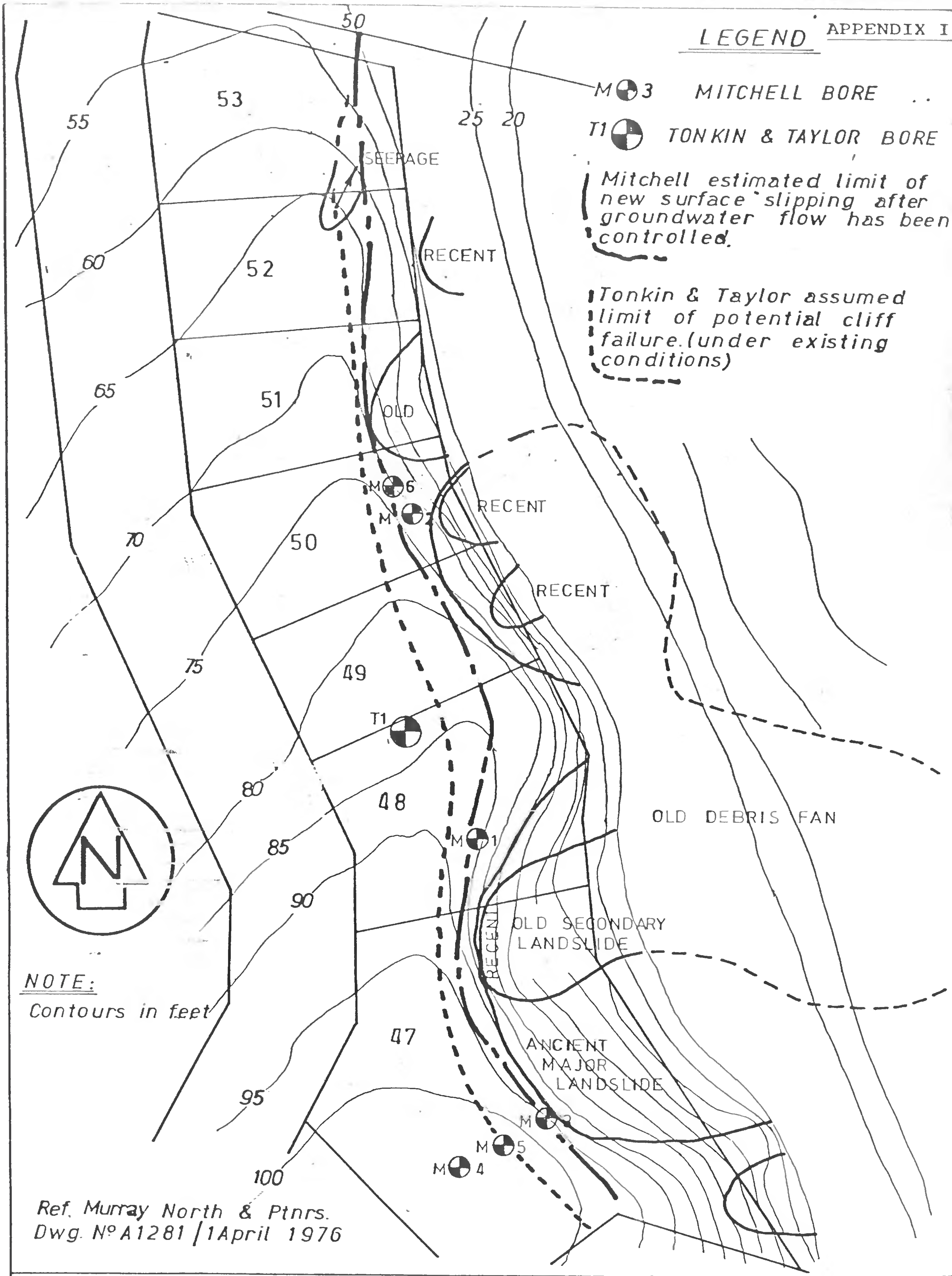
2. That in terms of this report, the Director of Planning and Development in co-operation with the County Engineer be requested to prepare suitable ordinances and maps to control subdivision, building and development within Zones 2 and 3, for incorporation in the District Planning Scheme by way of a scheme change or variation.

3. That in those areas within Zone 1, building and development be permitted to take place under normal bylaw control and that, where necessary, the Chief Inspector be authorised to allow dispensation from Council's yard requirements, to retain the usefulness of sections for building purposes.

October 1980

I.D. McKenzie
COUNTY ENGINEER

APPENDIX I



OMOKOROA POINT LAND STABILITY INVESTIGATION

MARGARET PLACE

TAURANGA COUNTY COUNCIL

APPENDIX 1

## OMOKOROA LANDSLIP RISK ZONE

Since the meeting of residents and ratepayers of Omokoroa County Town on 17th June last, a number of the owners of sea front properties on the north-western side of the peninsula have had the opportunity to study the extracts from the report on Omokoroa land stability, and the accompanying drawings, prepared by Messrs Tonkin & Taylor.

We are greatly concerned at the serious effect that two of the recommendations of the report will have, not only on the sea front property owners, but also on the whole of the Omokoroa County Town area, if adopted by Council.

These recommendations are that a landslip risk zone, as shown on the drawings, would be established and that on lots not yet built on no dwellings would be allowed within an arbitrary set back distance of 6 metres from the defined risk zone. This building restriction would of course affect not only the owners of vacant sections, but also all property owners within the risk zone area.

The Chairman of the County Council indicated at the Ratepayers' meeting that when Council made its decision it would be implemented by way of an alteration to the Tauranga County Council District Scheme.

The reasons for our concern are as follows:-

1. In the area where the proposed risk zone line substantially encroaches upon section boundaries, viz. from lot 23 Ruamoana subdivision right through to lot 35 in the Hamurana subdivision, there are 10 vacant sections, 13 sections on which homes have been built and are at present owned by absentee owners, and 17 sections on which permanent residents have their homes.

If the proposed risk zone line and 6 metre set back building restriction is adopted, it would appear that 5 of the 10 vacant sections could have an average sized house built on them, and that probably only 7 of the 30 sections with houses at present on them would have room behind the proposed building restriction line on which to build another house if any of the present homes were lost by fire, removed, or demolished. Even the building of additions in front of the 7 houses would not, in most cases, be permitted. However, it is extremely doubtful whether any of the section owners with room to build or rebuild would be interested in doing so if the risk zone line were established.

This means that the proposed building restriction would render virtually all of the vacant lots valueless and would make all the lots with houses on them either unsaleable or saleable at only a fraction of their previous market value.

2. In the area from Walnut Grove to lot 24 of Ruamoana subdivision the risk zone line is almost entirely either on or beyond the section boundaries. ~~A building restriction 6 metres behind the risk zone line is almost entirely either on or beyond the section boundaries~~. A building restriction 6 metres behind the risk zone would therefore impose no greater restriction than the present Council building line restriction of 6 metres from a rear boundary, i.e. the right to build or rebuild houses upon these sections would not be affected.

However, the sale value and saleability of all these properties would surely be very much lessened when prospective purchasers were informed that a risk zone line ran along the front of the sections. The mere mention of the word "risk" would be enough to frighten most people away.

3. In the area referred to in the previous two paragraphs there are 38 sections with dwellings and 15 vacant sections. If an average value of $50,000 is taken for the house properties and $20,000 for the vacant sections, we arrive at a total value of $2.2 million at a most conservative estimate. This will serve to emphasise to Council the reason for the concern of the owners involved.

4. While the degree of hardship inflicted upon each owner would vary from property to property, the owners most seriously affected would be (1) those who have invested in properties upon which they planned to build homes, or upgrade existing dwellings into permanent homes, and who would be unable to raise further finance to purchase sections and build elsewhere, and (2) those who found it necessary for health or economic reasons (e.g. change of job location) to move, and would be unable to sell their properties.

5. With the properties referred to in paras. (1) and (2) rendered either valueless or substantially down valued, the result would be an increased rates burden to be faced by the rest of the community. Thus the whole of the Omokoroa township would be seriously affected.

Sections rendered valueless would ultimately revert to the County, with the consequent problem and additional cost of keeping such areas maintained and tidy.

There could also be the question of claims for compensation to be faced by Council. After all, every subdivision was approved by Council and building permits were issued for all homes erected.

6. If Council proceeds with the proposed risk zone line and 6 metre back building restriction on the north-west side of the peninsula, then presumably all other risk areas would be investigated and appropriate risk zones established. We refer particularly to the south east side of the peninsula where many slips have occurred immediately in front of some of the houses and sections, and to the lower Harbour View Road area where slips have occurred regularly over the years.

With a further large number of properties down valued, the rates burden for the remaining property owners would become still heavier.

7. If risk zones right around and within the peninsula are written into the District Scheme, the whole locality would be detrimentally affected, both as regards value and saleability of properties, not just those properties within the risk zone area. The high level of rates which would apply in non-slip risk areas would be a decided deterrent to prospective buyers, and indeed many would not even bother to come out to Omokoroa to inspect properties for sale, because the locality would, for all time, be known as "the place where it is risky to buy because of slips". This aspect is having its effect right now, as any land agent will confirm.

......./3

8. Another very real problem would be in respect of mortgages and insurance covers on dwellings already erected. If properties were no longer saleable, mortgages would no doubt have to be repaid as they fell due and would not be able to be refinanced. Insurance companies would also probably reconsider the extent to which they were prepared to grant cover.

9. If a dwelling were partially destroyed by fire, would the Council be prepared to grant a permit to restore the building? If so, would the owner of a vacant section next door be entitled to ask for a permit to build in line with the damaged building, i.e. forward of the risk zone restriction? If the Council would not grant a permit to restore the damaged house, who would stand the loss on the undamaged portion unable to be utilised? These are just some of the problems which would arise.

Having covered some of the main areas of concern, let us turn now to matters which we feel should be considered by Council before it makes a decision.

1. We feel that some information with regard to the slips that have occurred around the Omokoroa peninsula and have been observed by residents during earlier years, may not have been known to Council's advisers when preparing their report.

Apart from the Bramley Drive slip, there have been only two major slips during the past 20 years. These occurred in 1962 in front of lot 30, Hamurana Road, and lots 15 and 17 in Kaharoa Avenue. In both these cases local residents were quite sure that the primary cause of the slips was the wrong disposal of stormwater from the roads above - Hamurana Road (from the school to the end of the road) and Kaharoa Avenue. The stormwater went into soak holes at the side of the roads, with overflow pipes discharging on to the ground immediately above the sections. In the case of the Hamurana Road slip, a further and much smaller slip occurred within the previous slip in 1968. The owners of the sections affected met representatives of the Council and County Town Committee on the site in December 1968 to discuss the problem. While Council representatives (understandably) would not admit that the disposal of stormwater from the road could have any bearing on the slip, they did agree that the discharge should not be taking place, and further agreed that they would take up with Council the question of the proper disposal of the stormwater. The result was that Hamurana Road was realigned and a stormwater disposal system installed which picked up the stormwater from Kaharoa Avenue and was piped to the sea.

The owner of the section in Kaharoa Avenue had taken steps in 1963 to drain and terrace his section, and planted poplars to stabilise the land. The owner of the section at 66 Hamurana Road (lot 30) put drainpipes into the seat of the further slip, and likewise planted poplars. No stormwater from the driveways and dwellings was disposed of by soak holes - it was taken to the sea by pipes and flume. In neither of these areas has there been any evidence of further slips since that time.

2. We are advised by long term residents in Kowhai Grove and McDonnell St. that before proper road stormwater disposal systems were installed for these roads by Council, the same sort of problem was encountered as with Hamurana Road and Kaharoa Avenue. In wet weather, streams of road stormwater would course across vacant land at the lower part of

......./4

the roads, resulting in slips at the edge of the peninsula. These can be pin-pointed on the drawings in the relevant areas (lots 25 and 31). No doubt the initial discharge was into soak holes, as was the case in Hamurana Road and Kaharoa Avenue.

3. All the other slips during the past 20 years or so have been of a comparatively minor nature, with of course the exception of the Bramley Drive slip. And here at least it must be conceded that there was a concentration of large modern homes built close together, in most cases, two level in concrete blocks and bricks, and with some concrete floors and concrete roof tiles, i.e. a tremendous weight of buildings on the highest point in the whole peninsula, with a very steep slope to the beach, on which a huge weight of felled trees rested. With stormwater and wastewater going into soak holes as well, this surely was a different situation from any other part of the peninsula.

4. Despite the quite extraordinary rainfall pattern last year, only one slip of any consequence occurred between Bramley Drive and the end of Hamurana Road. This was below lot 34 Hamurana Road, right on the edge of the peninsula at the beach. A large cave had developed in previous years, principally due to sea erosion, but probably accentuated by seepage from soakholes, and it was the area above the "shell" carrying a great weight of trees, which collapsed.

5. Around the peninsula, particularly from the west side of the Bramley Drive slip down to Hamurana Road and on through Mr Cooney's property, there are a number of much older slips, in between ridges which stretch out to the coastline. These slips are marked on the drawings as "very old" etc. and must have happened in the distant past. The faces have weathered back and in most cases descend to the sea in a series of steps which form a slope that is not too steep and is heavily covered in Pohutukawas and other trees and vegetation.

We feel that as these slips have already occurred and have long since stabilised, there must surely be little chance of further serious slipping, provided the other recommendations of the consultants are followed, particularly if stormwater is kept out of the ground and sea erosion at the base is prevented.

6. Although the people who live on the sea frontage properties do not claim to be experts, at least they are in a position to observe changes that occur along the coastline. Very many of these knowledgeable people know from their own observations that marine erosion has had, and will continue to have, a very serious effect on the stability of the edge of the peninusla in some cases. We respectfully suggest that the consultants have not placed sufficient importance and emphasis on this aspect of the problem.

7. We feel that Council should make it mandatory for all stormwater from the whole of the present built up area of Omokoroa to be taken to the sea wherever practicable (not only from future buildings and subdivisions).

The beneficial effect of keeping all this additional water from entering the ground, plus the other recommendations of the consultants, such as cutting back leaning trees, suitable planting of areas of recent or active slipping, and construction of walls to prevent sea erosion, must surely lessen the risk of further slips. Obviously the problem of

......./5

replacing septic tanks with a reticulated sewerage system must also be tackled. Meanwhile, to use field tiles instead of soakholes for the discharge of effluent would no doubt be helpful.

8. Taking into account all the matters we have raised, we would ask Council to consider whether it is really necessary to write into the District Scheme a risk zone line and 6 metre back building restriction right around the peninsula, with the disastrous consequences to Omokoroa township we have already outlined. There appears to be no need to adopt a risk zone line in front of the Crapp Reserve, the majority of the Crapp subdivision sea frontage sections, all of the Walnut Grove sections, and all but 4 of the Ruamoana subdivision sea frontage sections, when present Council regulations would not in any case allow houses to be built within the proposed 6 metre step back from the proposed risk zone line.

As regards the remaining 4 sea frontage properties in Ruamoana, and the one section on the east side of the Bramley Drive slip, some particular building restriction would be necessary, in view of their proximity to the slip.

Of the sea frontage sections from the western side of the Bramley Drive slip right through to the end of Hamurana Road, all but 6 are already built on. We would hope that Council may be prepared to agree that the proposed landslip risk line over this part of the coastline is likewise not justified, because:-

a) Only two slips of major size have occurred in the past 20 years, the likely cause being discharge of road stormwater into soakholes (paras 1 and 2).

b) The other large slips are very old, have long since stabilised, and are covered with mature trees and heavy growth (para 5).

c) The recommendations of the consultants regarding remedial measures to be taken (no soakholes, prevention of sea erosion, etc.) will still further reduce the risk of slips.

The Council Chairman, at the recent Ratepayers' meeting, spoke of the need for Council to have regard to the safety of ratepayers and their property. We earnestly request that the problems we have outlined in these submissions should also be given the most serious consideration by Council.

(Mr) G. Pendleton
Walnut Grove
Pendleton

(Mr) R.R. Clark
Ruamoana Place
R.R. Clark

(Mrs) P.G. Carroll
McDonnell Street
P.G. Carroll

(Mr) K.N. Allen
Kowhai Grove
K. Allen

(Mrs) J.M. Wardill
Kaharoa Avenue
J.M. Wardill

(Mr) K.D. Grant
Hamurana Road
K.D. Grant

OMOKOROA
24/7/80

APPENDIX III

## OMOKOROA LAND STABILITY INVESTIGATION

Since the original submissions were prepared on 24th July last we have had the opportunity of making a thorough study of the full Tonkin & Taylor Report. Mr McKenzie has also pointed out the implications of Section 641 of the Local Government Amendment Act 1979 and the responsibility this places upon Council.

As stated in our previous submissions, the line drawn by Tonkin & Taylor encroaches upon Sections from Lot 23 Ruamoana Place to Lot 35 Hamurana Road inclusive. There are 40 sections in this area which would require some building restrictions beyond the usual County ordinance of 6m from a back boundary. Tonkin & Taylor have defined their line by using the formula of 1: 2.25, i.e. that for every metre in height of the peninsula, slips could occur to a distance back of 2.25m. This supposition is based on measurements they made of the major slips that have occurred in the Omokoroa coastal area from the Crapp Historic Reserve to the end of the proposed Cooney subdivision beyond Hamurana Road.

There are 17 of these slips, details of which are given on Page 37 of the Tonkin & Taylor report. On that same page, Tonkin & Taylor say "these slips span a long period, probably at least a few hundred years." In fact, only 3 of the 17 slips have occurred within living memory, and at least 2 of those are due to man made conditions, i.e. Hamurana Road and Bramley Drive.

The following points should be noted:-

1. Only 6 of the ~~19~~ 17 slips are of the ratio of 1: 2.0 and beyond.

2. Only 1 slip reached 1: 2.2 and that is on the section adjoining the Bowling Green (Lot 32 Kowhai Grove) i.e. at almost the lowest point in the peninsula. This is not one slip but rather a series of surface erosions which would have occurred probably more than 100 years ago judging by the stumps of old mature pine and/or gum trees that were in the area of the "slip" when the section was taken over by the present owner about 20 years ago.

3. 3 slips are in the ratio of 1: 2.1, one in the Crapp Historic Reserve, one in Kaharoa Ave. (much older than the 20 years shown on the map) and one in the proposed new Cooney subdivision where the height of the peninsula is low.

4. 2 slips are in the 1: 2.0 ratio, one in the proposed new Cooney subdivision and the other in Hamurana Road.

5. 15 of the 17 listed slips are in the area from Lot 23 Ruamoana Place to the proposed new Cooney subdivision. Only 2 are of recent origin - the Bramley Drive slip and the one in Hamurana Road (caused by road storm water in 1962).

6. Hence 13 of these 15 slips are old slips, completely stabilised and covered in native trees. Having occurred, presumably even Tonkin & Taylor do not anticipate a repetition, otherwise they would have allowed for another slip to take place behind the existing ones, including Bramley Drive.

7. It does seem therefore that Tonkin & Taylor have been unduly cautious in establishing a line in the ratio of 1: 2.25 round the whole peninsula.

8. It is surely being doubly cautious to suggest a further ~~slip~~ step back of 6m. from their line as a building restriction.

9. Tonkin & Taylor have made no allowance for the beneficial effects which will occur if their recommendations regarding keeping water out of the ground etc. are adopted.

We give in the table below the situation regarding the 40 sections from Lot 23 Ruamoana Place to Lot 35 Hamurana Road, depending on whether a building restriction is established (a) on the Tonkin & Talyor line plus 6m step back, (b) on the Tonkin & Taylor line itself and (c) if a line were established on the 1: 2.0 ratio.

With the usual 5 m. restriction from the front boundary and assuming a house of 10m. in depth, a distance of 15m. from the front boundaries would enable houses to be built (or rebuilt). In the case of R.O.W. sections or 2 level houses, some dispensation would also be required to be given by Council.

| | T.& T. line + 6 m. | | T.& T. line | | 1: 2.0 m line | |
|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out |
| Sections | 7 | 3 | 8 | 2 | 10 | 0 |
| Absentee Owners of Houses | 4 | 10 | 12 | 2 | 13 | 1 |
| Permanent Residents | 7 | 9 | 11 | 5 | 15 | 1 |
| | 18 | 22 | 31 | 9 | 38 | 2 |

From this it can be seen that by observing some flexibility Council could move from a situation where the present Tonkin & Taylor line plus 6m back restriction renders 22 of the 40 properties valueless or unsaleable, to a point where all but 2 of the 40 sections could be used and even those 2 could be used, with a slightly less area available. The critical factor is that every owner will need to know the position now, to enable him or her to use or dispose of a section or to dispose of a house if already built.

We feel that if Council is able to arrive at some answer whereby the "encroached on" sections in the Cooney and Crapp subdivisions can be utilised, then likewise it should be possible to come to some decision which will accommodate the owners of the 40 sections from Lot 23 Ruamoana Place to Lot 35 Hamurana Road.

If this can be done it is to be hoped that it will be by some means other than by a line drawn in the County District Scheme as proposed by Tonkin & Taylor, with all the serious consequences outlined in our previous submissions.

KD Grant
........................
K.D.Grant
(for the Group of Six Owners)

23rd September 1980

Harrington House,
Cnr Willow & Harrington Streets,
Tauranga, New Zealand.
Phone 82-530 P.O. Box 257

4 February 1982

| | |
|---|---|
| FILE REFERENCE | |
| DATE RECEIVED | 5 FEB 1982 |
| PRINCIPAL INITIALS | N |
| FOR ACTION BY | CPG |

Messrs Tonkin & Taylor,
Consulting Engineers,
P.O. Box 5271,
AUCKLAND.

Mr Gulliver

Dear Sir,

Omokoroa Point Land Stability Planning Appeal

I write following my discussion with Mr Gulliver and now enclose herewith a proposed draft of evidence.

You must feel free to make any amendments you wish to this. It is only a draft and you must remember that it is your evidence and not mine. I would however like to discuss any alterations with you.

I enclose also for your records a copy of the variation under appeal. This comprises the insertion in the Scheme Statement of the District Scheme a new clause 21.1.9 in respect of land stability at Omokoroa and the identification by notation on the planning maps of the areas defined as being vulnerable to long term land slip risk. These are enclosed for you.

I have sent a copy of this draft of evidence to Mr McIntyre of Messrs Murray North Partners who is the County's planning consultant in order that he may make any comments that he wishes in respect of the draft. He will probably contact you directly to discuss it with you.

Please telephone me if you wish to discuss the evidence with me.

I confirm that the appeal is set down to commence on Monday 22nd February at 2 p.m. I will know during the week beforehand more accurately when we will be heard. It may not necessarily be that Monday afternoon.

Please note that I am required to supply to Counsel for the Appellants a copy of the evidence no later than Friday 12th February.

Yours faithfully,

J.L. Saunders

Encls

Mr Saunder - Barrister. 9.30

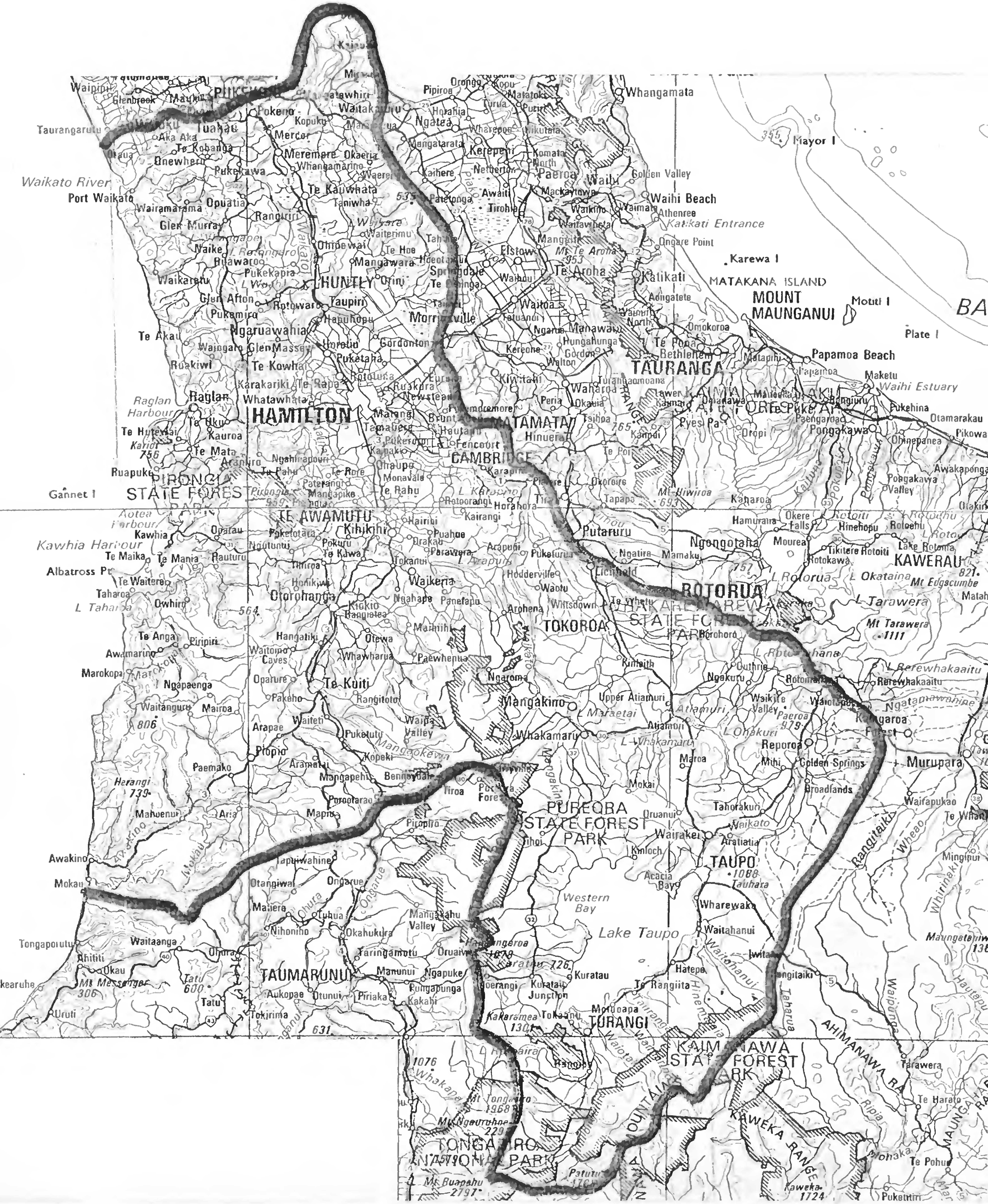
T.C.C. - district planning maps.

locals object. to rationalisation.

22nd Feb. need to be in attendance. for X-examination.

Copy of report.

| 11.00. | Wed.


Waipipi
Pukekohe
Taurangarutu
Tuakau
Pokeno
Mercer
Meremere
Waikato River
Port Waikato
Te Kauwhata
Rangiriri
Glen Murray
Ohinewai
Huntly
Taupiri
Ngaruawahia
Te Akau
Te Kowhai
Raglan
Raglan Harbour
Hamilton
Te Uku
Te Mata
Karioi 756
Ruapuke
Gannet I
Pirongia State Forest Park
Te Awamutu
Kihikihi
Kawhia
Kawhia Harbour
Aotea Harbour
Albatross Pt
L Taharoa
Otorohanga
Te Anga
Marokopa
Waitomo Caves
Te Kuiti
Piopio
Herangi 739
Awakino
Mokau
Tongaporutu
Mt Messenger 306
Uruti
Ohura
Taumarunui
Whangamata
Ngatea
Paeroa
Waihi
Waihi Beach
Katikati Entrance
Katikati
Te Aroha
Mt Te Aroha 953
Morrinsville
Matamata
Cambridge
Tirau
Putaruru
Tokoroa
Mangakino
Whakamaru
Mayor I
Karewa I
Matakana Island
Mount Maunganui
Motiti I
Plate I
Tauranga
Te Puke
Papamoa Beach
Maketu
Pongakawa
Otamarakau
Pikowai
Kaimai Range
Mt Hiwiroa 693
Ngongotaha
Rotorua
L Rotorua
L Rotoiti
L Okataina
L Tarawera
Mt Tarawera 1111
Kawerau
Mt Edgecumbe 821
Whakarewarewa State Forest Park
Atiamuri
L Ohakuri
Reporoa
Kaingaroa Forest
Murupara
Pureora State Forest Park
Wairakei
Taupo
Tauhara 1088
Lake Taupo
Western Bay
Kinloch
Acacia Bay
Hauhungaroa 1078
Kuratau
Turangi
Tokaanu
Kakaramea 1301
Kaimanawa State Forest Park
Kaimanawa Mountains
Mt Tongariro 1968
Mt Ngauruhoe 2291
Tongariro National Park
Mt Ruapehu 2797
Kaweka Range
Kaweka 1724
Ahimanawa Ra
Te Pohue

The soil sample supplied to Soil Bureau, D.S.I.R., (sample 4/13), was also subjected to an electron microscopic scan. The results indicate that the Halloysite is of an unusual spherical variety as shown in Fig. 6.1. The soil structure consists essentially of a mass of halloysite spheres with diameters of about 0.2 microns with no evidence of cementation between particles. These particles appear to be single crystalline units and not aggregations of smaller particles. It seems that the sensitivity of the soils results from very low attraction or bonding forces between the loosely packed particles. Thus although clay mineral particles predominate in the soil, long range interparticle forces are essentially absent and structural collapse can readily occur. The studies carried out on this soil by Soil Bureau lends some support to the inactive - particle theory of soil sensitivity (Cabrera & Smalley, 1973).

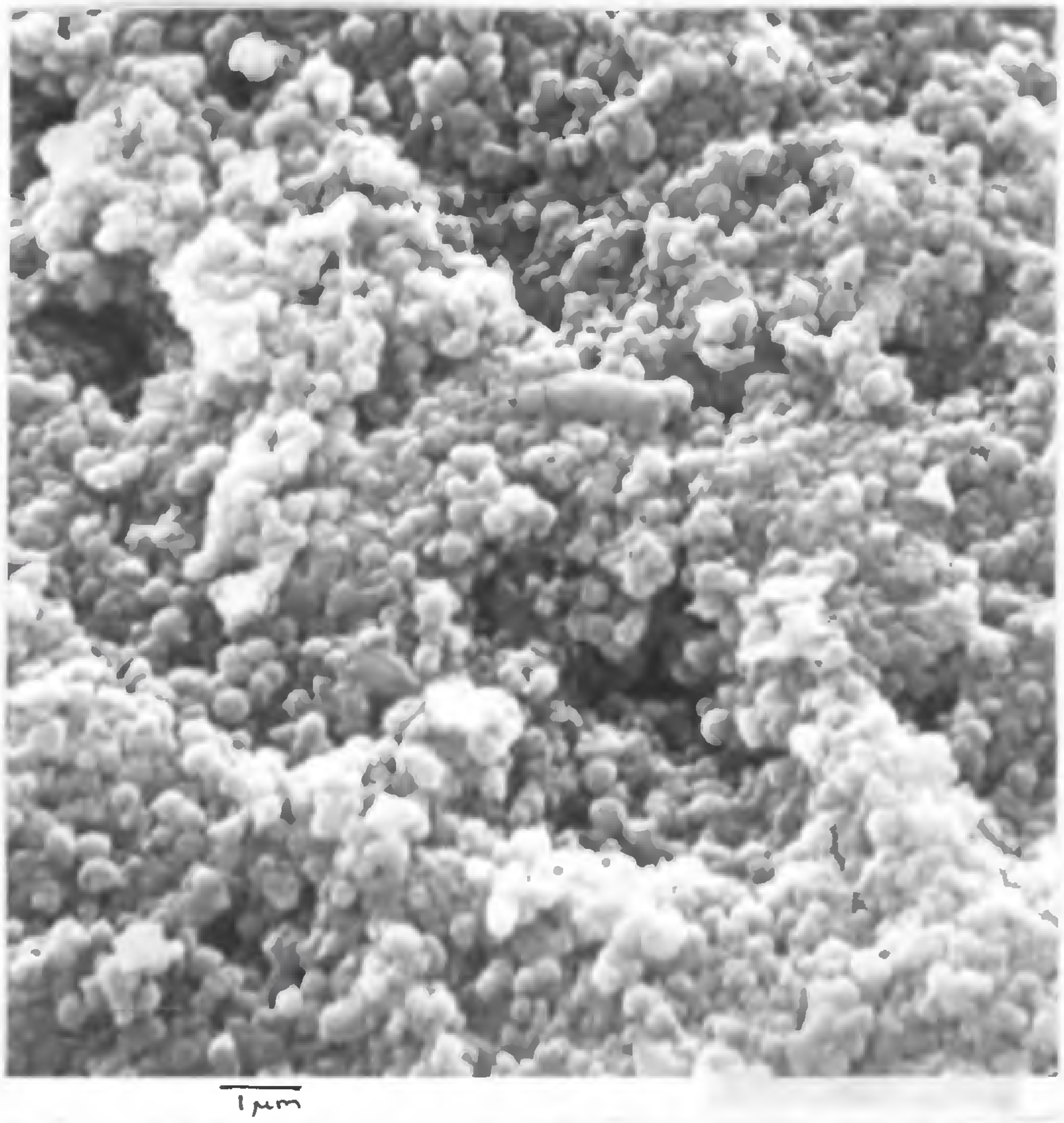
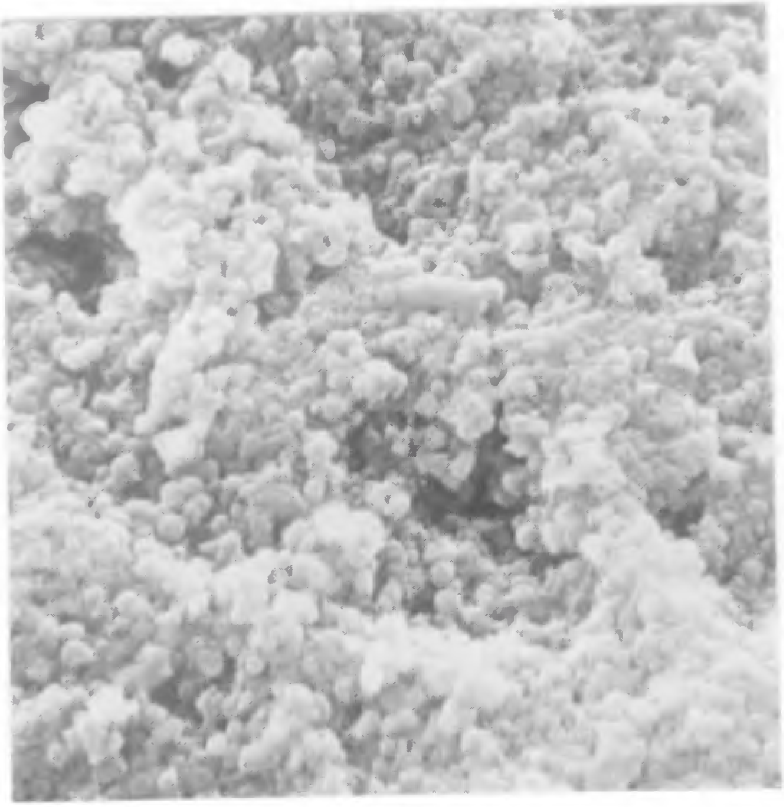


Fig. 6.1 Scanning electron microscope picture of spherical halloysite particles comprising sensitive soil from borehole 4, depth 20.6 m. Magnification 7,500 times.



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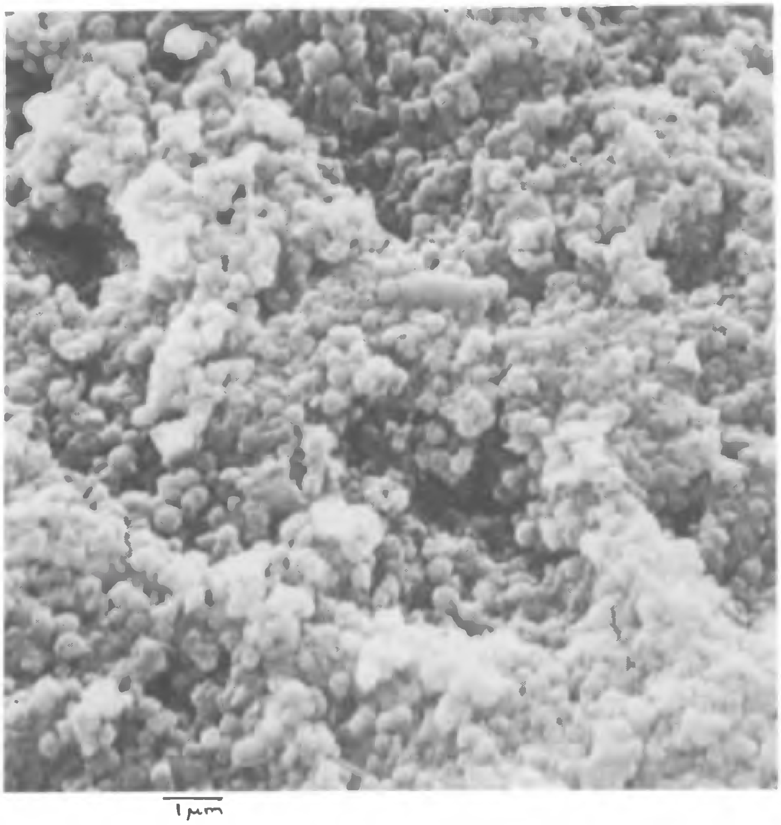

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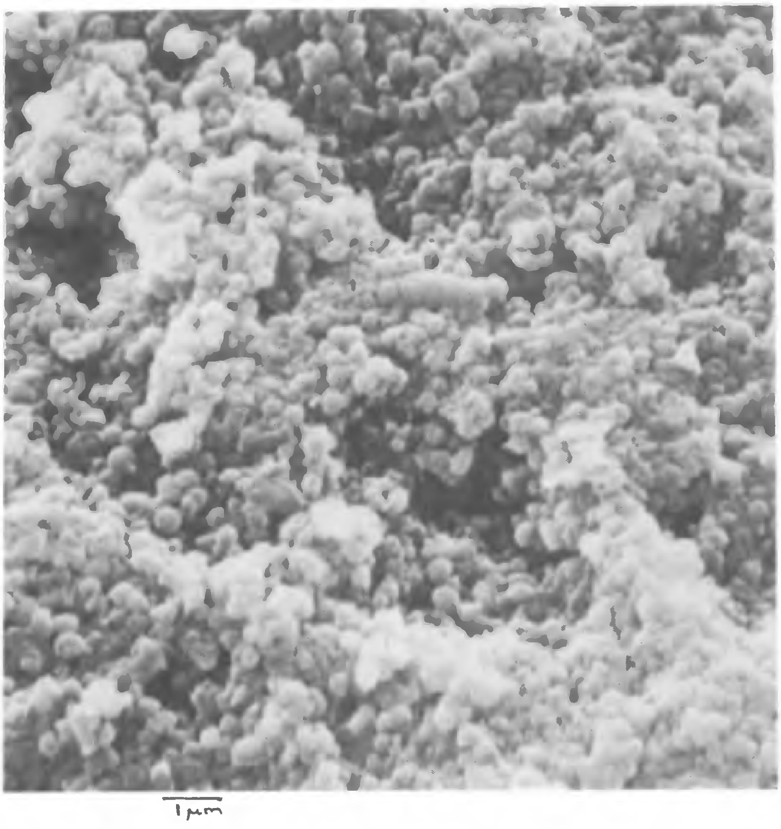

Fig. 6.1 Scanning electron microscope picture of spherical halloysite particles comprising sensitive soil from borehole 4, depth 20.6 m. Magnification 7,500 times.

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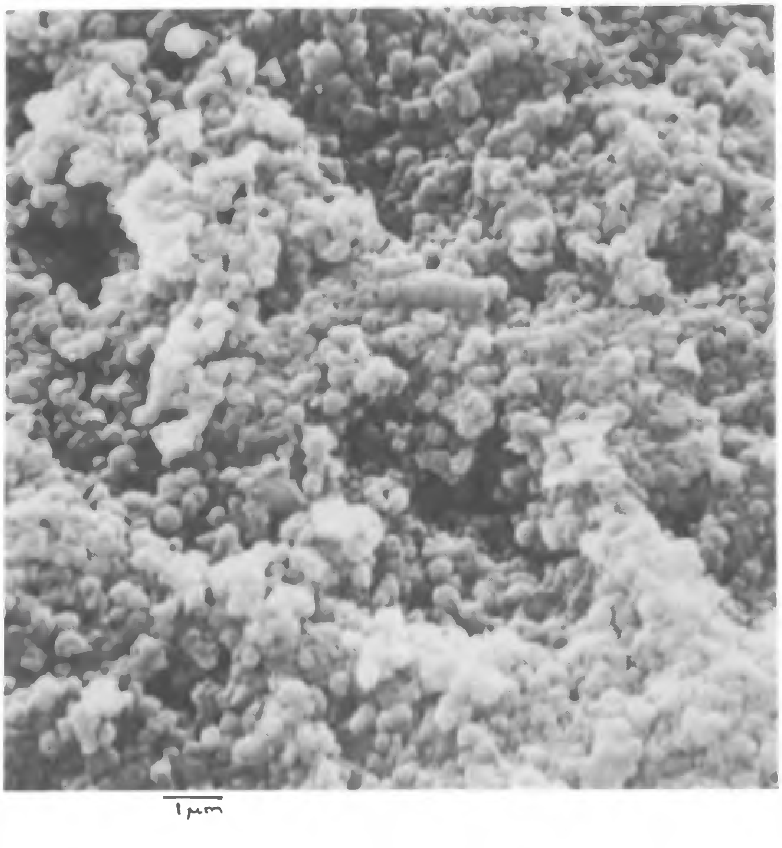

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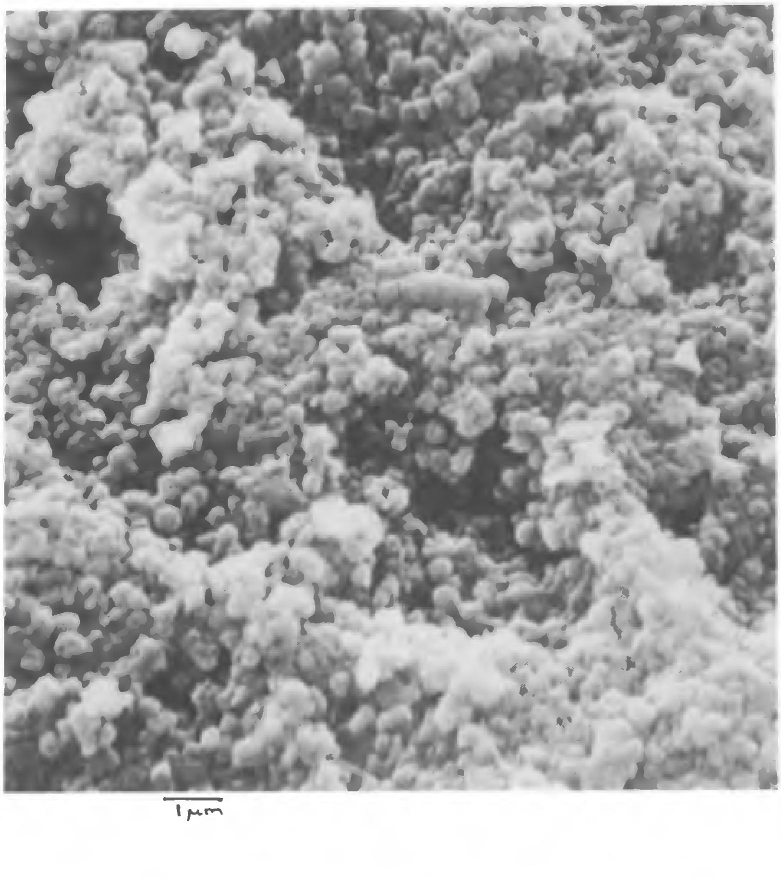

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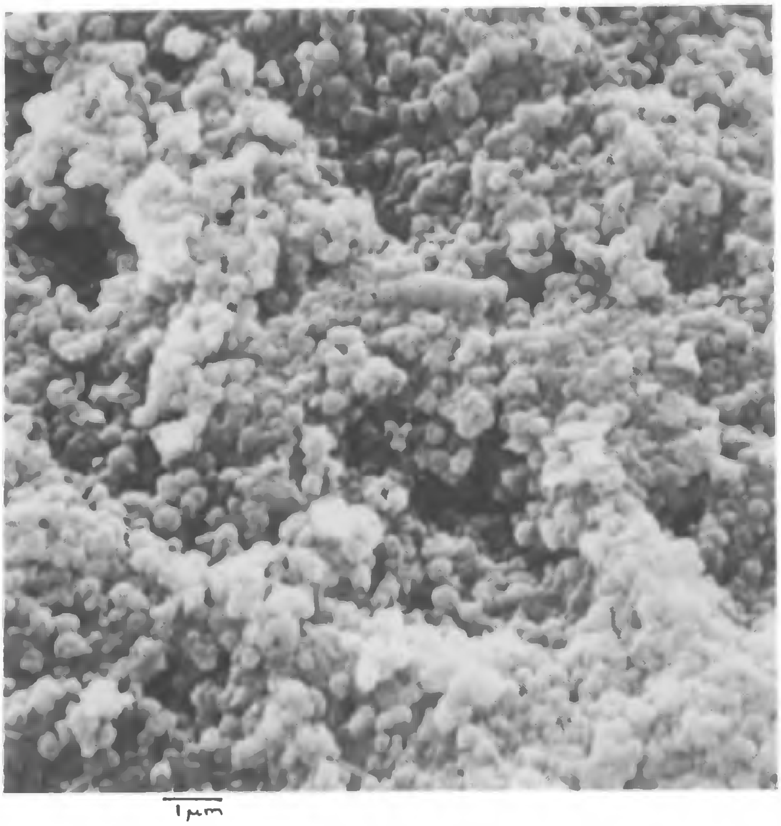
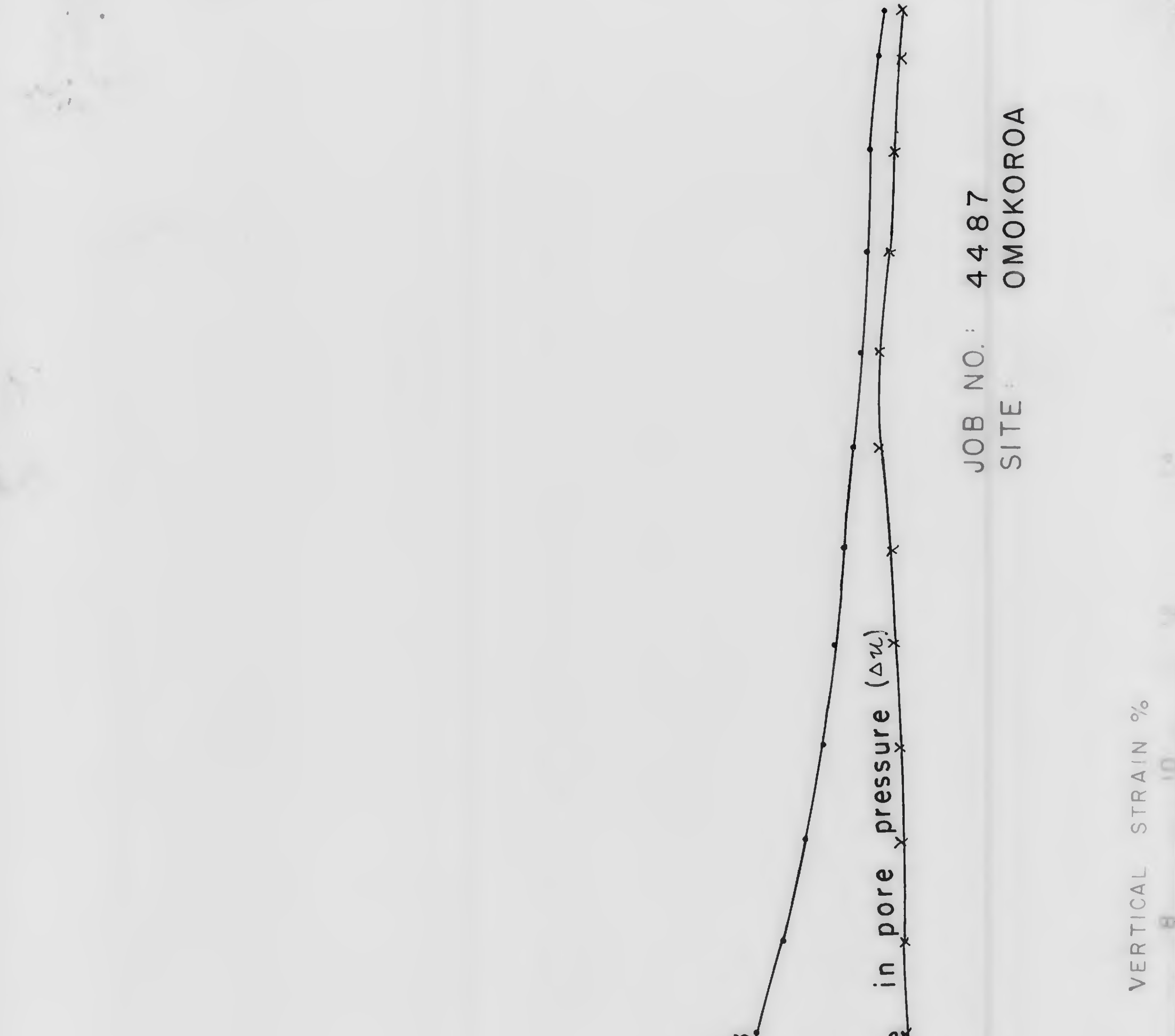


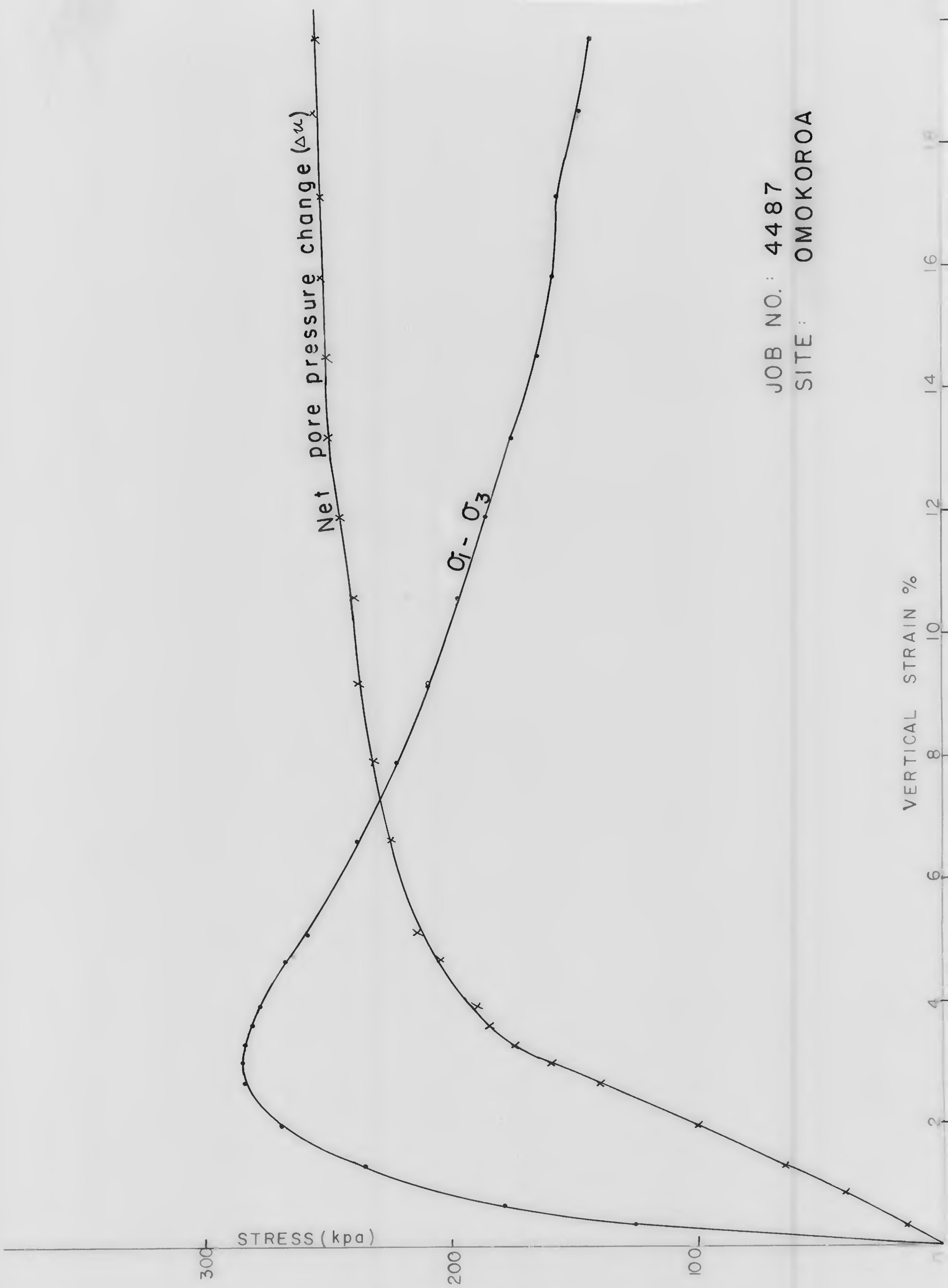
Fig. 6.1 Scanning electron microscope picture of spherical halloysite particles comprising sensitive soil from borehole 4, depth 20.6 m. Magnification 7,500 times.



## TRIAXIAL COMPRESSION TEST
## STRESS/STRAIN RELATIONSHIP

BOREHOLE: 5 SAMPLE: 10 DEPTH: 22·2 m
EFFECTIVE CONSOLIDATION PRESSURE 150 kPa

FIG. 2

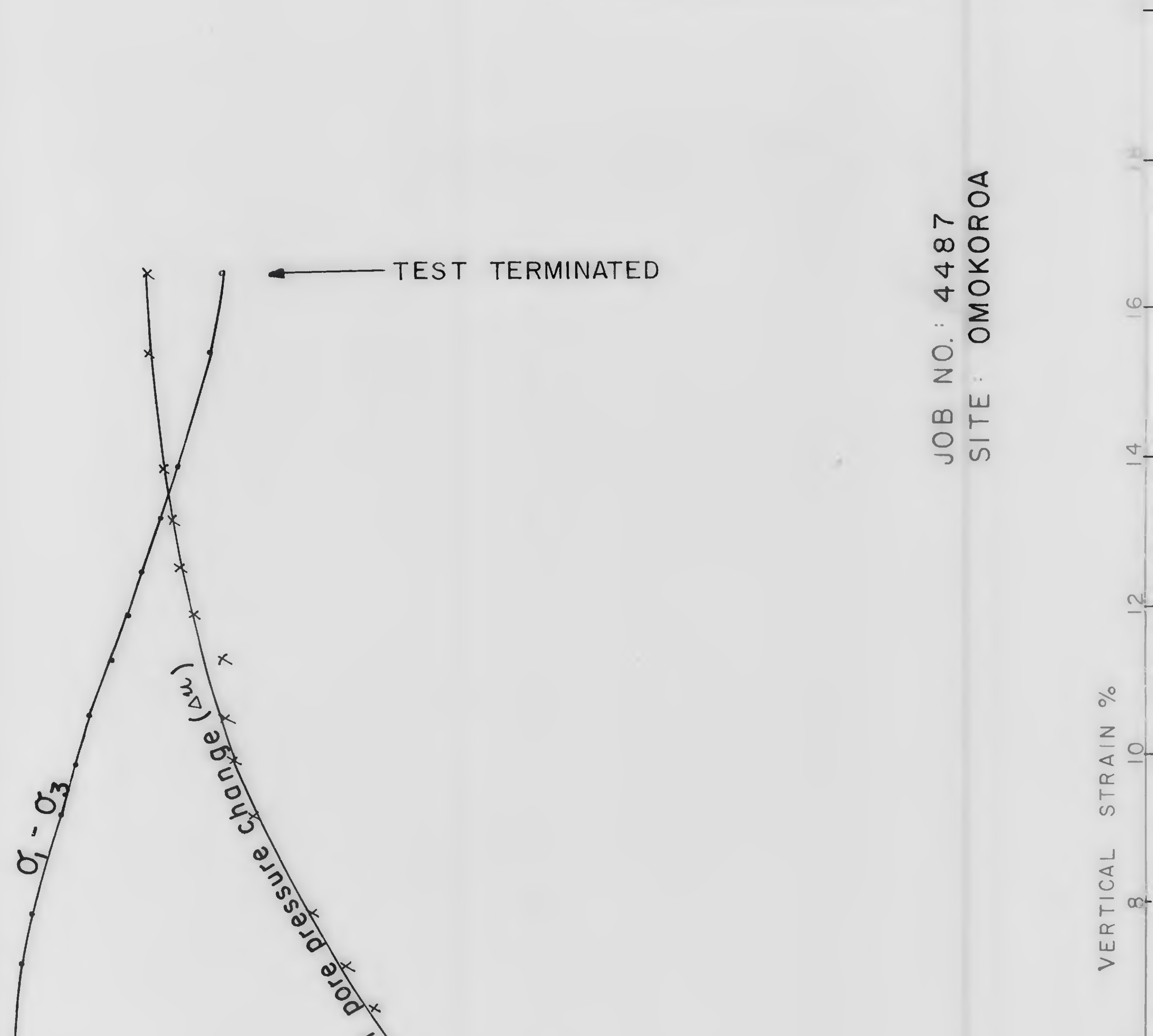


JOB NO.: 4487
SITE: OMOKOROA

## TRIAXIAL COMPRESSION TEST
## STRESS/STRAIN RELATIONSHIP

BOREHOLE: 5 SAMPLE: 10 DEPTH: 22·2 m
EFFECTIVE CONSOLIDATION PRESSURE: 300 kPa

FIG. 3



# TRIAXIAL COMPRESSION TEST
## STRESS/STRAIN RELATIONSHIP

BOREHOLE: 5 SAMPLE: 10 DEPTH: 22·2 m
EFFECTIVE CONSOLIDATION PRESSURE: 450 kPa

FIG. 4