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Narrabeen-Collaroy Fishermans Beach

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Criteria for the Siting and Design of Foundations for Residential Development

Prepared for Warringah Shire Council

GEOMARINE Report No. 69021R02
February, 1991

Preface

This report comprising recommendations for the siting of and foundation design specifications for residential beachfront development at Collaroy~Narrabeen~Fishermans Beach has been prepared jointly by **GEOMARINE P/L** and **Coffey Partners International Pty. Ltd.**

GEOMARINE is responsible for the broad concept and scope of the studies and has undertaken the site specific coastal process assessments, the hazard definition and the definition and mapping of the various stability zones referenced. It has recommended the broad scope of foundation types that are applicable for the various identified stability zones of the frontal dune. Specifically, therefore, **GEOMARINE** is responsible for the preparation of **Sections 1, 2, 3, 4.1** and **4.2**.

COFFEY has undertaken the field investigations and data acquisition, the laboratory testing programme and the analysis of foundation loadings leading to the preparation of the charts for foundation design. Specifically, therefore, **COFFEY** is responsible for **Sections 4.3, 4.4, 4.5, 5.1 5.2** and **5.3** and **Appendices A,B** and **C**.

The study was designed and co-ordinated and the report was produced by **GEOMARINE**.

Contents

Summary and Recommendations

This report presents a comprehensive description, assessment and definition of hazards relating to coastal beachfront development at Narrabeen~Collaroy~Fishermans Beach. The aim of the report is to provide comprehensive criteria for the appropriate siting and foundation design of new development.

The report presents a detailed assessment and quantification of coastal process factors at Narrabeen~Collaroy~Fishermans Beach. A stability assessment is presented that takes account of field data obtained from a drilling and *in-situ* testing programme undertaken along the frontal dune and laboratory data from grading and direct shear box tests.

The stability assessment has been used to define various zones requiring particular standards for building foundations and these have been mapped both within the report and on three sheets provided separately at 1:2,000 scale. The foundation design criteria have been developed for residential beach developments in each of the zones and the following recommendations are made:

- In the *Zone of Wave Impact* residential developments should not be constructed.
- In the *Zone of Slope Adjustment* pile foundations should be used and these should be designed to withstand the structural axial and lateral design loads in addition to the loads induced in the pile by soil "slumping" past the piles during severe beach erosion.

- In the *Zone of Reduced Foundation Capacity* either spread footings or piles can be used, but the foundations must generate adequate resistance within the underlying *Stable Foundation Zone* to resist the design axial and lateral structural loads.
- In the *Stable Foundation Zone* foundations can be designed by conventional means to resist the design axial and lateral structural loads.

Recommendations are made for:

- assessing the loads and moments induced in a pile by a slumping soil mass;
- the requirements for a geotechnical investigation; and
- assessment of the geotechnical parameters required for foundation design.

The results of drilling at eight sites in the Collaroy-Narrabeen Beach areas have been presented and design parameters for these specific areas have been developed.

Finally, design charts have been prepared to aid the calculations involved in the foundation design process.

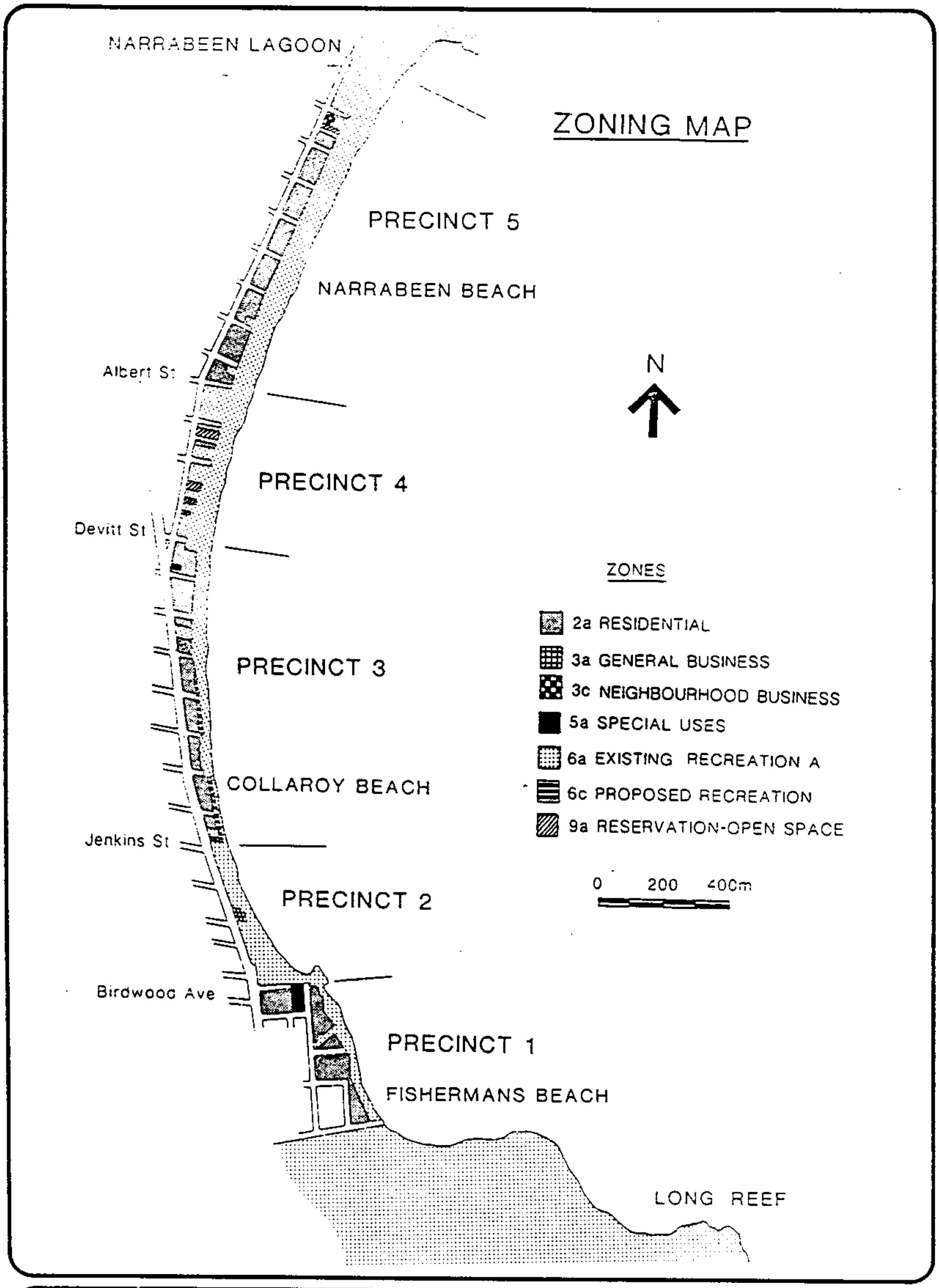
It is recommended that specialist geotechnical advice be sought in order to properly plan and execute the geotechnical investigations required for beach and coastal residential developments and carry out the geotechnical design of the foundations.

1. Introduction

Storm erosion presents a hazard to properties along Narrabeen-Collaroy Beach and Fishermans Beach (**Figure 1.1**). Studies to date undertaken by the Public Works Department (**P.W.D., 1987**) and Council (**W.S.C., 1988; W.S.C., 1989**) have shown that much of the beachfront development at Collaroy (south of Devitt Street) and a number of dwellings at Narrabeen are under threat from severe storm erosion. In the longer term the risk to properties at Collaroy-Narrabeen Beach is likely to increase should sand continue to be removed from the beach by natural processes and this threat may be exacerbated also should the prognosis of a sea level rise resulting from the *Greenhouse Effect* come to fruition.

Council is considering options for the long term management of the beachfront at Narrabeen-Collaroy Beach and Fishermans Beach. These options are aimed at maintaining and enhancing the recreational amenity of the beach and protecting property at risk. However, until such works are carried out Council cannot approve developments in hazardous areas without taking adequate precautions to ensure the safety of any new buildings. To this end Council has specified criteria comprising adequate setbacks and special foundation conditions for any new development in the hazardous areas that will ensure its safety until the longer term management options are implemented.

This report presents the details of the determination of building setbacks and foundation design criteria required for new residential development to ensure its safety and to allow Council to consider applications *in the interim* while exercising its *Duty of Care*.



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Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

Location Diagram

Reference: W.S.C., 1989

Figure 1.1

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2. Coastal Process Factors Relating to Forehore Stability

2.1 Water Levels, Wave Runup and Seepage

2.1.1 Preamble

During storms the ocean water level and that at the shoreline is often higher than the normal tide level. While these higher levels are infrequent and last only for short periods they may exacerbate any storm damage on the foreshore. Elevated water levels allow larger waves to cross the offshore sand bars and reefs and break at higher levels on the beach.

The components of elevated storm water levels comprise astronomical, meteorological and global factors. All of the components do not act or occur necessarily independently of each other but their coincidence and degree of interdependence generally is not well understood.

BLAIN BREMNER & WILLIAMS P/L, Consulting Engineers, and **LAWSON AND TRELOAR P/L**, Coastal, Ocean and Port Consulting Engineers, in conjunction with **WEATHEREX Meteorological Services P/L** and on behalf of the Public Works Department, have carried out detailed studies of historical events which have caused elevated ocean levels on the N.S.W. coast (**PWD Report Nos. 85041, 86005 and 86026**).

2.1.2 Astronomical and Meteorological Components of Water Level

The storm water level depends primarily on:

- the prevailing astronomical tide;
- the intensity, scale, direction and speed of movement of the storm;
- the bathymetry of the coastal area including the presence or otherwise of offshore reefs and islands; and
- the shape of the coastline including the topography of the nearshore areas which may be inundated.

Tides

The astronomical tide, generated by the gravitational attraction of the moon, the sun and other planets, is the largest single component contributing to the total water level measured above a low water datum on the New South Wales coast.

On most days there are two high tides and two low tides (semi-diurnal tides), but not usually of the same levels. The tidal ranges vary significantly throughout each lunar month and from month to month. The Highest Astronomical Tide is 1.1m (approximately) above Australian Height Datum. The frequency of occurrence of the very high and low tides increases around Christmas time and in the mid-winter months.

Storm Surge

Storm surge is caused by the local rise in ocean level resulting from the drop in atmospheric pressure (the *inverse barometer* effect) and by piling up water against the shore as a result of the wind stress caused by the strong onshore winds generated by the low pressure system. For the low pressure system of the severe storms in May, 1974 the estimated central pressure was 986mb which would have resulted in a pressure surge of 0.28m above the predicted tide level.

The maximum wind speeds estimated for the 1974 storms of 90knots would have produced a wind set-up of approximately 0.19m along an open coastline (**Lawson & Treloar, 1985**).

Shoreline Wave Setup and Surf Beat

The breaking action of waves results in an increase in water levels, known as wave setup, in the surf zone. The physics of wave setup are described by **BATTJES (1974)** for the case of spilling breakers. Wave setup may be perceived as the conversion of part of the wave's kinetic energy into potential energy.

The amount of wave setup will depend on many factors including, among other things, the type, size and periods of the waves, the nearshore bathymetry and the slope of the beach.

In many cases waves tend to propagate in groups of large and then small waves. This wave grouping has the effect of inducing water level changes at the shore with periods in the order of several minutes and which are amplified in shallow water. These longer period water level fluctuations are often called surf beat and may have amplitudes of up to a few metres at the shoreline during severe storms.

Wave setup may be calculated using simplified methods found in the Shore Protection Manual **(C.E.R.C., 1984)** or by using computer methods where the offshore slopes are complex and natural wave spectra are being considered **(after GODA, 1975)**. Some field measurements of wave setup at a number of locations on the New South Wales coast have been made by the Public Works Department **(P.W.D., 1988; NIELSEN, 1988; DAVIS & NIELSEN, 1988)**.

On the New South Wales coast during severe storms wave setup can be some one to two metres and makes the largest contribution to elevated water levels above the tide. While the amount of wave setup varies according to the water depth a value of 1.4m has been adopted as a design wave set-up at the shoreline of Collaroy Beach **(W.S.C., 1988; W.S.C., 1989)**.

Shelf Waves

Continental shelf waves cause medium-term variations in mean sea level of up to 0.2m over the time scales of days to weeks.

2.1.3 Global Processes

Very large scale processes acting over the globe causing significant water level variations include:

- tectonic changes;
- tsunamis;
- eustatic changes; and
- global-scale meteorological oscillations.

Tectonic Changes

Tectonic movements in the earth's crust over an extended area are often perceived as changes in ocean water levels. However, in New South Wales it is believed that there are no tectonic changes occuring which may affect sea levels along the coast.

Tsunamis

Tsunamis are caused by earthquakes on or near the sea bed and commonly, albeit misleadingly, are called *tidal waves*. Studies of the tide gauge records obtained at Fort Denison from 1867 have identified a number of water level anomalies resulting from tsunamis. The largest were 1.07m recorded in 1868 and 1877. More recently a tsunami resulting from a severe earthquake in Chile in 1960 caused the water level at Fort Denison to oscillate 0.84m over a 45 minute period. This rapid change induced very strong currents within the harbour, as well as in the other nearby ports and bays, causing considerable damage to boats and shoreline structures.

Eustatic Changes

Eustatic sea level changes are those resulting from changes in the volume of water frozen in the polar ice caps. While the geological history has many ice ages the ocean levels have remained relatively stable over the past 6,000 years. There are no confirmed indications of any significant change in the forseeable future. However, there may be possible changes resulting from the *Greenhouse Effect*.

The term *Greenhouse Effect* is used to describe a postulated warming of the earth due to the accumulation in the atmosphere of certain gases, and in particular carbon dioxide resulting from the burning of fossil fuels.

The Board of Engineering of the Institution of Engineers, Australia issued a *Policy On The Greenhouse Effect* (1/5/15) in August, 1989. The policy statement, *inter alia*, expresses a recognition by the Institution of a need for engineering practice to take into account the potential impacts of the *Greenhouse Effect*. It states also that engineers have a professional responsibility to ensure that their activities reflect the best information available at the time. However, while the Institution has established a committee to prepare guidelines for the incorporation of the effects of climate change in coastal engineering design, to date no guidelines have been issued.

The current consensus of scientific opinion is that such changes could result in global warming of 1.5° to 4.5°C over the next 30 to 50 years. Such a warming could lead to a number of changes in climate, weather and sea levels. These in turn could cause significant changes to coastal alignments and erosion. Global warming may produce also a world-wide sea level rise caused by the thermal expansion of the ocean waters. The **U.S. Na-**

tional Research Council, 1987 presents a range of sea level rise scenarios of between 0.13m to 0.32m by the year 2036; that is 50 years from 1986 (**Technical Memorandum 88/02** appended states **GEOMARINE** policy regarding eustatic sea level changes). It is predicted that the severity and frequency of storms will increase, rainfall intensity could increase and there could be a more severe wave climate. However, the likely degree of change in these processes has not been quantified. For hazard definition at Collaroy-Narrabeen Beach Council has adopted the following values:

TABLE 2.1 Values for Greenhouse sea level rise

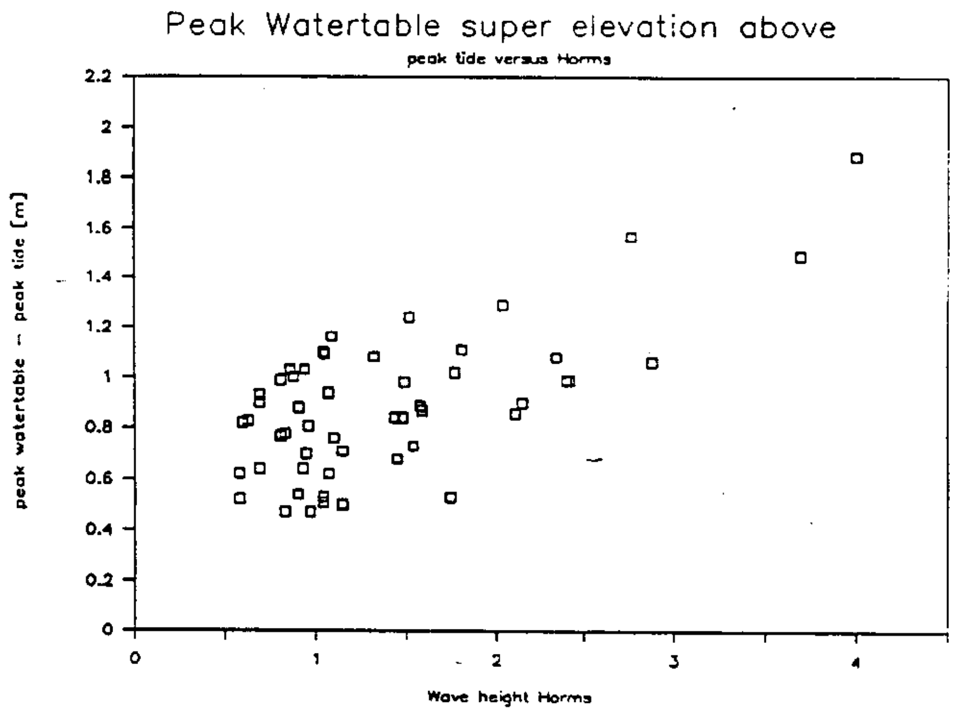
Development	Planning Period	Sea Level Rise
Open space	25 years	0.05m
Residential	50 years	0.23m
Intensive development	100 years	1.17m

El Nino Southern Oscillation
Global meteorological and oceanographic changes such as the El Nino Southern Oscillation in the eastern southern Pacific Ocean cause medium-term variations in mean sea level of up to 0.1m.

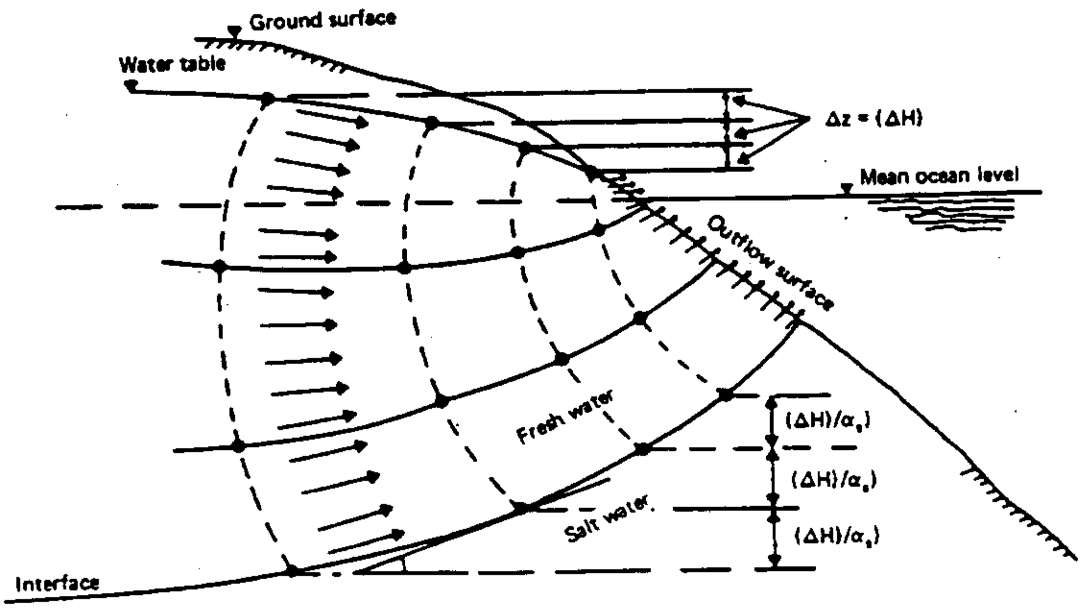
2.1.4 Wave Runup

The energy of a wave is dissipated finally as the water runs up the beach or shoreline. Wave run-up is the vertical distance the wave will reach above the level of the tide, storm surge and wave setup and can be several metres.

Wave run-up at any particular site is very much a function of the beach profile, the surface roughness and other shoreline features on which the breaking waves impinge. Physical model results for run-up levels are available in the Shore Protection Manual for simple profiles and wave conditions. At Collaroy Beach from *The Breakers* to *The Marquesas* wave run-up from R.L. 7m to 8m (respectively) has been adopted for hazard definition.



Super-elevation of peak dune water table due to various incident wave conditions (P.W.D., 1988).



Hydraulic conditions at the ocean interface resulting from freshwater surcharge of the dune (Kashef, 1987).

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Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

Groundwater and Flow Conditions in a Sand Dune

Figure 2.1

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2.1.5 Seepage

The water table inside the beach will follow the movements of the swash zone up and down in response to changing tides and wave conditions. When storms raise the average water levels on the beach above those of the normal tide the levels in the dune may rise correspondingly. The super-elevation of peak water tables in the dune above the peak tide level has been measured by the Public Works Department for some wave conditions as shown here in **Figure 2.1**. Should the beach water levels fall rapidly, say with a drop in wave height on the beach with a falling tide, the water table in the dune may remain elevated for some time as the water slowly seeps out **(PUBLIC WORKS DEPARTMENT, 1988)**. While under normal tide conditions the water table in the beach may be elevated some 0.5m above the average water level, during storms and on the falling stages of the tide the differences may be several metres. As shown in Figure 2.1 also, heavy groundwater inundation of fresh water may become perched on top of the saline wedge with seepage occurring over the beach section to depth.

Seepage forced by water table gradients may reduce the effective frictional shear strength of soils, thereby lowering considerably the stability of the dune. The generalised case of parallel seepage through a uniform sand slope has been solved and indicates a reduction in the stable maximum slope to about half that for no seepage **(LAMBE & WHITMAN, 1969)**. In the case of a rapid drawdown in the water level on the beach the maximum seepage pressures may be expected at the toe of the dune escarpment, reducing significantly the stability of the overall dune face. Heavy rainfall often associated with severe storms may cause ponding behind a frontal dune, thereby increasing the seepage pressures at the toe of the dune escarpment. Elevated water tables will reduce also the foundation loading capacity.

2.2 Beach and Dune Erosion

The amount of sand eroded from the beach berm and foredunes will have a significant bearing on the stability of the foreshore in its eroded state. The frontal dune (or foredune) is part of the beach that can become mobilised during storms. It is likely that a severe storm will erode the beach back into the toe of the frontal dune. While the face of an accreted frontal dune typically may have a relatively low grade down to the beach as a result of the build-up of the incipient foredunes at its toe, during times of severe storm erosion the dune face will be cut and will stand up at very steep angles. At this time the dune face is unstable and likely to slump.

The few measurements of storm sand erosion (*Storm Erosion Demand* in cubic metres of sand above A.H.D. for each metre of beach length; i.e. m^3/m) from open coast beaches on the Australian eastern seaboard include:

- $200m^3/m$ at Narrabeen Beach (**P.W.D., 1987**) for the storms in 1974;
- $240m^3/m$ at Wamberal Beach (**P.W.D., 1985b**) for the storms in 1974;
- $200m^3/m$ at Avoca Beach (**GOSFORD CITY COUNCIL, 1989a**) for the storms in 1974;
- $275m^3/m$ at Copacabana Beach (**GOSFORD CITY COUNCIL, 1989b**) for the storms in 1974;
- $200m^3/m$ for the storms in 1974 and $250m^3/m$ for the storms in 1986 at Forresters Beach (**GOSFORD CITY COUNCIL, 1990**);
- $190m^3/m$ at Terrigal Beach for the 1978 storms (**P.W.D., 1984 & 1985b**);
- a total of $320m^3/m$ from Iluka Beach during the storms of May and September, 1977 (**P.W.D., 1985a**);
- $170m^3/m$ to $430m^3/m$ from the Gold Coast beaches and dunes during the 1967 storms (**McGRATH, 1968**); and
- $260m^3/m$ to $320m^3/m$ from the beach and dune at Byron Bay over the period 23rd June, 1987 to 8th February, 1990 and encompassing the two severe storms of December, 1988 and April, 1989 (**P.W.D., 1990**).

For the stability assessment of the frontal dune at Collaroy/Narrabeen Beach an allowance of $200m^3/m$ (at *The Breakers*) to $250m^3/m$ (at *The Marquesas*) of sand erosion above A.H.D. has been made for storm erosion (to be applied to the average of available beach profile data).

The P.W.D. study of Fishermans Beach presented no data relating to *Storm Erosion Demand*. While photogrammetric data similar to that for Collaroy-Narrabeen were available for Fishermans Beach they showed no erosion from the 1974 storms; in fact they showed accretion. In the absence of any measured erosion on the beach the **Hazard Definition** study advised a value of $100m^3/m$ for *Storm Erosion Demand*. However, since that study additional data have become available for storm erosion on such protected beaches which allows for a revision of the earlier estimates.

GEOMARINE has completed recently studies of storm erosion on some somewhat protected beaches such as Pearl Beach and Ocean/Umina Beach for the Gosford City Council (**GOSFORD CITY COUNCIL, 1990b & c**, in prep.). For these studies wave data were available from direct field measurements as presented in the **GEOMARINE (1988b)** report on the coastal processes of Broken Bay. At Pearl Beach, where wave height coefficients are some 70% of those for open ocean beaches such as Collaroy-Narrabeen, a storm erosion demand was measured at 125m^3/m at the most exposed (northern) section of the beach (see **GOSFORD CITY COUNCIL, 1990b**). For Ocean/Umina Beach a reduction to approximately 60% in the wave coefficients was correlated to actual storm erosion of 100m^3/m (see **GOSFORD CITY COUNCIL, 1990c**).

These data verify earlier analytical assessments of the relationship between storm erosion and wave height proposed in the Public Works Department's assessment of erosion at Boomerang Beach (**P.W.D., 1985a**); that is, subaerial beach storm erosion being a direct function of wave height squared (for a specific storm duration).

On the basis of wave studies undertaken at Collaroy-Narrabeen-Fishermans Beach (**GEOMARINE, 1988a**), the unrefracted deepwater significant design wave height parameter for Fishermans Beach is some 40% to 45% (SE to NE respectively) of that for Narrabeen Beach where the *Design Storm Erosion Demand* is some 250m^3/m (for SE storms). On the wave energy basis as defined above, therefore, a *Storm Erosion Demand* for Fishermans Beach can be evaluated analytically and is 40m^3/m to 50m^3/m, which is higher than the maximum variation measured on the beach over the 45 year record. We recommend that Council adopt now 50m^3/m for the *Design Storm Erosion Demand* in lieu of the 100m^3/m as provided originally in the design parameters of the **Hazard Definition** study, and we propose to adopt this value now for the current exercise in defining the hazard zones for Fishermans Beach. However, we see no reason to vary the parameters adopted for Collaroy-Narrabeen Beach at this stage.

During severe storms the beach berm will scour below the low levels that are observed on the low tides immediately following storms. While sand is mobilised and taken into suspension under wave action at the toe of the dune escarpment, it is not necessarily removed following the passage of a wave and may leave the impression that the level of erosion is above that which actually occurs. Following storms, the beach berm begins to recover very quickly and even within a few hours of lower swell conditions the amount of sand deposited at the top of the swash can be considerable. The depth of mobilisation will be below any post-storm measurements or observations.

Berm levels on natural beaches following storms have been measured as low as 0.5m A.H.D. However, drilling on Narrabeen Beach has indicated erosional disconformities in the beach sands in front of the natural dune at a level of -1m A.H.D. **(GEOL. SURVEY N.S.W., 1982)**. Drilling at the back of the beach berm at Wooli, northern N.S.W. shows disconformities consistently at a level of approximately -1.0m A.H.D. **(GEOL. SURVEY N.S.W., 1985)**. Two boreholes taken at the back of the beach berm on Dee Why Beach indicated beach sand overlying organic fill and sandy clay at approximately -0.8m and -1.5m A.H.D. **(PUBLIC WORKS DEPARTMENT, 1977)**. These data indicate consistently a scour level of -1.0m A.H.D. (approximately) on open ocean beaches. For the determination of hazard zones on Collaroy-Narrabeen Beach a scour level of -1.0m (A.H.D.) has been adopted with a level of 0m (A.H.D.) for Fishermans Beach.

2.3 Coastal Process Design Parameters

The coastal process design parameters adopted for defining the hazard at Collaroy-Narrabeen Beach and Fishermans Beach as discussed above are summarised in **Table 2.2**.

Hazard Definition Parameters

Precinct Parameter	P1	P2	P3	P4	P5
Storm Erosion (m^3/m/annum)	50	200	250	250	250
Wave setup (m)	0.8	1.3	1.4	1.5	1.6
Inundation Level (m on A.H.D.)	6	7	8	9	9
Beach Scour Level (m on A.H.D.)	0.0	-1.0	-1.0	-1.0	-1.0

3. Stability Assessment

3.1 Introduction

Stability computations can serve as a guide to determining safe setback distances on frontal dunes that are prone to wave attack and slumping during storms. A generalised stability assessment has been carried out for the foreshore areas composed of unconsolidated dune sand based on field data comprising drilling and in-situ field testing (**Appendix B**) and soil properties determined from laboratory testing (**Appendix C**).

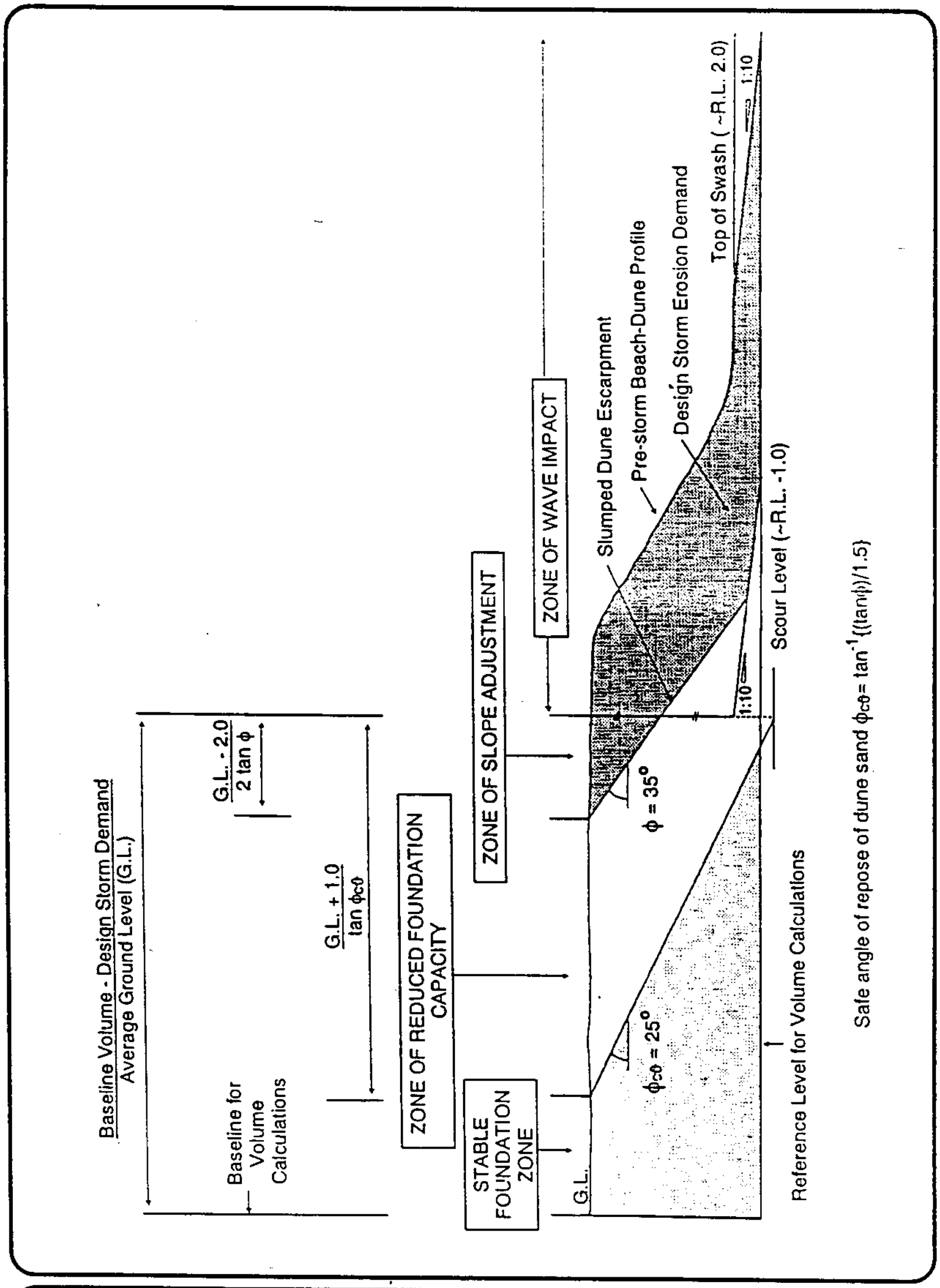
3.2 Factors Of Safety

The greatest uncertainties in stability problems arise in the selection of the pore water pressure and strength parameters. The error associated with the method of analysis, in the order of 10% in computed factors of safety for the better available techniques, is small compared to that arising from the selection of strength parameters. This is the reason for applying factors of safety to stability analyses (**LAMBE & WHITMAN, 1969**).

Where there is sound and detailed knowledge of the soil stratigraphy, as determined from drilling, and a detailed assessment of the strength of the various soil strata, as determined from in-situ field testing and laboratory testing, a factor of safety of 1.5 with respect to shearing strength is commonly adopted and has been adopted for this study.

3.3 Extent of Hazard

The application of the stability assessment is presented schematically in **Figures 3.1.** A number of zones are delineated; a *Zone of Wave Impact*, a *Zone of Slope Adjustment*, a *Zone of Reduced Foundation Capacity* and a *Stable Foundation Zone*.



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Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

Schematic Representation of Stability Zones

Figure 3.1

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The *Zone of Wave Impact* delineates an area where any structure or its foundations would suffer wave attack during a severe storm. It is that part of the beach that is seaward of the dune erosion escarpment.

A *Zone Of Slope Adjustment* was delineated to encompass that portion of the seaward face of the dune that would slump to the natural angle of repose of the dune sand following removal by wave erosion of the *Design Storm Erosion Demand*. That presents the steepest stable dune profile under the conditions specified.

A *Zone Of Reduced Foundation Capacity* for building foundations was delineated to take account of the reduced bearing capacity of the sand adjacent to the dune erosion escarpment. It was considered that structural loads should be transmitted only to soil foundations outside the zone within which the Factor of Safety was less than 1.5 during extreme scour conditions at the face of the dune. This allows for the design assumption that the soil may develop its full bearing capacity.

Structures not piled and located within the *Zone of Slope Adjustment* and seaward may be subject to foundation failure (soil slip and subsequent undermining) associated with a severe storm erosion event. Foundations for structures within the *Zone of Slope Adjustment* should comprise piles embedded to a sufficient depth within the *Stable Foundation Zone* to develop within that zone adequate capacity to support the vertical loads applied by the structure and differential horizontal soil pressures on the piles from the soil above the wedge failure plane.

For the same conditions, landward of the *Zone of Slope Adjustment* structures not adequately piled would be founded in a zone that could be considered to have an inadequate factor of safety (*Zone of Reduced Foundation Capacity*). Foundations for structures within this zone should comprise piers embedded to a sufficient depth within the *Stable Foundation Zone* to develop within that zone the capacity to support the vertical loads applied.

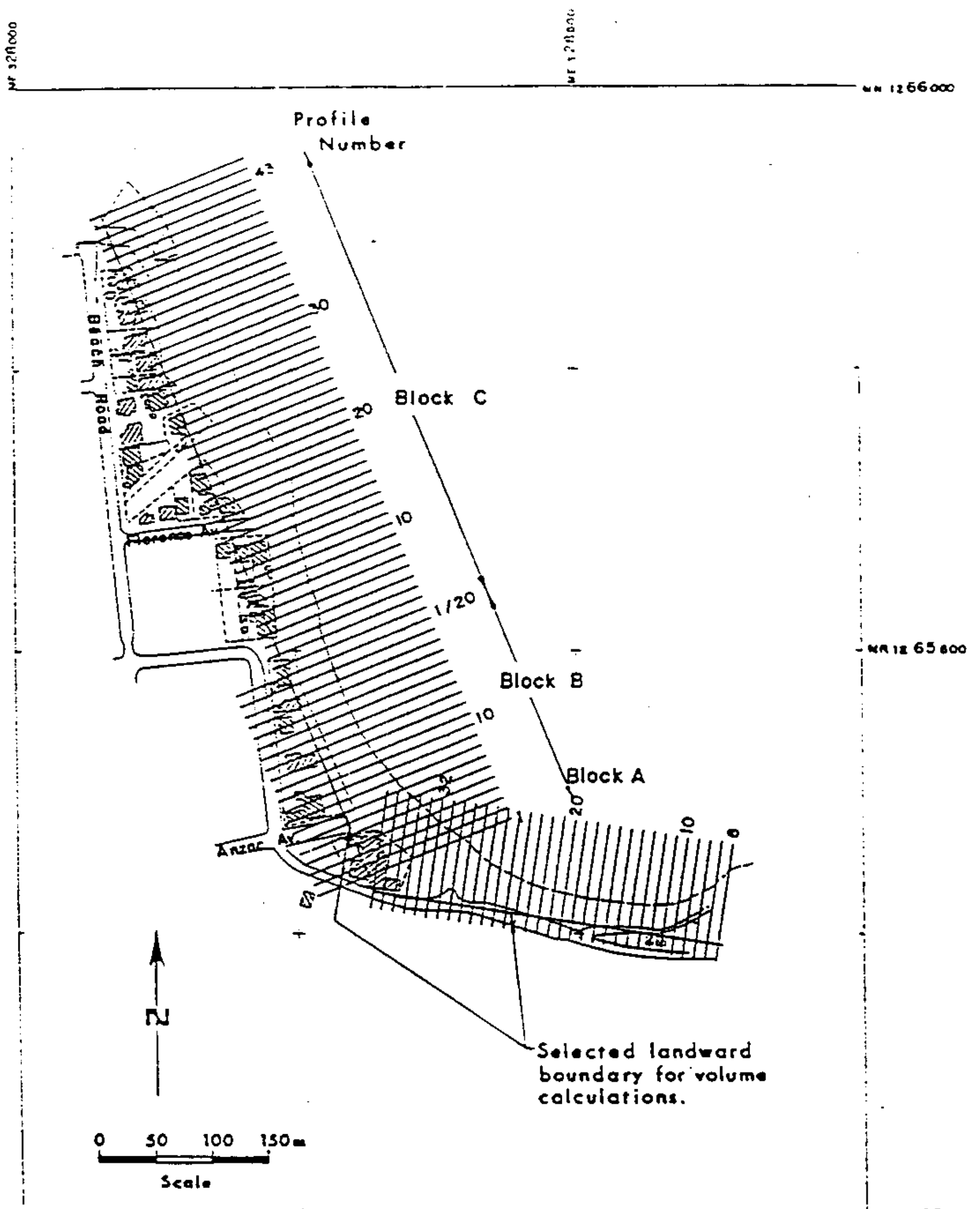
3.4 Methods of the Calculations

The basis for the calculations comprised the hazard definition design parameters defined in Chapter 2 and the photogrammetric survey data obtained for Council by the Public Works Department. Sand volumes along the beach were calculated initially by the Department for the following dates of survey photography; 1941, 1951, 1956, 1961, 1970, 1972, 1974, 1985, and 1986. These are presented as cross-sectional areas of the dune and beach at shore-normal (approximately) profile lines spaced at 20m centres along the beach; the area being calculated as that area of cross-section above a datum of 0m (A.H.D.) and seaward of an arbitrary baseline and to the 2m beach contour (see **Figures 3.2, 3.3** and **3.4**).

The sand volumes calculated from each year of photography were averaged both spatially and temporally. The calculations were undertaken at the following locations (refer **Figures 3.2** to **3.4**):

Block B	Profiles	10-13;
Block C	Profiles	1-4;
		10-13;
		23-26;
Block D	profiles	9-12;
		30-31;
Block E	Profiles	1-4;
		19-22
		22-25
		32-35
Block F	Profiles	13-16;
		25-28;
Block G	Profiles	6-9;
		24-27;
		50-53.

At each location the profiles were averaged. For Collaroy-Narrabeen Beach the average volume thus calculated for each year then was discounted for the assessed long term erosion rate of $1.5m^3$/m/annum, the oldest profiles therefore being discounted the most. The average sand storage volume for the period of record was determined by summing the quotients of each of the discounted sand volumes with the average time period between each of the preceding and following surveys (for example, given that photography was available in 1941,1951, 1956,... the time period quotient for the average sand volume for 1951 is 5 + 2.5 = 7.5 years) and dividing the sum of these quotients by the period of survey record (1941 to 1991 = 50 years). For Fishermans Beach, while the same general procedure was applied, there was no discounting of sand volumes because the Public Works Department studies indicated that there was no long term sand loss from Fishermans Beach.



NOTES

1. Base drawing is a photogrammetric plot from 7.4.1985 aerial photography. Structures shown are those visible in 1985.

2. Base drawing is derived from vertical aerial photography and therefore represents roof outlines of structures which generally do not coincide with the walls of the structures or the "building line".

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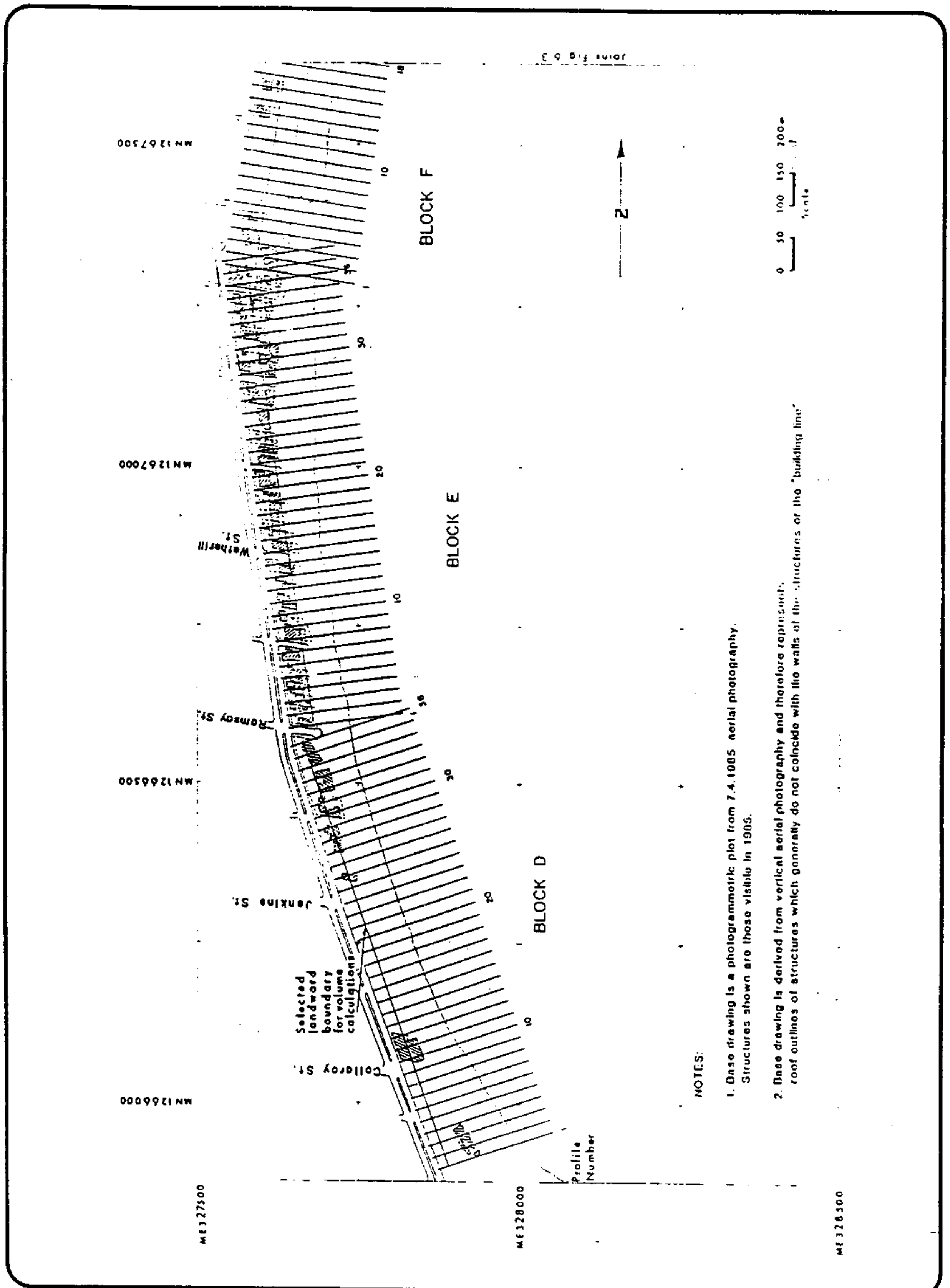
Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development
Profile Locations Fishermans Beach

Reference: P.W.D., (1987).

Figure 3.2



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Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

Profile Locations Collaroy Beach

Reference: P.W.D., (1987).

Figure 3-3

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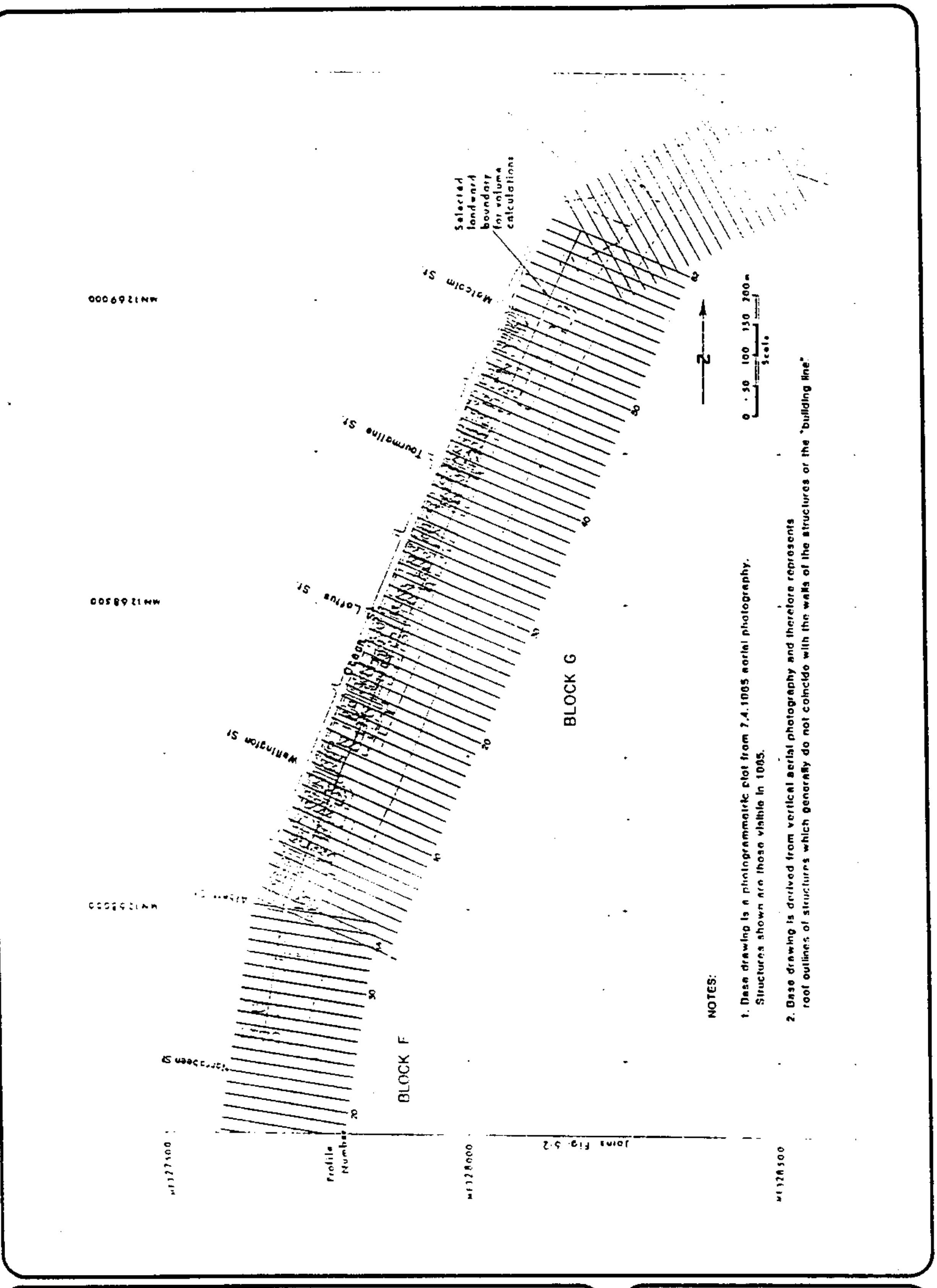

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Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

Profile Locations Narrabeen Beach

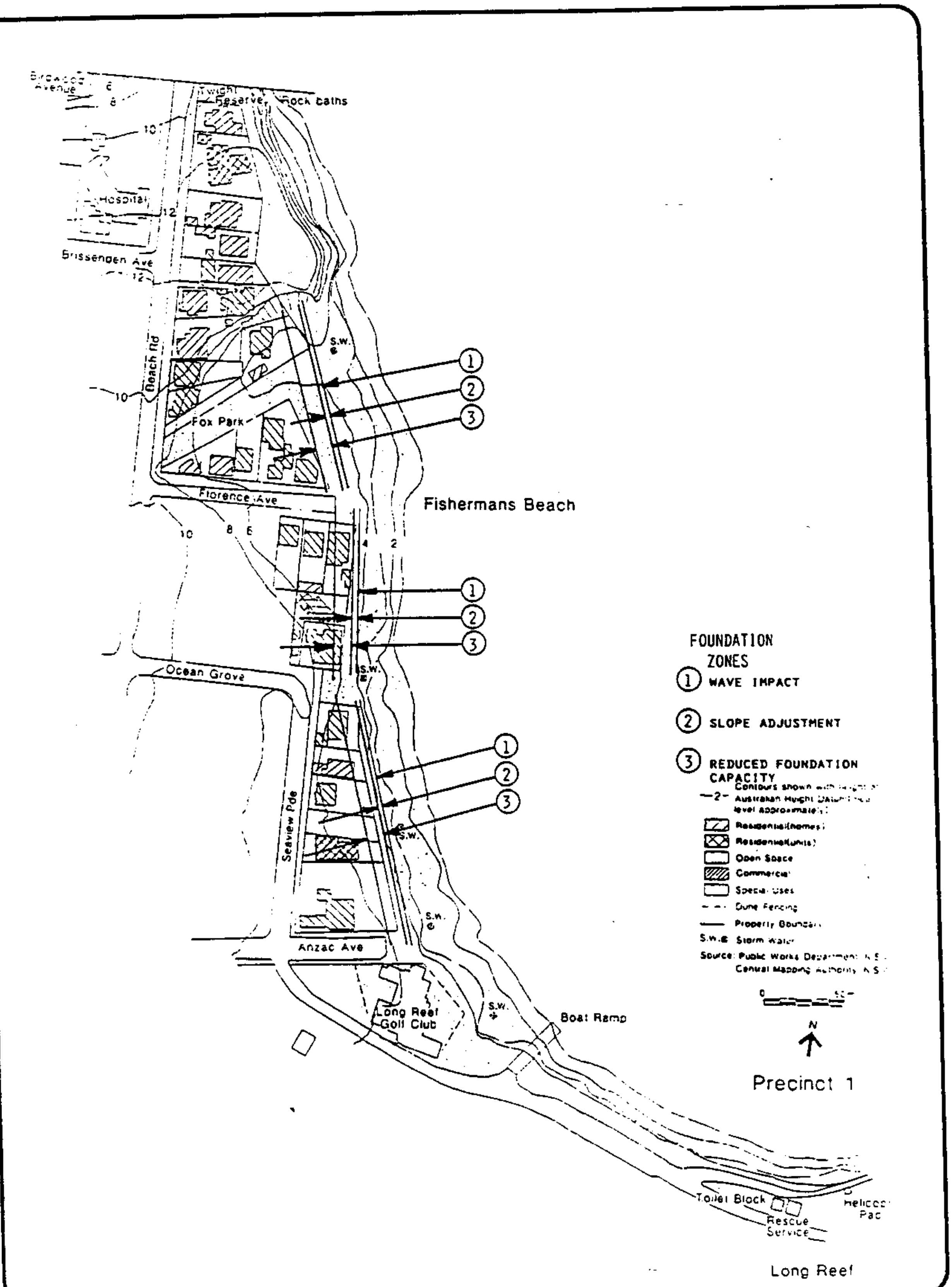
Reference: P.W.D., (1987).

Figure 3.4

COFFEY GEOMARINE

To determine the extent of *Immediate Impact*, the storm erosion demand is subtracted from the available sand storage (**Figure 3.1**). The storm erosion profile is idealised as comprising a steep dune escarpment at a slope of the natural angle of repose of dune sand to the top of the swash zone at low tide, taken to be 2m (approximately on A.H.D.), then a steep nearshore beach face of slope 1:10 down to 0m (A.H.D.), the datum for the reference volume calculations. The distance from the top of this storm profile to the baseline is determined by dividing the difference between the baseline volume and the design storm erosion demand by the average ground level existing at the top of the dune seaward of the baseline, and subtracting from that an allowance for the slumping of the dune escarpment to its natural angle of repose as determined from the height of the dune face (Ground level (A.H.D.) - 2m(A.H.D.)) divided by twice the value of the tangent of the friction angle (ϕ) of the sand (**Figure 3.1**). A flatter dune face slope extending landward from the limit of beach scour and incorporating a *Factor of Safety* of 1.5 ($\tan \phi_{cv} = \tan\phi/1.5$) defines the limit of the *Zone of Reduced Foundation Capacity* beyond which surface footings can be used safely.

The delineations of the various foundation zones determined in this way are presented in **Figures 3.5** to **3.11**. We note here that these Figures present only the hazard definition existing at present and do not take account of the longer term scenario of future progressive erosion of the beach sands resulting from the identified long term beach movements and the likelihood of a *Greenhouse* sea level rise.



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Foundation Design Criteria for Residential Development

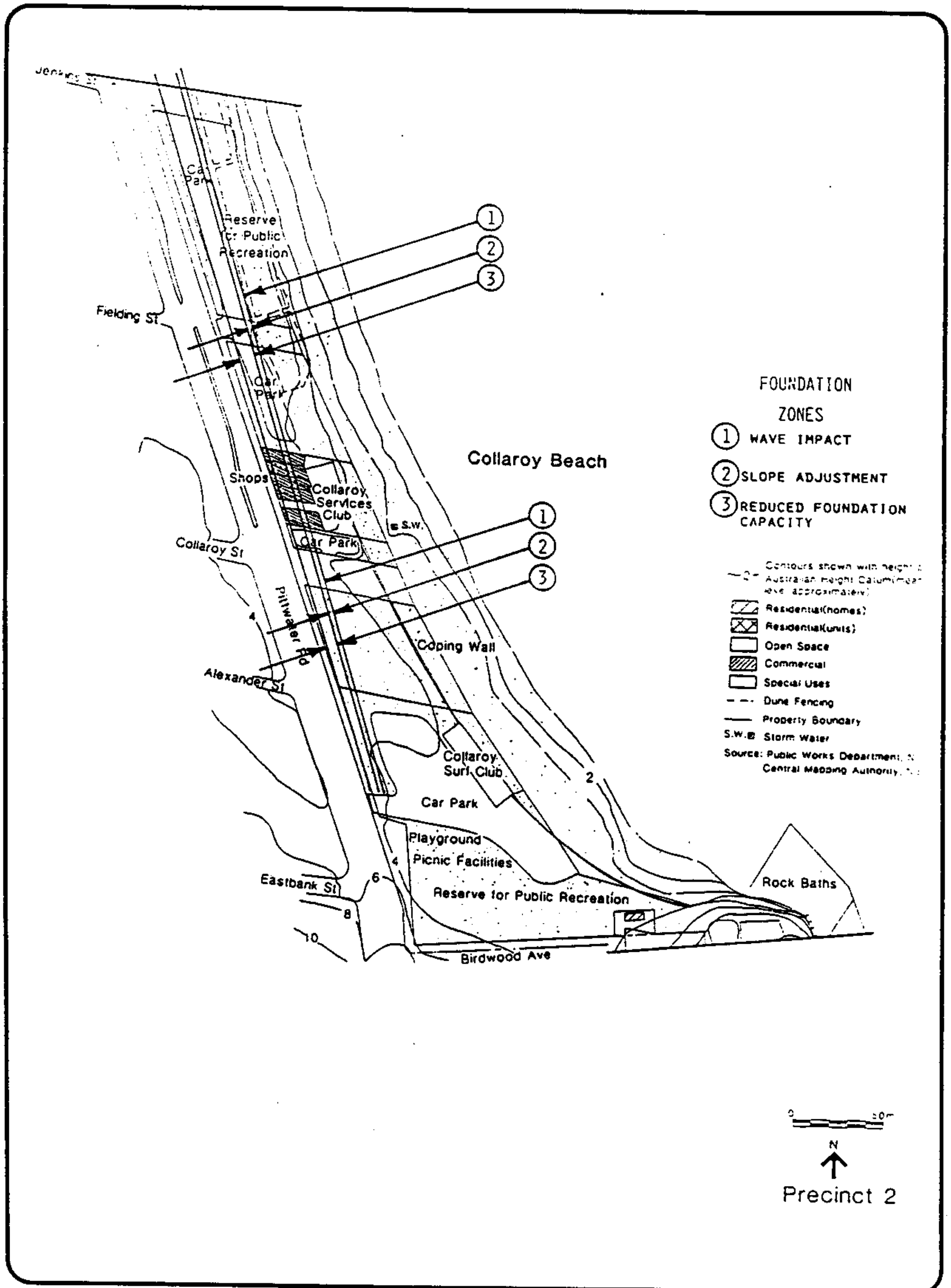
Stability Zones

Precinct 1

Figure 3.5

COFFEY

GEOMARINE



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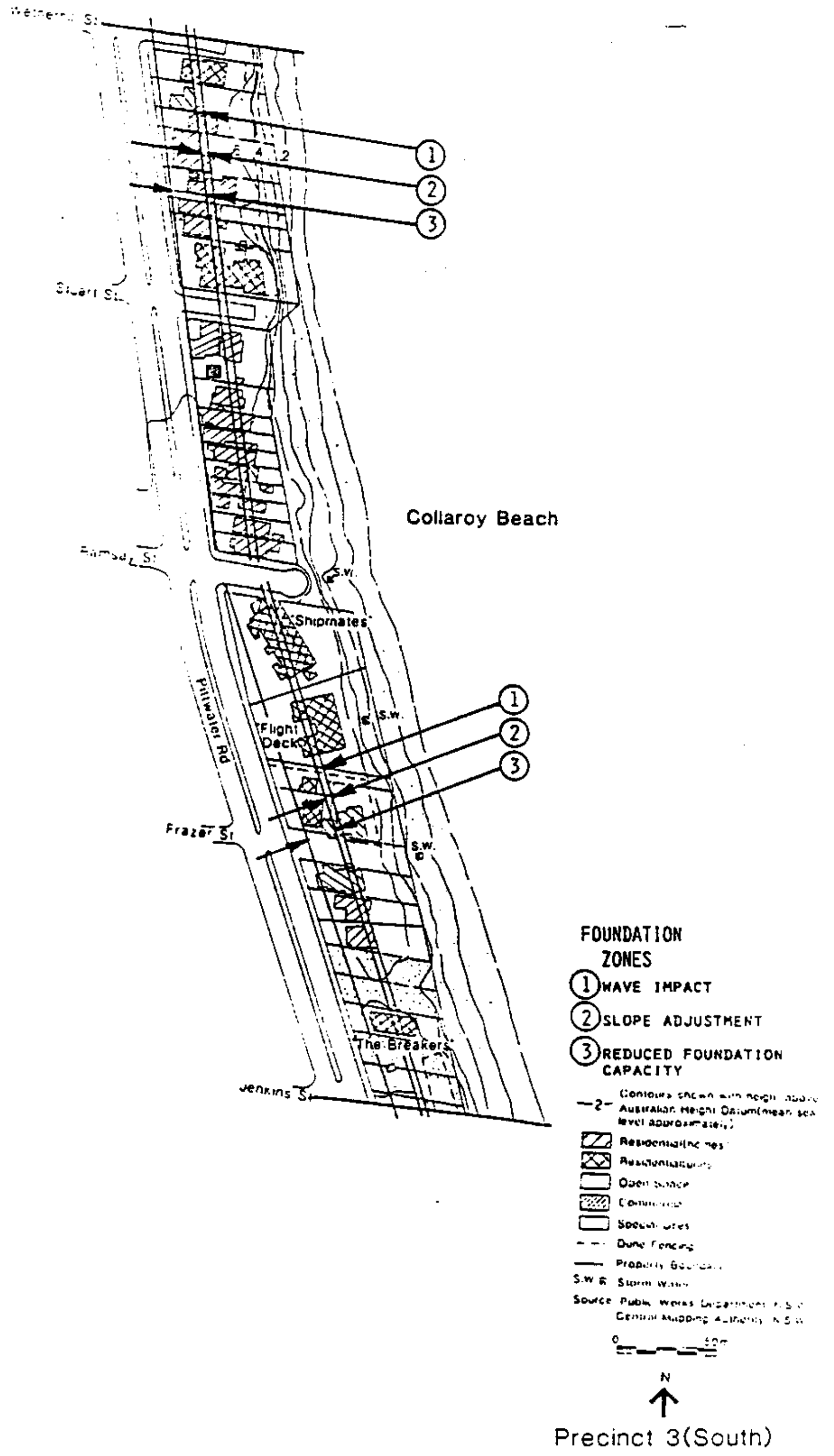
Stability Zones
Precinct 2

Figure 3.6

GEOMARINE

COFFEY



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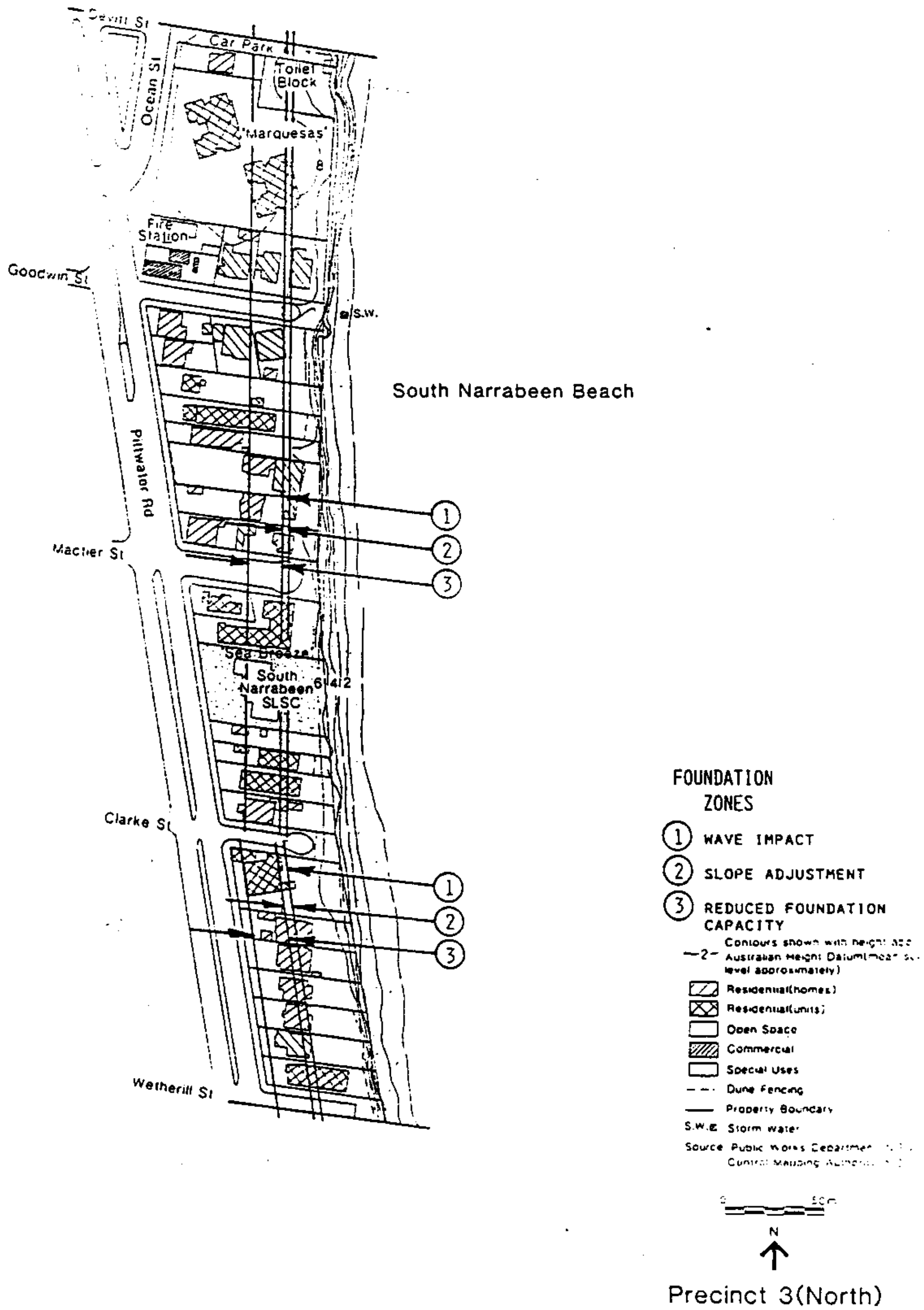
Stability Zones
Precinct 3 (South)

Figure 3.7

COFFEY

GEOMARINE



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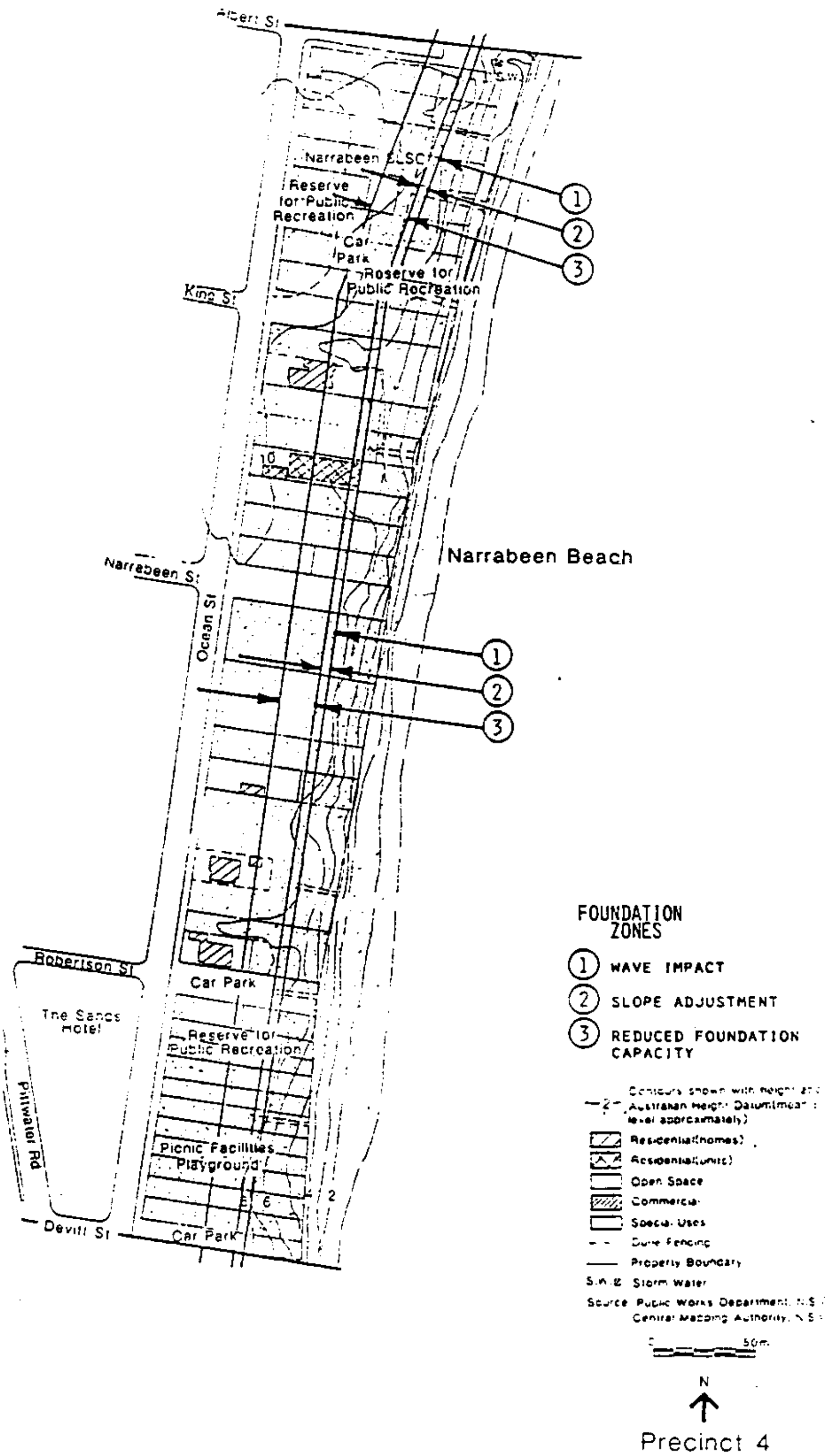
Stability Zones
Precinct 3 (North)

Figure 3.8

GEOMARINE

COFFEY



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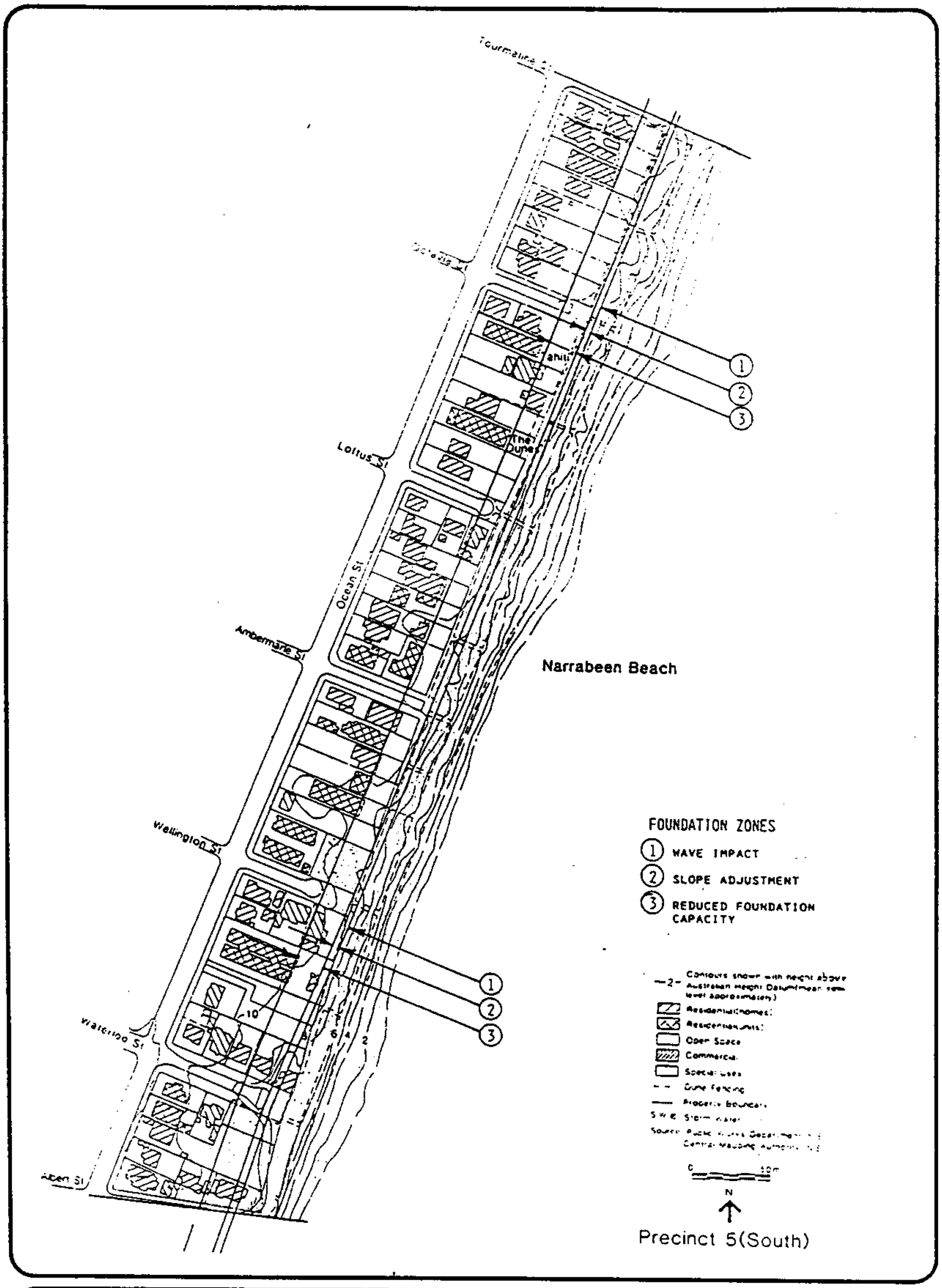
Stability Zones
Precinct 4

Figure 3.9

COFFEY

GEOMARINE



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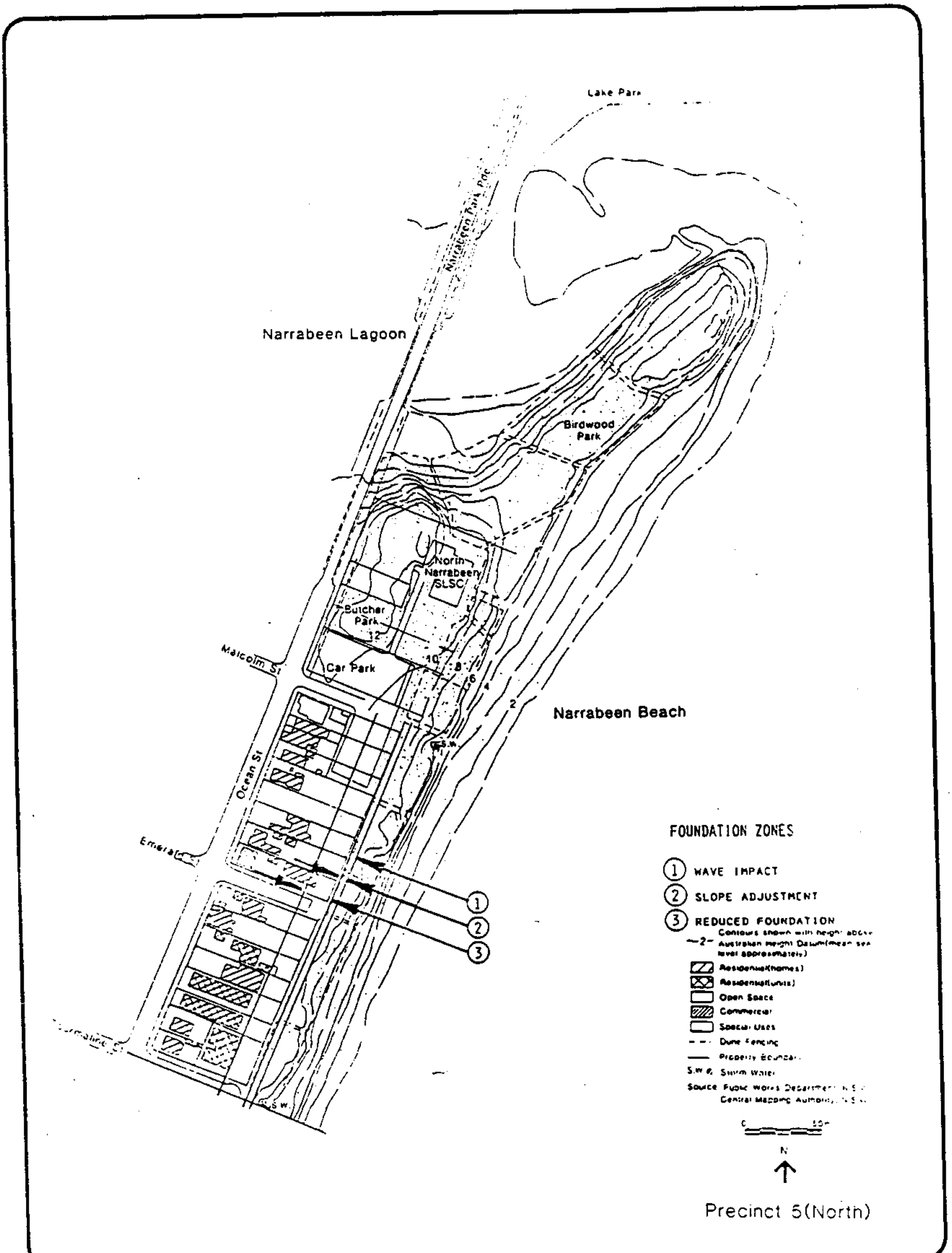
Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

Stability Zones
Precinct 5 (South)

Figure 3.10

GEOMARINE

COFFEY



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Narrabeen-Collaroy-Fishermans Beach
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Stability Zones
Precinct 5 (North)

Figure 3.11

COFFEY

GEOMARINE

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Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

1967 Storm Damage
Collaroy

Plate
4.1

GEOMARINE

COFFEY

4. Considerations for Foundations of Single Residential Dwellings

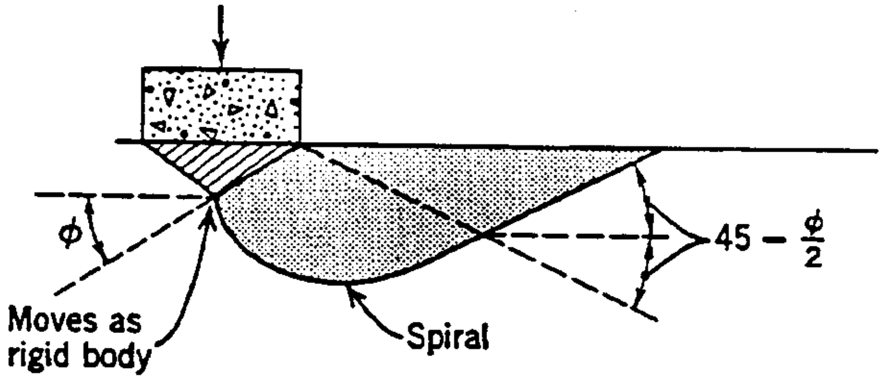
4.1 Introduction

Many domestic beachfront structures (homes) that have been destroyed during storms in New South Wales were lost as a result of failure of the soil mass rather than from direct wave impact loadings on the foundations. The inadequacy of standard foundations for houses located at the forefront of dunes is exemplified in **Plate 4.1** which shows the shoring up required to prevent the collapse of a dwelling at Collaroy during the storms of 1967.

There are no **Standards Association of Australia** codes of practice for the design and/or construction of foundations for domestic buildings in the active zone of the beach. The Institution of Engineers, Australia provides no guidelines nor is there any local government building code for such foundations in New South Wales. While there are engineering structures such as loading wharves and jetties designed for such locations, these are of a commercial nature or associated with defence and can bear a risk greater than that which is appropriate for domestic structures.

In determining appropriate design conditions for domestic foundations we consider it unacceptable that piling be subject to wave loading in the surf zone.

The factors that come under consideration in the design of structures on dunes include the extent of dune scour, the zone of slope adjustment and the structure foundation/soil interactions.



(after Terzaghi and Peck, 1967)

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Foundation Design Criteria for Residential Development

Failure Zones for Shallow Footings

Figure
4.1

GEOMARINE

COFFEY

4.2 Types of Foundations

4.2.1 Shallow Foundations

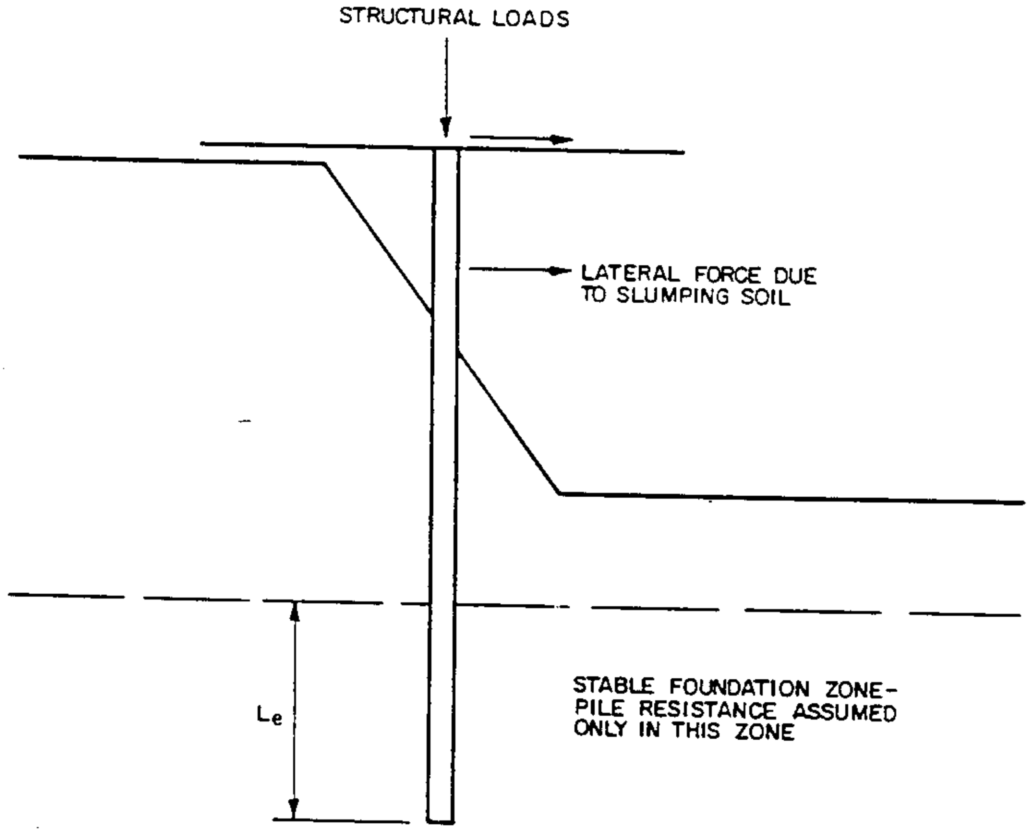
Shallow foundations include piers, strip footings and slabs. In common building standards the bearing capacity of such footings has been determined generally for the case of a horizontal bed. The failure zone of a shallow footing extends laterally (**Figure 4.2**) and, for shallow foundations located at or near the ground surface, should such a zone be located within the zone of potential slip failure then the bearing capacity of the footing would be reduced according to the extent of the zone of interference. To allow the soil to develop its ultimate bearing capacity such a footing would need to be set back such that the failure lines were beyond the failure zone of the stability analysis, that is, outside the design slip surface having an adequate Factor of Safety. This is the *Stable Foundation Zone.*

4.2.2 Piled and Piered Foundations

Structures may be founded on piles in such a way that the load is transmitted to strata below any possible failure zone within the dune. In this way a structure could be located within the *Zone Of Slope Adjustment*, albeit outside the zone of wave impact loading, and could, therefore, be located above the soil mass that has a factor of safety against slumping generally less than 1.5. For a soil to develop its shear strength the strain required along the failure plane is far greater than the strain required to shear a pile. Therefore, should a long pile intersect a possible failure plane, that is, should it be located partly within the soil mass for which the Factor of Safety is less than 1.0 (*Zone Of Slope Adjustment*), consideration will need to be given to the horizontal loads that may be applied to the pile should the slope slump and soil arching between piles occur. In the *Zone of Reduced Foundation Capacity* piers founded to a depth into the *Stable Foundation Zone* would not need to be designed for horizontal soil loading.

4.2.3 Seawalls

That a foreshore slope is lined with a seawall will not necessarily ensure its stability during extreme conditions. Vertical and non-porous seawalls are vulnerable and subject to sudden collapse should toe scour be coupled with a build up of water pressure behind the wall. Such walls are likely to experience scour at their toes additional to what otherwise may occur, thereby reducing further the stability of the slope.



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Schema for Pile in Zone of Slope Adjustment

Figure
4.2

GEOMARINE

COFFEY

The zone of possible slip failures is likely to extend beyond and below any seawall lining of a frontal dune face. To optimise the stability of protected foreshores any seawall should be designed to be permeable and constructed at a relatively flat slope, particularly if development is to be allowed close to the crest.

4.3 Foundations in the Zone of Slope Adjustment

Pile foundations should be used in this zone and should be designed to support the following loads:

- axial loads transmitted from the structure;
- lateral loads transmitted from the structure; and
- lateral loads developed by slumping of the soil past the piles.

4.3.1 Design for Structural Axial Loads

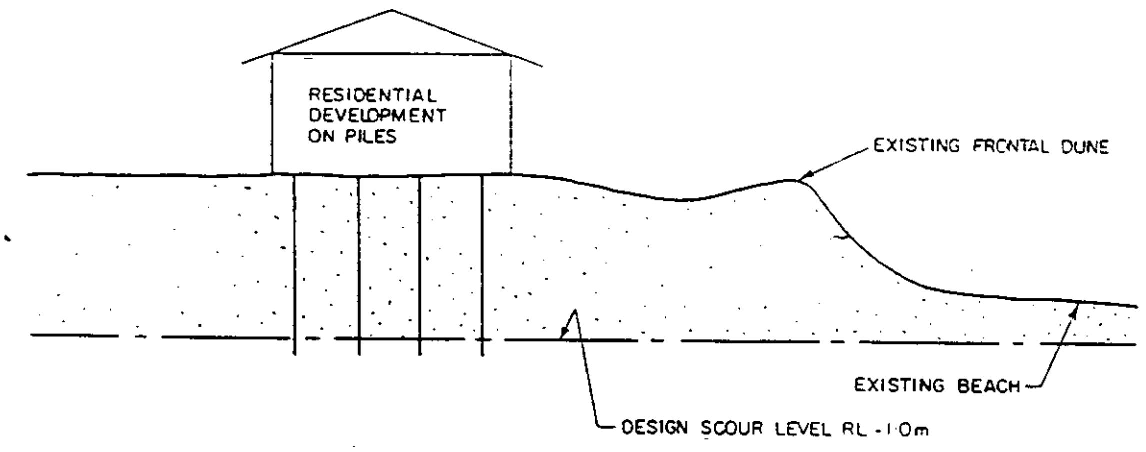
The piles should be designed in the conventional manner to satisfy the requirements of:

- an adequate factor of safety against geotechnical failure (i.e. failure of the supporting soil);
- an adequate factor of safety against structural failure of the piles themselves; and
- acceptable settlements under the design load.

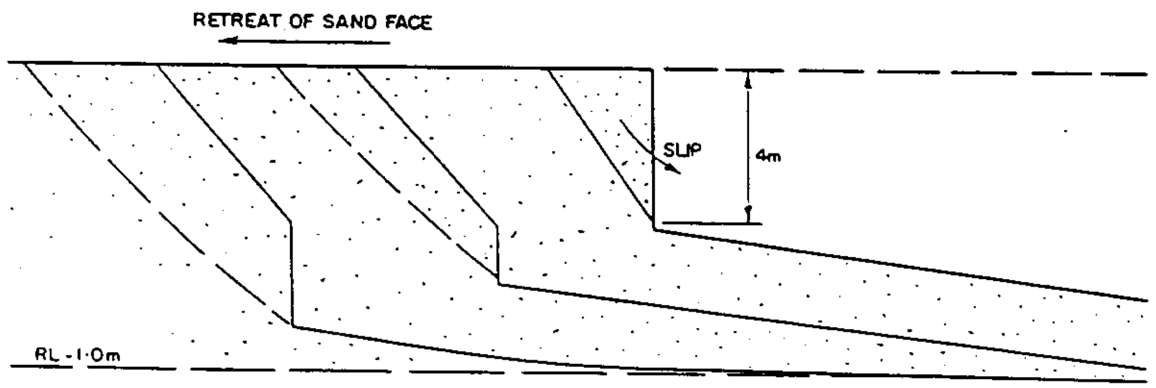
The Australian Standard Piling Code, AS2159-1978 (which is presently under revision), provides a basis for design for both load capacity and settlement. The required geotechnical parameters are:

- skin friction (shaft resistance) f_s;
- end bearing capacity f_b; and
- soil Young's modulus E_s.

Methods of assessing these parameters and of calculating axial capacity and settlement are given in the Piling Code. However, in assessing the geotechnical capacity of the pile, only that portion of the pile below scour level should be assumed to be effective in resisting the applied structural loads (see **Figure 4.2**). Similarly, when assessing the settlement of the pile, the settlement of the pile head should be taken as the sum of the compression of that portion of the pile above scour level, and the settlement of that portion of the pile below scour level.



DESIGN PROBLEM



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Foundation Design Criteria for Residential Development

Soil Failure Schema
Adopted for Pile Design

Figure 4.3

GEOMARINE

COFFEY

4.3.2 Design for Structural Lateral Loads

As with structural axial loads, the design of piles for structural lateral loads requires that the following criteria be satisfied:

- an adequate factor of safety against geotechnical failure of the piles;
- an adequate factor of safety against structural failure of the piles; and
- acceptable lateral deflections under the design loads.

The Australian Standard Piling Code again provides suitable approaches for the design of piles subjected to lateral loading. When applying these approaches, lateral resistance of the soil should only be assumed to exist below scour level.

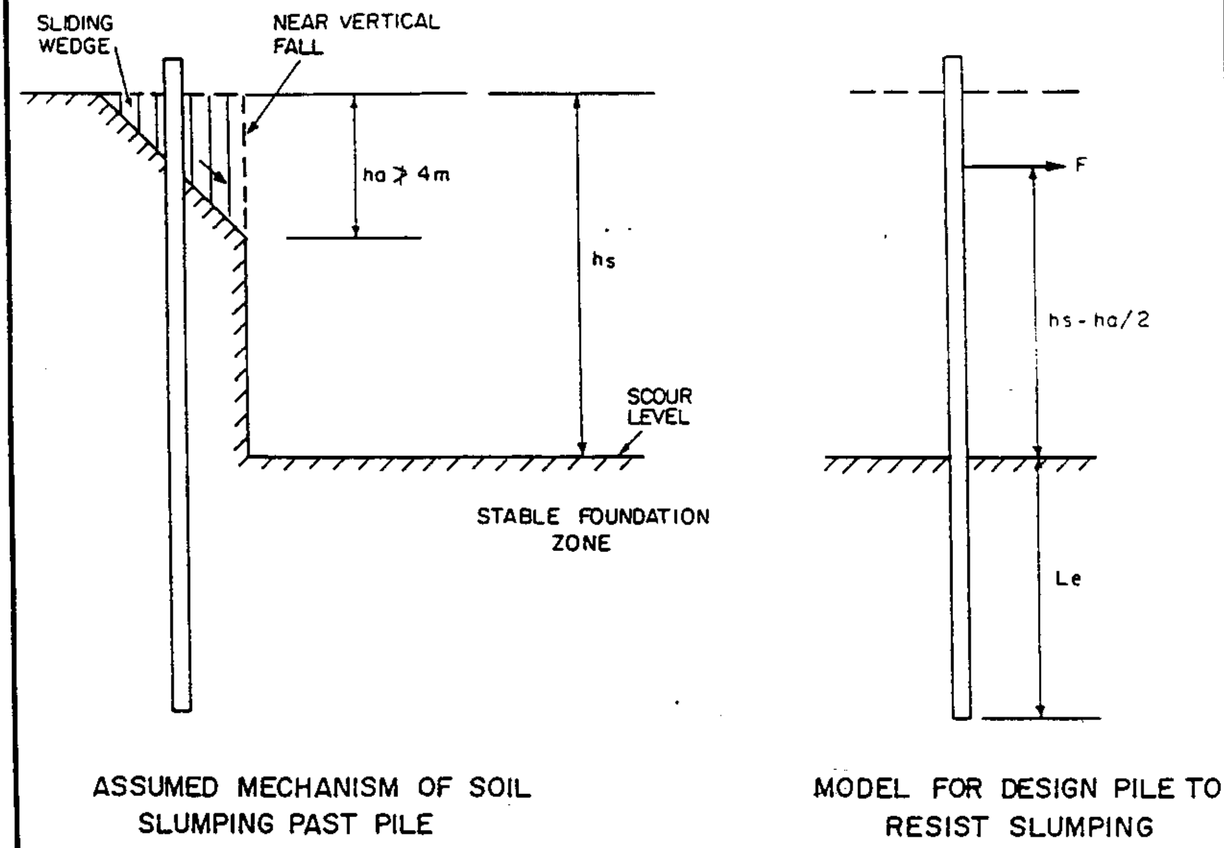
4.3.3 Design for Soil Slumping Past Piles

There are no well established criteria for this aspect of design, and therefore the treatment in this section is more extensive than for the design of piles subjected to axial or lateral structural loadings.

As with structural loadings, the design of piles to withstand soil slumping must consider:

- the lateral geotechnical capacity of the piles;
- the lateral structural capacity of the piles; and
- the lateral deflection of the pile caused by the slumping.

Assessment of the geotechnical and structural capacities of the piles requires an estimate of the forces and bending moments induced in a pile by slumping of the soil past the pile.
It is postulated that the mechanisms of collapse of an eroded sand face retreating beneath a piled structure are as shown in **Figure 4.3**. It is assumed that a vertical face can form and then slump past the piles. Based on fundamental principles of soil mechanics, equations have been developed for lateral loads on piles due to wedge failure of sand behind a retreating vertical face. These equations are presented in **Appendix A**. A key feature is that the maximum bending moment depends on the cube of the vertical face height. There is, however, a limit to the vertical face height which can exist and, if it is assumed that a maximum suction of 40 to 50kPa can be sustained within the sand (over a short time interval when the sand is wet), then it is found that the maximum height of the vertical sand face that can be sustained is about 4m.



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Soil Loading Criteria for Pile Design

Figure 4.4

GEOMARINE

COFFEY

It is recommended that a maximum vertical face height of 4m be adopted for design. The resulting mechanism of soil slumping past the pile is illustrated in **Figure 4.4**, together with the model of the pile for design to withstand the slumping forces.

For practical calculations, it is further assumed that:

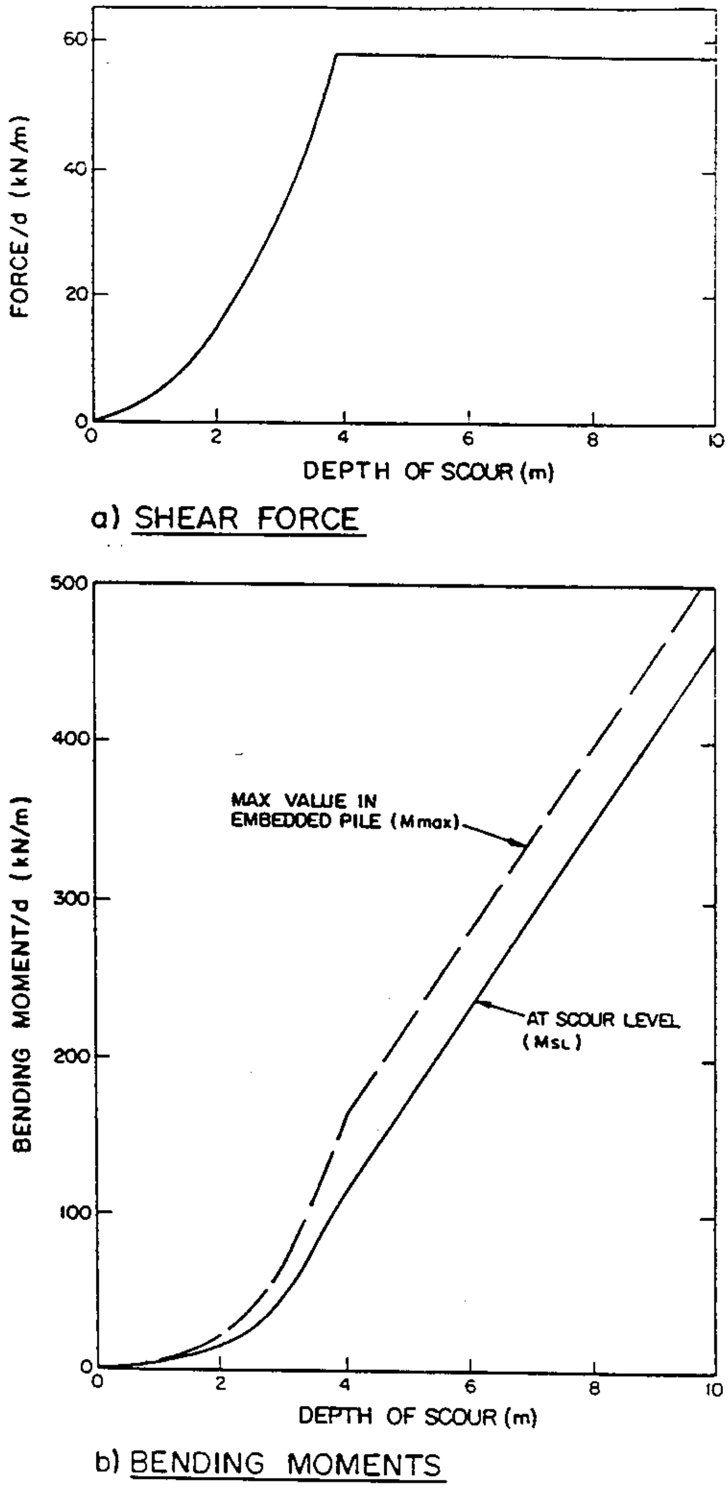
- the vertical face, after it slumps, comes to rest (at least temporarily) at a slope angle of 45°; and
- each pile is acted upon by a wedge with a maximum width B = 3d, where d = pile diameter or width, unless the piles are spaced more closely than 3d centre-to-centre, in which case B = the centre-to-centre spacing between the piles.

Making these assumptions and adopting typical parameters for the slumping sand (assumed to be in a relatively loose condition) of friction angle $\phi = 30^{\circ}$ and unit weight $\gamma = 18$ kN/m^3, the computed force and bending moment in the pile are shown in **Figure 4.5** as a function of the depth of scour. Because of the assumption made regarding a 4m maximum slump height, the force on the pile reaches a maximum value for scour heights equal to or greater than 4m (see **Figure 4.5a**); however, the bending moments continue to increase linearly with increasing scour depth, because of the increasing moment arm.

Figure 4.5b gives two curves:

- the bending moment at scour level (i.e. at the top of the supporting soil); and
- the maximum bending moment in the pile; this occurs in the portion of the pile embedded in the stable soil below scour level (it is assumed here that full soil resistance is mobilised above the point of maximum moment).

The curves in **Figure 4.5** provide the basis for design of the pile. It is considered reasonable to assume that, if the sand slumps past the pile, it will be in a relatively loose condition. However, if the friction angle of the soil or the unit weight differ markedly from the values adopted for **Figure 4.5**, the force and bending moment in the pile should be computed from the equations in **Appendix A**, bearing in mind the assumptions outlined above. **Figure A2** in **Appendix A** shows the effect of soil condition on the maximum shear force and bending moment at scour level. Assuming that B remains equal to 3 pile diameters, both the shear and bending moment decrease as the sand becomes more dense. Hence, the assumption of a loose sand in design will tend to be conservative.



DESIGN PARAMETERS

$\phi = 30°$
$\beta = 45°$
$\gamma = 18 kN/m^3$
$B = 3c$

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Shear Force and Bending Moments in Pile due to Slumping Sand Wedge

Figure 4.5

GEOMARINE

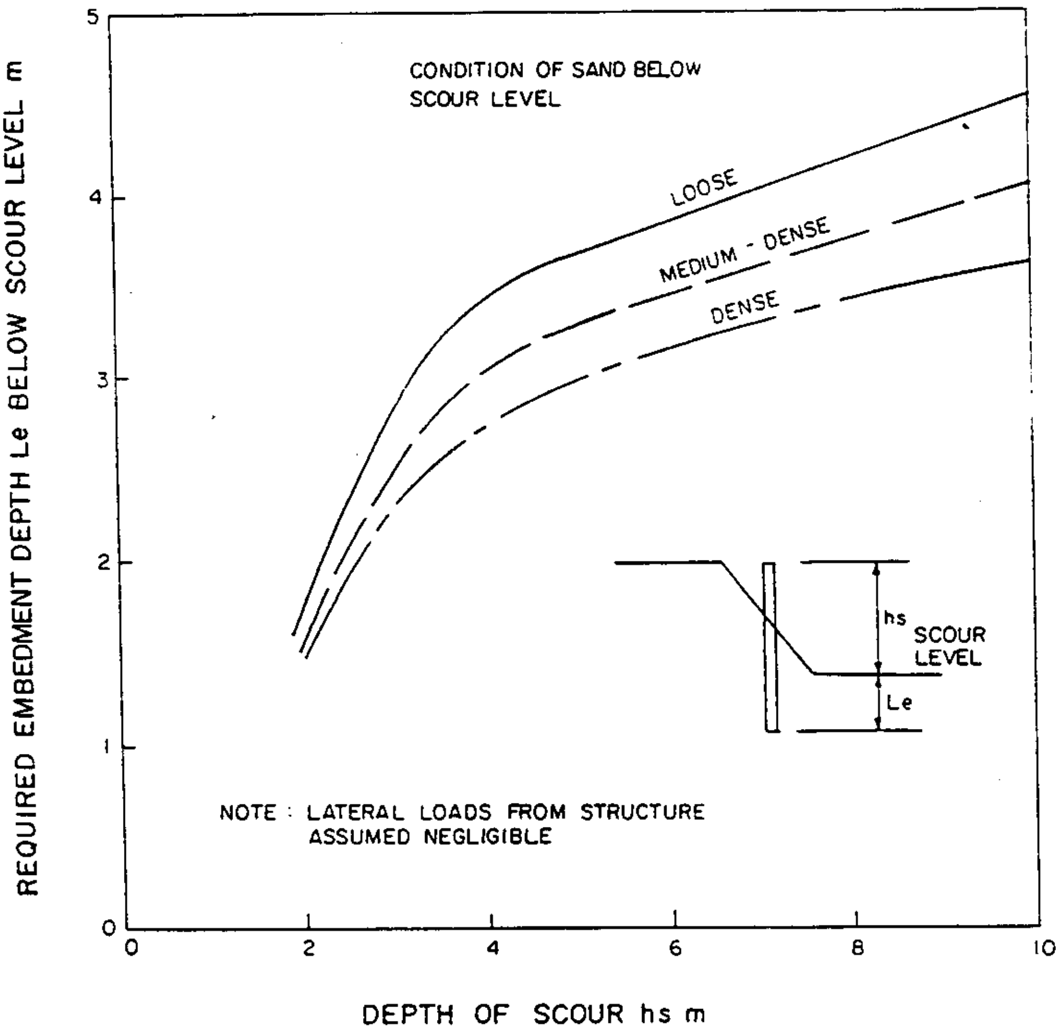
COFFEY

For geotechnical design, the pile must be embedded to a sufficient depth to resist the shear force and bending moment applied to the pile at scour level. Because of the likely extreme nature of the scouring process, it is considered that a *Factor Of Safety* of 1.5 should be adequate in this case. Using conventional lateral bearing capacity theory for piles (e.g. as presented in the Australian Standard Piling Code), it is possible to compute the required depth of embedment to develop a *Factor Of Safety* of 1.5 against lateral geotechnical failure. **Figure 4.6** plots the required embedment depth so computed, as a function of the depth of scour, h_s. Curves are shown for three sand conditions below scour level (in all cases the supporting sand is assumed saturated):

- loose sand, for which a friction angle ϕ of 30^o and an effective unit weight of $\gamma = 18kN/m^3$ are assumed;
- medium dense sand (assumed $\phi = 35^o$, $\gamma = 19kN/m^3$);
- dense sand (assumed $\phi = 38^o$, $\gamma = 20kN/m^3$).

As would be expected, the required depth of embedment L_e decreases as the sand becomes more dense. However, for most practical circumstances, L_e appears to lie within the range of 2.5 to 4.5m. It should, however, be emphasised that this required embedment depth is for the lateral forces due to soil slumping only; consideration must be given also to the embedment requirements for structural axial and lateral loadings.

For structural design of the pile, the pile section should be designed to withstand the maximum bending moment M_{max} as shown in **Figure 4.5**, with an appropriate margin of safety.
For assessment of lateral deflections due to the slumping of the slope, the model shown in **Figure 4.4** can be used, and conventional methods of calculation (e.g. as in the Australian Standard Piling Code) employed. The lateral deflection and rotation of the pile at the scour level are computed by assuming the pile to be subjected to the lateral force and bending moment (M_{max}) shown in **Figures 4.5a** and **4.5b** respectively. The additional deflection above the scour level (due to rotation and bending of the free-standing portion of the pile) is then computed and added to the deflection of scour level to obtain the lateral deflection of the structure. This value does not represent a permanent deflection, and will be at least partially recovered when the sand face retreats past the pile.



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Required Embedment Depth of Piles in Zone of Slope Adjustment

Figure 4.6

GEOMARINE

COFFEY

It should be noted also that the slumping of the slope will tend to induce an additional axial force in the pile due to the effects of negative friction. However, because of the values of negative skin friction near the top of the pile are likely to be low in sands, it is found that this additional axial force is generally negligible (typically of the order of 2 kN or less).

4.4 Foundations in the Zone of Reduced Foundation Capacity

In this zone, either shallow or deep foundations can be used, and should be designed to support the structural axial and lateral loadings. As before, the questions of geotechnical capacity, structural capacity and deformations under the design loads must be considered. Conventional methods of foundation analysis may be used; however, allowance must be made in the assessment of the geotechnical capacity of the foundation for the reduced resistance due to the proximity of the slumped soil escarpment. In the absence of adequate theoretical procedures for making such assessments, it is recommended that the required load capacity of the foundation be developed within the underlying Stable Foundation Zone, and that no allowance be made for the resistance of the soil in the soil above this zone. Thus, referring to Figure 4.7, for a spread footing, the base of the footing should be completely within the stable foundation zone, and it is assumed that no resistance is developed in the soil above the line A-A. For a pile foundation, no resistance is assumed above line B-B, so that the required axial and lateral capacity must be developed in the stable zone below this level. These assumptions are likely to be conservative, but it is believed that they provide a reasonable basis for foundation design, given the present state of knowledge. With these assumptions, the foundations in the zone may be designed by conventional foundation engineering principles. The parameters required for design are discussed below.

4.5 Geotechnical Parameters Required for Design

A summary of the main geotechnical parameters required for foundation design in coastal and beach developments is given in **Table 4.1**. Practical methods of assessing these parameters are discussed below.

Parameter; Definition	Uses
f_{all}; allowable bearing pressure	estimation of size of shallow foundation
f_s; pile skin friction	calculation of ultimate shaft capacity of pile
f_b; pile end bearing capacity	calculation of ultimate end bearing capacity of pile
E_s; Young's modulus of soil	calculation of foundation movements; different values are generally applicable for shallow and pile foundations, and for axial and lateral movements
γ; unit weight ϕ; friction angle	estimation of ultimate lateral capacity of pile and assessment of additional lateral force and moment developed in pile by slumping soil

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Summary of Main Geotechnical Parameters Required

Table 4.1

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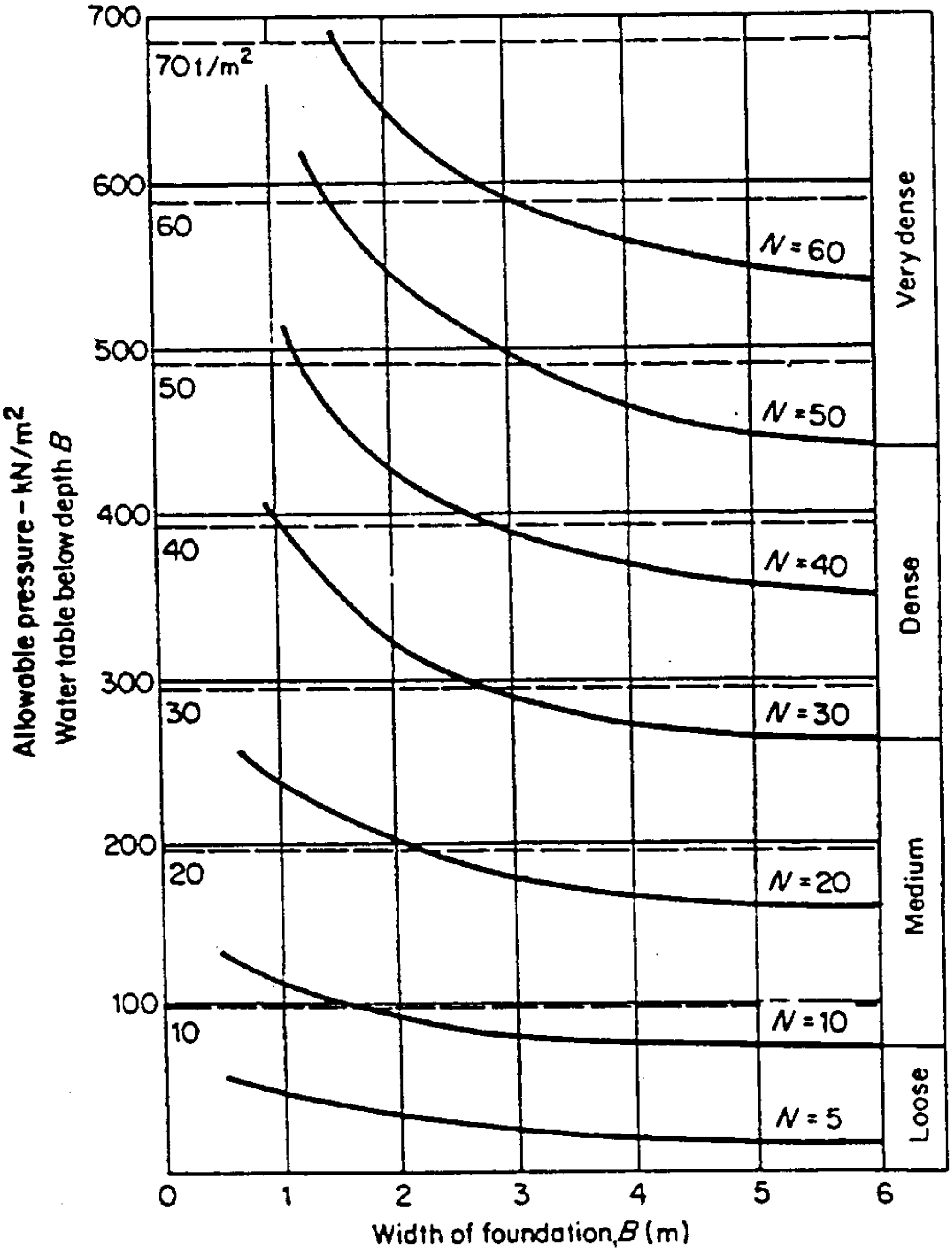
COFFEY



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Allowable Bearing Pressures for Foundations in Sands Based on SPT Results

Figure 4.8

COFFEY

GEOMARINE

Values of F, f_{sl}, N_q and f_{bl} for Piles in Silica Sand

Condition of Soil	Relative Density	Skin Resistance				Ultimate Base Resistance			
		Displacement Piles (1)		Non Displacement Piles (2)		Displacement Piles		Non Displacement Piles	
		F	f_{sl} kPa	F	f_{sl} kPa	N_q	f_{bl} MPa	N_q	f_{bl} MPa
Loose	0.2-0.3	0.8	25	0.3	10	60	2.0	25	0.8
Medium-loose	0.3-0.4	0.9	35	0.4	16	75	3.0	40	1.6
Medium	0.4-0.6	1.0	50	0.5	25	100	5.0	60	3.0
Medium-dense	0.6-0.75	1.2	65	0.65	35	130	7.0	80	4.2
Dense	0.75-0.9	1.5	85	0.8	45	180	10.0	100	5.5
Very dense	>0.9	1.75	100	0.9	50	210	12.0	120	7.0

1. Including cast in place piles of hammered shaft construction.

2. Assuming close supervision of construction is exercised.

$$f_s = F\sigma_v' \leq f_{sl} \qquad \text{... (2)}$$

where:

σ_v' = vertical effective stress;
F = skin friction factor; and
f_{sl} = limiting value of skin resistance.

Values of F and f_{sl} are shown in **Table 4.2** for normal silica-based sands. f_s may also be correlated approximately with standard penetration test (SPT) data. For piles in silica sand, **Meyerhof (1956)** suggests the following correlation for the average skin friction f_s along the pile shaft:

$$f_s = 2C_T\overline{N} \text{ kPa} \qquad \text{... (3)}$$

where:

$\overline{N}$ = average SPT value along shaft;
C_T = 1.0 for large displacement piles; and 0.5 for small displacement piles and for bored piles.

Alternative correlations with static cone penetration test data are summarised in **Poulos (1989)** and are shown in **Figure 4.9**.

The above values are used to estimate the ultimate pile shaft capacity by integrating the skin friction over the surface area of the pile shaft. A suitable factor of safety, typically 2.5, needs to be applied to the ultimate value to obtain an allowable value of shaft capacity.

4.5.3 Pile End Bearing Resistance f_b

The draft revised Australian Piling Code suggests that f_b can be estimated as follows:

$$f_b = \sigma'_{vb} N_q \leq f_{b1} \qquad \text{... (4)}$$

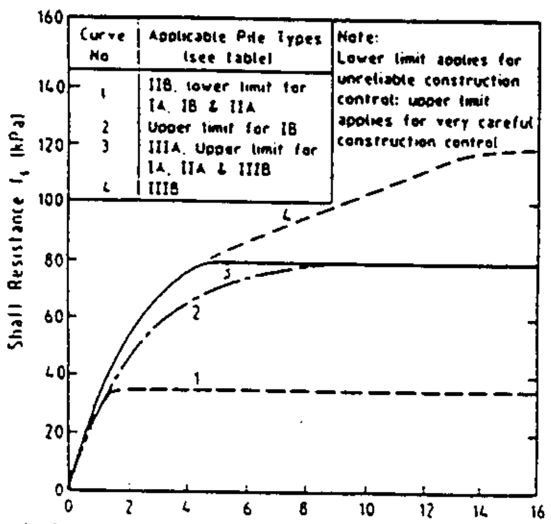
where:

σ'_{vb} = effective vertical overburden pressure at level of pile tip;
N_q = bearing capacity factor; and
f_{bl} = limiting value of end bearing resistance.

Recommended values of N_q and f_{bl} are shown in **Table 4.2**.

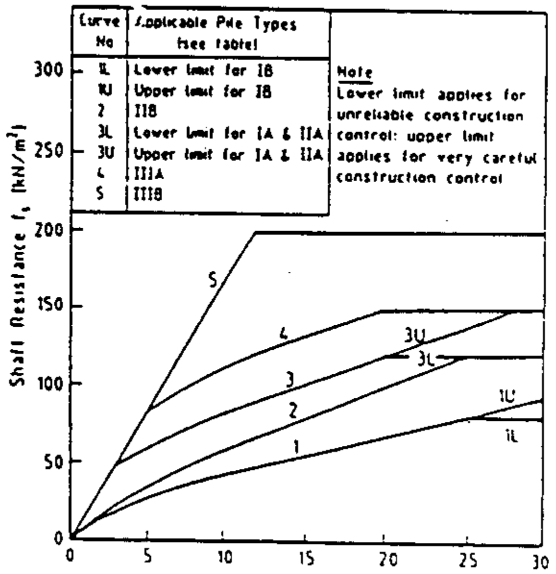
Pile Category	Type of pile
IA	Plain bored piles, mud bored piles, hollow auger bored piles, cast screwed piles
IB	Cased bored piles Driven cast piles
IIA	Driven precast piles Prestressed tubular piles Jacked concrete piles
IIB	Driven steel piles Jacked steel piles
IIIA	Driven grouted piles Driven rammed piles
IIIB	High pressure grouted piles (d > 0.25 m) Type II micropiles

CLAYS



(a) Cone resistance q_c (MPa)

SANDS



(b) Cone Resistance q_c (MN/m²)

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Correlations Between Ultimate Shaft Resistance and Static Cone Resistance

Figure 4.9

GEOMARINE

COFFEY

Correlations between f_b and SPT data are summarised in **Poulos (1989)**, and can be expressed as:

$$f_b = KN \text{ MPa} \quad \text{... (5)}$$

where:

N = average SPT value in vicinity of pile tip; and
K = factor depending on pile and soil type.

K ranges from about 0.4 for driven piles in sand to 0.1 for bored piles in sand.

f_b can be roughly correlated also with static cone penetration resistance data:

$$f_b = K_1 q_c \quad \text{... (6)}$$

where:

q_c = average cone resistance in vicinity of pile tip;
K_1 = factor which generally lies between 0.1 and 0.55, depending on soil and pile type.

The above values are used to estimate the ultimate end bearing capacity of the pile by multiplying by the area of the pile base. A suitable factor of safety, typically 2.5, needs to be applied to the ultimate value to obtain an allowable value of pile base load.

4.5.4 Young's Modulus E_S

Because soil is not an elastic material, the equivalent value of Young's modulus to be used for foundation deformation calculations will depend on the type of foundation and the type of loading, as well as the type of soil. Different methods of calculation may also require different correlations to be employed.

4.5.4.1 Shallow Foundations

One of the procedures more commonly used for estimating settlements of shallow foundations on sands is that proposed by **Schmertmann (1970)** and summarised in **Tomlinson (1986)**. In this method, E_s is correlated with the static cone resistance q_c as follows:

$$E_s = \alpha q_c \quad \text{... (7)}$$

where:

α = 2.5 for circular and square foundations; and 3.5 for strip or long (length/breadth > 10) rectangular foundations, and is interpolated between the above values for rectangular foundations.

An alternative approach for settlement estimation, based on SPT data, has been proposed by **Burland and Burbridge (1985)** and is summarised also in **Tomlinson (1986)**.

4.5.4.2 Pile Foundations

(a) Axial Loading

For axially loaded piles in sand the Australian Standard Piling Code suggests the average values of E_s shown in **Table 4.3** for driven piles. Some correlations between E_s and cone penetration resistance are summarised in **Poulos (1989)**.

Table 4.3 Typical Values of Young's Modulus for Driven Axially Loaded Piles in Silica Sand

Soil Type	E_s (MPa)
Loose sand	42
Medium sand	70
Dense sand	90
Very dense sand	200

(b) Lateral Loading

For laterally loaded piles in sand, it is frequently assumed that Young's modulus increases linearly with depth, so that:

$$E_s = C_2 N_h Z \quad \text{... (8)}$$

where:

C_2 = 1.0 for dry and moist sands; and
= 0.66 for saturated sands.

Values of N_h suggested by the Australian Standard Piling Code are shown in **Table 4.4**. Alternative correlations for this case have been proposed by **Kishida and Nakai (1977)** who suggest:

$$E_s = 1.6N \text{ MPa} \quad \text{... (9)}$$

where:

N = SPT value.

Table 4.4 Typical Values of Soil Modulus Gradient for Laterally Loaded Piles in Sand

Soil Type	N_h (MPa/m)
Loose sand	1.6
Medium dense sand	4.8
Dense sand	12.6

4.5.5 Unit Weight, γ

The unit weight of a soil is related to its void ratio, e, and the unit weight of water γ_w and will be in the range between the dry unit weight γ_d and the saturated unit weight γ_{sat}, where:

$$\gamma_d = G\gamma_w/(1 + e) \qquad ...(10)$$

$$\gamma_{sat} = (G + e)\gamma_w/(1 + e) \qquad ...(11)$$

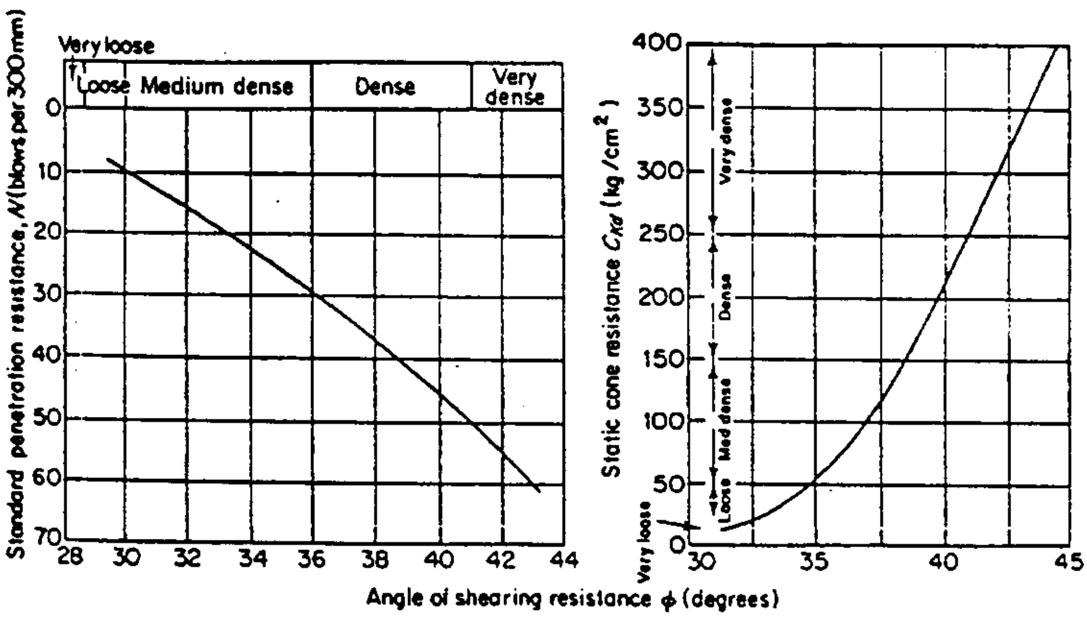
where:

G = specific gravity of soil particles, typically 2.68 for quartz sands

When a site investigation has established the level of the water and enabled the void ratio to be estimated, the value of γ can readily be calculated. For common ranges of void ratios in sands (between 0.5 and 0.9), γ will lie between 13.4 and 20.8 kN/m^3, although more commonly the range is narrower, between 16 and 20 kN/m^3.

4.5.6 Angle of Friction ϕ

The angle of friction of a sandy soil may be established by means of laboratory testing, the most convenient test for this purpose being a direct shear test. Correlations have also been suggested between ϕ and the results of conventional insitu tests, and two such correlations are shown in **Figure 4.10 (Tomlinson, 1986)**. ϕ may be influenced also by the shape of the sand grains and tends to be lower for sands with rounded grains than for those with angular grains.



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Determination of φ from In-situ Tests

Figure
4.10

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5. Typical Foundation Conditions and Requirements for the Collaroy-Narrabeen-Fishermans Beach Areas

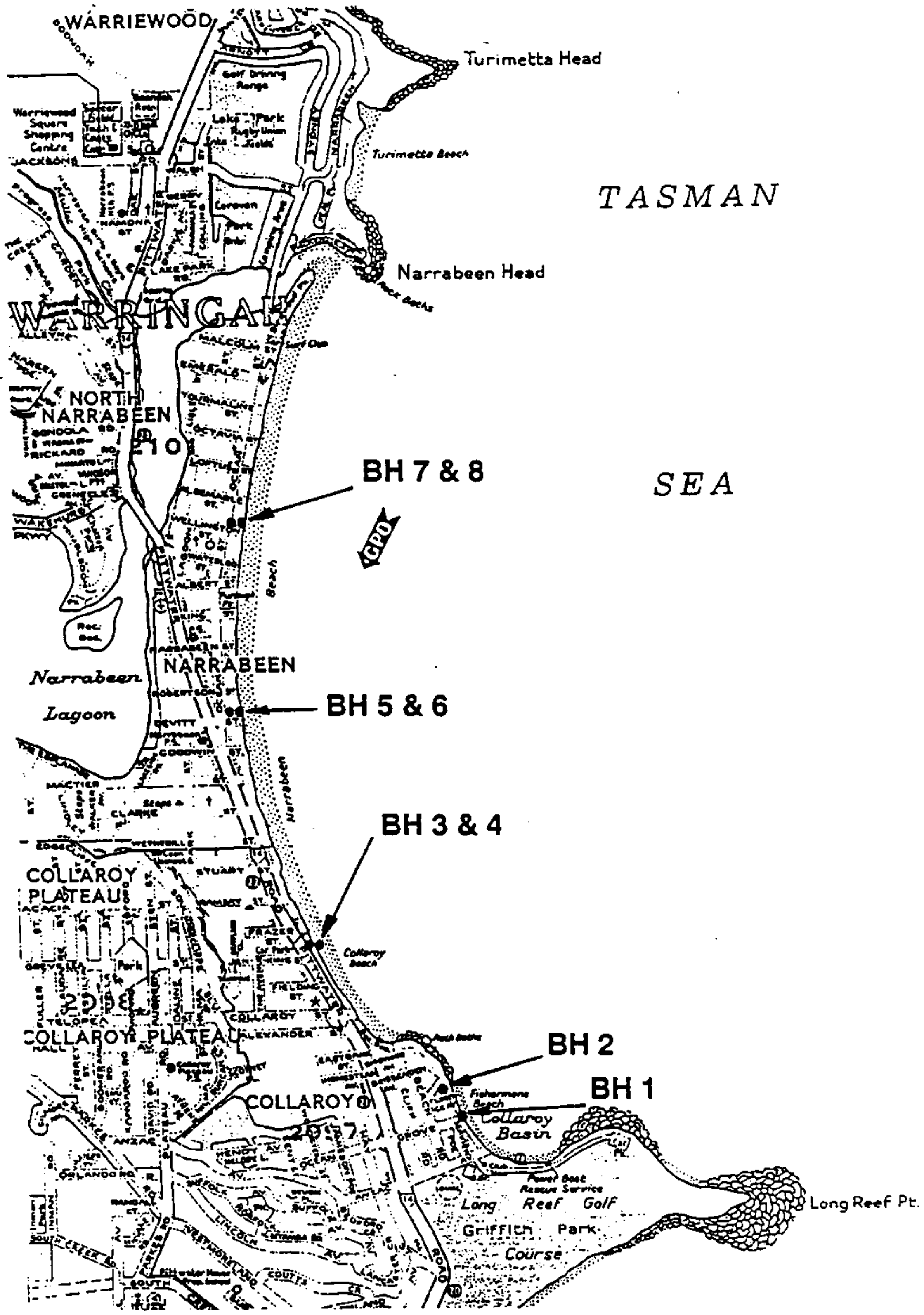
5.1 Introduction

In this section the design procedure is used with appropriate geotechnical parameters for the Collaroy-Narrabeen-Fishermans Beach areas to develop typical foundation design requirements. However, it is neither possible nor desirable to develop "standard" foundation designs as the geotechnical conditions and structural loads vary from project to project.

5.2 Results of Investigation and Assessment of Design Conditions

Field investigations at specific sites were carried out between 30th November and 4th December 1990. Field work comprised auger drilling together with electric friction cone testing. Eight holes were drilled to maximum depths of 10m at locations shown in **Figure 5.1**.

The soil profile encountered in the boreholes is shown in the logs presented in **Appendix B**. The logs of boreholes 3 to 8 have been summarised into cross sections which are presented in **Appendix B**. The cross sections provide also a profile of SPT results and water level recordings.



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Borehole Locations

Figure 5.1

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BH No.	Location	Depth Range (m)	SPT (N)	Broad Classification
BH1	Fishermans Beach South end	0.0 to 1.3		Fill and topsoil
		1.3 to 2.9	5	Medium dense alluvial clayey sand
		2.9 to 5.7	13	Hard, high plasticity alluvial clay
		5.7 to 10.5	19	Hard, medium plasticity residual clay
BH2	Fishermans Beach North end	0.0 to 1.2		Fill
		1.2 to 3.7	2	Loose beach sand with shell fragments
		3.7 to 4.7	1	Very loose clayey sand
		4.7 to 5.7	R	EW-HW claystone
BH3	Collaroy Beach North end	0.0 to 0.3		Fill
		0.3 to 1.6	5	Medium dense dune sand
		1.6 to 3.7	31	Very dense dune sand
		3.7 to 5.0	41	Very dense cemented beach sand
		5.0 to 7.1	5	Loose beach sand
		7.1 to 8.6	3	Loose estuarine clayey sand
		8.6 to 9.3	15	Stiff to very stiff estuarine clay
BH4	Collaroy Beach North end	0.0 to 7.8	20-35	Dense to very dense dune sand
		7.8 to 9.3		Very dense estuarine clayey sand
		9.3 to 10.1		Estuarine sandy clay
BH5	Narrabeen Beach South end	0.0 to 0.8		Fill
		0.8 to 5.5	10-15	Medium dense to dense dune sand
		5.5 to 10.1	40	Very dense dune sand
BH6	Narrabeen Beach South end	0.0 to 0.9		Fill
		0.9 to 5.2	8-12	Medium dense to dense dune sand
		5.2 to 7.0	30	Dense dune sand
		7.0 to 10.25	R	Very dense indurated sand
BH7	Narrabeen Beach	0.0 to 1.1		Fill
		1.1 to 8.3	10-15	Medium dense dune sand
		8.3 to 10.2	R	Very dense indurated sand
BH8	Narrabeen Beach	0.0 to 5.3	10-15	Medium dense dune sand
		5.3 to 7.8	12->30	Medium to very dense dune sand
		7.8 to 10.25	>30	Very dense indurated sand

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Narrabeen-Collaroy-Fishermans Beach
Foundation Design Criteria for Residential Development

Broad Geotechnical Parameters

see Figure 5.1 for borehole locations

Table 5.1

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Boreholes 5 to 8 encountered a fairly uniform profile of medium grained sands containing little or no fines. Below the water table, these sands became cemented by calcareous and iron oxide cements. Boreholes 3 and 4 encountered a layer of sandy clay at about RL -1m which graded into a grey high plasticity clay at RL -3m in BH3. Boreholes 1 and 2 encountered dune sands overlying weathered shale and claystone.

Laboratory testing on selected samples consisted of particle size gradings and direct shear testing. The results of laboratory testing are presented in **Appendix C**.

Based on the results of the field investigations and the laboratory data our assessments of the broad geotechnical conditions at the various locations investigated are summarised in **Table 5.1**. At almost all locations, hard clay or dense sand layers are encountered at depths ranging between about 5 and 9m below surface level. Such layers appear to be very suitable for providing foundation support. Typical values of unit weight and angle of friction are shown in **Table 5.2**. As a first approximation, the foundation design parameters can then be estimated as follows:

(a) **Shallow Foundations**

f_{all}	**Figure 4.8**
E_s	Equation 7

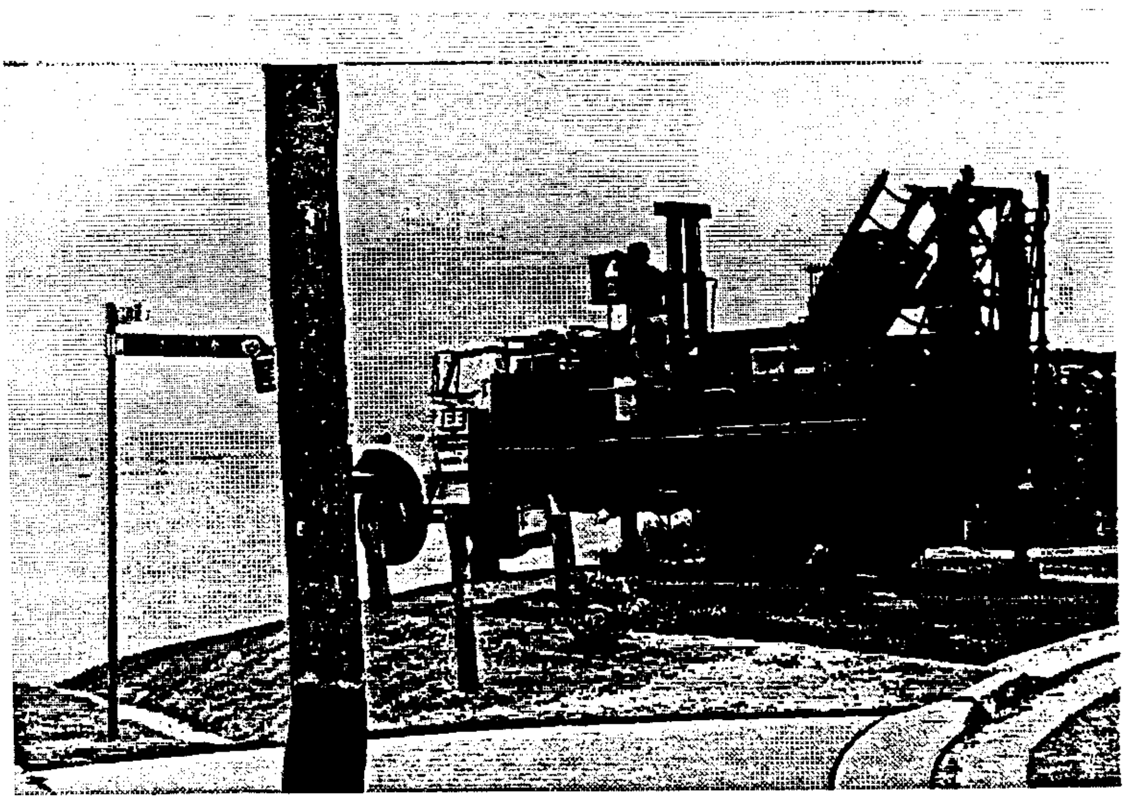
(b) **Pile Foundations**

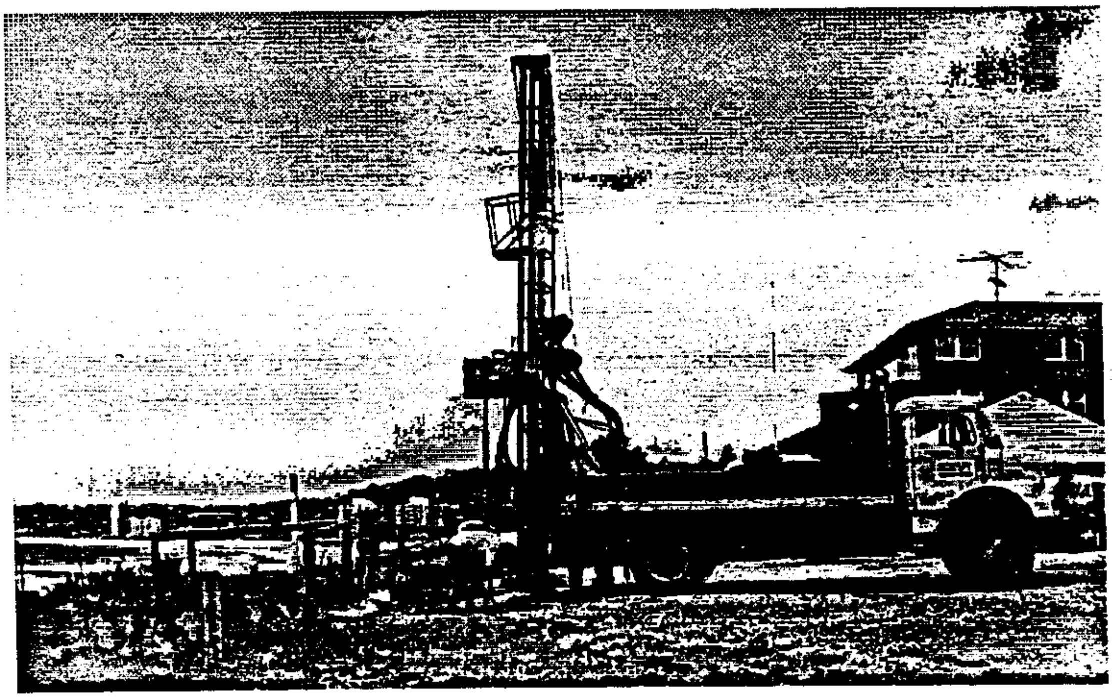
f_s	**Table 4.2**, Equations 2 and 3
f_b	**Table 4.2**, Equations 4 to 6
E_s (axial loading)	**Table 4.3**
E_s (lateral loading)	**Table 4.4**, Equations 8 and 9

Table 5.2 Typical Values of Unit Weight and Angle of Friction for the Collaroy-Narrabeen Beach Areas

Soil Type	Typical γ* (kN/m^3)	Typical ϕ (degrees)
Loose sand	18	30
Medium dense sand	19	35
Dense Sand	20	38
Clay	18	N/A

*saturated unit weight





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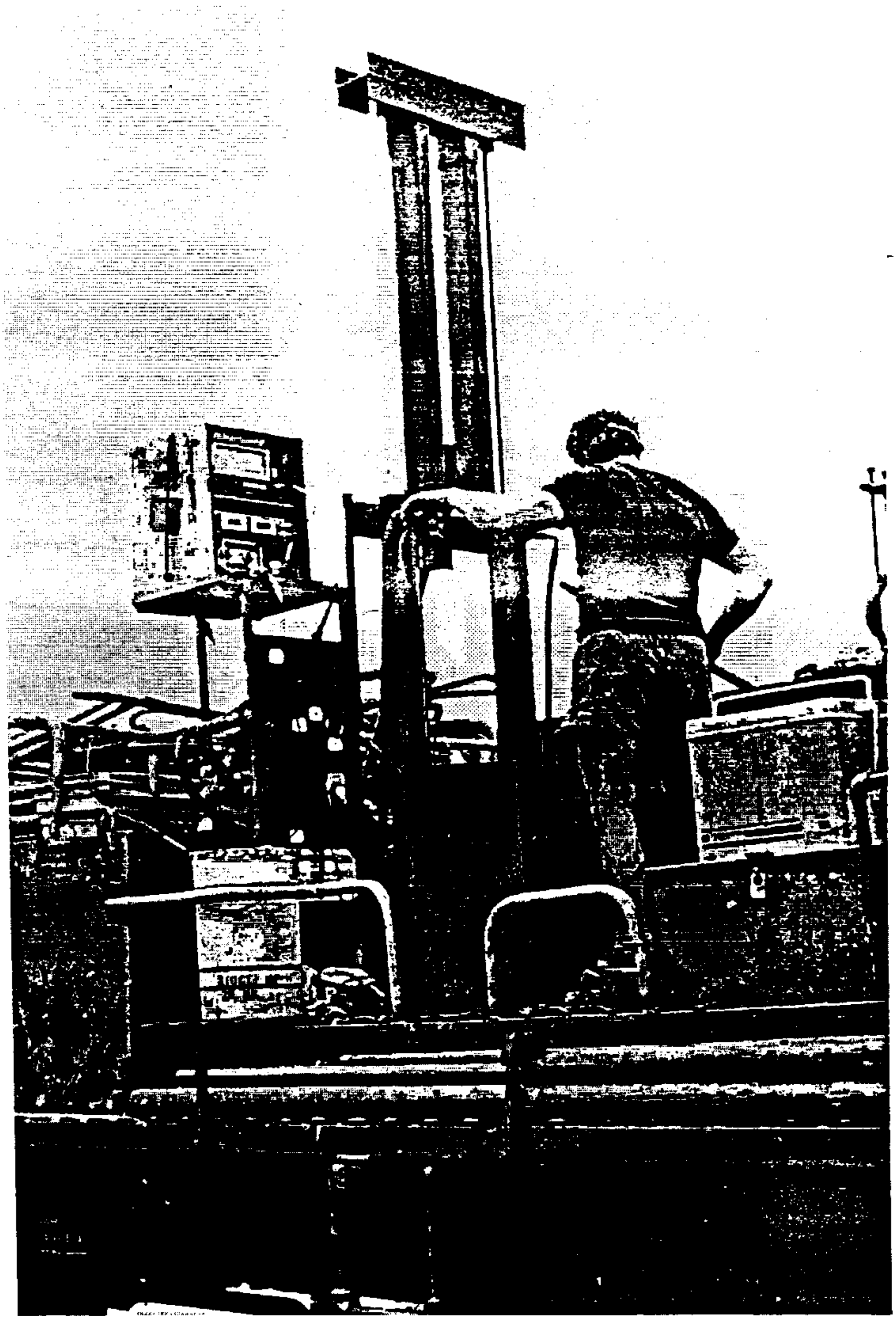
Foundation Design Criteria for Residential Development
Foundation Investigations
November, 1990

Plate
5-1

COFFEY

GEOMARINE



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Detailed View of Dutch Cone Penetrometer Rig

Plate 5.2

GEOMARINE

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5.3 Foundation Requirements

5.3.1 Zone of Slope Adjustment

In this zone only piles can be used for foundation support and such piles must be designed to withstand forces and moments induced in the pile by a slumping soil face as well as structural vertical and lateral loads.

The minimum depth of embedment of such piles into the underlying stable zone is indicated in **Figure 4.6**. For the depths of scour likely to be encountered in the Collaroy-Narrabeen area the required minimum embedment depth below scour level is likely to be between 3 and 4m. However, the pile must be checked also for axial and lateral structural loadings to ensure that the embedment depth is adequate for the effects of combined loading and that the pile section is not overstressed under the combined action of structural and soil loadings.

5.3.2 Zone of Reduced Foundation Capacity

In this zone, either piles or shallow foundations may be used to support the structural, vertical and lateral loads, but the resistance must be developed from the stable soil below the zone of reduced foundation capacity.

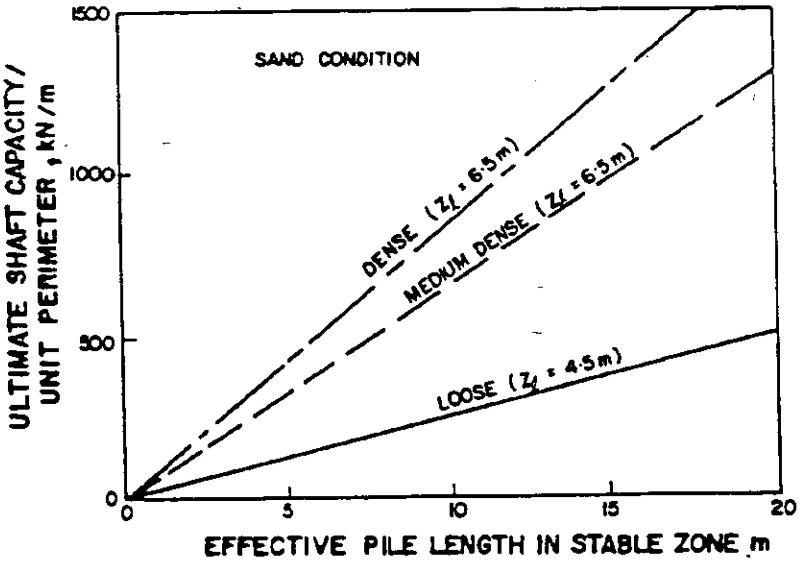
To provide some guidance on the axial load capacity and settlement of piles in the Collaroy-Narrabeen-Fishermans Beach areas the recommended design parameters have been used to prepare design charts which are shown in **Figures 5.2** and **5.3**.

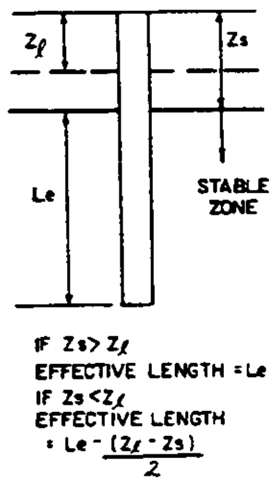
Figure 5.2 shows the ultimate shaft capacity, per unit perimeter, as a function of effective pile length in the stable zone. When the depth from the soil surface to the stable zone, z_s, exceeds the depth, z_l, at which the skin friction reaches its limiting value, the effective pile length is equal to the length, L_e, within the stable zone. If z_s is less than z_l, the effective length is reduced as shown in **Figure 5.2** to allow for the fact that the design skin friction has not reached a constant value.

Figure 5.3 shows the ultimate end bearing capacity of a pile as a function of base diameter. In this figure it is assumed that the pile base lies below the depth z_l required for the limiting end bearing pressure to be developed.

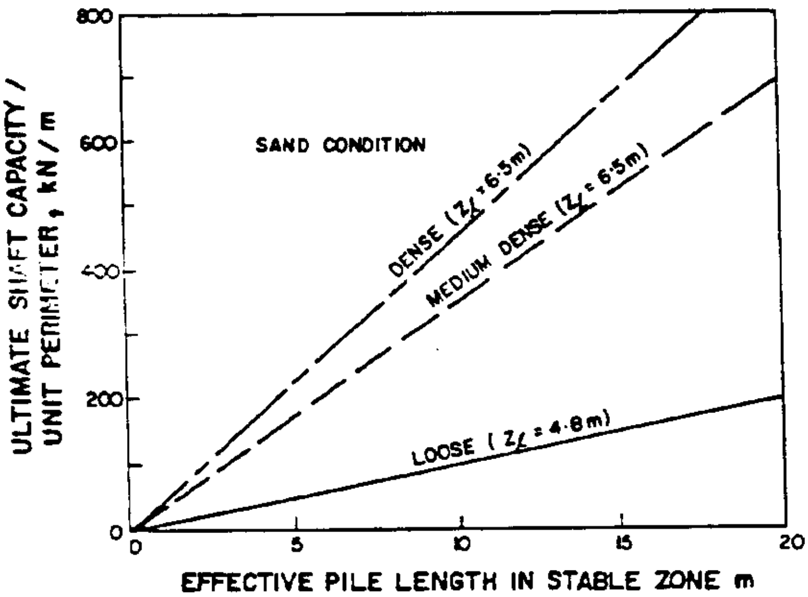
Figures 5.4 to **5.9** show the settlement per unit load for both driven and bores piles in sands of different densities. These charts have been prepared using typical design parameters and the approach described in **Poulos** (1989).

The settlement referred to is for the portion of the pile within the stable zone. Group effects should be allowed for, for example, as suggested in **Poulos (1989)**. To this settlement must be added the compression of the pile above the stable layer, assuming that no load transfer occurs within the zone of reduced foundation capacity. A simple chart for estimating this compression is given in **Figure 5.10**, assuming that the equivalent Young's modulus of the pile section is 25000 MPa. This chart would be applicable to concrete piles and to steel tube piles with a steel area of about 12% of the gross cross-sectional area of the piles.





a) DISPLACEMENT PILES



b) NON - DISPLACEMENT PILES

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Design Charts for Ultimate Pile Shaft Capacity in Sand

Figure 5.2

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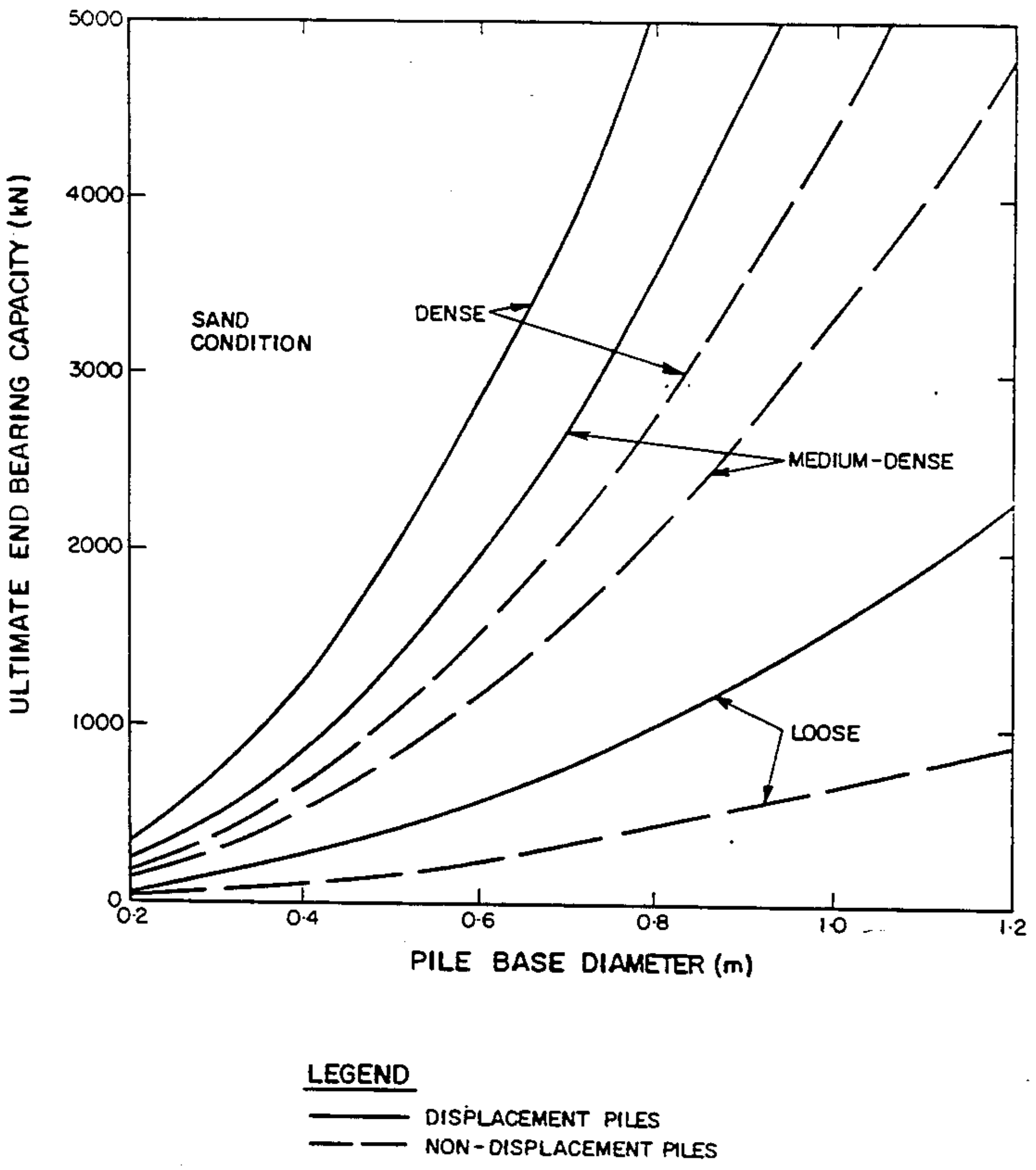

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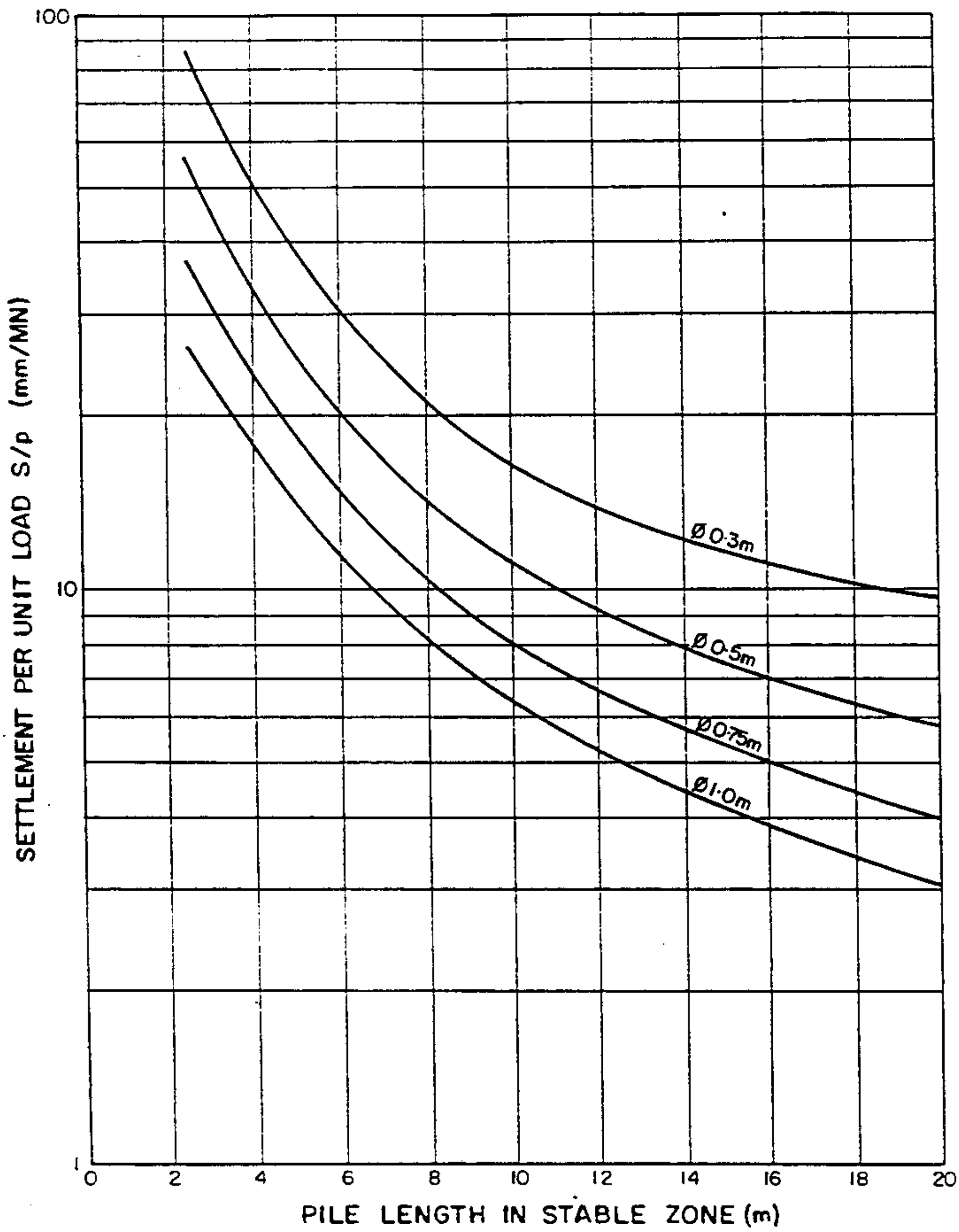
Design Chart for Ultimate Base Load Capacity in Sand

Figure 5.3

GEOMARINE

COFFEY



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Design Chart for Settlement of Single Driven Pile in Loose Sand

Figure 5.4

COFFEY

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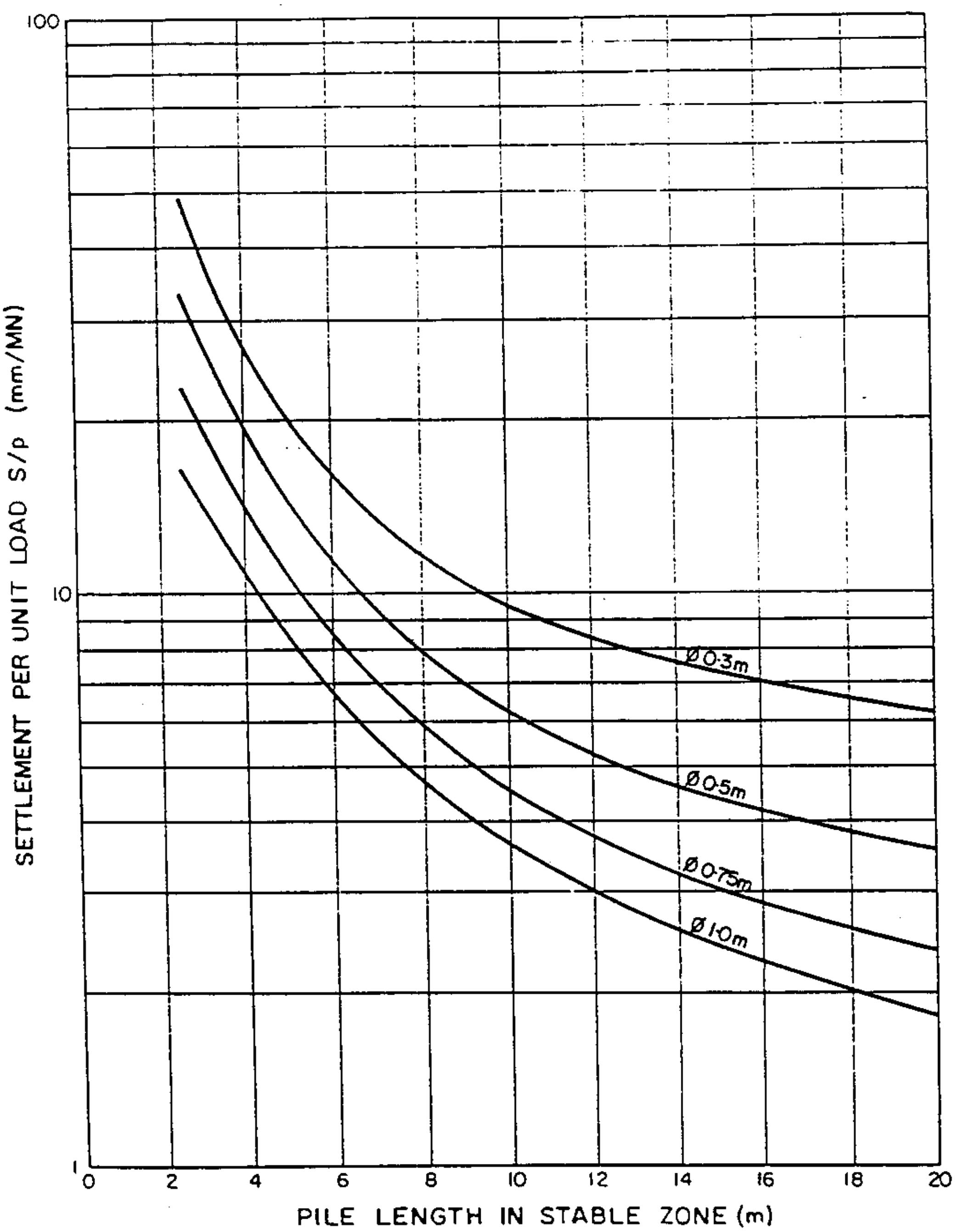

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Design Chart for Settlement of Single Driven Pile in Medium-Dense Sand

Figure 5.5

GEOMARINE

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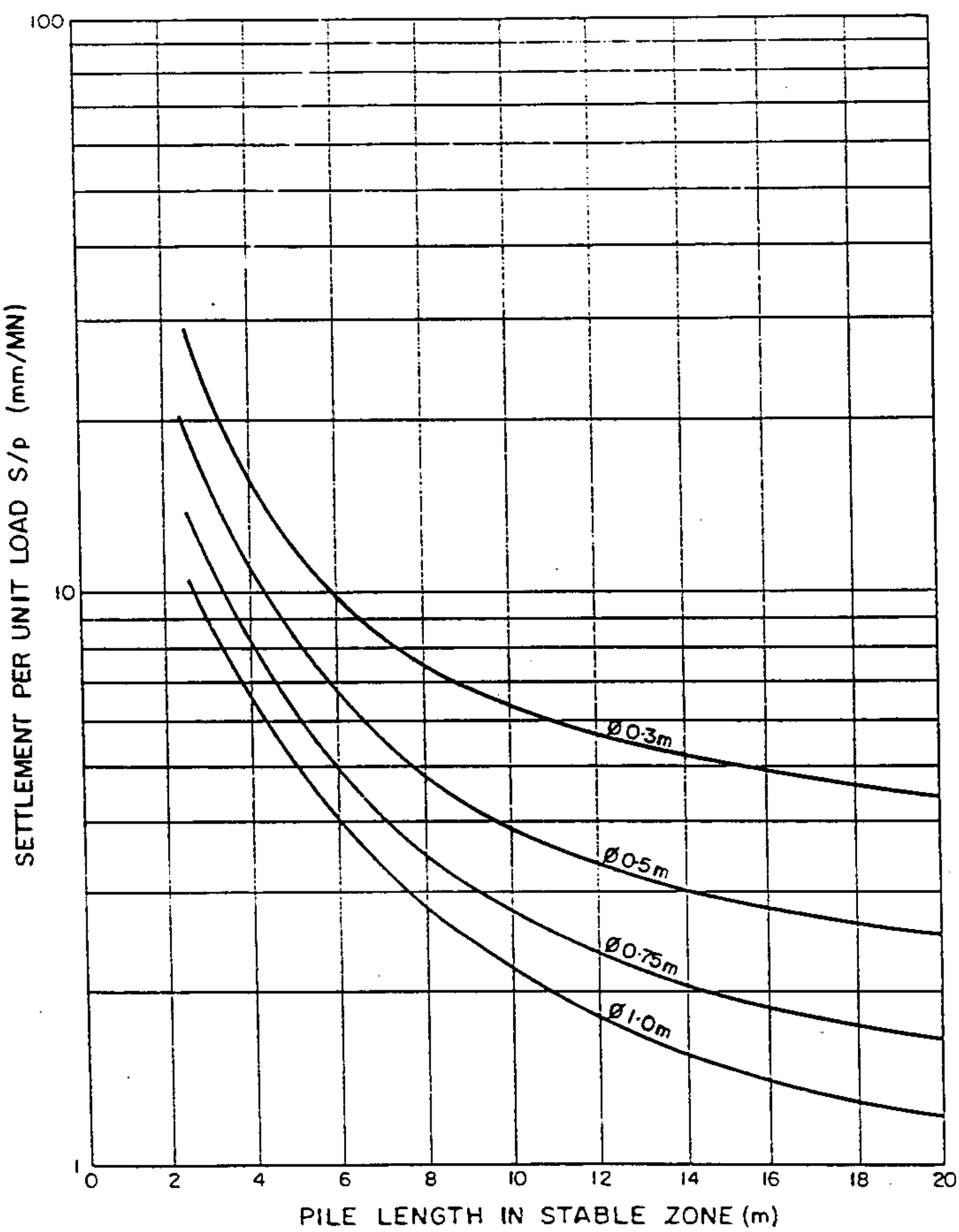

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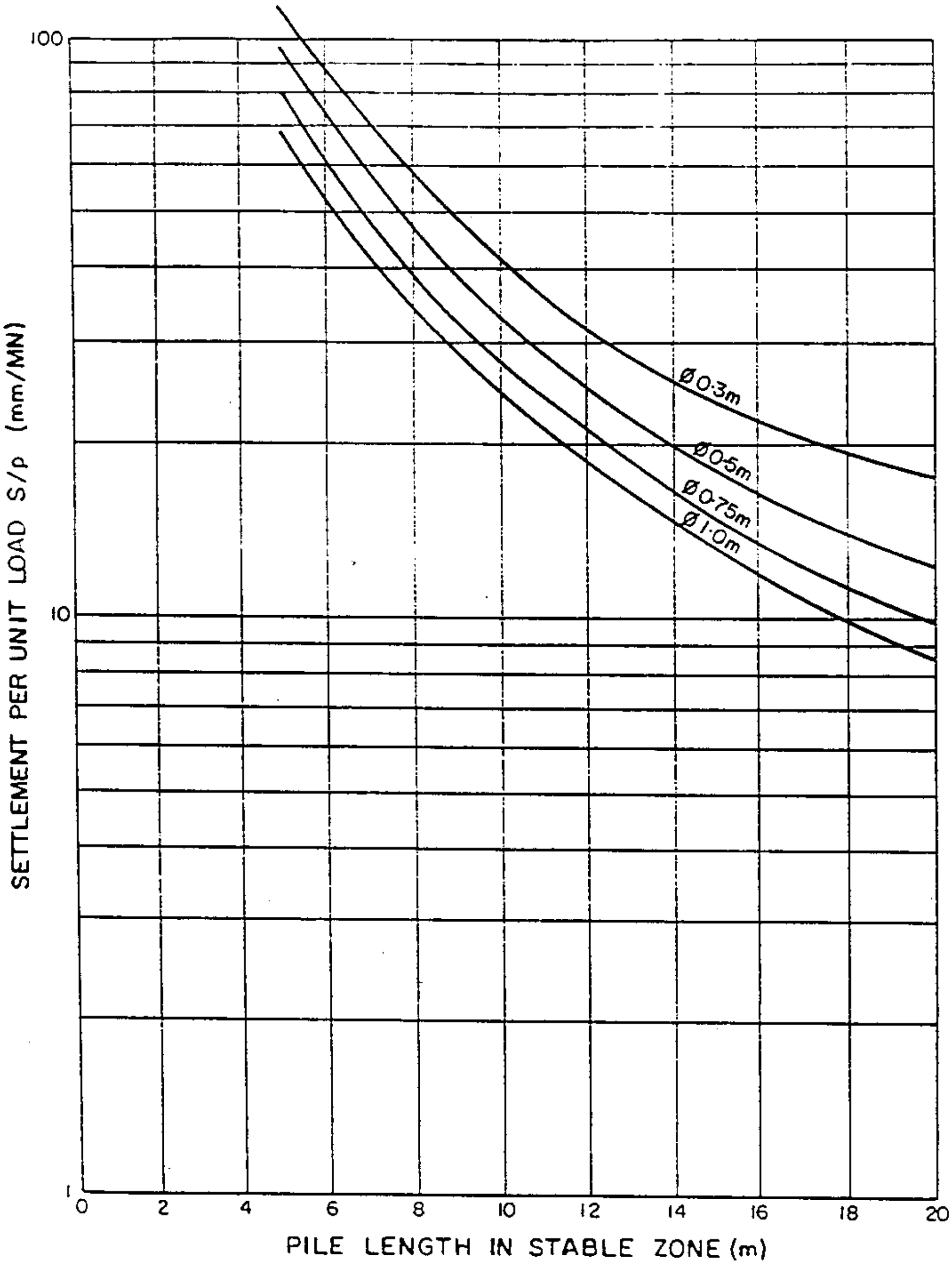
Design Chart for Settlement of Single Driven Pile in Dense Sand

Figure 5.6

COFFEY GEOMARINE



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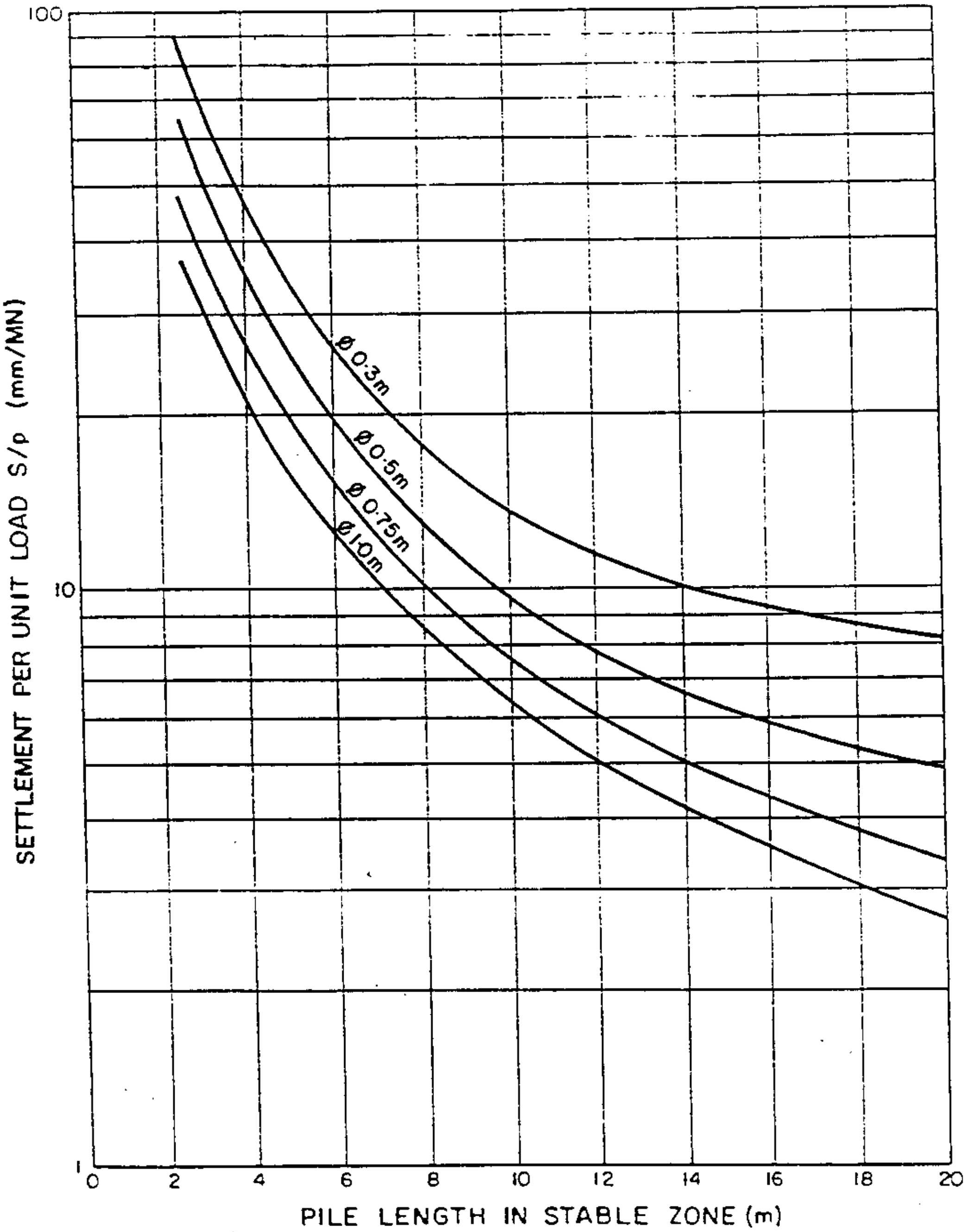
Design Chart for Settlement of Single Bored Pile in Loose Sand

Figure 5.7

GEOMARINE COFFEY



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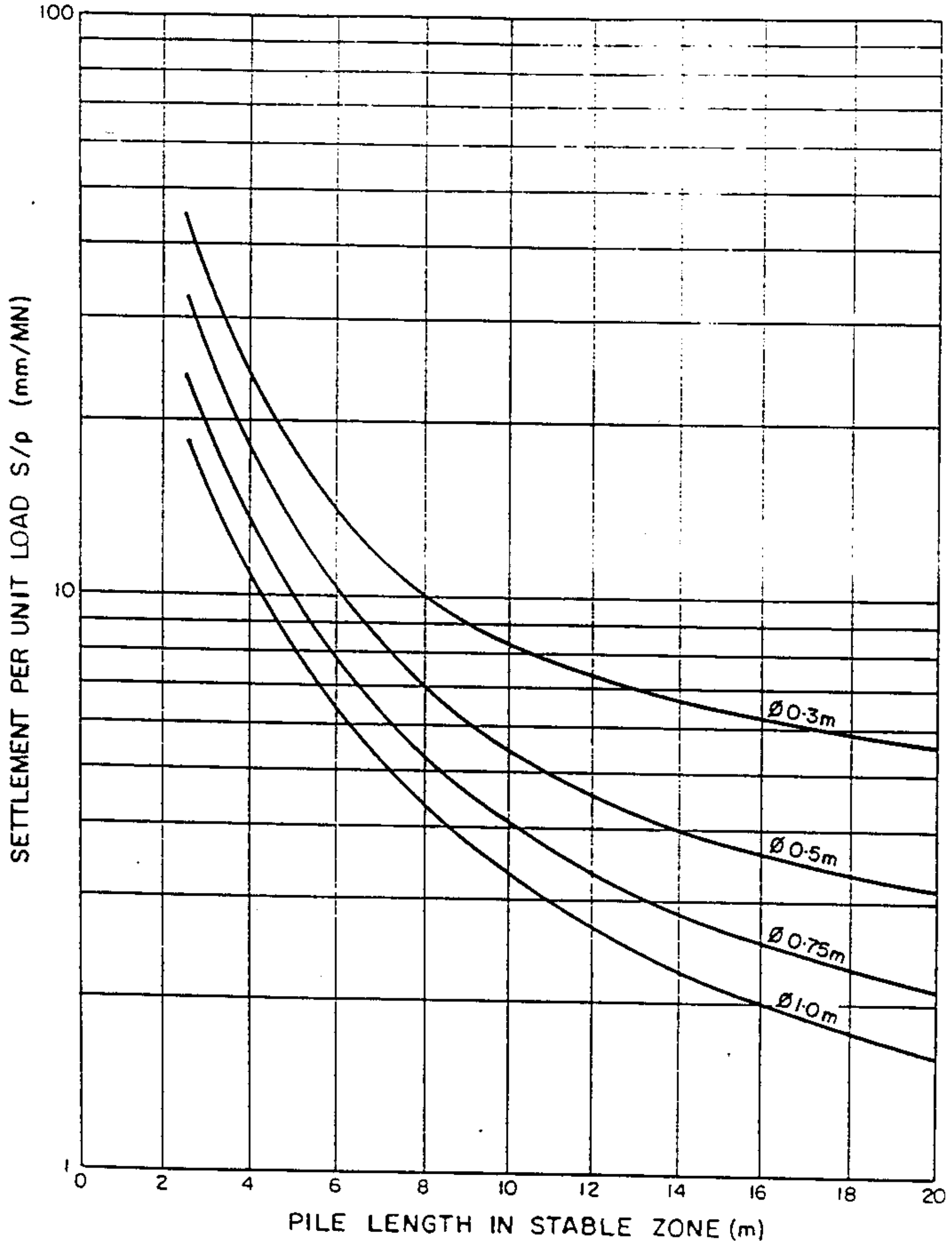
Design Chart for Settlement of Single Bored Pile in Medium-Dense Sand

Figure 5.8

COFFEY

GEOMARINE



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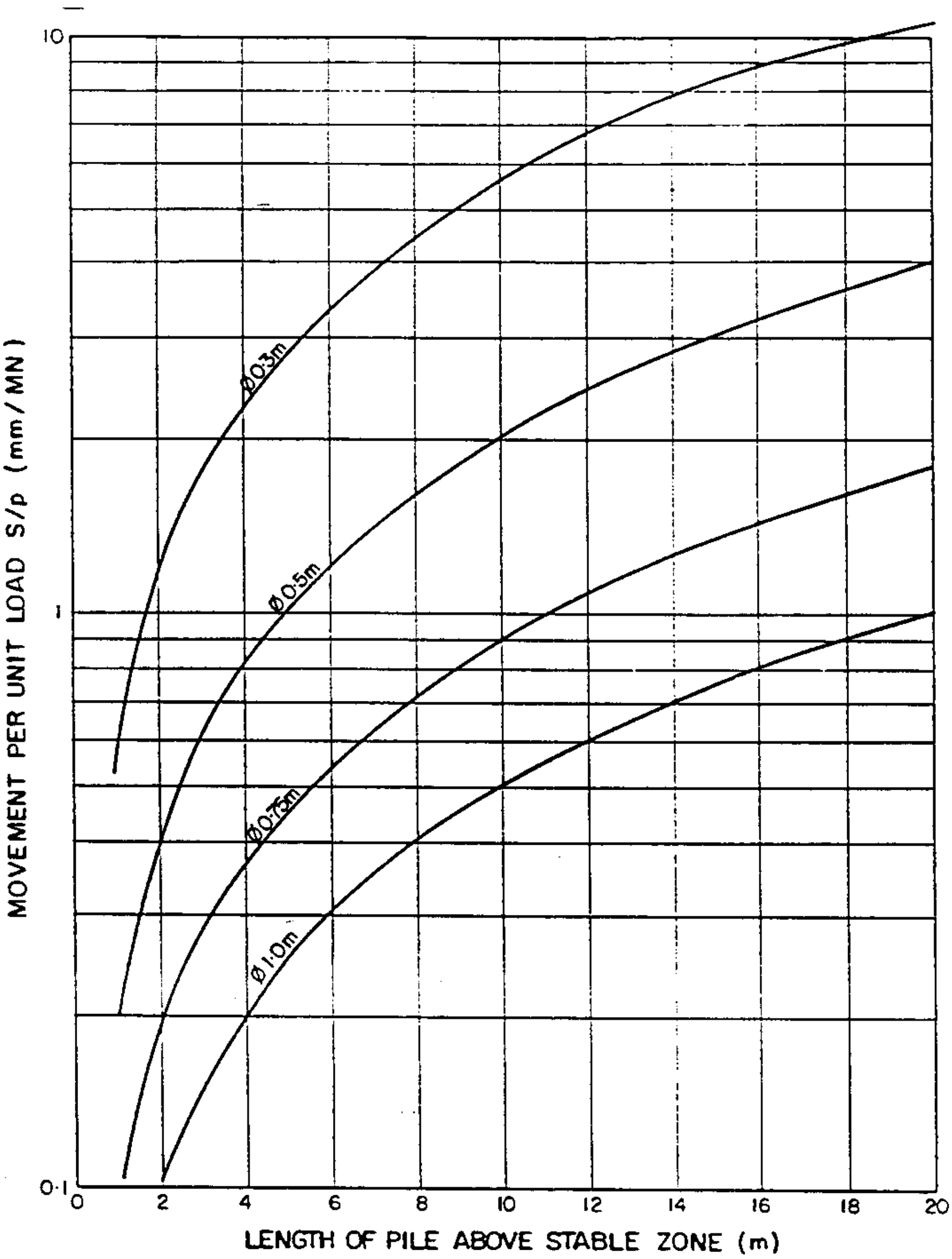
Design Chart for Settlement of Single Bored Pile in Dense Sand

Figure 5.9



NOTE - ASSUMED PILE MODULUS = 25 000 MPa

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Design Chart for Pile Head Movement due to Compression above Stable Zone

Figure 5.10

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Appendix A

Derivation of Forces on Piling

Equations for Forces Acting on a Pile Due to a Collapsing Vertical Sand Face

It is assumed that the soil fails along a plane sliding surface (i.e. that "wedge" failure of the soil occurs), as shown in **Figure A1(a)**, and that the resulting pressure on the pile is as shown in **Figure A1(b)**. From statics, the total force acting on the upper part of the pile (to depth h) is (for a cohesionless soil):

$$F_1 = 0.5\,Bh^2\,\gamma\,\cot\beta\,\tan(\beta-\phi) \qquad \text{... (A1)}$$

where:

B = width of failing wedge;
γ = unit weight of soil;
h = height of soil which collapses past the pile;
β = slope angle of soil wedge; and
ϕ = angle of internal friction of soil.

Similarly, the force F_2 on the lower part of the pile (from depth h to h_s) is:

$$F_2 = F_1\,(h_s/h - 1) \qquad \text{... (A2)}$$

where:

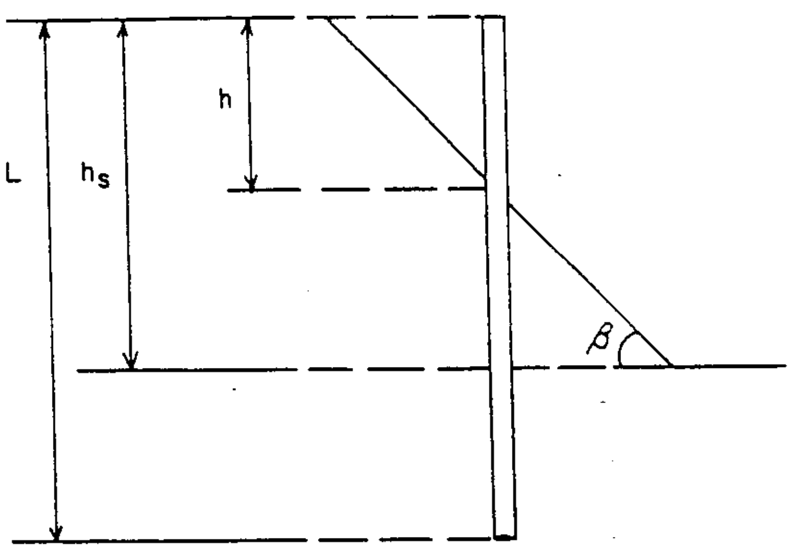
h_s = depth of scour (or erosion) of soil.

It can be shown that, for the postulated mechanism, the maximum force on the pile occurs when $h = h_s/2$. For the particular case, the maximum shear force, V_{max}, and maximum bending moment, M_{max}, in the pile above the stable soil surface are expressed as follows:

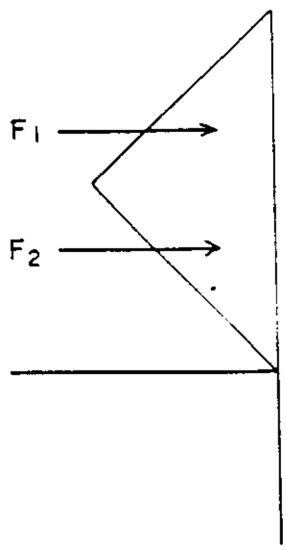
$$V_{max} = 0.25\,h_s^2 B\gamma\,\cot\beta\,\tan(\beta-\phi) \qquad \text{... (A3)}$$

$$M_{max} = 0.125\,h_s^3 B\gamma\,\cot\beta\,\tan(\beta-\phi) \qquad \text{... (A4)}$$

For calculations involving piles in moist beach sand it is considered that $\phi = 30^\circ$, $\beta = 45^\circ$ and $B = 3d$ (where d = pile diameter or width) are usually reasonable design parameters.



(a) ASSUMED SLOPE FAILURE MECHANISM



(b) ASSUMED LATERAL PRESSURE DIAGRAM

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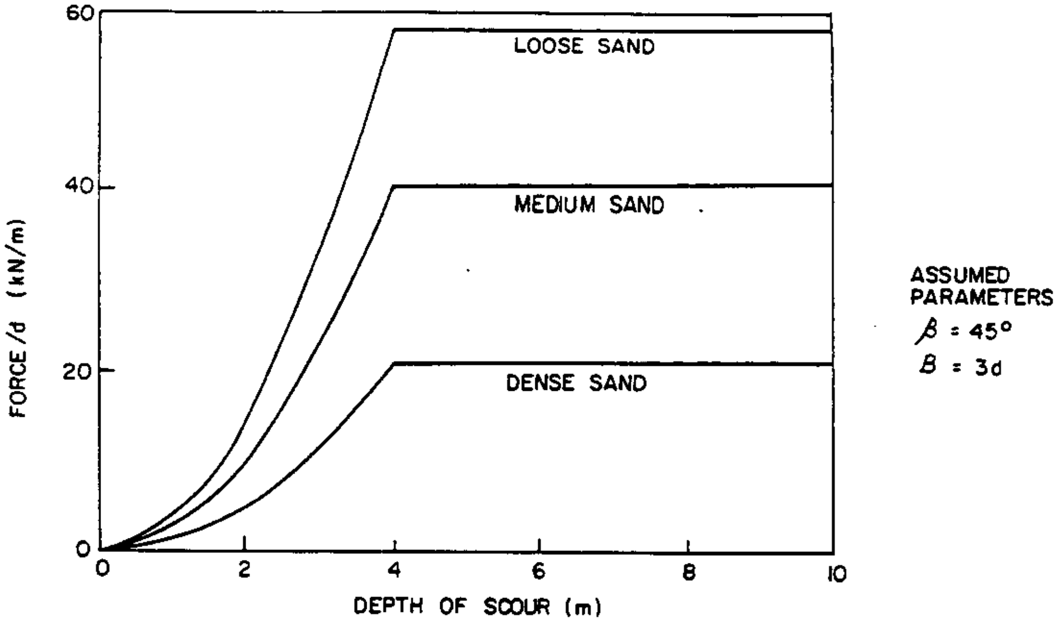
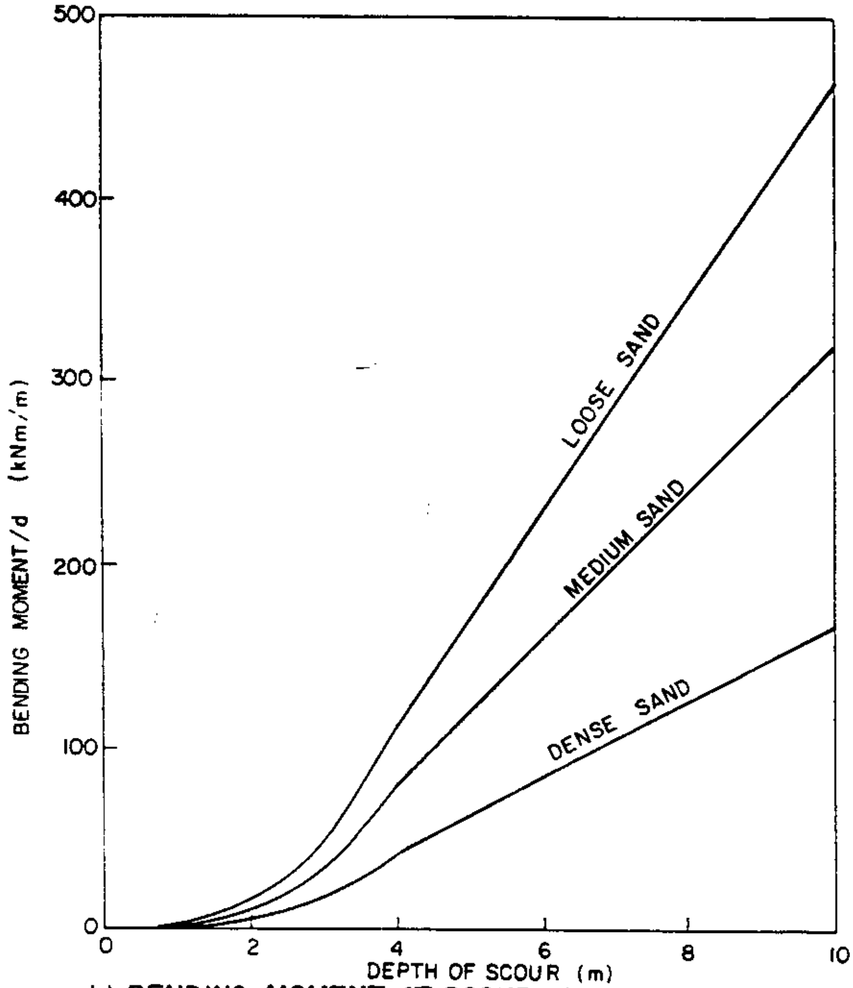
drawn	HGP/LT.	GEOMARINE PTY LTD BEACH DEVELOPMENT DESIGN CRITERIA NARRABEEN TO COLLAROY BEACH ASSUMED FAILURE MECHANISM AND LATERAL PRESSURE DISTRIBUTION	COFFEY	FIGURE A1
approved	[signature]			
date	11/8/92			
scale				job no: S7589/1



a) SHEAR FORCE



b) BENDING MOMENT AT SCOUR LEVEL

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drawn	HGP/LT	GEOMARINE PTY LTD BEACH DEVELOPMENT DESIGN CRITERIA NARRABEEN TO COLLAROY BEACH EFFECT OF SAND DENSITY ON SHEAR FORCE AND BENDING MOMENTS DEVELOPED IN PILE DUE TO SLUMPING FACE	COFFEY	FIGURE A2
approved	[signature]			
date	10/11/91			
scale				job no: S9425/1

Appendix B

Field Data

Geotechnical Investigations for the Narrabeen-Collaroy-Fishermans Beach Areas

A field investigation at specific sites was carried out between 30th November and 4th December 1990. Field work consisted of an auger drilling programme, together with electric friction cone testing. Eight holes were drilled to maximum depths of 10m at locations shown on **Figure 5.1.**

Drilling was carried out using an Edson 3000 truck mounted drilling rig equipped with continuous spiral flight augers. SPT tests were carried out in sands at intervals of 1.5m. The samples returned were retained for laboratory testing. Drilling, sampling and testing of the boreholes was carried out in the full time presence of an Engineering Geologist who produced engineering logs of all holes. These logs are presented together with explanation sheets defining the terms and symbols used in their preparation.

The holes were located by taking tape measurements relative to existing site features which are presented in "Borehole Location Sketches". Electric friction cone probes were carried out at each borehole location using a truck mounted "MACSIL" electric friction cone penetrometer. The results of these tests are presented. In general, the results of the cone penetration tests are consistent with the material characteristics inferred from the borehole logs and from the standard penetration test (SPT) data.

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descriptive terms soil and rock

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Explanation Sheet 1

SOIL DESCRIPTIONS

Classification of Material based on Unified Classification System (refer SAA Site Investigation Code AS1726–1975 Add. No. 1 Table D1).

Moisture Condition based on appearance of soil

dry Looks and feels dry; cohesive soils usually hard, powdery or friable, granular soils run freely through hands.

moist Soil feels cool, darkened in colour; cohesive soils usually weakened by moisture, granular soils tend to cohere, but one gets no free water on hands on remoulding.

wet Soil feels cool, darkened in colour; cohesive soils weakened, granular soils tend to cohere, free water collects on hands when remoulding.

Consistency based on unconfined compressive strength (Qu) (generally estimated or measured by hand penetrometer)

term	very soft		soft		firm		stiff		very stiff		hard
Qu kPa		25		50		100		200		400	

If soil crumbles on test without meaningful result, it is described as **friable**.

Density Index (generally estimated or based on penetrometer results).

term	very loose		loose		medium dense		dense		very dense
density index I_D %		15		35		65		85	

ROCK DESCRIPTIONS

Weathering based on visual assessment

term	criterion
Fresh:	Rock substance unaffected by weathering.
Slightly Weathered:	Rock substance affected by weathering to the extent that partial staining or partial discolouration of the rock substance usually by limonite has taken place. The colour and texture of the fresh rock is recognisable; strength properties are essentially those of the fresh rock substance.
Moderately Weathered:	Rock substance affected by weathering to the extent that staining extends throughout whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Highly Weathered:	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and signs of chemical or physical decomposition of individual minerals are usually evident. Porosity and strength may be increased or decreased when compared to the fresh rock substance, usually as a result of the leaching or deposition of iron. The colour and strength of the original fresh rock substance is no longer recognisable.
Extremely Weathered:	Rock substance affected by weathering to the extent that the rock exhibits soil properties - i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.

Strength based on point load strength index, corrected to 50 mm diameter - Is(50) (refer I.S.R.M., Commission on Standardisation of Laboratory and Field Tests, Suggested Methods for Determining the Uniaxial Compressive Strength of Rock Materials and the Point Load Strength Index, Committee on Laboratory Tests Document No. 1). (Generally estimated: x indicates test result).

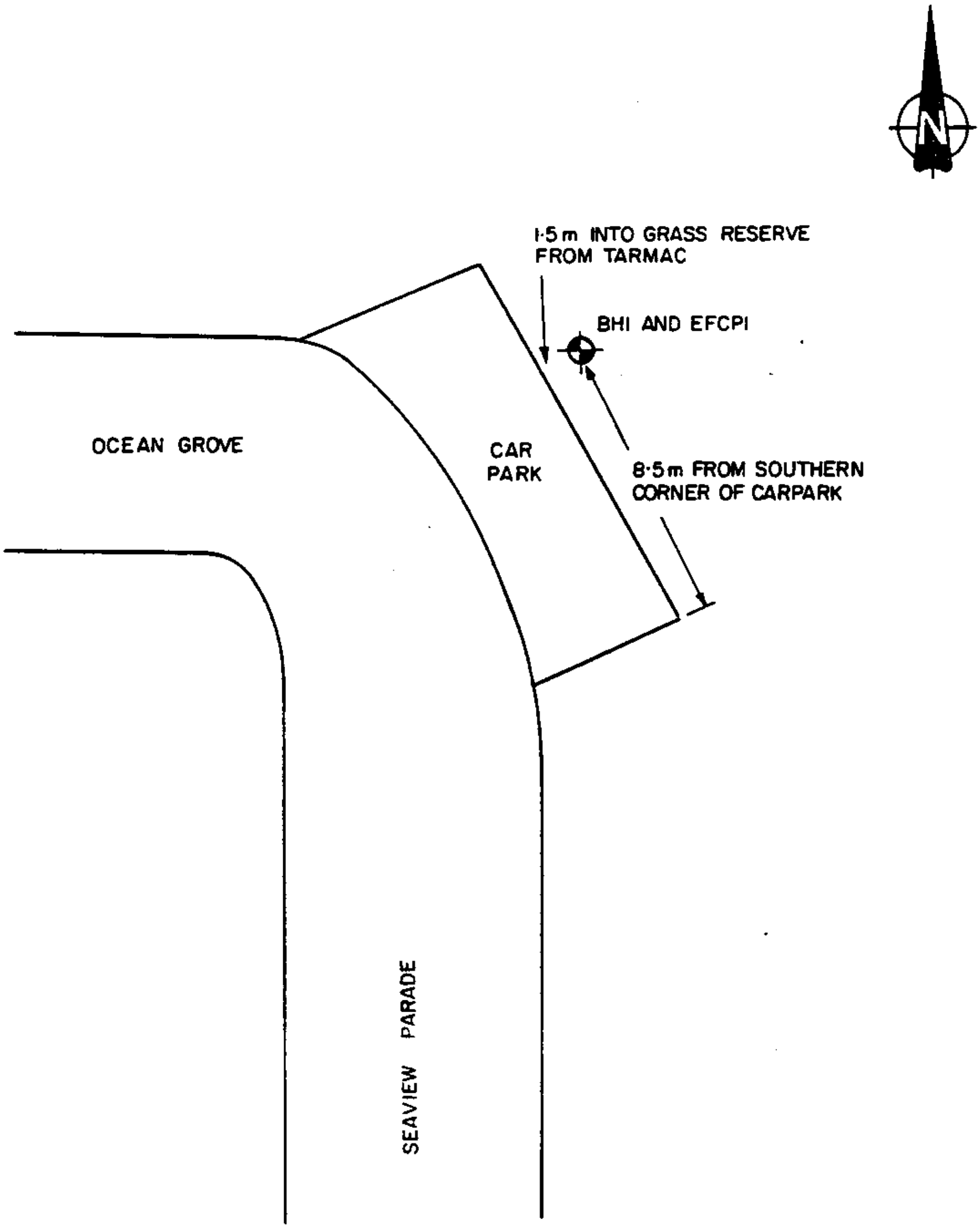
classification	extremely low		very low		low		medium		high		very high		extremely high
Is (50) MPa		0.03		0.1		0.3		1		3		10	

The unconfined compressive strength is typically about 20 x I_{S50} but the multiplier may range, for different rock types, from as low as 4 to as high as 30.

Defect Spacing

classification	extremely close		very close		close		medium		wide		very wide		extremely wide
spacing m		0.03		0.1		0.3		1		3		10	

Defect description uses terms contained on AS1726 table D2 to describe nature of defect (fault, joint, crushed zone, clay seam (etc.) and character (roughness, extent, coating etc.).



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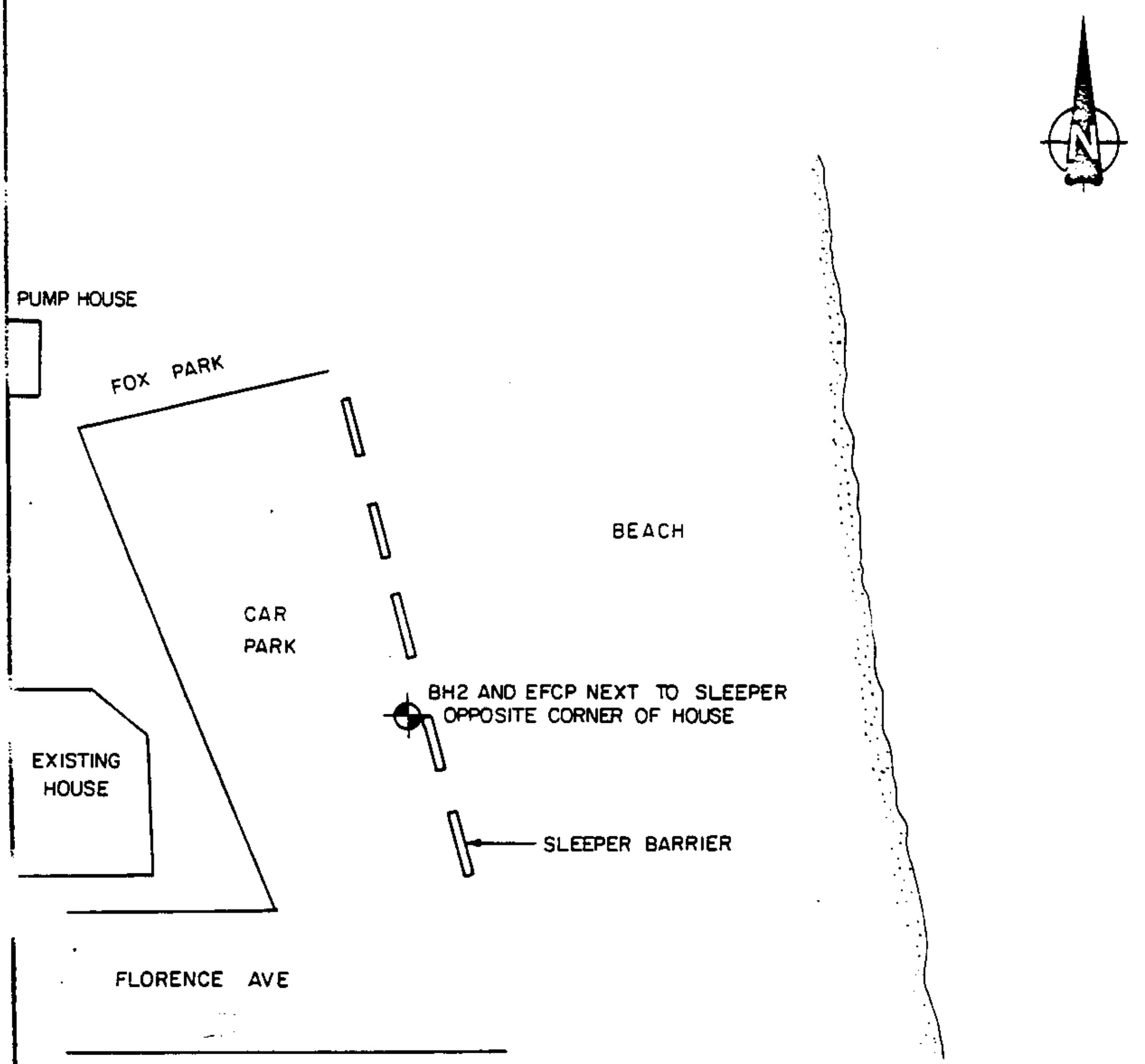
drawn	SRM / LT	GEOMARINE PTY LTD BEACH DEVELOPMENT DESIGN CRITERIA NARRABEEN TO COLLAROY BEACH LOCATION OF BOREHOLE I	FIGURE BI
approved			
date	10/1/91		
scale	NTS		job no: S9425/1



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drawn	SRM / LT
approved	[signature]
date	10/1/91
scale	NTS

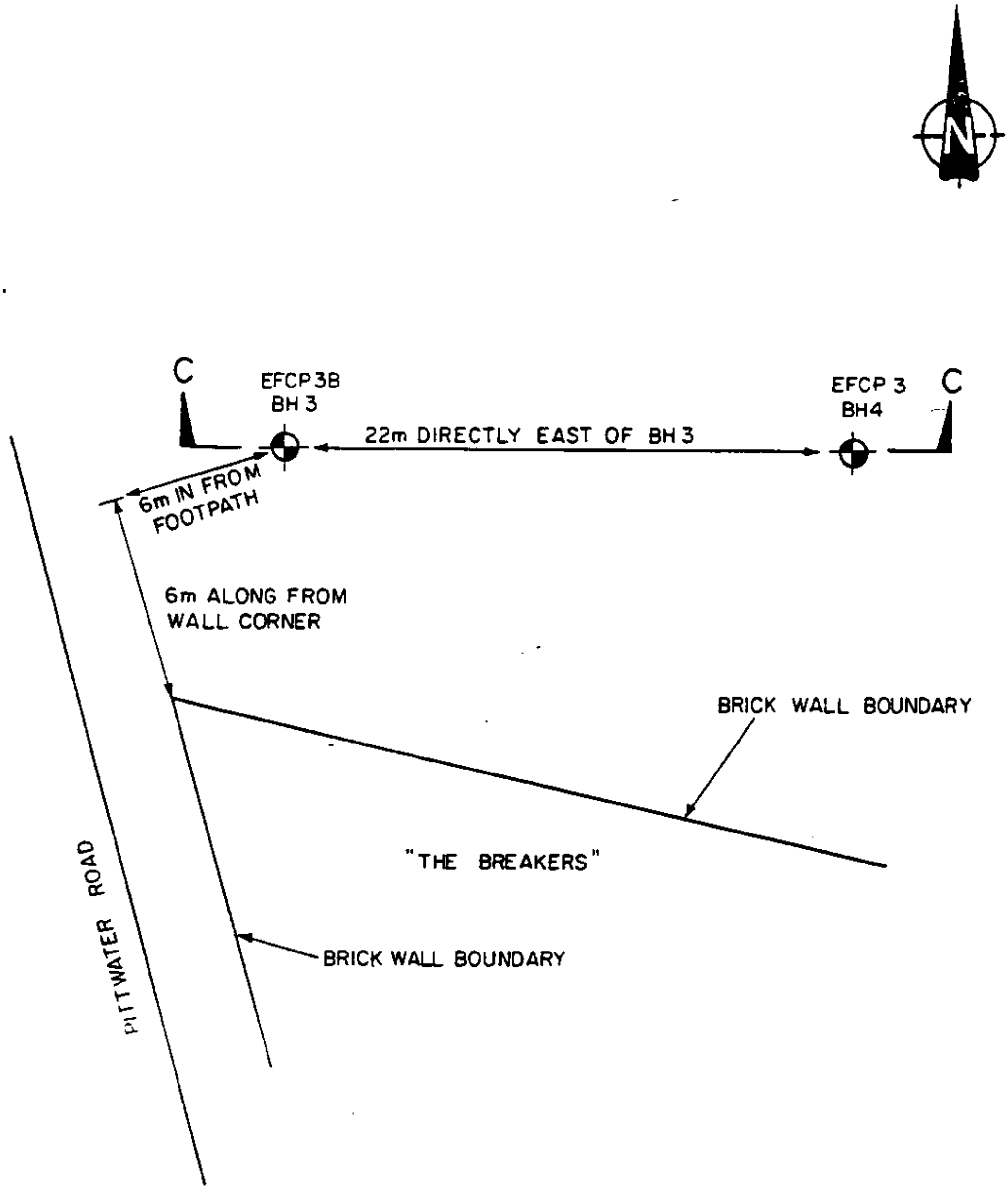
GEOMARINE PTY LTD
BEACH DEVELOPMENT DESIGN CRITERIA
NARRABEEN TO COLLAROY BEACH

LOCATION OF BOREHOLE 2

COFFEY

FIGURE B2

job no: S94 25/1



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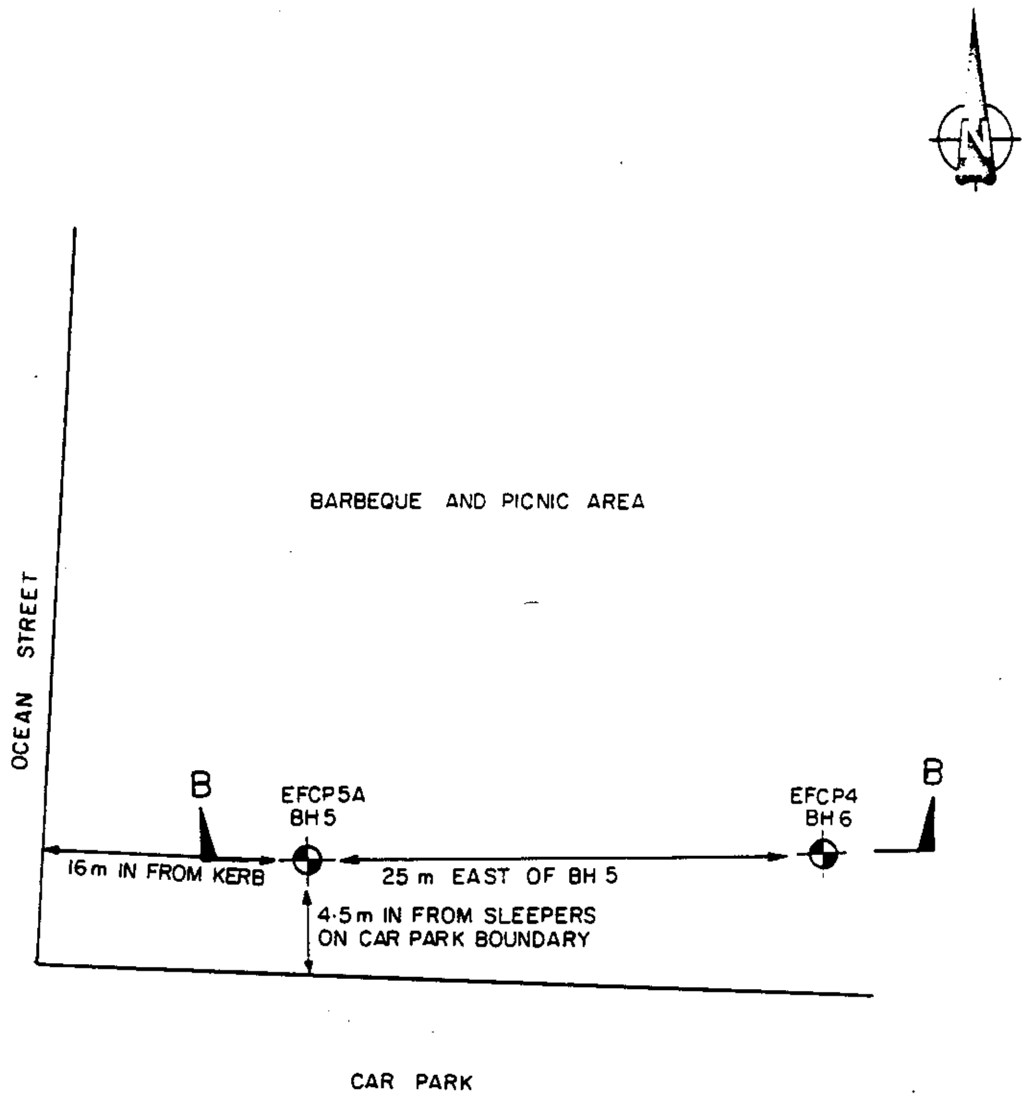
drawn	SRM / LT	GEOMARINE PTY LTD BEACH DEVELOPMENT DESIGN CRITERIA NARRABEEN TO COLLAROY BEACH LOCATION OF BOREHOLES 3 AND 4	FIGURE B3
approved	[signature]		
date	10/1/81		
scale	NTS		job no: S9425/1



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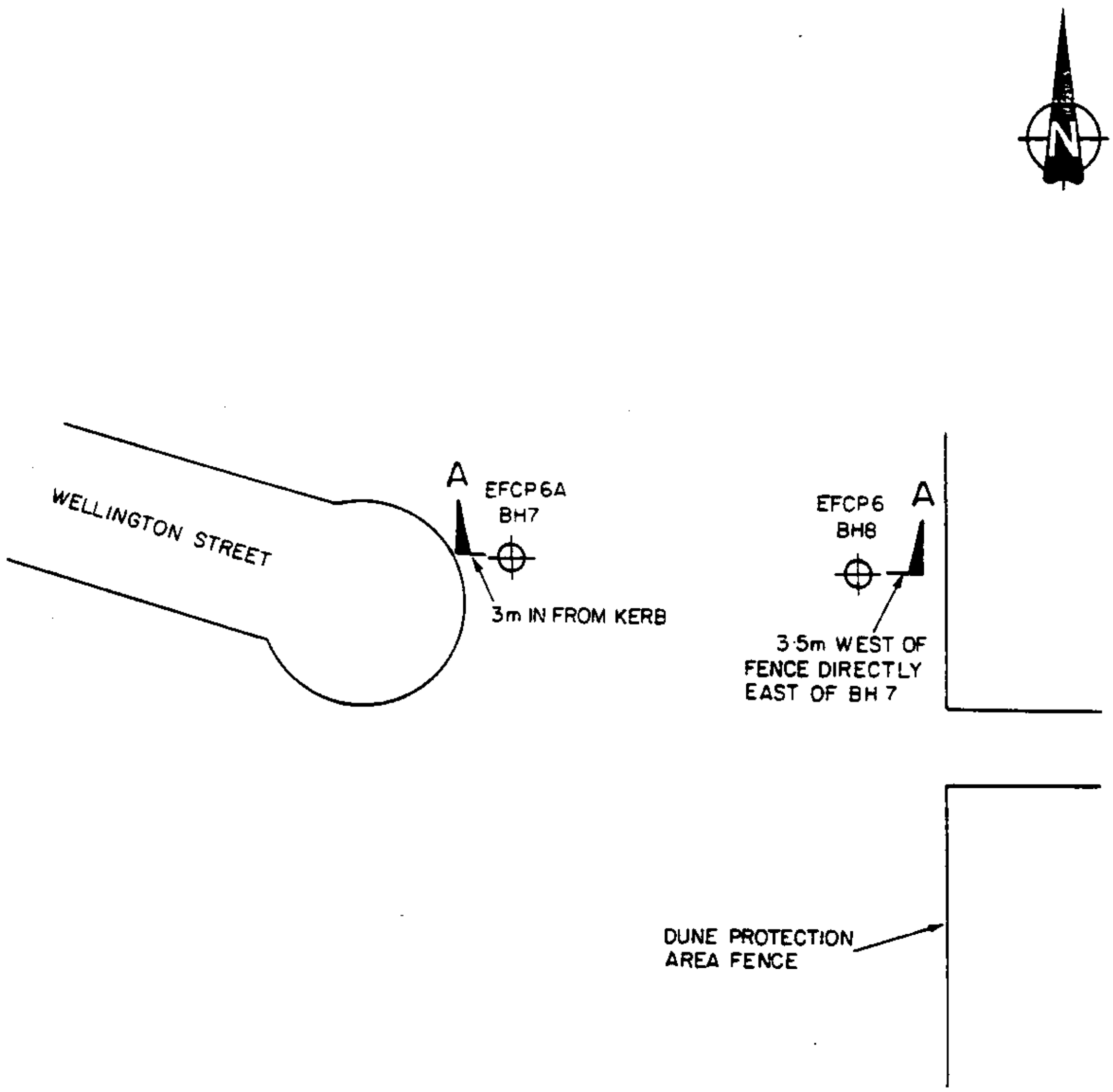
drawn	SRM / LT	GEOMARINE PTY LTD BEACH DEVELOPMENT DESIGN CRITERIA NARRABEEN TO COLLAROY BEACH LOCATION OF BOREHOLES 5 AND 6	COFFEY	FIGURE B4
approved	[signature]			
date	10/1/91			
scale	NTS			job no: S9425/1



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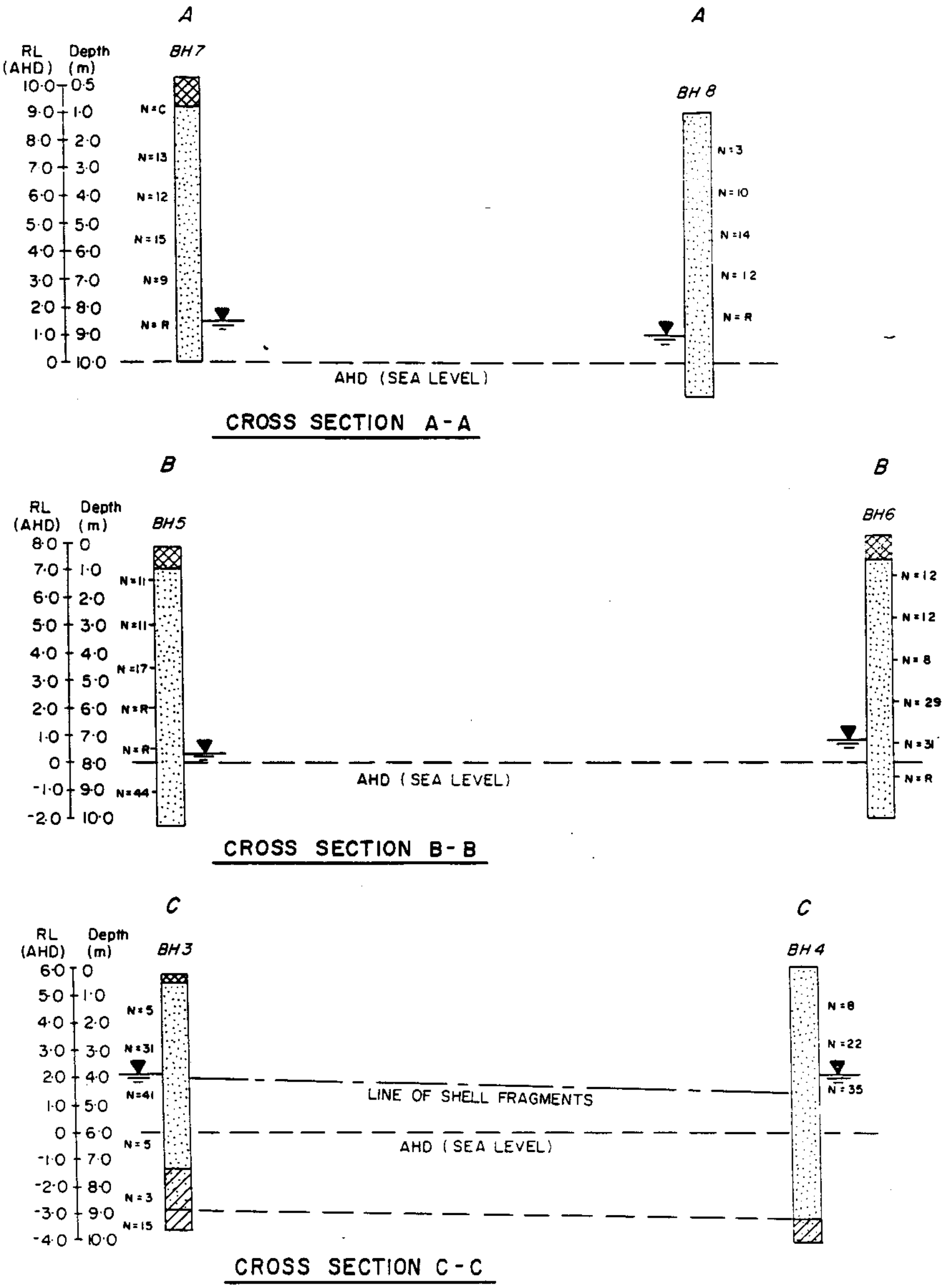
drawn	SRM / LT	GEOMARINE PTY LTD BEACH DEVELOPMENT DESIGN CRITERIA NARRABEEN TO COLLAROY BEACH LOCATION OF BOREHOLES 7 AND 8	COFFEY	FIGURE B5
approved	[signature]			
date	10/1/91			
scale	NTS			job no: S9425/1



Coffey Partners International Pty Ltd		Consulting Engineers in the geotechnical sciences Incorporated in NSW		
drawn	SRM/LT	GEOMARINE PTY LTD BEACH DEVELOPMENT DESIGN CRITERIA NARRABEEN TO COLLAROY BEACH CROSS SECTIONS AA, BB AND CC	COFFEY	FIGURE B6
approved				
date	10/1/91			
scale				job no: S9425/1

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engineering log - borehole

COFFEY

borehole no BH1
sheet 1 of 2
office job no S9425 1

client	GEOMARINE PTY LTD	hole commenced	4-12-90
principal	WARRINGAH SHIRE COUNCIL	hole completed	4-12-90
project	BEACH DEVELOPMENT DESIGN CRITERIA	logged by	SRM
borehole location	SEE DRAWING No B1	checked by	MAB

drill model and mounting: EDSON 3000 - TRUCK; slope: -90 DEG; R.L.Surface: 6.3 m
hole diameter: 100mm; bearing; datum: AHD

method	penetration 1 2 3	support	water	notes samples tests etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
ADT		NIL			6				FILL. Sand fine to medium grained, grey brown, some gravel	M			FILL
						1		SM	TOPSOIL. Silty Sand fine to medium grained, dark grey		MD	X	TOPSOIL
				4 3 2 N*=5	5			SC	CLAYEY SAND fine to medium grained, light grey - yellow. Clay high plasticity				ALLUVIUM
					4	2							
				5 3 2 N*=5									
					3	3		CH	CLAY: high plasticity, grey & red brown, trace amounts of sand	>Wp			ALLUVIUM
			▽	5 6 7 N*=13	2	4					H		
					1				... sand, clay				
				5 ... 13 N*=19				CL	CLAY medium plasticity, grey red yellow mottled, trace of fine sand	<Wp			RESIDUAL CLAY with relict structures Blocky texture
					0	6							
				6 9 10 N*=19	-1	7			becoming EW claystone, red brown		H	X	

METHOD
AS auger screwing*
AD auger drilling*
R roller tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e.g. ADT

SUPPORT
C casing
M mud
N nil

PENETRATION
no resistance
ranging to
refusal

WATER
not measured
water level
water outflow
water inflow

NOTES samples and tests
U50 undisturbed sample 50 mm diameter
D disturbed sample
N standard penetration test
N* SPT + sample recovered
Nc SPT with solid cone
V vane shear
P pressuremeter
Bs bulk sample
R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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Incorporated in NSW

engineering log - borehole

COFFEY

borehole no **BH1**

sheet 2 of 2

office job no S9425/1

client	GEOMARINE PTY LTD	hole commenced	4.12.90
principal	WARRINGAH SHIRE COUNCIL	hole completed	4.12.90
project	BEACH DEVELOPMENT DESIGN CRITERIA	logged by	SRM
borehole location	SEE DRAWING No B1	checked by	MAB
drill model and mounting	EDSON 3000 TRUCK	slope -90 DEG	R.L. surface 5.3 m
hole diameter	100mm	bearing	datum AHD

method	penetration 1 2 3	support	water	notes samples, tests, etc.	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	structure and additional observations
ADT								CI	CLAY medium plasticity, grey, red, yellow mottled, trace of fine sand	M	H	RESIDUAL CLAY with relict structures
				8, 10, 22 N*=32		9			Some bands of ironstone			
					-1							
				13, 15 N=R	-2	10						SPT refusal 22 blows for 50mm
									Borehole BH1 Terminated at 10.45 m			
					-3	11						
					-4	12						
					-5	13						
					-6	14						
					-7	15						

METHOD
- AS auger screwing*
- AD auger drilling*
- R roller/tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- C casing
- M mud

PENETRATION 1 2 3
- no resistance
- ranging to
- refusal

WATER
- not measured
- water level
- water outflow
- water inflow

NOTES samples and tests
- U50 undisturbed sample 50 mm diameter
- D disturbed sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- V vane shear
- P pressuremeter
- Bs bulk sample
- R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

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Incorporated in NSW

engineering log - borehole

COFFEY

borehole no **BH2**
sheet 1 of 1

office job no: S9425-1

client:	GEOMARINE PTY LTD	hole commenced:	30/11/90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	30/11/90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SRM
borehole location:	SEE DRAWING No B2	checked by:	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope:	-90 DEG	R.L.Surface:	4.1 m
hole diameter:	100mm	bearing:		datum:	AHD

method	penetration 1 2 3	support	water	notes samples, test, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
ADT		NIL			4				FILL: Sand medium to coarse grained red brown, with some gravel	M			FILL sandstone & concrete gravel
					3	1			Layer of coarse gravel 100mm thick				Beach sand contains shell fragments
								SP	SAND: medium to coarse grained yellow brown, some fine gravel				Beach sand contains shell fragments
				0, 1, 1 N*=2	2	2					L		
					1	3							
				0, 1, 0 N*=1									SPT travelled 450mm with one blow
					0	4		SP	CLAYEY SAND: fine to coarse grained, yellow brown, trace of fines				
									Gravelly layer 300mm thick	W			
									CLAYSTONE: yellow red grey very low strength EW - HW				EW - HW CLAYSTONE
				10, 27 N*=R	-1	5							
									Becoming carbonaceous, HW very low strength				
					-2	6			Borehole BH2 Terminated at 5.70 m				
					-3	7							

METHOD		SUPPORT		NOTES samples and tests		CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION		CONSISTENCY/DENSITY INDEX	
AS	auger screwing*	C	casing	U50	undisturbed sample 50 mm diameter	based on unified classification system		VS	very soft
AD	auger drilling*	M	mud	D	disturbed sample			S	soft
R	roller tricone	PENETRATION 1 2 3	no resistance ranging to refusal	N	standard penetration test			F	firm
W	washbore			N*	SPT + sample recovered			St	stiff
CT	cable tool			Nc	SPT with solid cone			VSt	very stiff
HA	hand auger	WATER		V	vane shear	MOISTURE		H	hard
DT	diatube	-	not measured	P	pressuremeter	D	dry	Fb	friable
*bit shown by suffix		▽	water level	Bs	bulk sample	M	moist	VL	very loose
B	blank bit		water outflow	R	refusal	W	wet	L	loose
V	V bit		water inflow			Wp	plastic limit	MD	medium dense
T	TC bit							D	dense
e.g	ADT							VD	very dense

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Incorporated in NSW

engineering log - borehole

COFFEY

borehole no **BH3**
sheet 1 of 2

office job no: S9425-1

client:	GEOMARINE PTY LTD	hole commenced:	4.12.90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	4.12.90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SRM
borehole location:	SEE DRAWING No B3	checked by:	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope	-90 DEG	R.L.Surface:	5.8 m
hole diameter:	100mm	bearing		datum:	AHD

method	penetration 1 2 3	support	water	notes samples, test, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa	structure and additional observations
ADT		NIL				0			FILL: Sand fine to medium grained, brown, trace of gravel	M			FILL
								SP	SAND: fine to medium grained, grey brown clayey layer at 1.1m				DUNE SAND
					5								
						1							
				2 . 2 . 3 N*=5							MD		
								SP	SAND: fine to medium grained, orange brown				
					4								
						2							
				8 . 15 . 16 N*=31	3						VD		
						3			Beach sand with calcareous cementation				
			water level										
					2			SP	SAND: medium grained, yellow brown, shells & trace of gravel				Beach sand with calcareous cementation
						4				W			Hole collapsing below water table
				5 . 12 . 29 N*=41									
					1								
						5							
					0								SPT at 5.9m returned empty
				3 . 2 . 3 N*=5		6					L		
					-1								
						7							
								SC	CLAYEY SAND: fine to medium grained, dark grey, clay high plasticity, trace of organics				Estaurine or marine deposits
				1 . 2 . 1 N*=3	-2								
						8							

METHOD
AS auger screwing*
AD auger drilling*
R roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e.g. ADT

SUPPORT
C casing
M mud

PENETRATION
1 2 3
no resistance ranging to refusal

WATER
* not measured
water level
water outflow
water inflow

NOTES samples and tests
U50 undisturbed sample 50 mm diameter
D disturbed sample
N standard penetration test
N* SPT + sample recovered
Nc SPT with solid cone
V vane shear
P pressuremeter
Bs bulk sample
R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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engineering log - borehole

COFFEY

borehole no BH3
sheet: 2 of 2
office job no S9425 1

client	GEOMARINE PTY LTD	hole commenced	4 12 90
principal	WARRINGAH SHIRE COUNCIL	hole completed	4 12 90
project	BEACH DEVELOPMENT DESIGN CRITERIA	logged by	SRM
borehole location	SEE DRAWING No D2	checked by	MAD

drill model and mounting	EDSON 3000 - TRUCK	slope	-90 DEG	R.L.Surface	5.6 m
hole diameter	100mm	bearing		datum	AHD

method	penetration 1 2 3	support	water	notes samples, test, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
W								SC	CLAYEY SAND: fine to medium grained, dark grey, clay high plasticity, trace of organics	D1			
				5 5 10 N* = 15	-3	9		CH	CLAY: high plasticity, grey & brown, with some sand fine to medium grained, trace of organics		St / VSt		ESTAURINE CLAY
					-4	10			Borehole BH3 Terminated at 9.35 m				
					-5	11							
					-6	12							
					-7	13							
					-8	14							
					-9	15							
					-10								

METHOD
- AS auger screwing*
- AD auger drilling*
- R roller tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- C casing
- M mud

PENETRATION
- no resistance
- ranging to
- refusal

WATER
- * not measured
- water level
- water outflow
- water inflow

NOTES samples and tests
- U50 undisturbed sample 50 mm diameter
- D disturbed sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- V vane shear
- P pressuremeter
- Bs bulk sample
- R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

Coffey Partners International Pty Ltd
Incorporated in NSW

COFFEY

borehole no: BH4
sheet 1 of 2

engineering log - borehole

office job no: S9425 1

client:	GEOMARINE PTY LTD	hole commenced:	4 12 90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	4 12 90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SRM
borehole location:	SEE DRAWING No 83	checked by:	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope	-90 DEG	R L Surface	6 1	m	
hole diameter	100mm	bearing		datum	AHD		

method	penetration 1 2 3	support	water	notes samples, test, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
ADT		NIL			6			SP	SAND: fine to medium grained, light yellow brown, little or no fines	M			DUNE SAND
				4 , 4 , 4 N* = 8	5	1					D		
					4	2							
				5 , 10 , 12 N* = 22	3	3							
			▽	6 , 14 , 21 N* = 35	2	4				W	VD		Hole collapsing before SPT at 4.6m
									Some coarser layers containing shells at 4.6m				
					1	5							
					0	6							
					-1	7			Trace amounts of gravel, sand coarser, some shells				
						8		SP	SAND: fine to medium grained, grey, some silt, patches of clay				ESTAURINE CLAYEY SAND

METHOD
- AS auger screwing*
- AD auger drilling*
- R roller tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- C casing
- M mud

PENETRATION
1 2 3
no resistance ranging to refusal

WATER
- • not measured
- ▽ water level
- water outflow
- water inflow

NOTES samples and tests
- U50 undisturbed sample 50 mm diameter
- D disturbed sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- V vane shear
- P pressuremeter
- Bs bulk sample
- R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

Coffey Partners International Pty. Ltd
Incorporated in NSW

engineering log - borehole

COFFEY

borehole no BH4
sheet 2 of 2
office job no. S9425 1

client	GEOMARINE PTY LTD	hole commenced	4 12 90
principal	WARRINGAH SHIRE COUNCIL	hole completed	4 12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	logged by	SRM
borehole location	SEE DRAWING No B2	checked by	MAB

drill model and mounting	EDSON 3000 - TRUCK	slope	-90 DEG	R.L.Surface	0 1 m
hole diameter	100mm	bearing		datum	AHD

method	penetration 1 2 3	support	water	notes samples, test,etc	RL	depth metres	graphic log	classification symbol	material soil type:plasticity or particle characteristics colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
ADT					-2			SP	SAND fine to medium grained, grey some silt, patches of clay	W	VD		ESTAURINE CLAYEY SAND
					-3	9							
								CH	SANDY CLAY: medium to high plasticity grey, sand fine to medium grained	>Wp			ESTAURINE CLAY
					-4	10							
									Borehole BH4 Terminated at 10.10 m				
					-5	11							
					-6	12							
					-7	13							
					-8	14							
					-9	15							
						16							

METHOD
- AS auger screwing*
- AD auger drilling*
- R roller tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- C casing
- M mud

PENETRATION
- no resistance ranging to refusal

WATER
- not measured
- water level
- water outflow
- water inflow

NOTES samples and tests
- U50 undisturbed sample 50 mm diameter
- D disturbed sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- V vane shear
- P pressuremeter
- Bs bulk sample
- R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION

based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

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Coffey Partners International Pty Ltd
Incorporated in NSW

engineering log - borehole

COFFEY

borehole no. **BH5**

office job no. S9423/1

client:	GEOMARINE PTY LTD	hole commenced:	4 12 90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	4 12 90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SRM
borehole location:	SEE DRAWING B4	checked by:	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope:	-90 DEG	R.L. Surface:	7.5 m
hole diameter:	100mm	bearing:		datum:	AHD

method	penetration 1 2 3	support	water	notes samples, test, etc	R.L.	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer	structure and additional observations
ADT		C							FILL: Sand fine to medium grained, grey brown, some gravel	M			FILL
					7	1		SP	SAND: fine to medium grained, yellow brown, little or no fines		D		DUNE SAND
				4, 5, 6 N*=11	6	2							
				5, 5, 6 N*=11	5	3			Trace amounts of shell fragments below 3.2m		MD		
				6, 8, 9 N*=17	4	4					D		
					3	5			Some coarser bands				
				14, 24, N*=R	2	6			Some thin layers of organic material from 6.2m		VD		refusal of SPT at 5.9m in indurated sand
			▽	10, 25, N*=R	1	7							
					0				Trace amount of sand below water table	W			

METHOD
AS auger screwing*
AD auger drilling*
R roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e.g. ADT

SUPPORT
C casing
M mud

PENETRATION
1 2 3
no resistance ranging to refusal

WATER
- not measured
▽ water level
water outflow
water inflow

NOTES samples and tests
U50 undisturbed sample 50 mm diameter
D disturbed sample
N standard penetration test
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear
P pressuremeter
Bs bulk sample
R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

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incorporated in NSW

engineering log - borehole

COFFEY

borehole no BH5

sheet 2 of 2

office job no. S9425 1

client	GEOMARINE PTY LTD	hole commenced	4.12.90
principal	WARRINGAH SHIRE COUNCIL	hole completed	4.12.90
project	BEACH DEVELOPMENT DESIGN CRITERIA	logged by	SRM
borehole location	SEE DRAWING B4	checked by	MAB

drill model and mounting	EDSON 3000 - TRUCK	slope	-90 DEG	R.L.Surface	7.8 m
hole diameter	100mm	bearing		datum	AHD

method	penetration 1 2 3	support	water	notes samples, test, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
ADT		NIL		9 16 28 N*=44	-1	9		SP	SAND fine to medium grained, yellow brown, little or no fines	M	VD		DUNE SAND
					-2	10			Slightly cemented sand with trace amounts of clay and shell fragments				
					-3	11			Borehole BH5 Terminated at 10.00 m				
					-4	12							
					-5	13							
					-6	14							
					-7	15							

METHOD
AS auger screwing*
AD auger drilling*
R roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e.g. ADT

SUPPORT
C casing
M mud

PENETRATION
1 2 3
no resistance
ranging to
refusal

WATER
not measured
water level
water outflow
water inflow

NOTES samples and tests
U50 undisturbed sample 50 mm diameter
D disturbed sample
N standard penetration test
N* SPT + sample recovered
Nc SPT with solid cone
V vane shear
P pressuremeter
Bs bulk sample
R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

187-230

Coffey Partners International Pty. Ltd
incorporated in NSW

engineering log - borehole

COFFEY

borehole no. **BH6**
sheet 1 of 2
office job no: S9425 1

client:	GEOMARINE PTY LTD	hole commenced:	30 11 90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	30/11/90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SRM
borehole location:	SEE DRAWINGB4	checked by:	MAB
drill model and mounting:	EDSON 3000 - TRUCK	slope: -90 DEG	R.L Surface: 8 2 m
hole diameter:	100mm	bearing:	datum: AHD

method	penetration 1 2 3	support	water	notes samples, test, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics colour, secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa	structure and additional observations
AD1		NIL			8				FILL: Snad fine to medium grained, light grey brown, some organics	D			FILL
				4 , 5 , 7 N*=12	7	1		SP	SAND: fine to medium grained yellow brown, little or no fines	M	D		DUNE SAND
					6	2							
				5 , 6 , 6 N*=12	5	3					MD		
				5 , 4 , 4 N*=8	4	4							
					3	5		SP	SAND: fine to medium grained, brown, trace of organics in layers		D		DUNE SAND with some shells
				6 , 10 , 19 N*=29	2	6							
			▽	6 , 15 , 16 N*=31	1	7		SP	SAND: coarse grained, yellow brown with increasing shell content	W			INDURATED SAND

METHOD
AS auger screwing*
AD auger drilling*
R roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e.g. AD1

SUPPORT
C casing
M mud

PENETRATION
1 2 3
no resistance
ranging to
refusal

WATER
• not measured
water level
water outflow
water inflow

NOTES samples and tests
U50 undisturbed sample 50 mm diameter
D disturbed sample
N standard penetration test
N* SPT + sample recovered
Nc SPT with solid cone
V vane shear
P pressuremeter
Bs bulk sample
R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Coffey Partners International Pty. Ltd
Incorporated in NSW

engineering log - borehole

COFFEY

borehole no.	BH6
sheet	2 of 2

office job no. S9425 1

client:	GEOMARINE PTY LTD	hole commenced:	30 11 90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	30/11/90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SRM
borehole location:	SEE DRAWINGB4	checked by:	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope:	-90 DEG	R.L.Surface:	8.2 m
hole diameter:	100mm	bearing:		datum:	AHD

method	penetration 1 2 3	support	water	notes samples, tests etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
ADT					0			SP	SAND: coarse grained, yellow brown, with increasing shell content	D			INDURATED SAND
				N*=R					Increasing fines content, but mostly coarse sand		VD		
					-1	9							
									Chunks of indurated sand returned on auger flights				
					-2	10							
									Borehole BH6 Terminated at 10.25 m				
					-3	11							
					-4	12							
					-5	13							
					-6	14							
					-7	15							

METHOD
- AS auger screwing*
- AD auger drilling*
- R roller/tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- C casing
- M mud

PENETRATION
1 2 3 — no resistance ranging to refusal

WATER
- • not measured
- water level
- water outflow
- water inflow

NOTES samples and tests
- U50 undisturbed sample 50 mm diameter
- D disturbed sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- V vane shear
- P pressuremeter
- Bs bulk sample
- R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

FE7-230

Coffey Partners International Pty Ltd
incorporated in NSW

engineering log - borehole

borehole no: **BH7**
sheet 1 of 2

office job no: S9425 1

client:	GEOMARINE PTY LTD	hole commenced:	30 11 90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	30 11 90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SPM
borehole location:	SEE DRAWING 86	checked by:	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope:	-90 DEG	R.L. Surface:	10.3 m
hole diameter:	100mm	bearing:		datum:	AHD

method	penetration 1 2 3	support	water	notes samples, test, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	structure and additional observations
ADT		NIL			10			SP	FILL. Sand fine to medium grained with some gravel	D		FILL
										M		
				2, 2, 2 N= 6	9	1		SP	SAND, medium grained, light yellow brown, little or no fines		MD	DUNE SAND trace of shells
					8	2						
				4, 6, 7 N*= 13	7	3						
				4, 5, 7 N*= 12	6	4						
					5	5						
				7, 9, 6 N*= 15	4	6						
				4, 4, 5 N*= 9	3	7						

METHOD
- AS auger screwing*
- AD auger drilling*
- R roller/tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- C casing
- M mud

PENETRATION
1 2 3
no resistance
ranging to
refusal

WATER
- • not measured
- water level
- water outflow
- water inflow

NOTES samples and tests
- U50 undisturbed sample 50 mm diameter
- D disturbed sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- V vane shear
- P pressuremeter
- Bs bulk sample
- R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

Coffey Partners International Pty Ltd
Incorporated in NSW

engineering log - borehole

borehole no: BH7
sheet 2 of 2
office job no: S9425/1

client	GEOMARINE PTY LTD	hole commenced	30.11.90
principal	WARRINGAH SHIRE COUNCIL	hole completed	30.11.90
project	BEACH DEVELOPMENT DESIGN CRITERIA	logged by	SRM
borehole location	SEE DRAWING 8c	checked by	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope	-90 DEG	R.L. Surface	10.3 m
hole diameter	100mm	bearing		datum	AHD

method	penetration	support	water	notes samples, tests, etc	RL	depth metres	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	structure and additional observations
AD1					2		SP	SAND: medium grained, light yellow brown, little or no fines	M	MD	DUNE SAND, trace of shells
			∇	12, 20 N*=R	1	9	SP	SAND: medium to coarse grained, light yellow orange & brown with some shell fragments. Concretions observed in shell fragments. Shell content increasing to >50% total	W	VD	DUNE SAND with indurated layers
					0	10		Borehole BH7 Terminated at 10.20 m			
					-1	11					
					-2	12					
					-3	13					
					-4	14					
					-5	15					

METHOD
- AS auger screwing*
- AD auger drilling*
- R roller/tricone
- W washbore
- CT cable tool
- HA hand auger
- D* diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. AD1

SUPPORT
- C casing
- M mud

PENETRATION
1 2 3 — no resistance ranging to refusal

WATER
- * not measured
- ∇ water level
- water outflow
- water inflow

NOTES samples and tests
- U50 undisturbed sample 50 mm diameter
- D disturbed sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- V vane shear
- P pressuremeter
- Bs bulk sample
- R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

Coffey Partners International Pty Ltd
Incorporated in NSW

COFFEY

engineering log - borehole

borehole no: BH8
sheet 1 of 2
office job no: S9425.1

client:	GEOMARINE PTY LTD	hole commenced:	30.11.90
principal:	WARRINGAH SHIRE COUNCIL	hole completed:	30.11.90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	logged by:	SRM
borehole location:	SEE DRAWING B6	checked by:	MAB

drill model and mounting:	EDSON 3000 - TRUCK	slope:	-90 DEG	R.L. Surface:	9.0 m
hole diameter:	100mm	bearing:		datum:	AHD

method	penetration 1 2 3	support	water	notes samples, test etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa	structure and additional observations
ADT		NIL			9	0		SP	SAND: fine to medium grained, light yellow brown, little or no fines	D			DUNE SAND with shell material
										M			
				1, 2, 1 N*=3	8	1					MD		
					7	2							
				3, 4, 6 N*=10	6	3							
					5	4							
				4, 7, 7 N*=14	4	5							
								SP	SAND: fine to medium grained, yellow brown orange, trace amounts of clay				
				4, 6, 6 N*=12					Layer of coarse sand & fine quartz gravel				
					3	6							
					2	7			Colour change to dark brown at about 7.0m				
				28, N*=R							VD		SPT - 40 blows for 20mm
									Indurated sand (?)				
			▽										Hole collapsing below water table
					1	8		SP	SAND: fine to coarse grained, light yellow brown, trace of clay				

METHOD
AS auger screwing*
AD auger drilling*
R roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e.g. ADT

SUPPORT
C casing
M mud

PENETRATION
1 2 3
no resistance ranging to refusal

WATER
not measured
water level
water outflow
water inflow

NOTES samples and tests
U50 undisturbed sample 50 mm diameter
D disturbed sample
N standard penetration test
N* SPT + sample recovered
Nc SPT with solid cone
V vane shear
P pressuremeter
Bs bulk sample
R refusal

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Coffey Partners International Pty. Ltd
incorporated in NSW

engineering log - borehole

borehole no **BH8**
sheet 2 of 2
office job no S9425 1

client	GEOMARINE PTY LTD	hole commenced	30.11.90
principal	WARRINGAH SHIRE COUNCIL	hole completed	30.11.90
project	BEACH DEVELOPMENT DESIGN CRITERIA	logged by	SRM
borehole location	SEE DRAWING B6	checked by	MAB

drill model and mounting	EDSON 3000 - TRUCK	slope	-90 DEG	R.L. Surface	9.0 m
hole diameter	100mm	bearing		datum	AHD

method	penetration 1 2 3	support	water	notes samples, test etc	R.L.	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa	structure and additional observations
ADT								SP	SAND, fine to coarse grained, light yellow brown, trace of clay	W	VD		
					0	9							
					-1	10							
									Borehole BH8 Terminated at 10.25 m				
					-2	11							
					-3	12							
					-4	14							
					-6	15							

METHOD
AS auger screwing*
AD auger drilling*
R roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e.g. ADT

SUPPORT
C casing
M mud

PENETRATION
1 2 3
no resistance
ranging to
refusal

WATER
• not measured
water level
water outflow
water inflow

NOTES samples and tests
U50 undisturbed sample 50 mm diameter
D disturbed sample
N standard penetration test
N* SPT + sample recovered
Nc SPT with solid cone
V vane shear
P pressuremeter
Bs bulk sample
R refusal

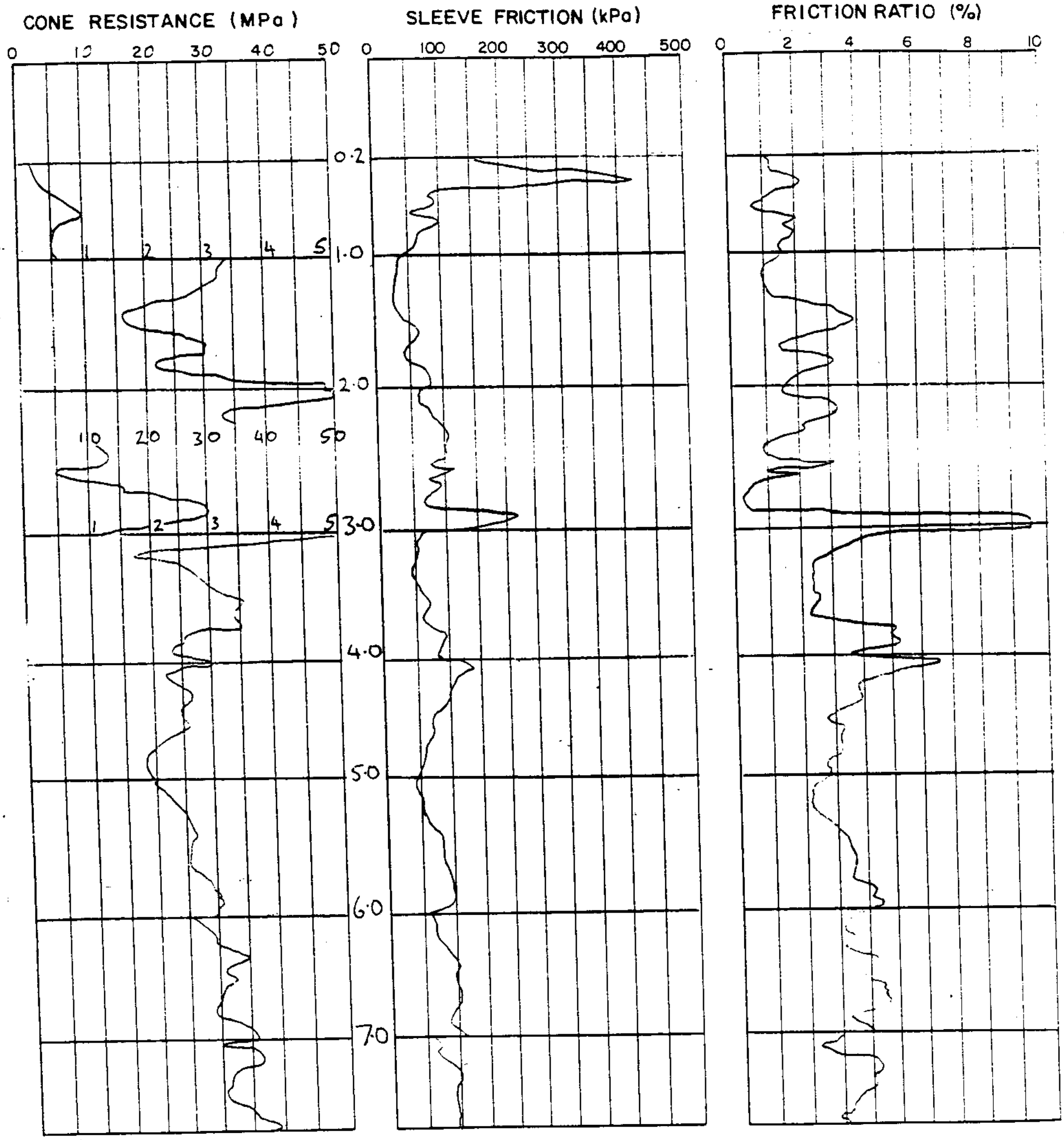
CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

187-230

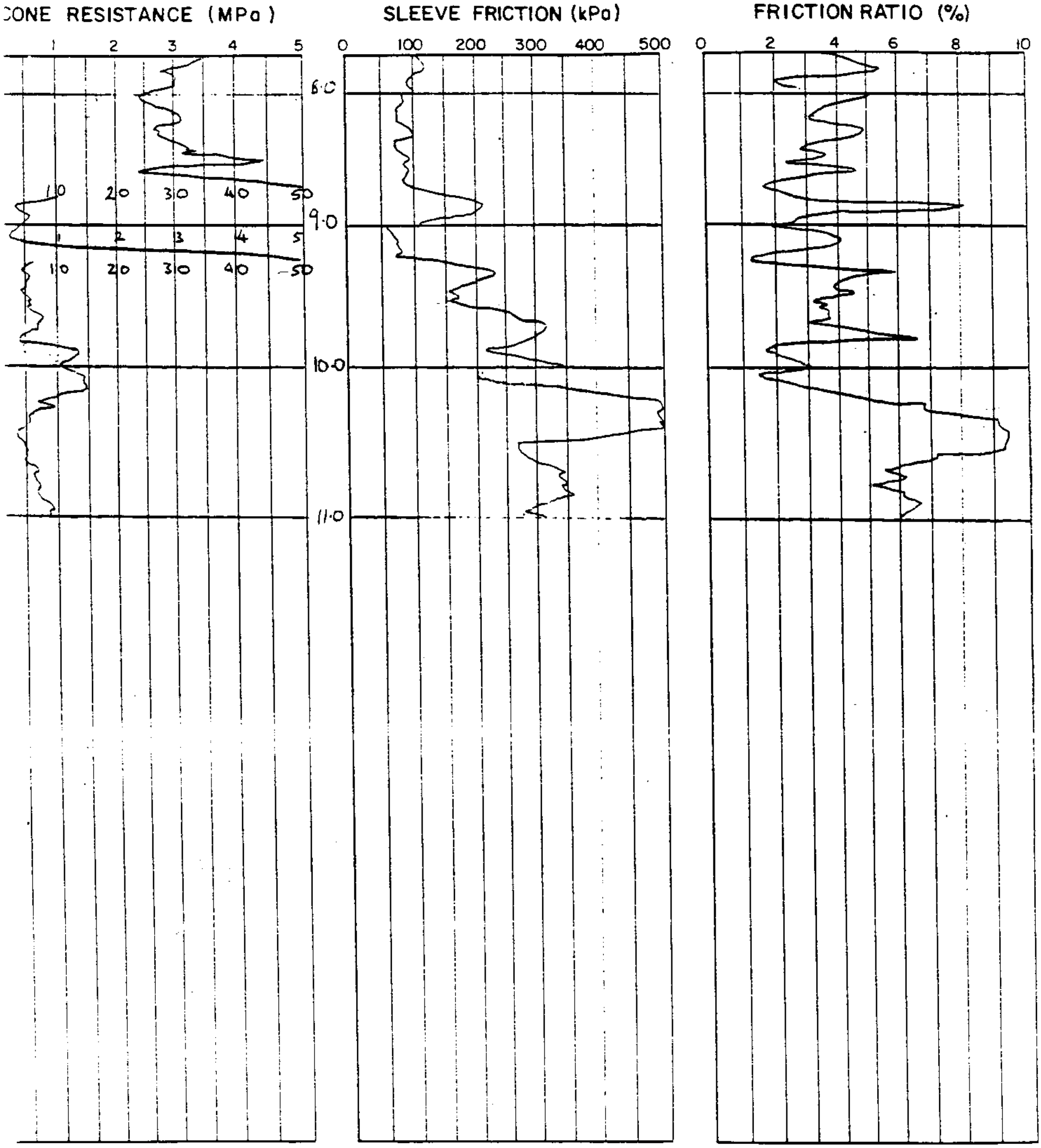
TEST STARTED - 0·2



TEST TERMINATED-

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP1

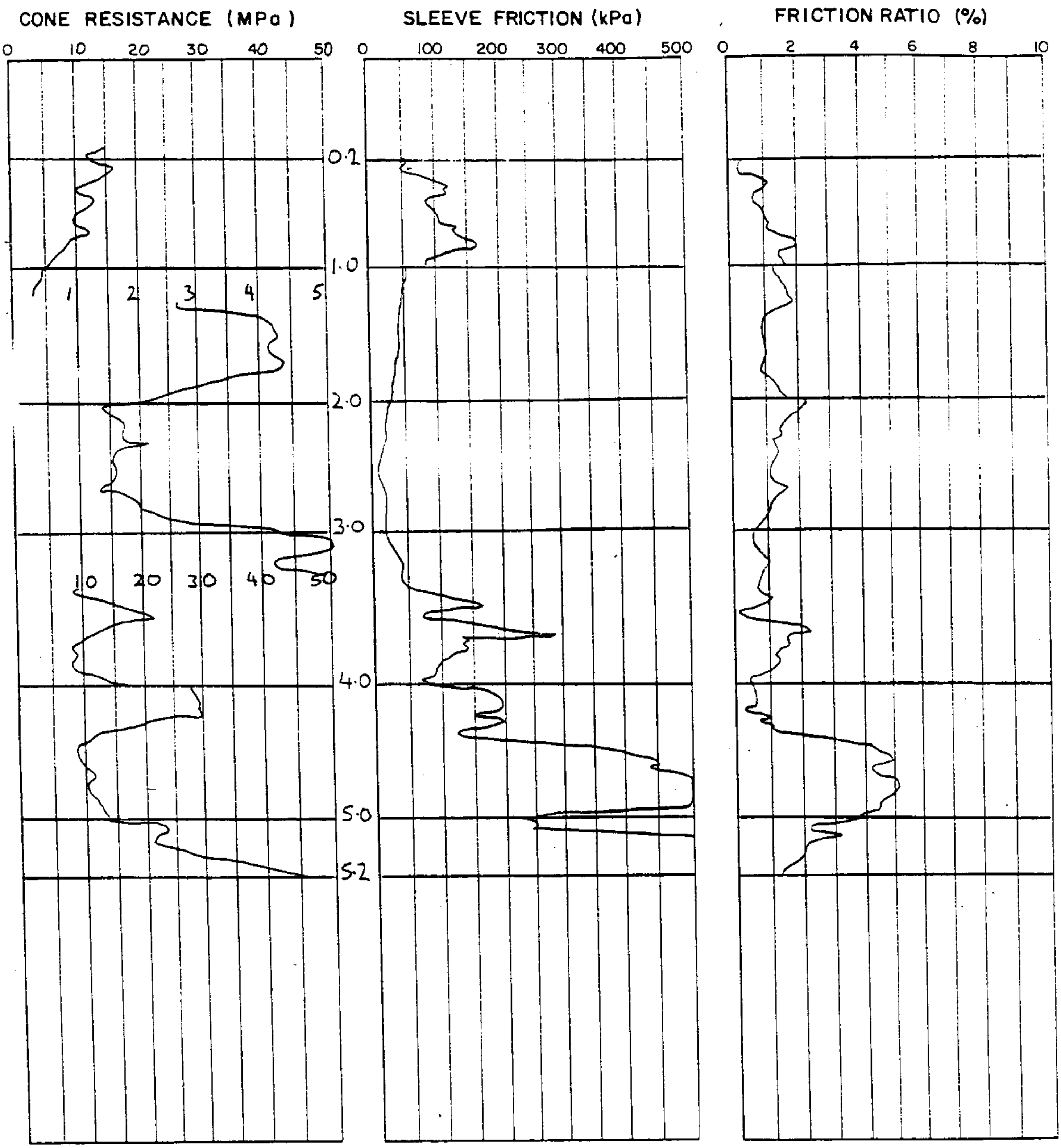
TEST STARTED -



TEST TERMINATED - 11.0

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP1

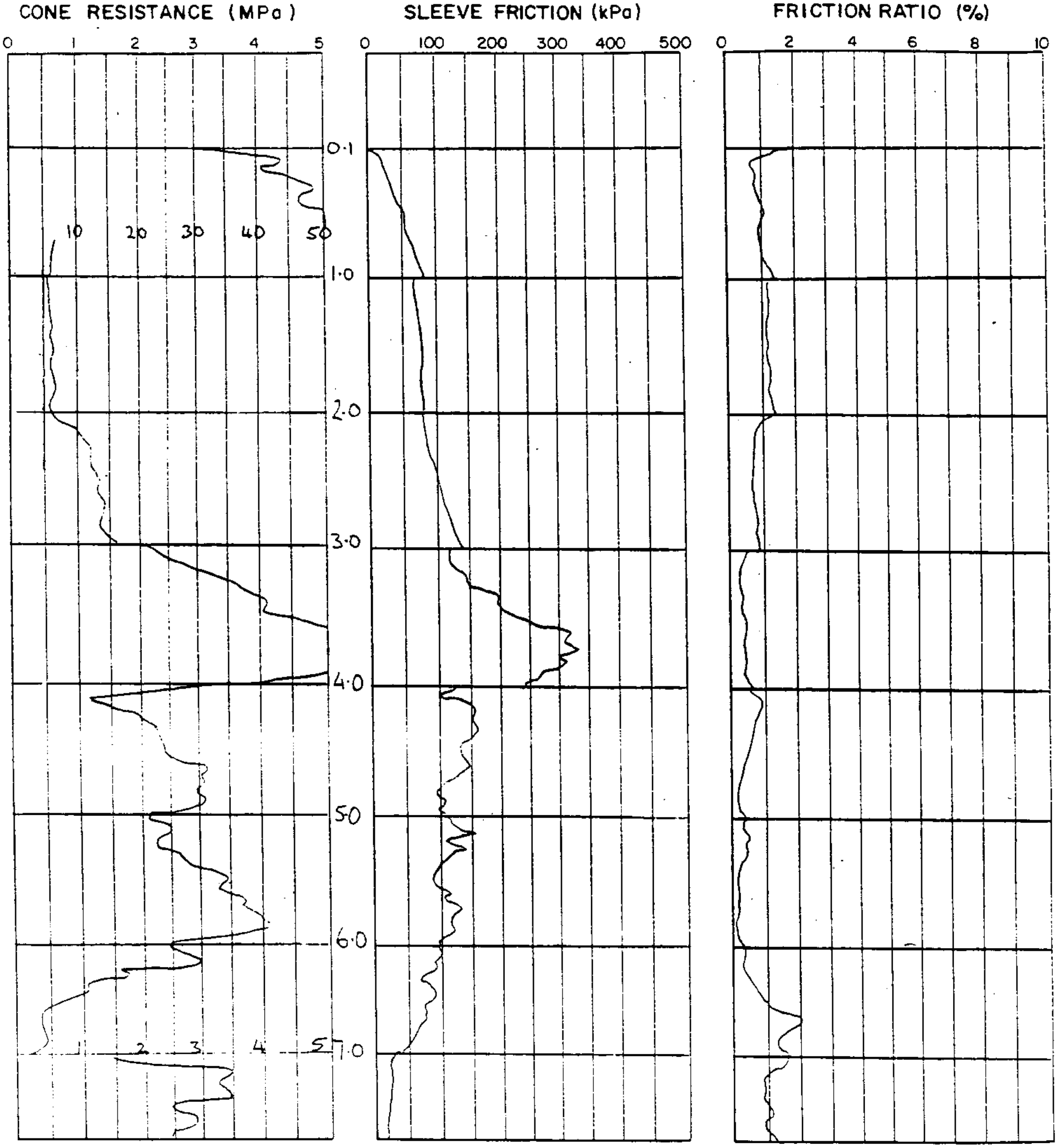
TEST STARTED - 0·2



TEST TERMINATED - 5·2

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP2

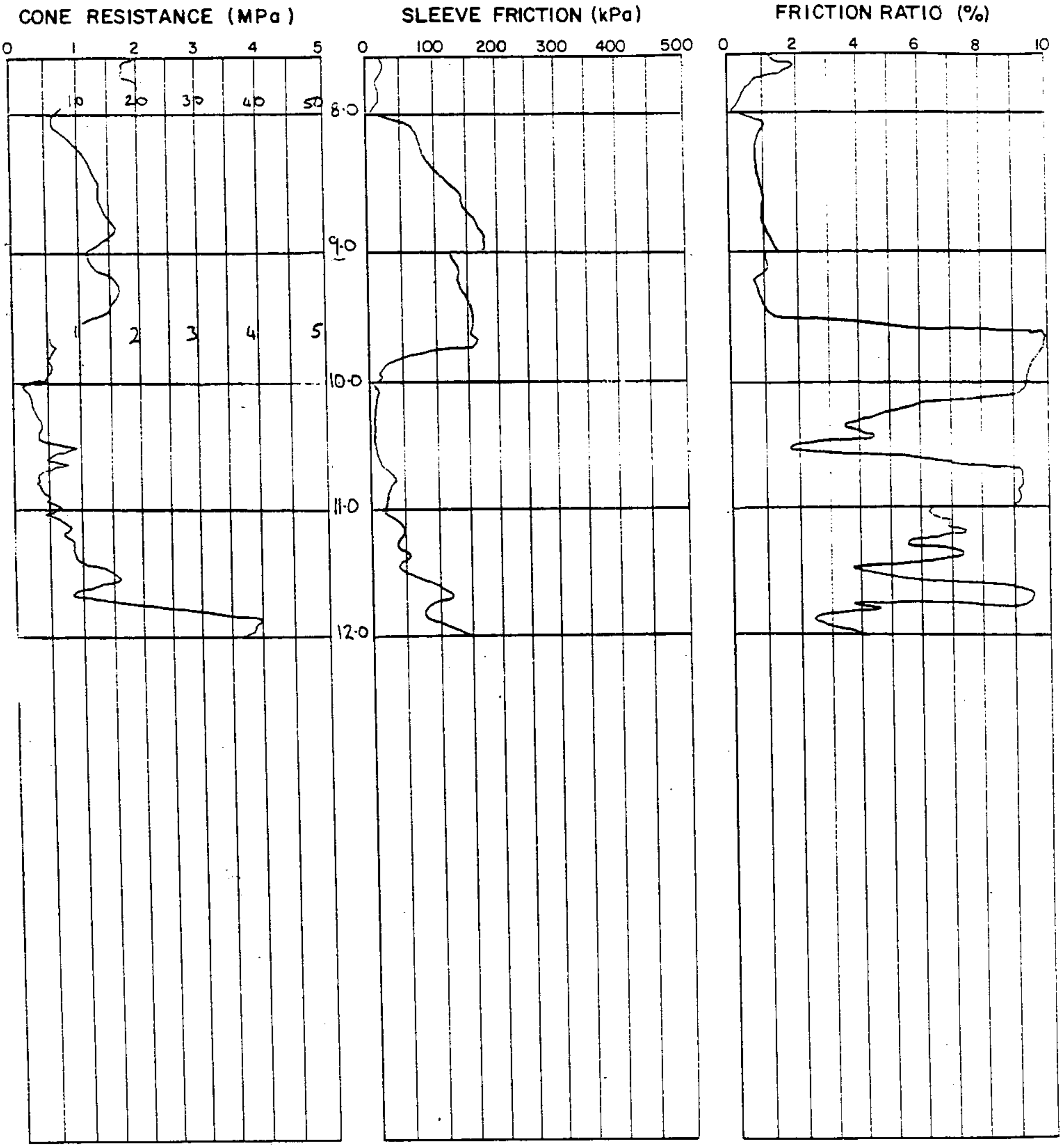
TEST STARTED - 0·1



TEST TERMINATED -

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP3

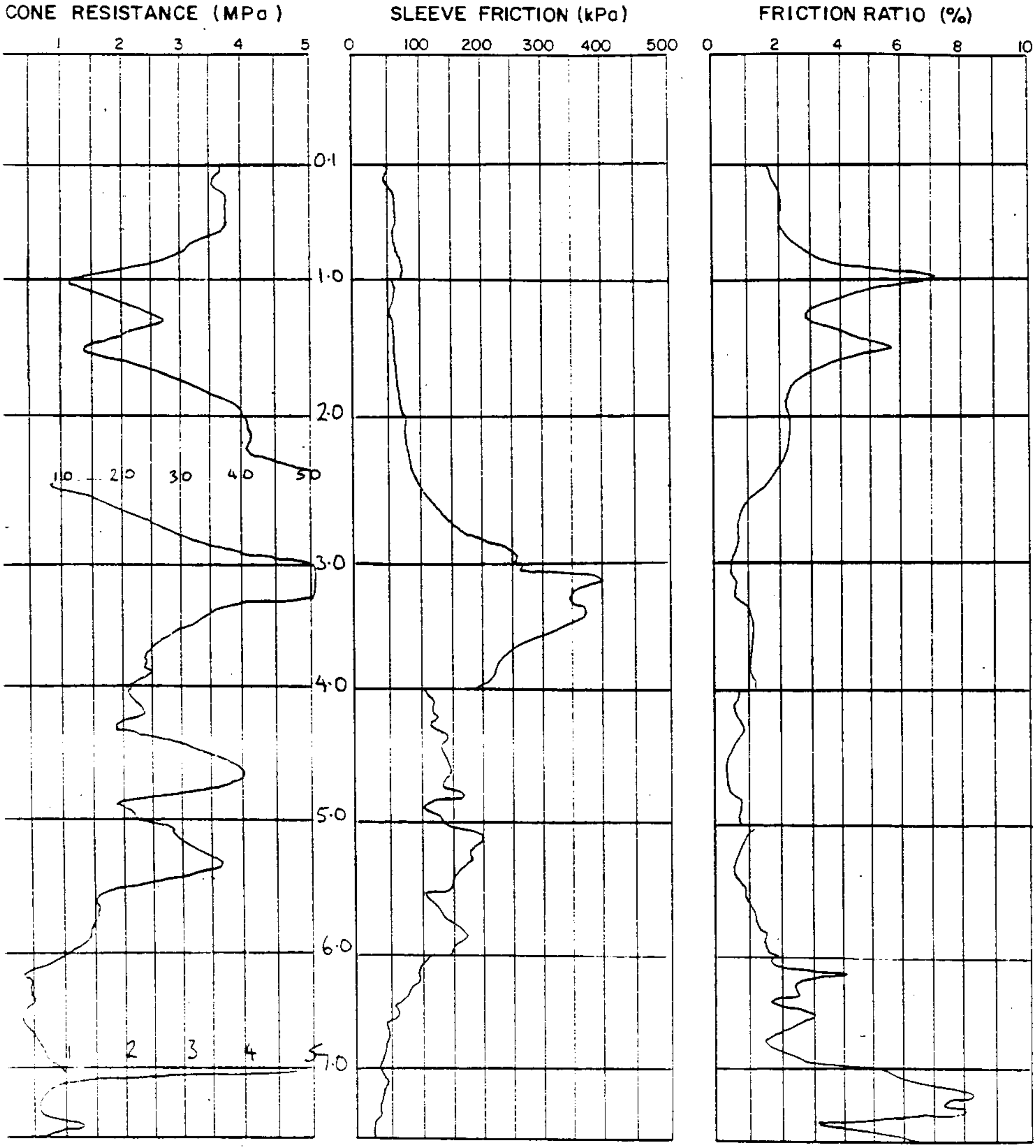
TEST STARTED -



TEST TERMINATED – 12·0m

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP3

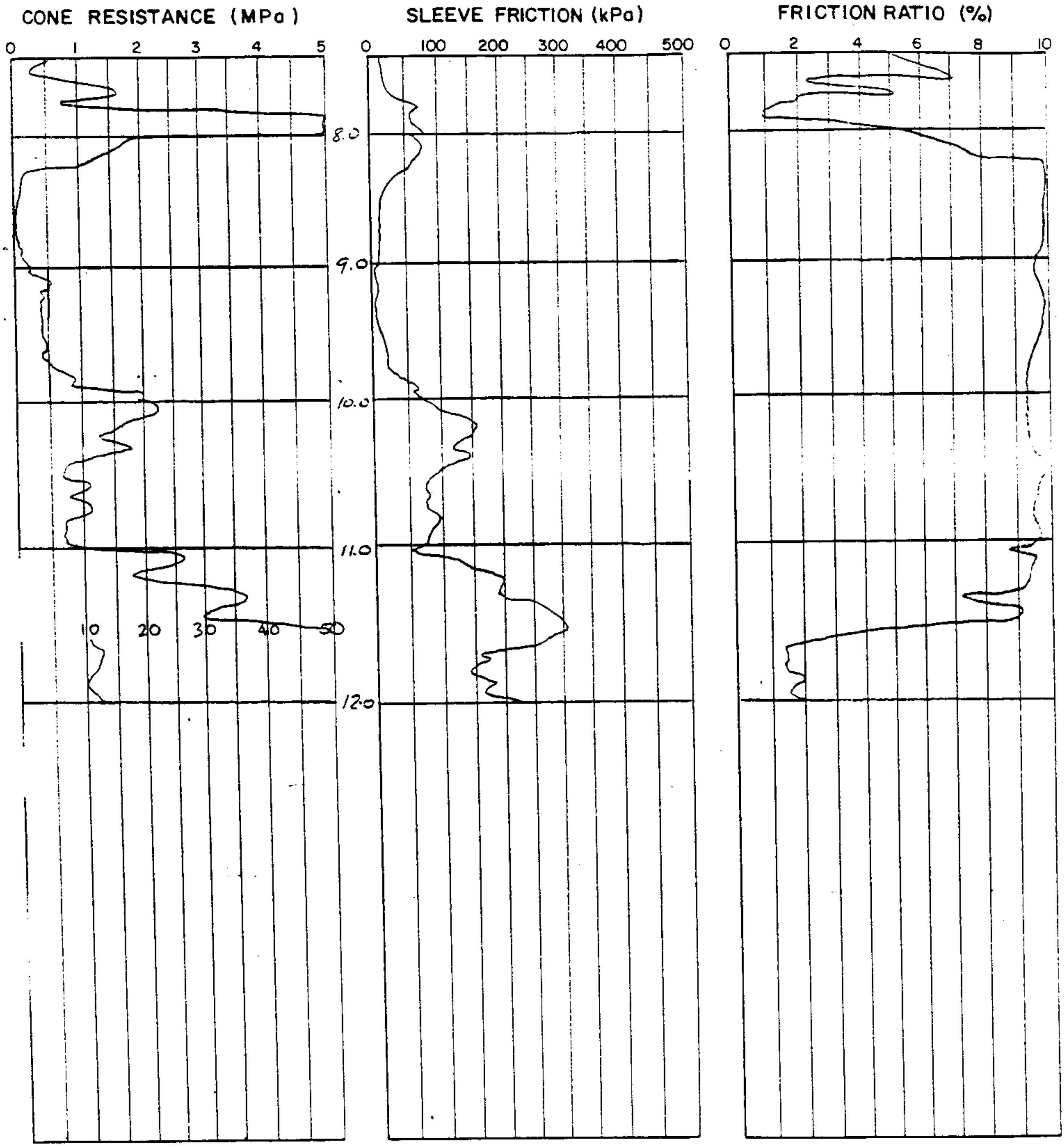
TEST STARTED - 0·1



TEST TERMINATED-

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP3B

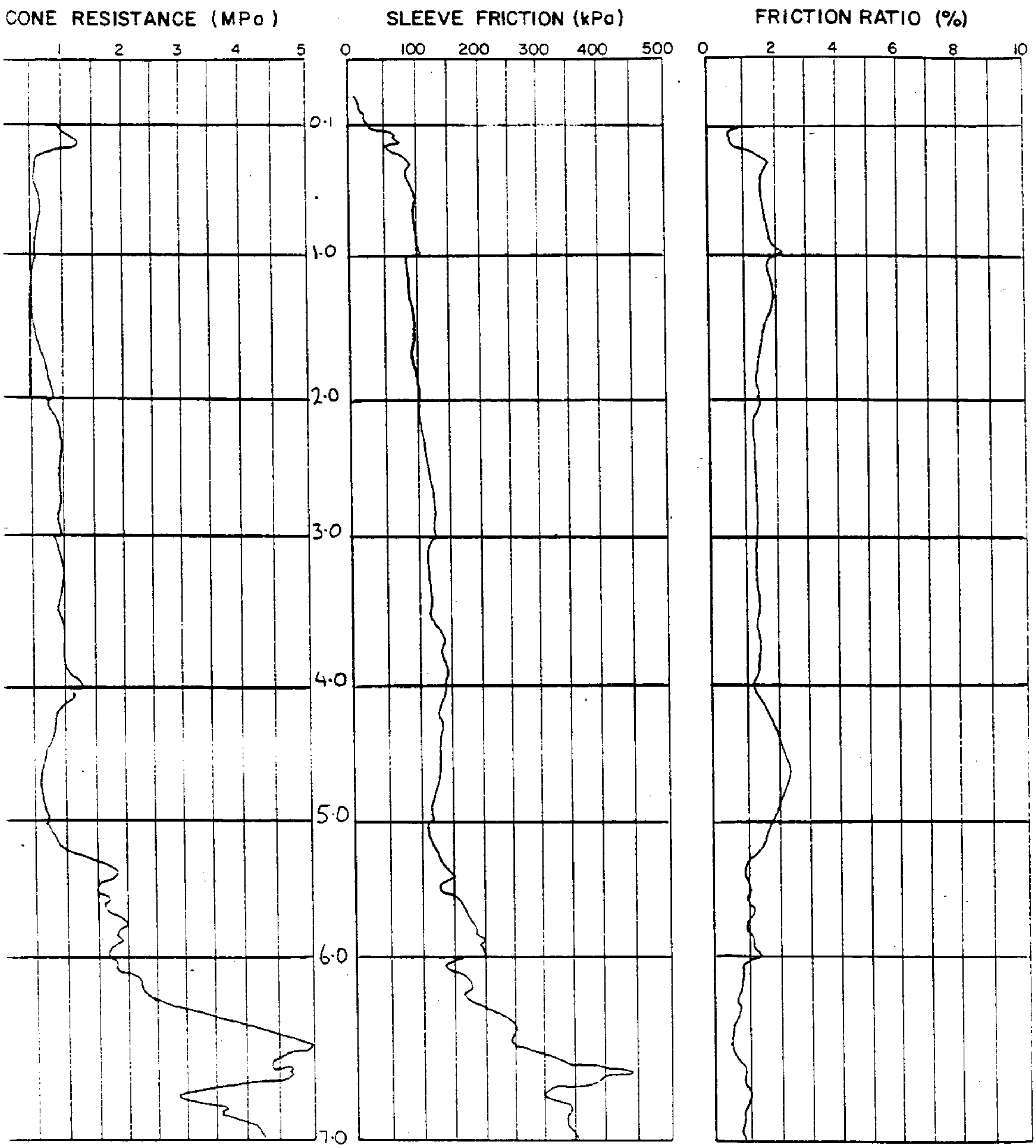
TEST STARTED -



TEST TERMINATED - 12.0

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP3B

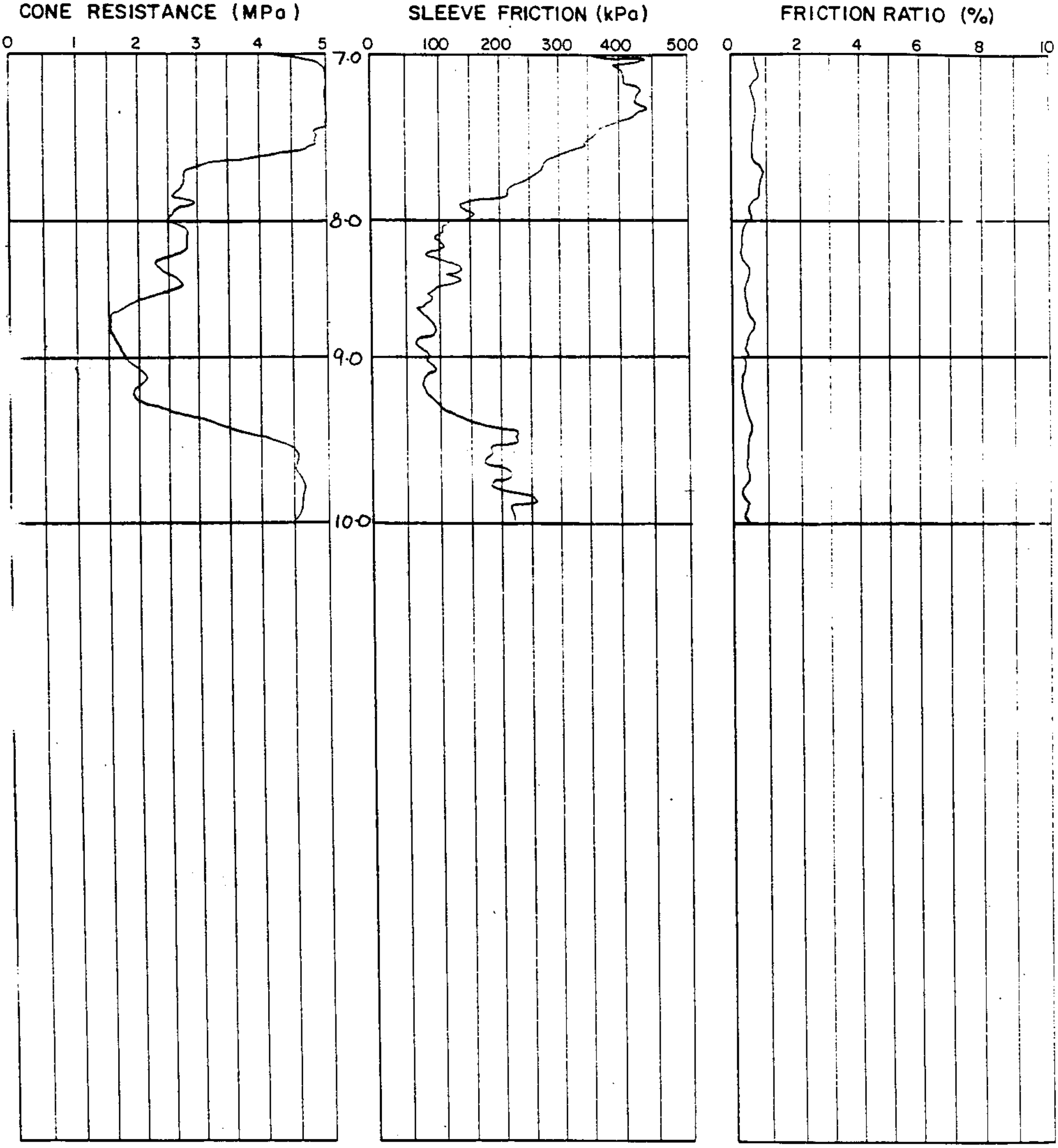
TEST STARTED - 0·1



TEST TERMINATED-

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP4

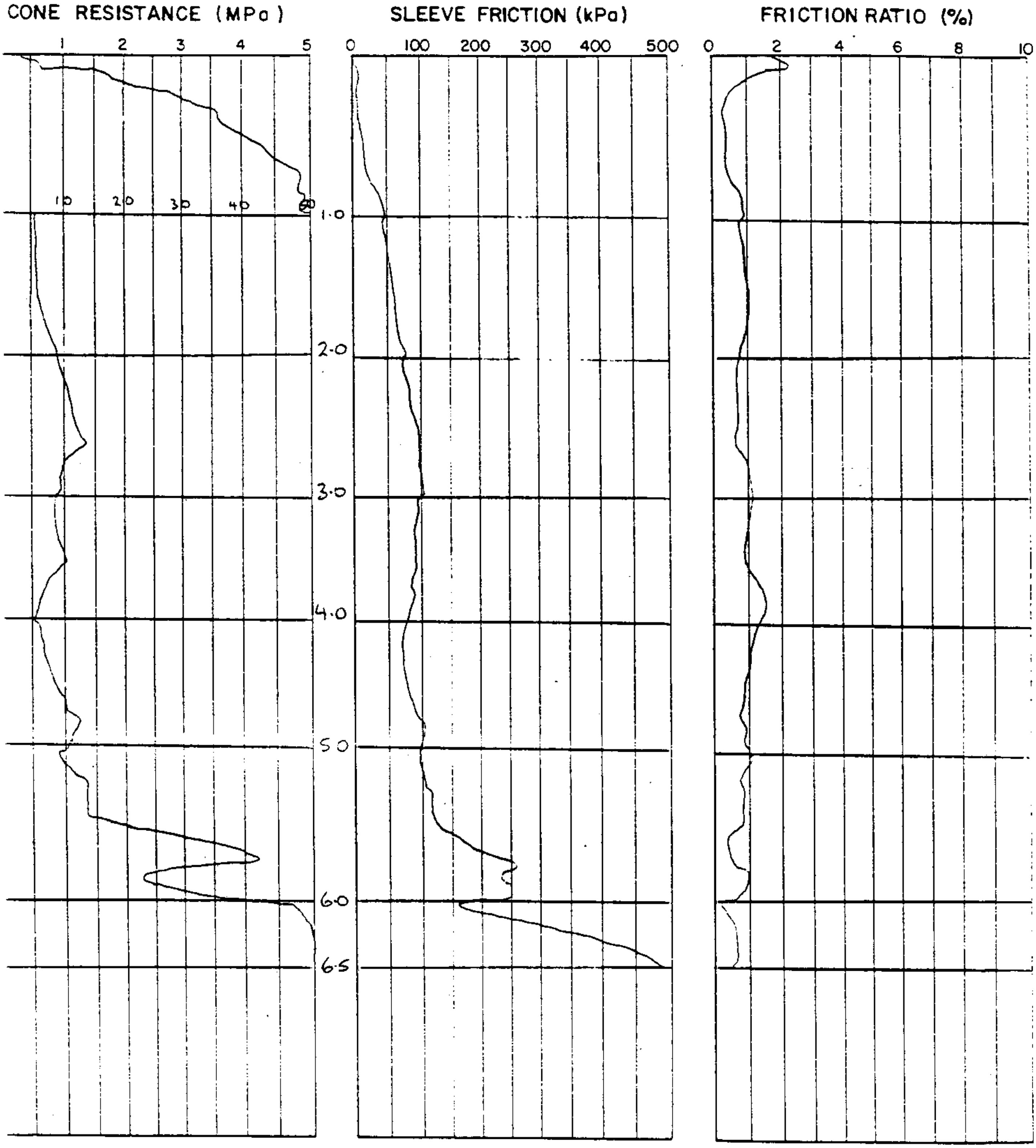
TEST STARTED -



TEST TERMINATED -

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP4

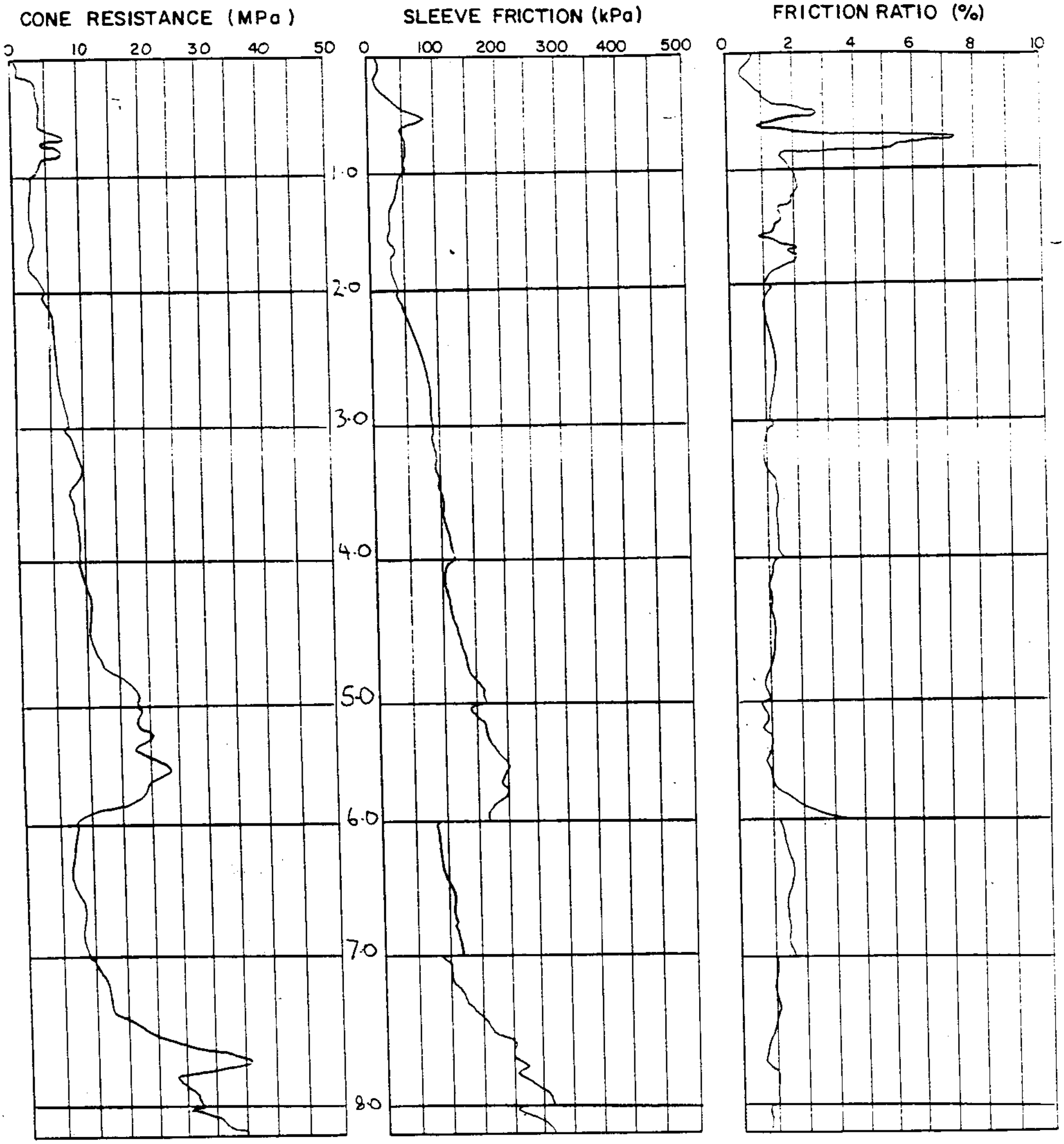
TEST STARTED - 0·1m



TEST TERMINATED - 6·5m

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP5A

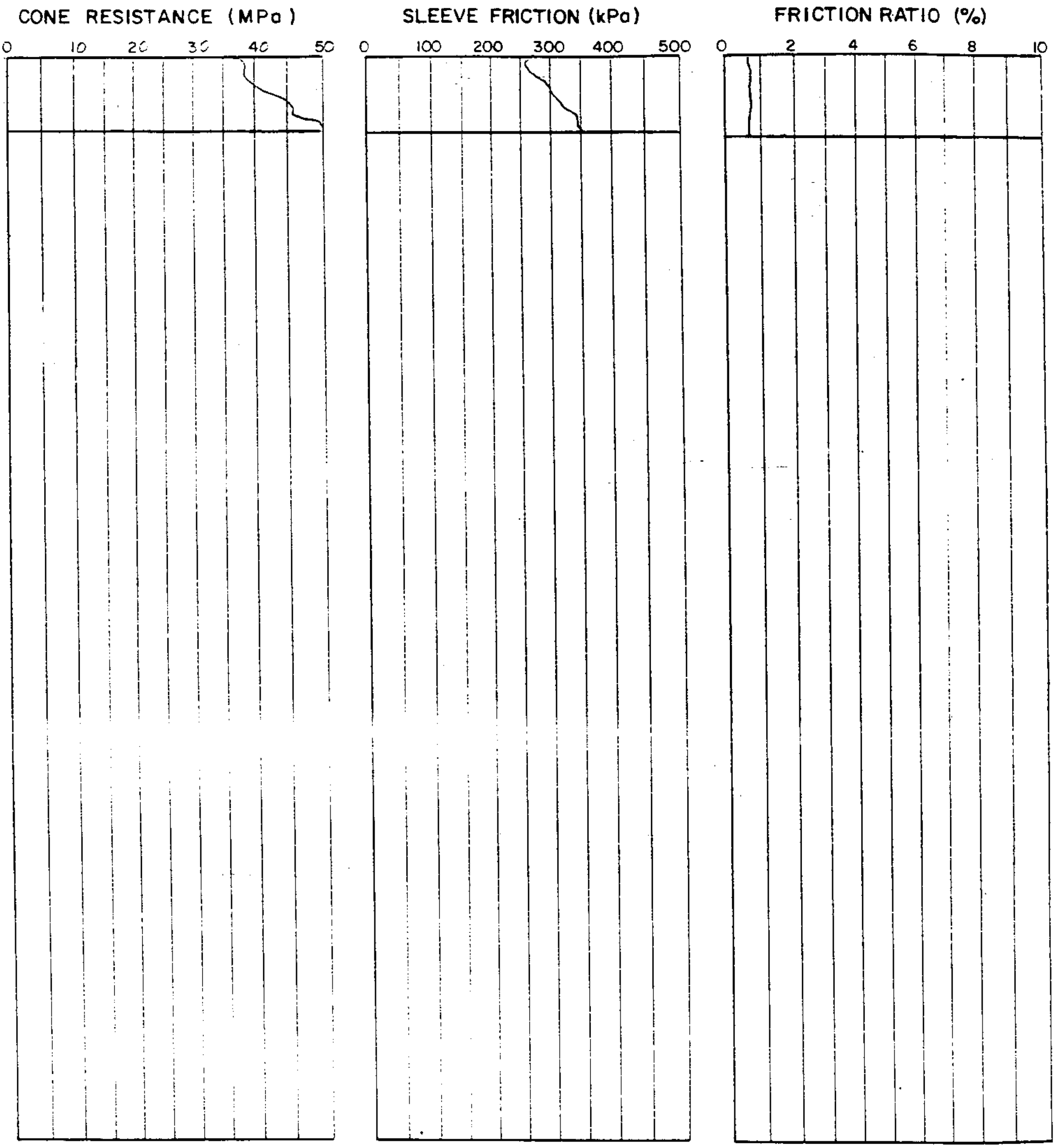
TEST STARTED - 0·1



TEST TERMINATED -

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP6A

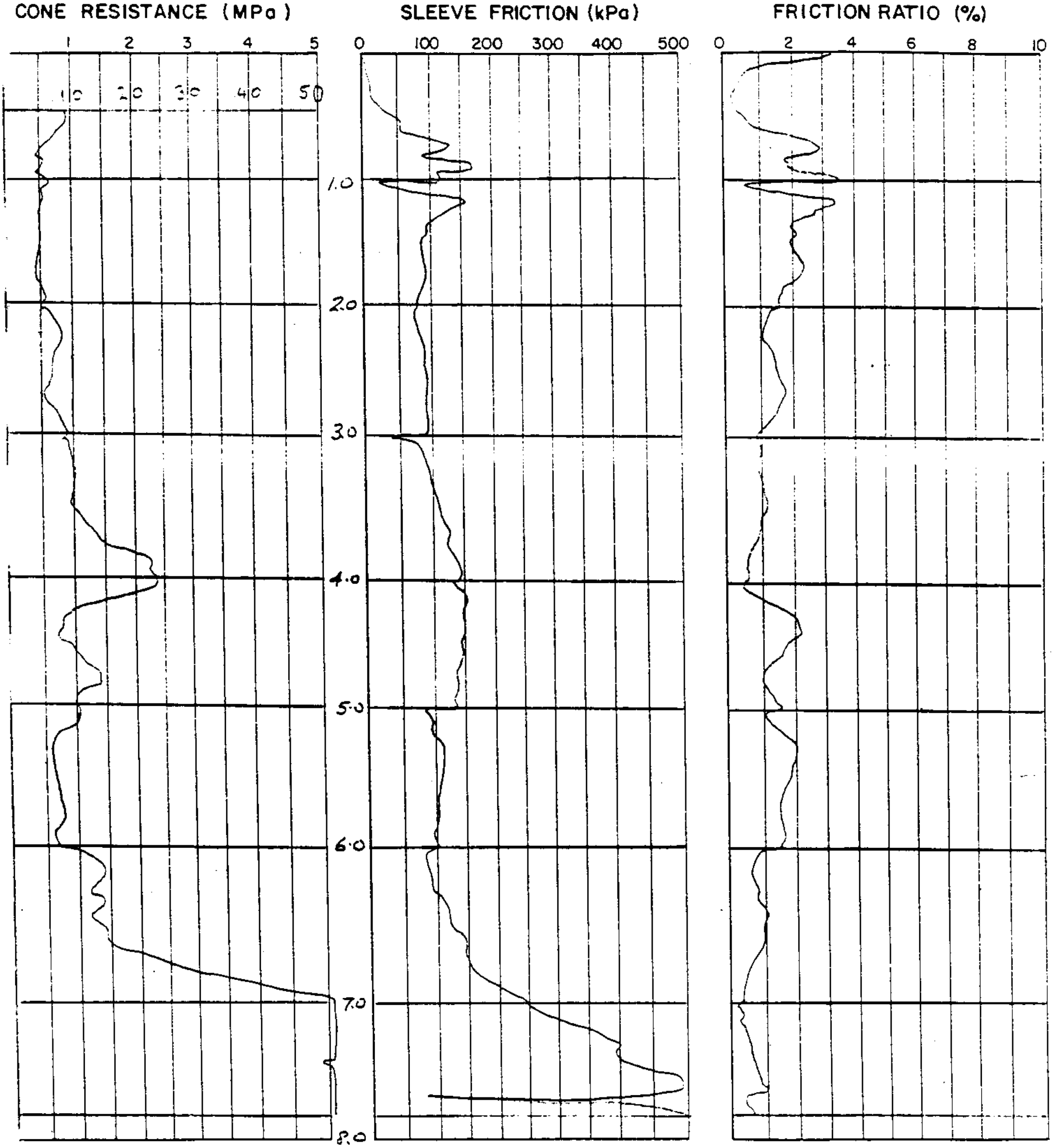
TEST STARTED -



TEST TERMINATED – 8·7m

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP6A

TEST STARTED - 0·1m



TEST TERMINATED - 7·7m

ELECTRIC FRICTION CONE PENETROMETER TEST - EFCP6

Appendix C

Laboratory Testing Data

Coffey Partners International Pty Ltd
Incorporated in NSW

direct shear test

COFFEY

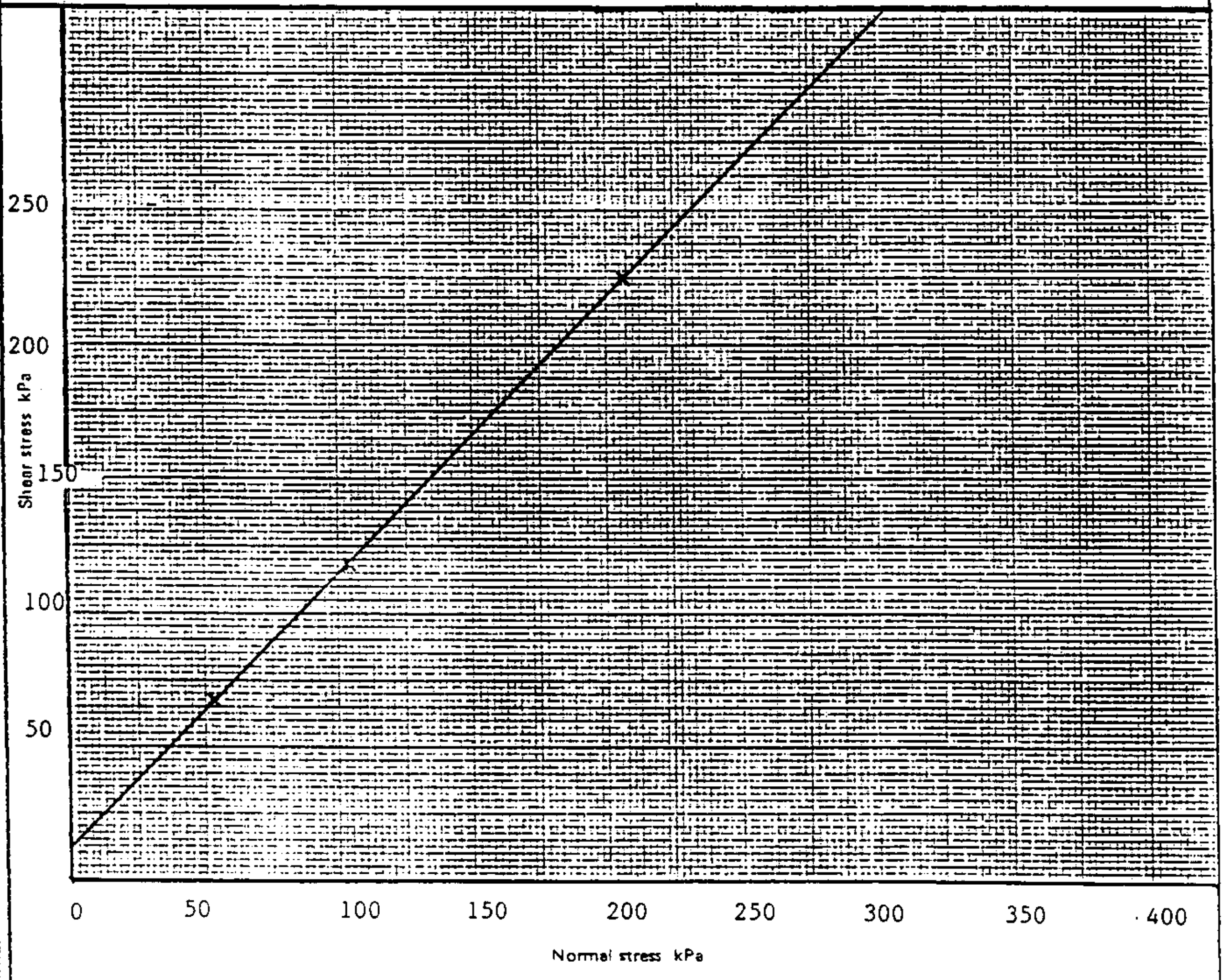
borehole	BH3
sheet	1 of 1

office: SYDNEY

client:	GEOMARINE PTY LTD	job no:	S9425/1
principal:	WARRINGAH SHIRE COUNCIL	date:	21-12-90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	tested by:	GC
location:	NARRABEEN TO COLLAROY BEACH	checked by:	JR

depth: 4.10 - 4.55m   sample type: 3 Single Stage remoulded   sample size: 71 x 71 x 34mm
type of test: consolidated Drained

material classification: (SC/SP) SAND, fine to coarse, yelllow-brown, some fines of low plasticity, trace of fine to medium gravel, trace of shell fragments.



Initial moisture content 17.8 %
Initial dry density 1.62 t/m^3
Cohesion C' 12.5 kPa
Angle of friction ϕ 45.5 °

remarks:

failure criteria: Peak Shear Stress

NATA

8 / 1 / 91

Authorised Signature James Russell

Coffey & Partners Pty. Ltd.

COFFEY

job no: S9425/1

sheet 1 of 1

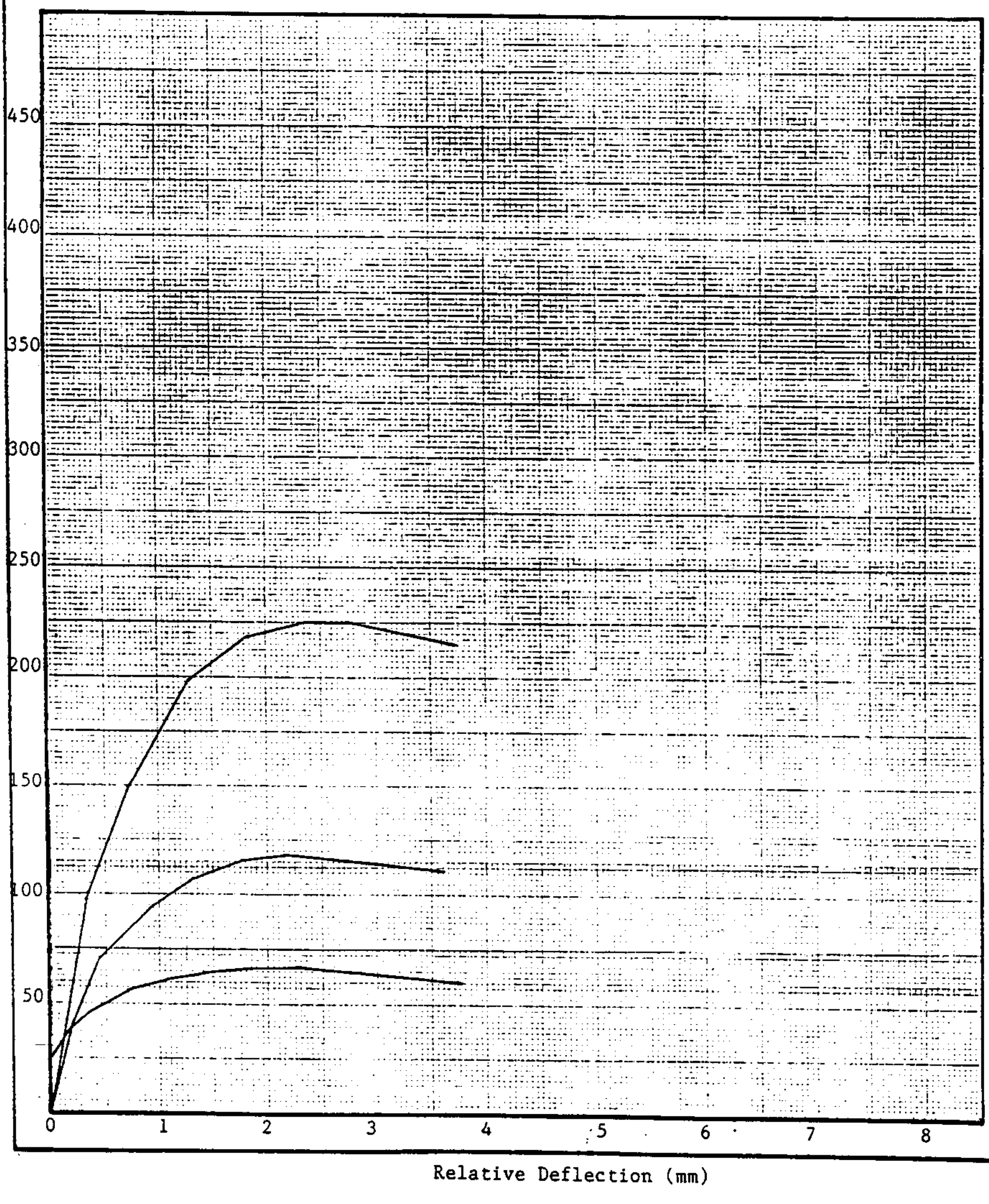
direct shear test

office: SYDNEY

client: GEOMARINE PTY LTD
principal: WARRINGAH SHIRE COUNCIL
project: BEACH DEVELOPMENT DESIGN CRITERIA
location: NARRABEEN TO COLLAROY BEACH

date: 4-1-91
tested by: GC
checked by: JR

borehole: BH3 depth 4.1 - 4.55m stress range: - kPa



Coffey Partners International Pty Ltd
Incorporated in NSW

direct shear test

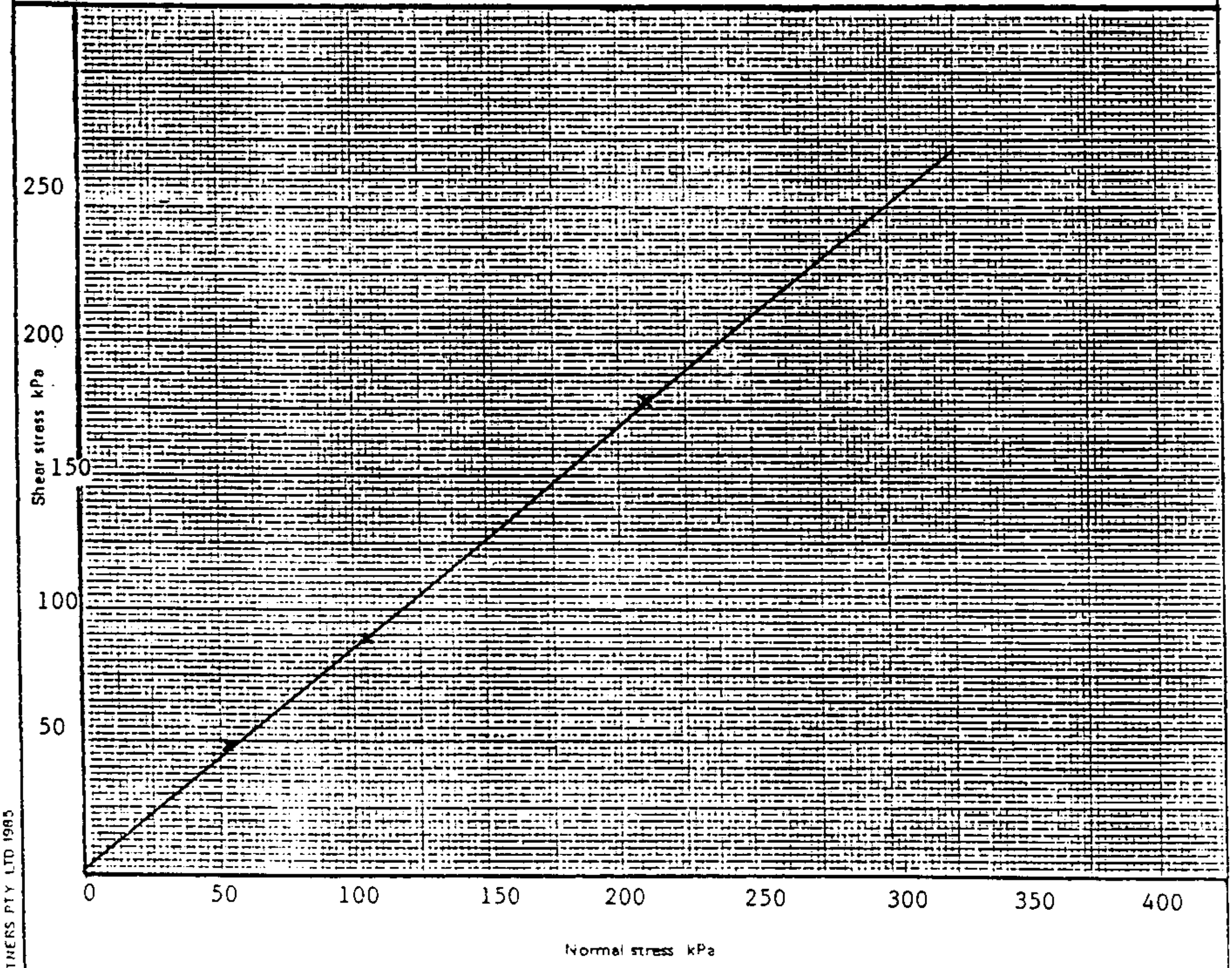
borehole: BH5
sheet 1 of 1

office: SYDNEY

client:	GEOMARINE PTY LTD	job no:	S9425/1
principal:	WARRINGAH SHIRE COUNCIL	date:	21-12-90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	tested by:	GC
location:	NARRABEEN TO COLLAROY BEACH	checked by:	JR

depth: 1.10 - 1.55m   sample type: 3 single stage - remoulded   sample size: 71 x 71 x 34mm
type of test: Consolidated Drained

material classification: (SP) SAND, fine to coarse, yellow-brown, trace of fines.



Initial moisture content 2.6 %
Initial dry density 1.54 t/m^3
Cohesion C' 2 kPa
Angle of friction ϕ 39.5 °

remarks:

failure criteria: Peak Shear Stress

NATA

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Coffey & Partners Pty. Ltd.

COFFEY

job no: S9425/1

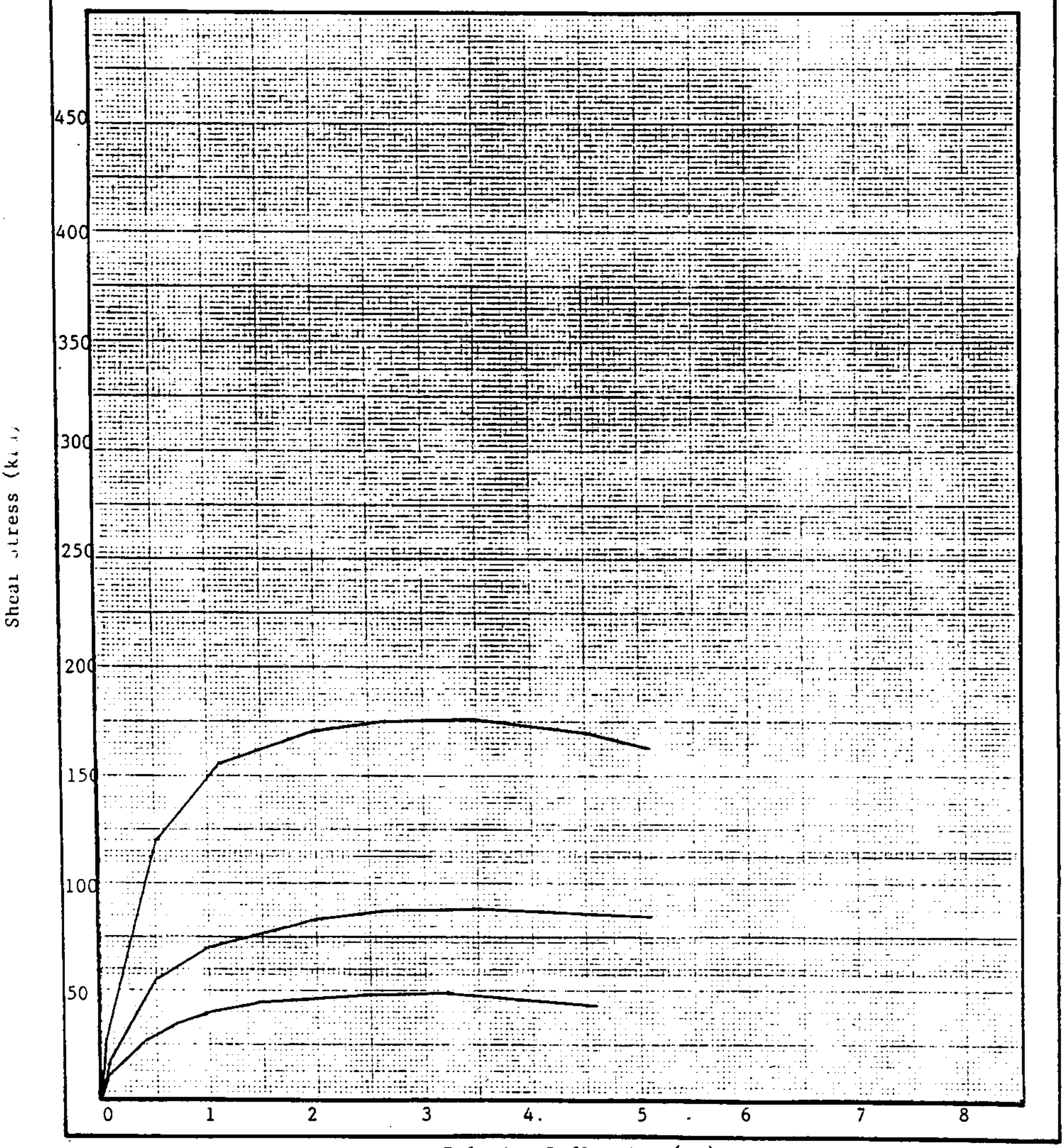
sheet 1 of 1

direct shear test

office: SYDNEY

client:	GEOMARINE PTY LTD	date:	4-1-91
principal:	WARRINGAH SHIRE COUNCIL	tested by:	GC
project:	BEACH DEVELOPMENT DESIGN CRITERIA	checked by:	JR
location:	NARRABEEN TO COLLAROY BEACH		

borehole: BH5 depth 1.10 - 1.55m stress range: - kPa



Coffey Partners International Pty Ltd
Incorporated in NSW

direct shear test

COFFEY

borehole BH7
sheet 1 of 1

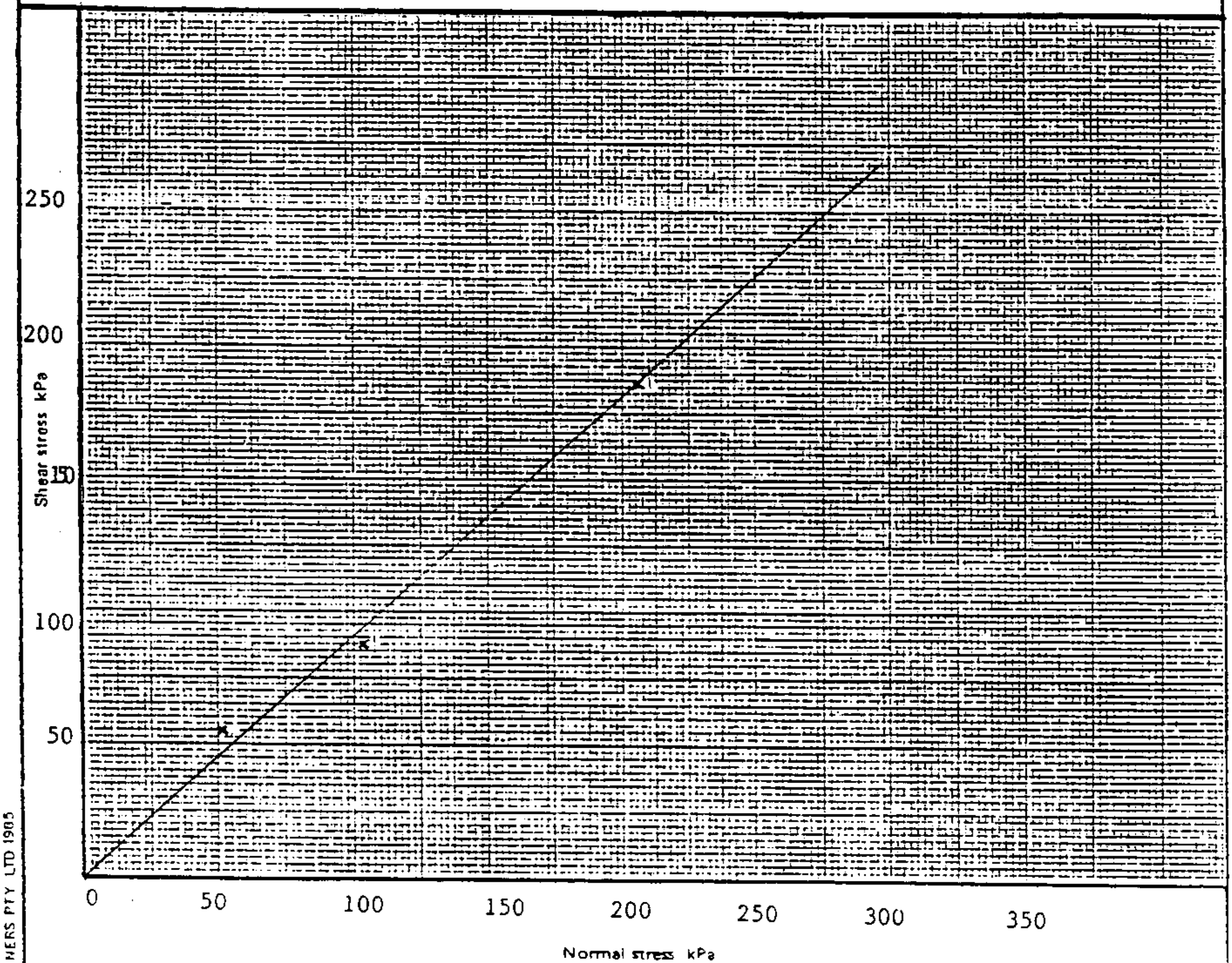
office: SYDNEY

client: GOEMARINE PTY LTD
principal: WARRINGAH SHIRE COUNCIL
project: BEACH DEVELOPMENT DESIGN CRITERIA
location: NARRABEEN TO COLLAROY BEACH

job no: S9425/1
date: 20/12/90
tested by: GC
checked by: JR

depth: 5.60 - 6.05m
type of test: Consolidated Drained
sample type: 3 single stage - remoulded
sample size: 71x71x34mm

material classification: (SP) SAND - fine to coarse, yellow brown, trace of fines



Initial moisture content .... 2.6 .... %
Initial dry density .... 1.58 .... t/m^3
Cohesion C' .... 0 .... kPa
Angle of friction ϕ .... 42 .... °

remarks:

failure criteria: Peak Shear Stress

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Authorised Signature James Russell

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Coffey & Partners Pty. Ltd.

COFFEY

job no: S9425/1

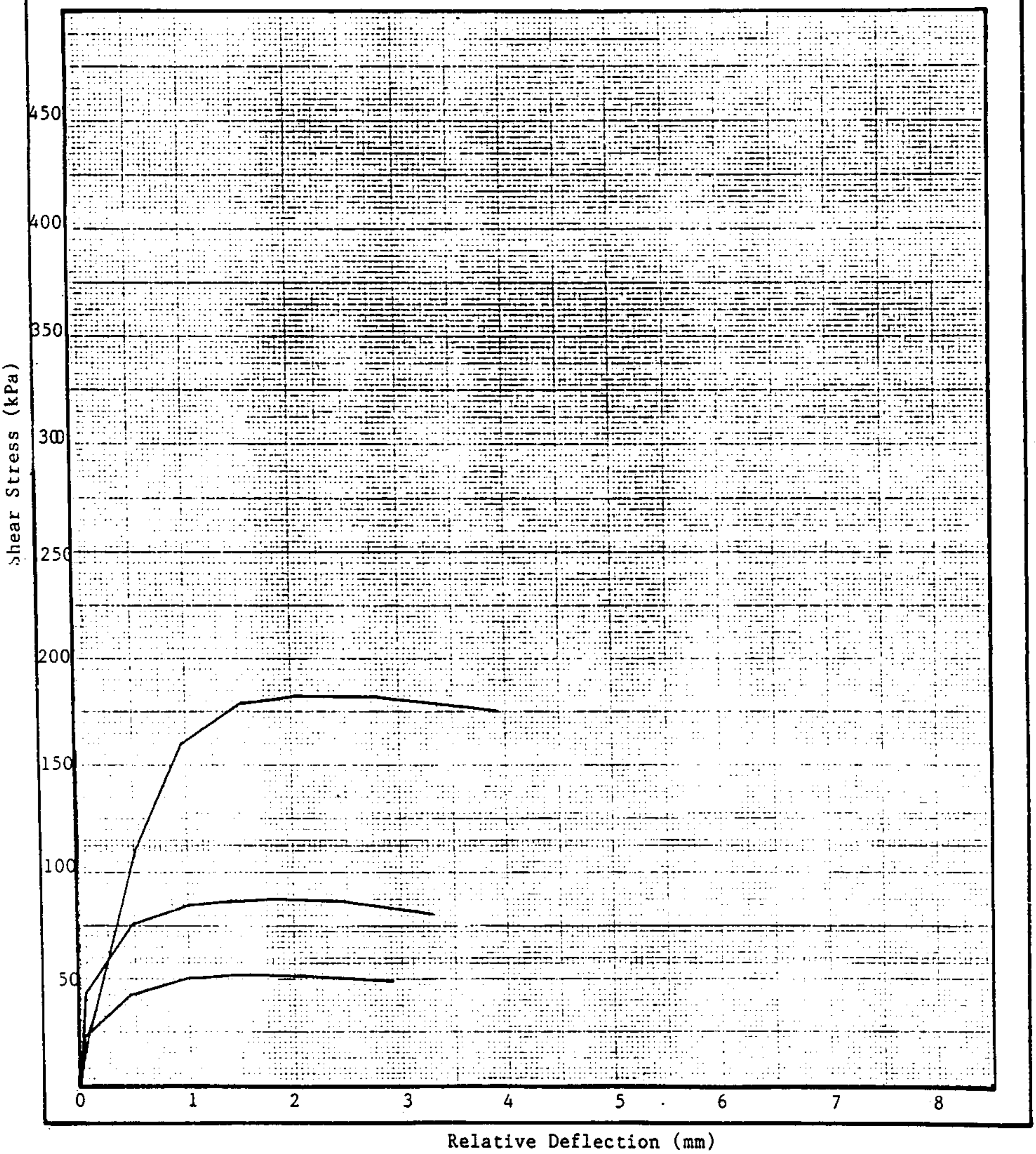
sheet 1 of 1

direct shear test

office: SYDNEY

client:	GEOMARINE PTY LTD	date:	4-1-91
principal:	WARRINGAH SHIRE COUNCIL	tested by:	GC
project:	BEACH DEVELOPMENT DESIGN CRITERIA	checked by:	JR
location:	NARRABEEN TO COLLAROY BEACH		

borehole: BH7 depth 5.6 - 6.05m stress range: - kPa



Coffey Partners International Pty Ltd
Incorporated in NSW

direct shear test

COFFEY

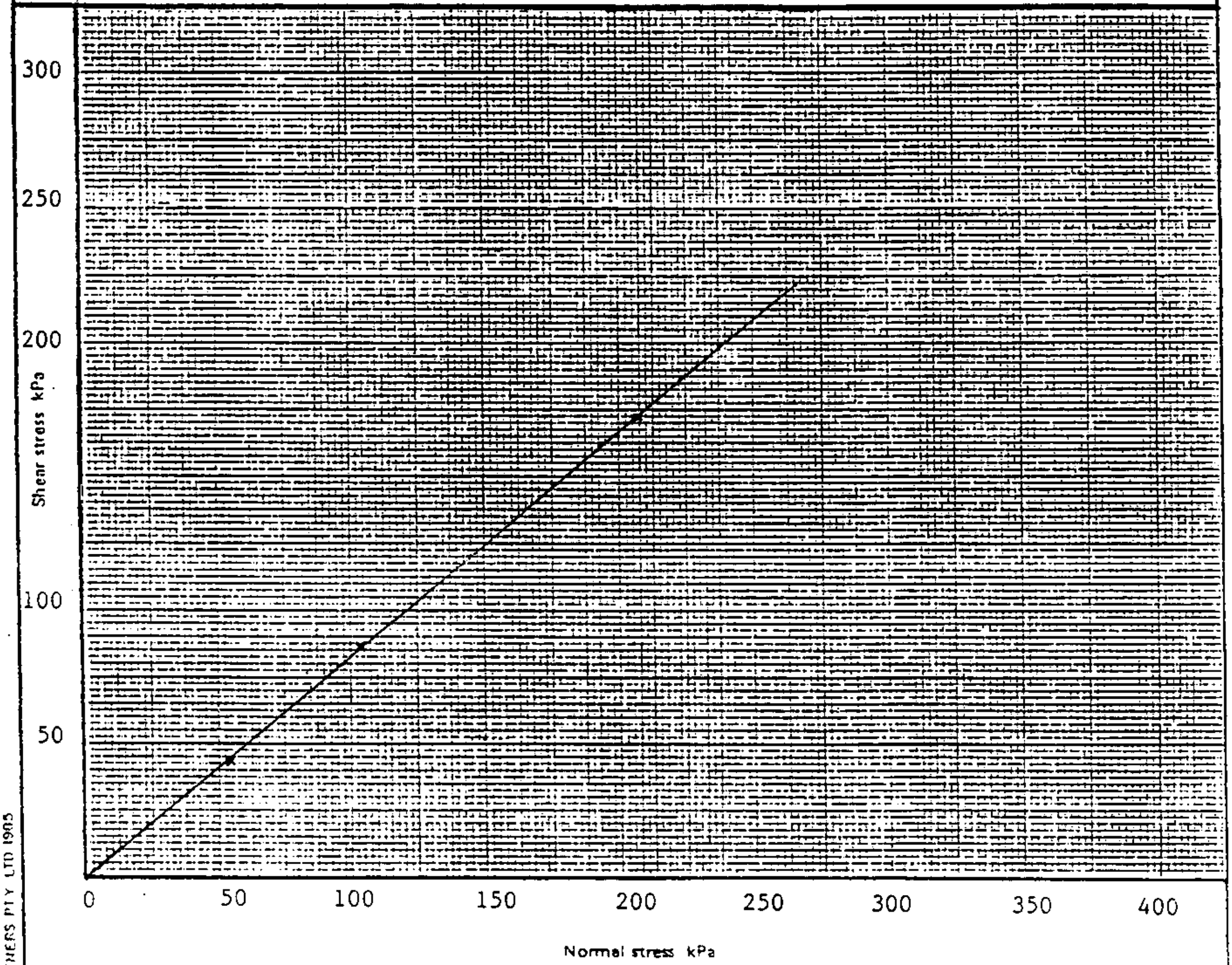
borehole:	BH8
sheet	1 of 1

office: SYDNEY

client:	GEOMARINE PTY LTD	job no:	S9425/1
principal:	WARRINGAH SHIRE COUNCIL	date:	20/12/90
project:	BEACH DEVELOPMENT DESIGN CRITERIA	tested by:	GC
location:	NARRABEEN TO COLLAROY BEACH	checked by	JR

depth: 1.00 -1.45m   sample type: 3 Singles Stage-remoulded   sample size: 71x71x33mm
type of test: Consolidated Drained Test

material classification: (SP) SAND - fine to coarse, yellow brown, trace of fines



Initial moisture content ......2.7...... %
Initial dry density ......1.57...... t/m³
Cohesion C' ......0...... kPa
Angle of friction ϕ' ......40...... °

remarks:

failure criteria: Peak Shear Stress

NATA

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090 -

Coffey & Partners Pty. Ltd.

COFFEY

job no: S9425/1

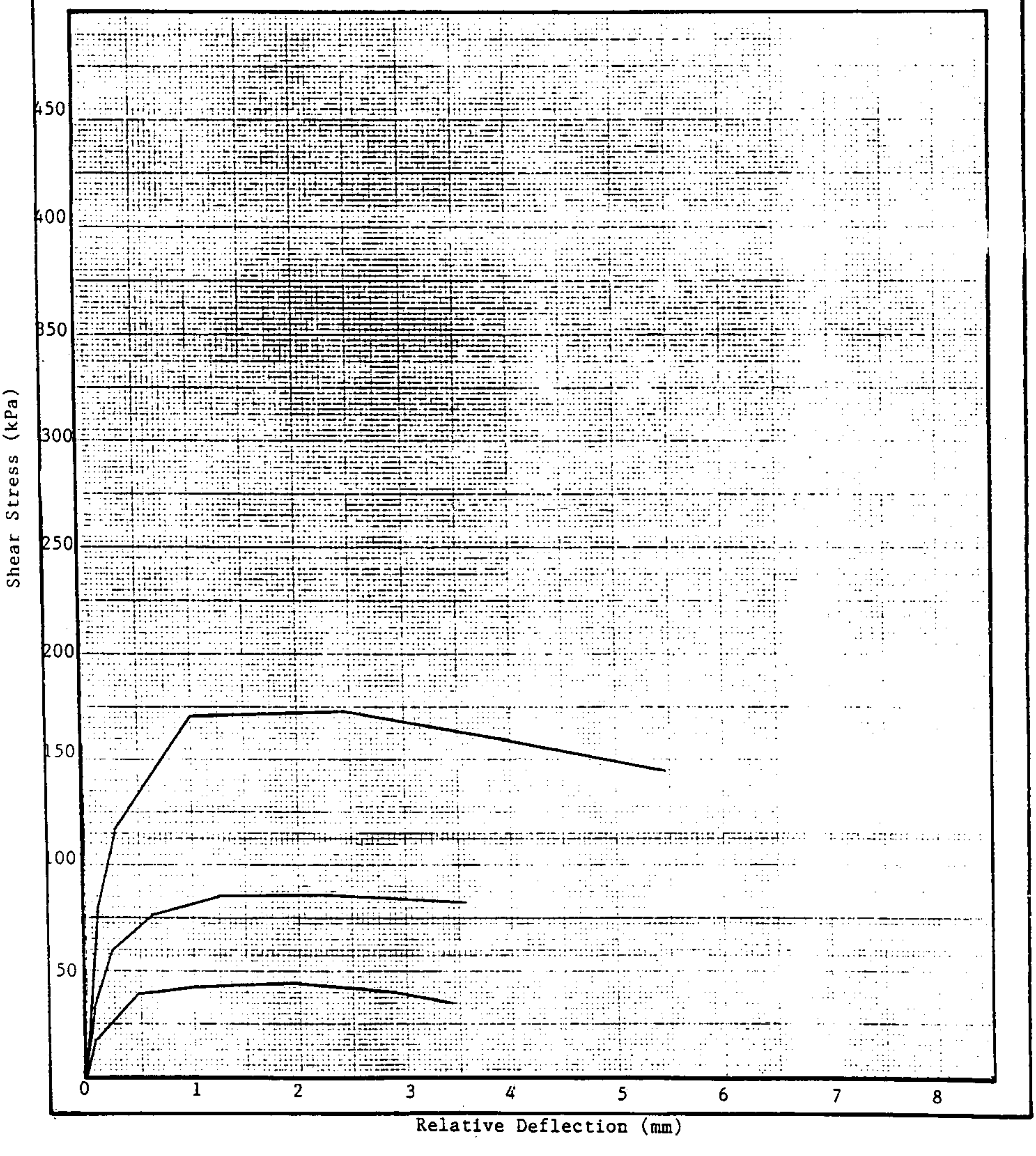
sheet 1 of 1

direct shear test

office: SYDNEY

client:	GEOMARINE PTY LTD	date:	4-1-90
principal:	WARRINGAH SHIRE COUNCIL	tested by:	GC
project:	BEACH DEVELOPMENT DESIGN CRITERIA	checked by:	JR
location:	NARRABEEN TO COLLAROY BEACH		

borehole: BH8 depth 1.00 - 1.45m stress range: - kPa



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particle size distribution

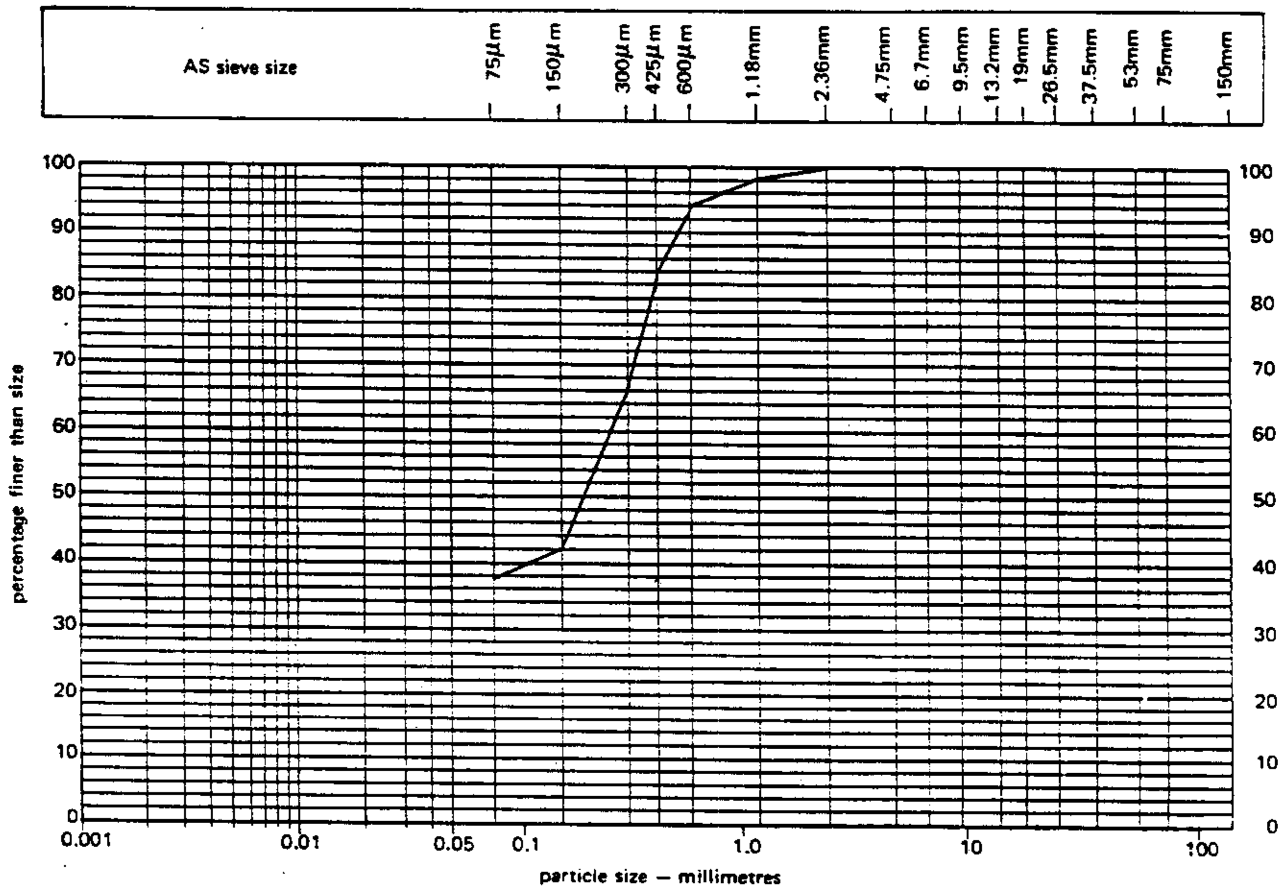
COFFEY

borehole no	BH1
sheet	1 of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

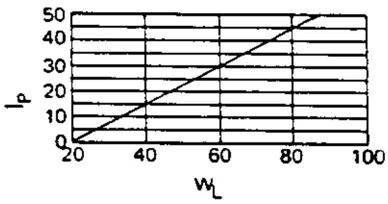
sample identification	BH1	depth	2.6-3.05m
test procedure	AS1289 C6.1 - 1977		



0.002	0.06			2.0			60			
clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

AS–1289

liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SC) Clayey SAND- fine to coarse, yellow brown, fines of low to medium plasticity.

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particle size distribution

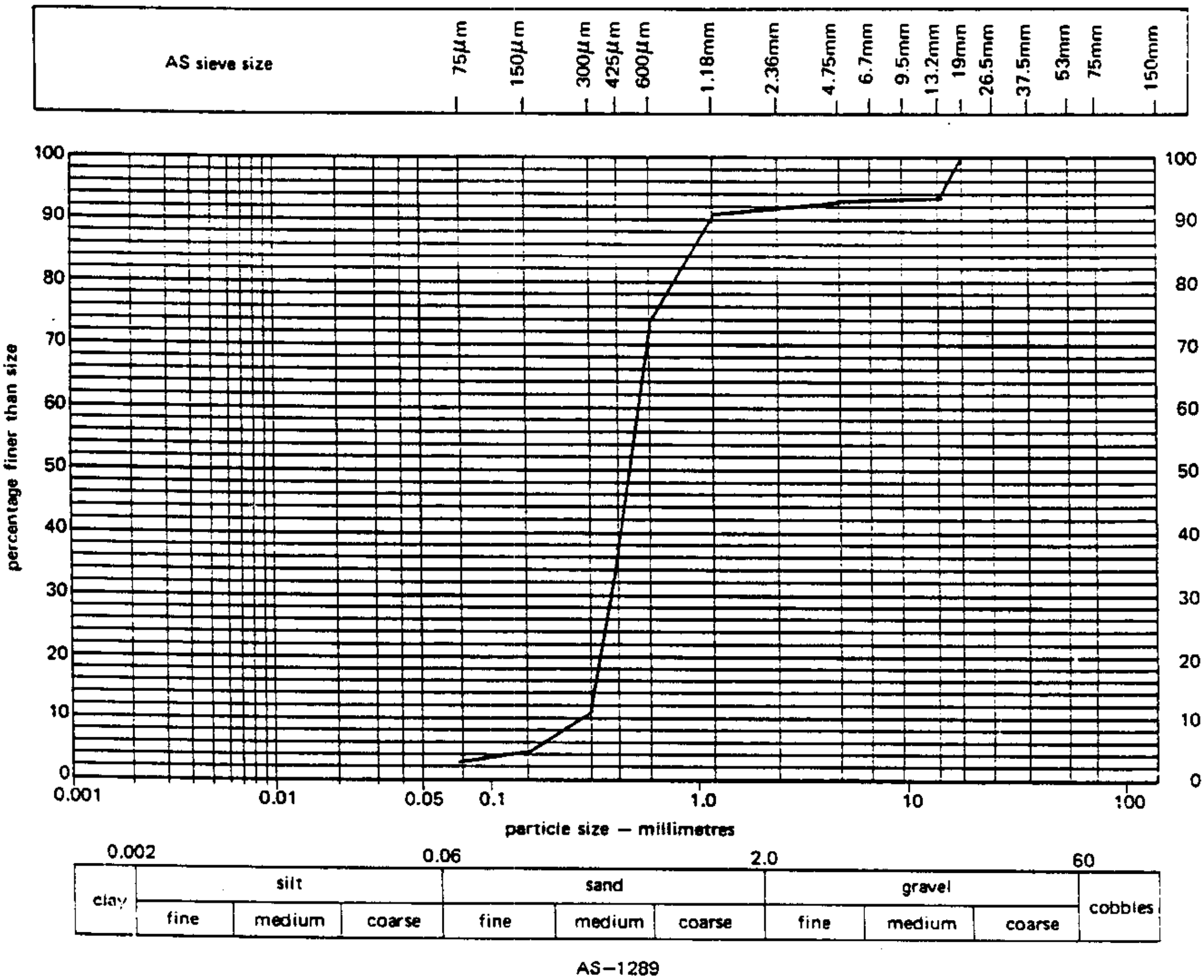
COFFEY

borehole no	BH2
sheet 1	of 1

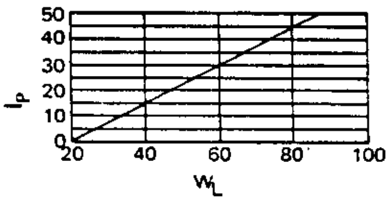
laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

sample identification	BH2	depth	2.0-2.45m
test procedure	AS1289 C6.1 - 1977		



liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SP) SAND- fine to coarse, yellow brown, some fine to medium gravel, trace of fines

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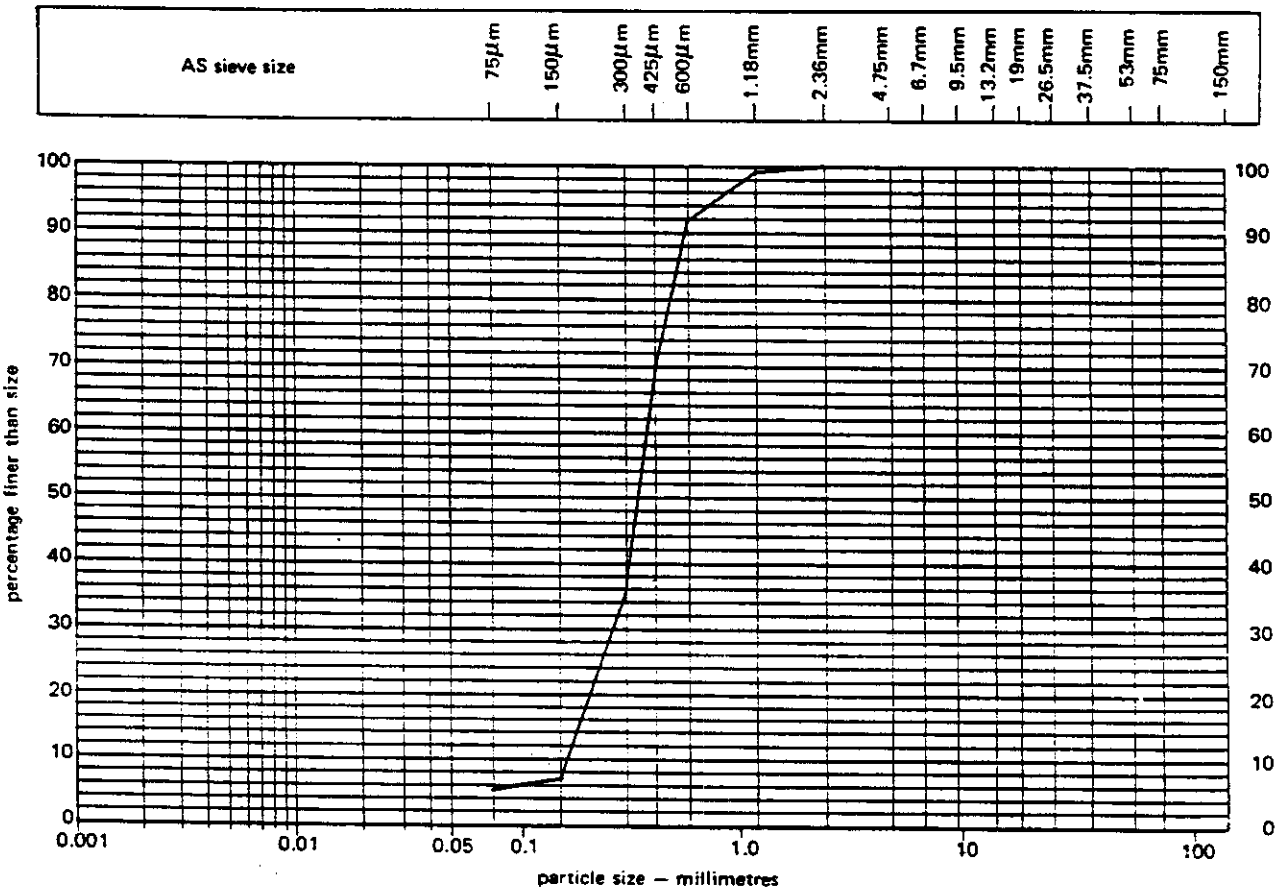
particle size distribution

COFFEY

borehole no	BH3
sheet 1	of 1

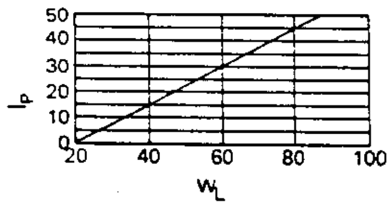
		laboratory	SYDNEY
client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21-12-90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC
sample identification	BH3	depth	2.6 - 3.05m
test procedure	AS1289 C6.1 - 1977		



0.002			0.06			2.0			60	
clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

AS–1289

liquid limit %	–
plastic limit %	–
plasticity index %	–
linear shrinkage %	–
particle density t/m³	–
natural moisture %	–



classification
(SM/SP) SAND, fine to coarse, yellow-brown, some fines

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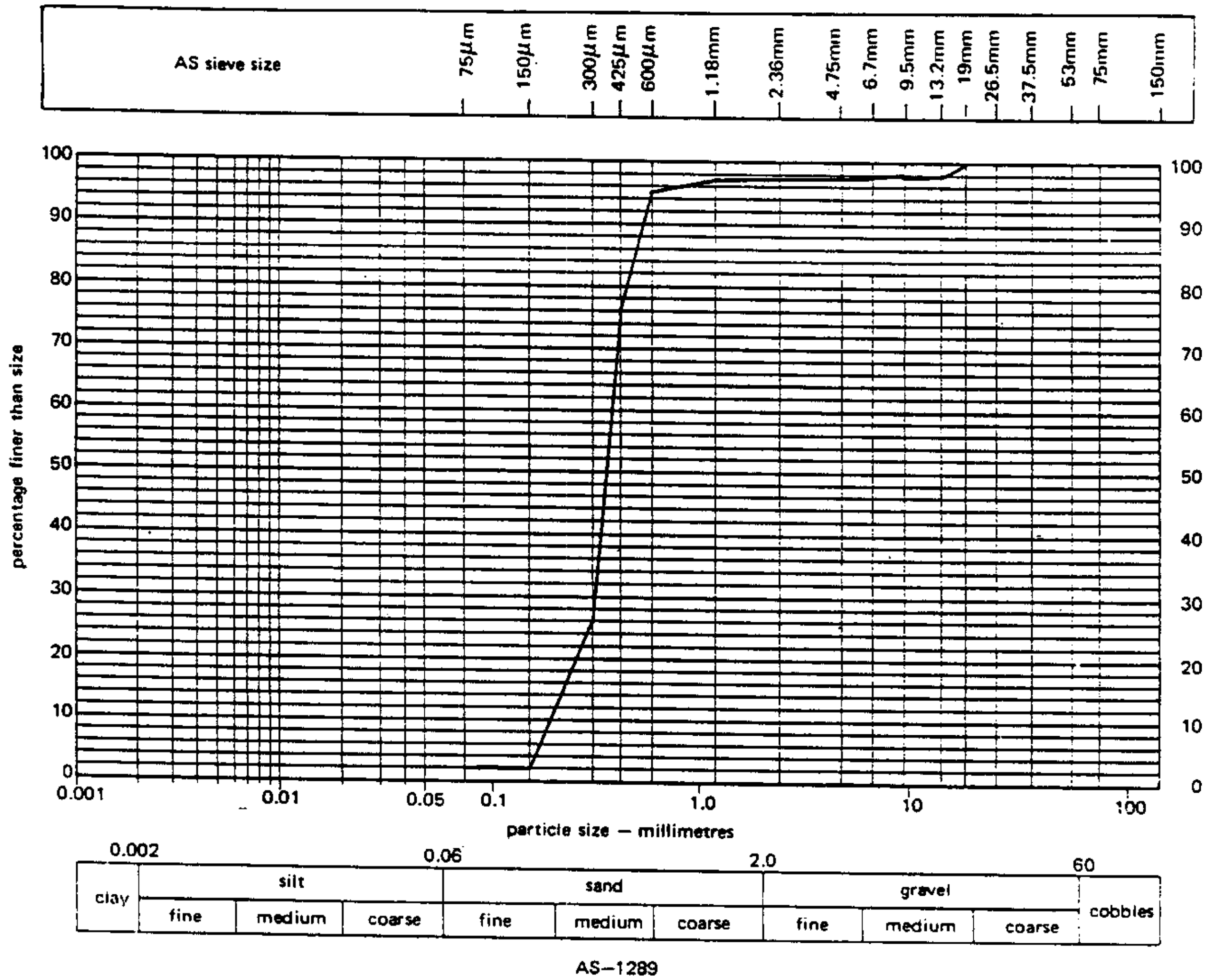
particle size distribution

COFFEY

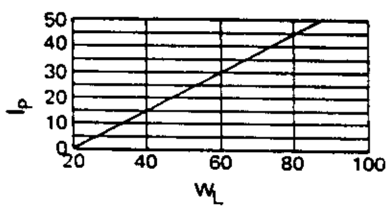
borehole no BH4
sheet 1 of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEAN TO COLLAROY BEACH	checked by	GC
sample identification	BH4	depth	1.10-1.55m
test procedure	AS1289 C6.1 - 1977		



liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SP) SAND - fine to coarse, yellow brown, trace of fines, trace of fine gravel.

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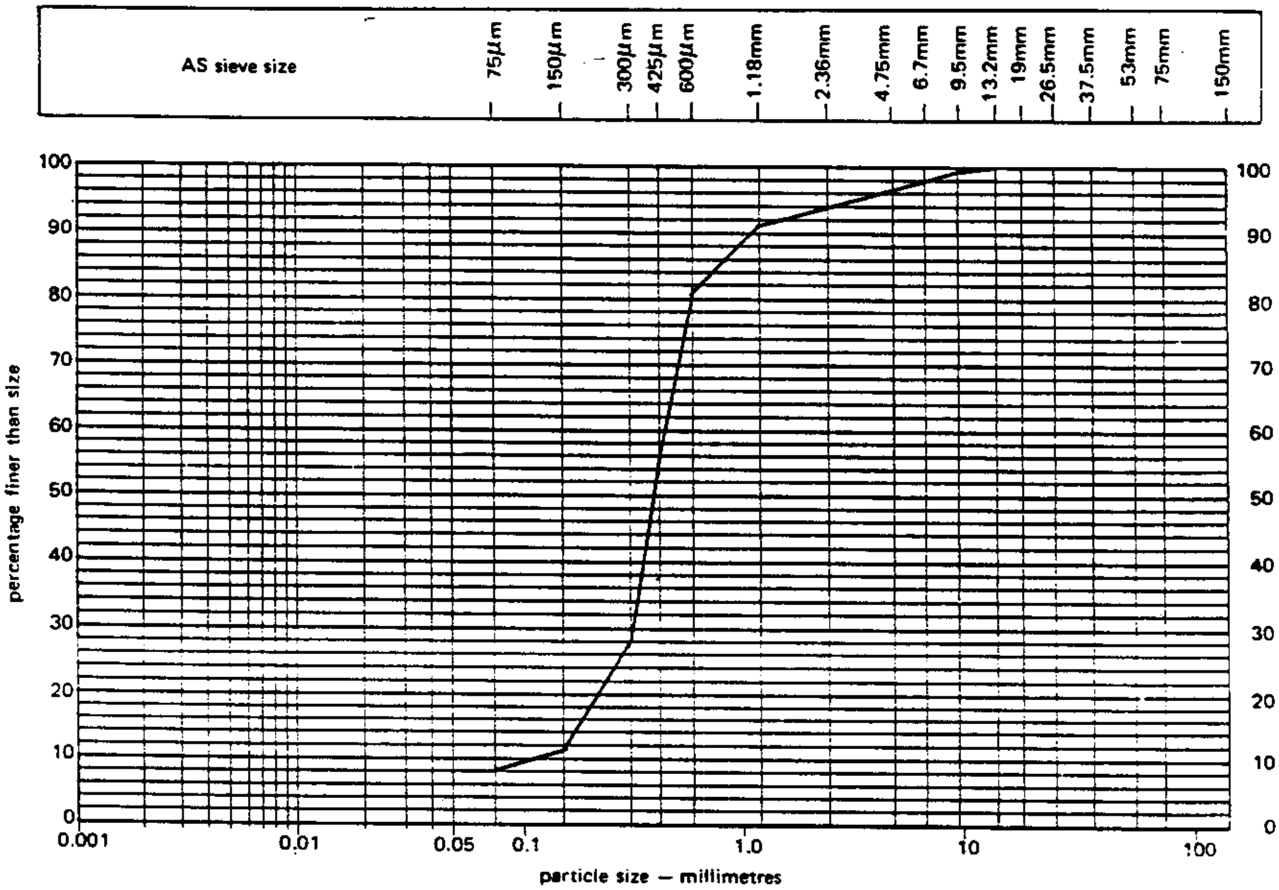
particle size distribution

COFFEY

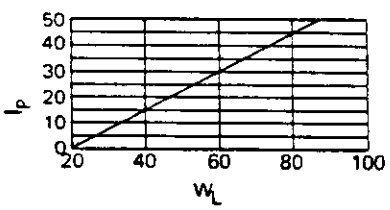
borehole no	BH4
sheet 1 of 1	

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC
sample identification	BH4	depth	4.1 - 4.5m
test procedure	AS1289 C6.1 - 1977		



liquid limit	%	
plastic limit	%	
plasticity index	%	
linear shrinkage	%	
particle density	t/m³	
natural moisture	%	



classification

(SC/SP) SAND -fine to coarse, yellow-brown, some fines, some fine to medium gravel.

NATA

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particle size distribution

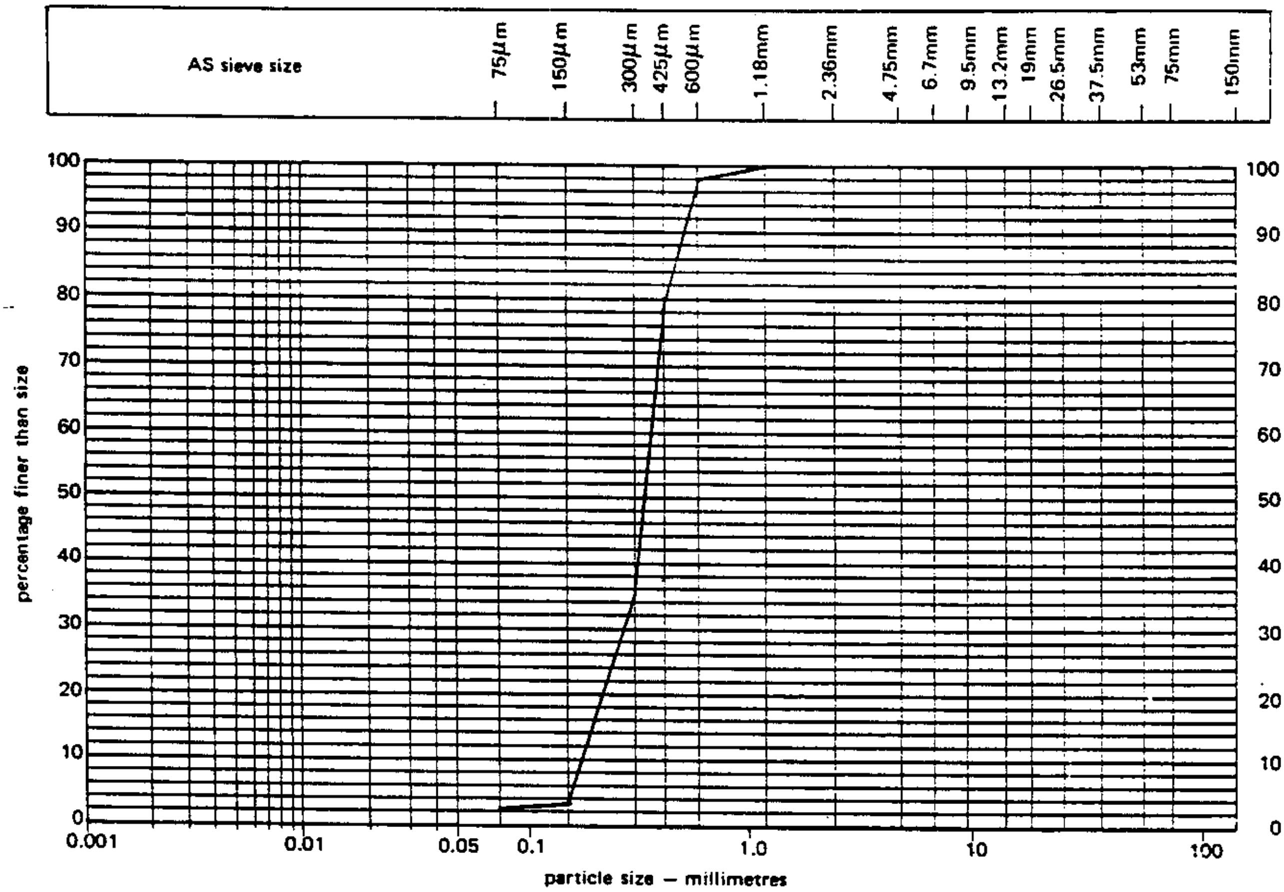
COFFEY

borehole no	BH5
sheet 1	of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

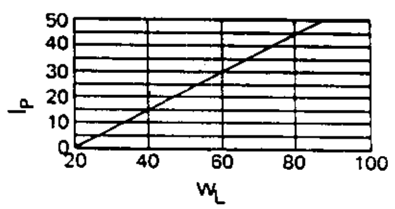
sample identification	BH5	depth	2.6-3.05m
test procedure	AS1289 C6.1 - 1977		



0.002			0.06			2.0			60	
clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

AS–1289

liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SP) SAND - fine to coarse, yellow brown, trace of fines

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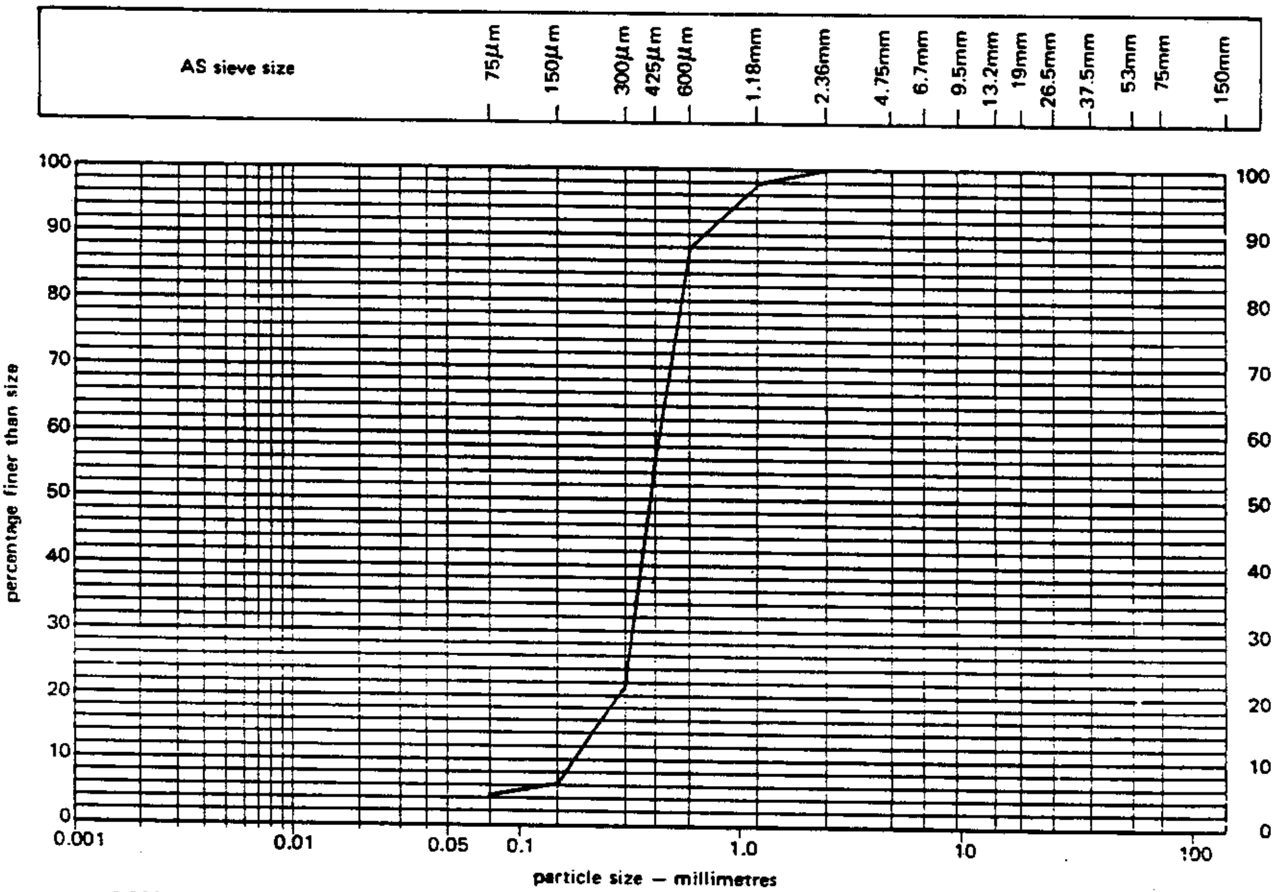
particle size distribution

borehole no	BH5
sheet 1	of 1

laboratory SYDNEY

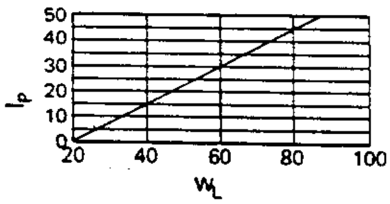
client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC
sample identification	BH5	depth	5.6 - 5.95m
test procedure	AS1289 C6.1 - 1977		



0.002			0.06			2.0			60
clay	silt			sand			gravel		cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse

AS–1289

liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SP) SAND-fine to coarse, yellow brown, trace of fines

8 / 91

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Incorporated in NSW ACN 003 692 019

particle size distribution

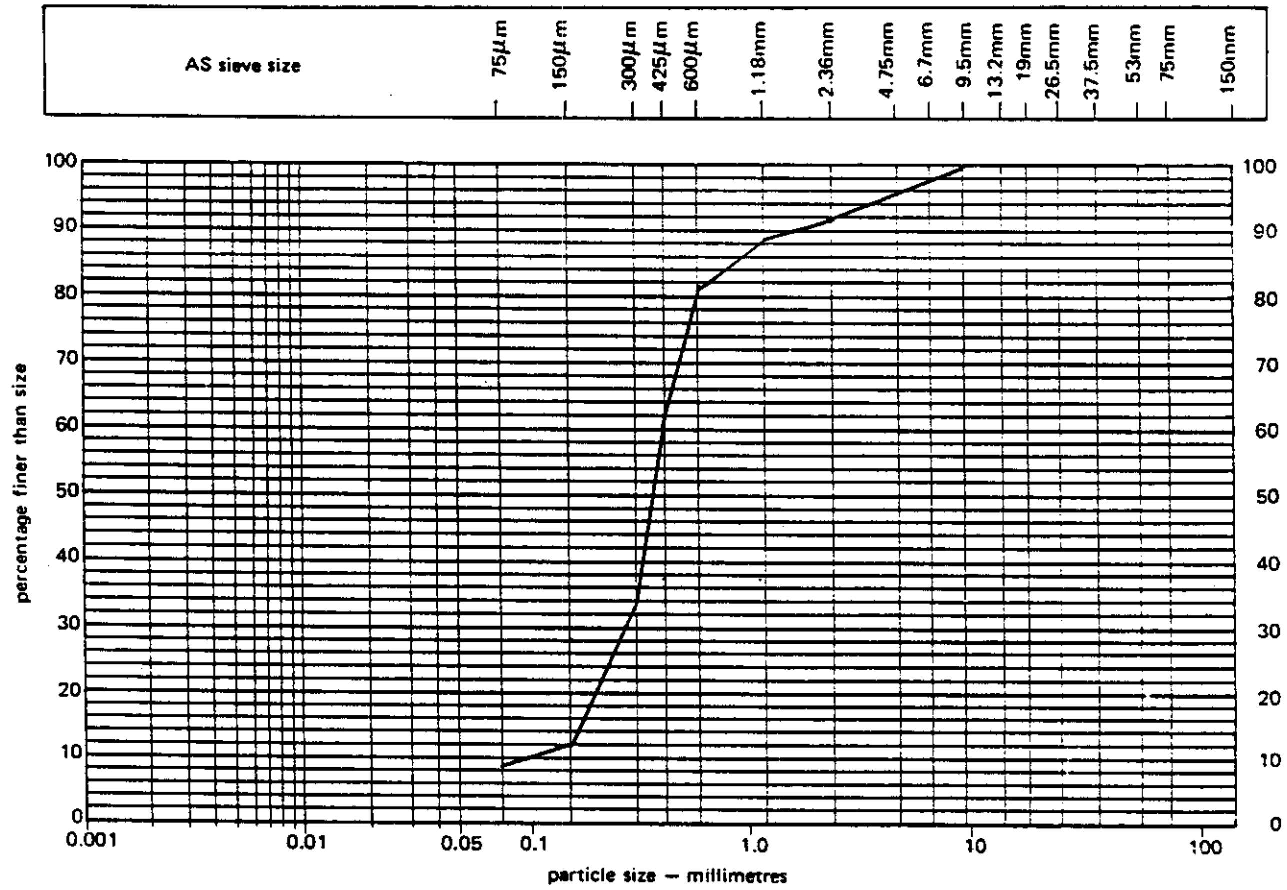
COFFEY

borehole no	BH5
sheet 1	of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

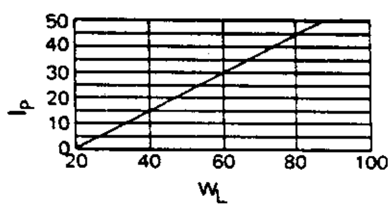
sample identification	BH5	depth	8.6 - 9.05m
test procedure	AS1289 C6.1 - 1977		



0.002			0.06			2.0			60
clay	silt			sand			gravel		cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse

AS–1289

liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SC/SP) SAND - Fine to coarse, yellow brwon, some fines, some fine to medium gravel. (gravel - cemented sands)

NATA

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Incorporated in NSW ACN 003 692 019

particle size distribution

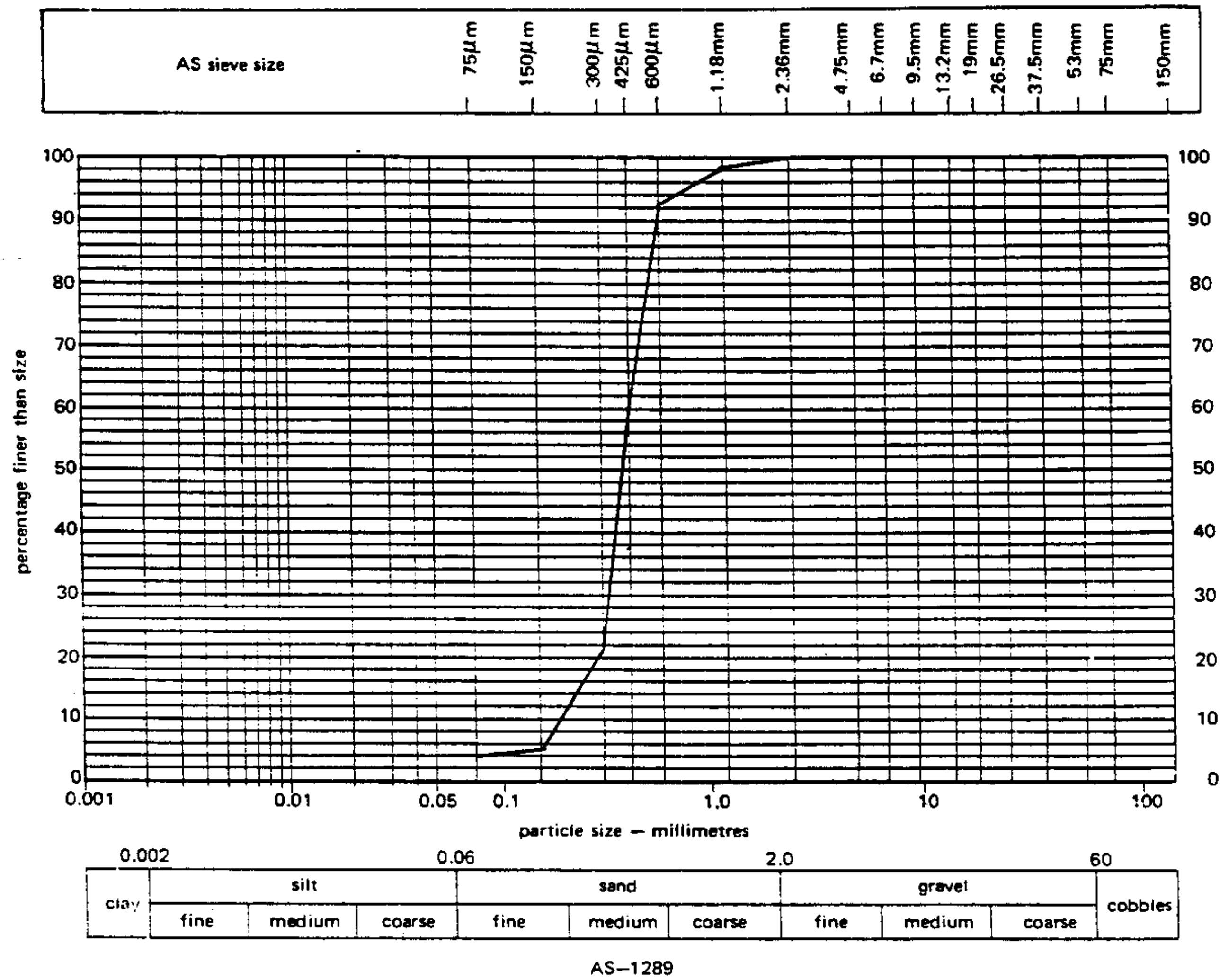
COFFEY

borehole no	BH6
sheet 1 of 1	

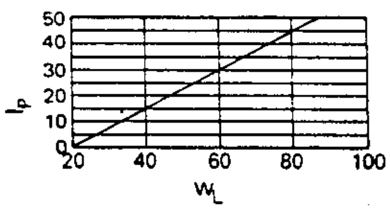
laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

sample identification	BH6	depth	1.1-1.55m
test procedure	AS1289 C6.1 - 1977		



liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SP) SAND- fine to coarse, yellow brwon, trace of fines

NATA

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Incorporated in NSW ACN 003 692 019

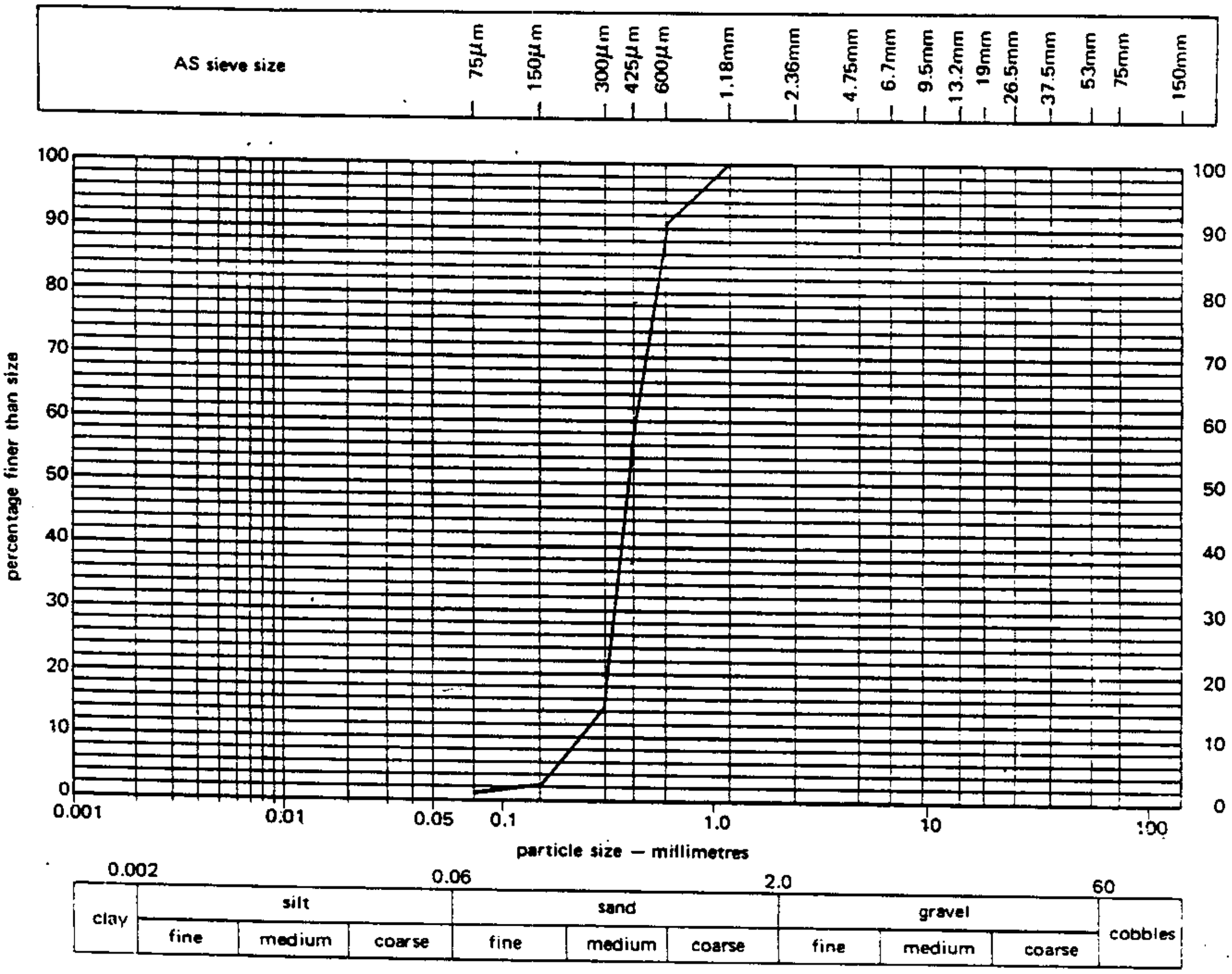
particle size distribution

COFFEY

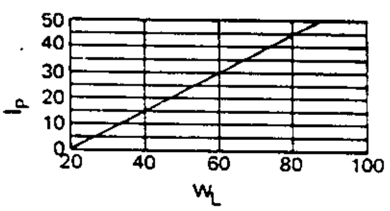
borehole no	BH6
sheet 1	of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC &KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC
sample identification	BH6	depth	4.1-4.55m
test procedure	AS1289 C6.1 - 1977		



liquid limit	%		
plastic limit	%		
plasticity index	%		
linear shrinkage	%		
particle density	t/m^3		
natural moisture	%		



classification

(SP) SAND - fine to coarse, yellow brown, trace of fines

NATA

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Incorporated in NSW ACN 003 692 019

particle size distribution

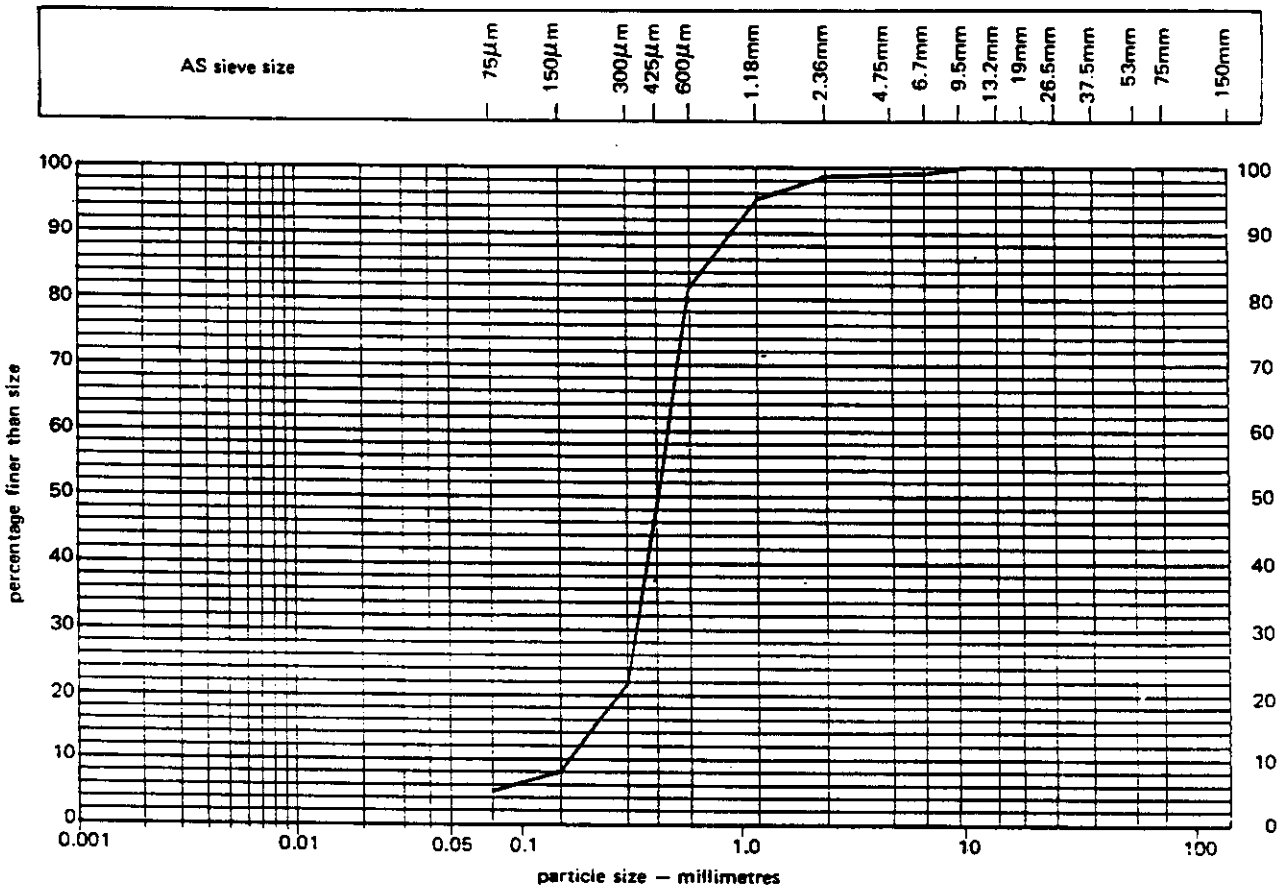
COFFEY

borehole no BH6
sheet 1 of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

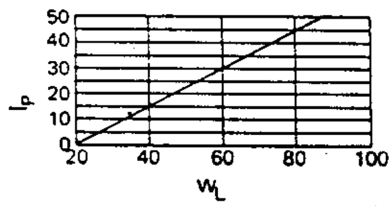
sample identification	BH6	depth	7.1 - 7.55m
test procedure	AS1289 C6.1 - 1977		



0.002		0.06			2.0			60	
clay	silt			sand			gravel		cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse

AS–1289

liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SC/SP)SAND - fine to coarse, yellow brown, trace of fine gravel, some fines.

NATA

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Coffey Partners International Pty Ltd
Incorporated in NSW ACN 003 692 019

particle size distribution

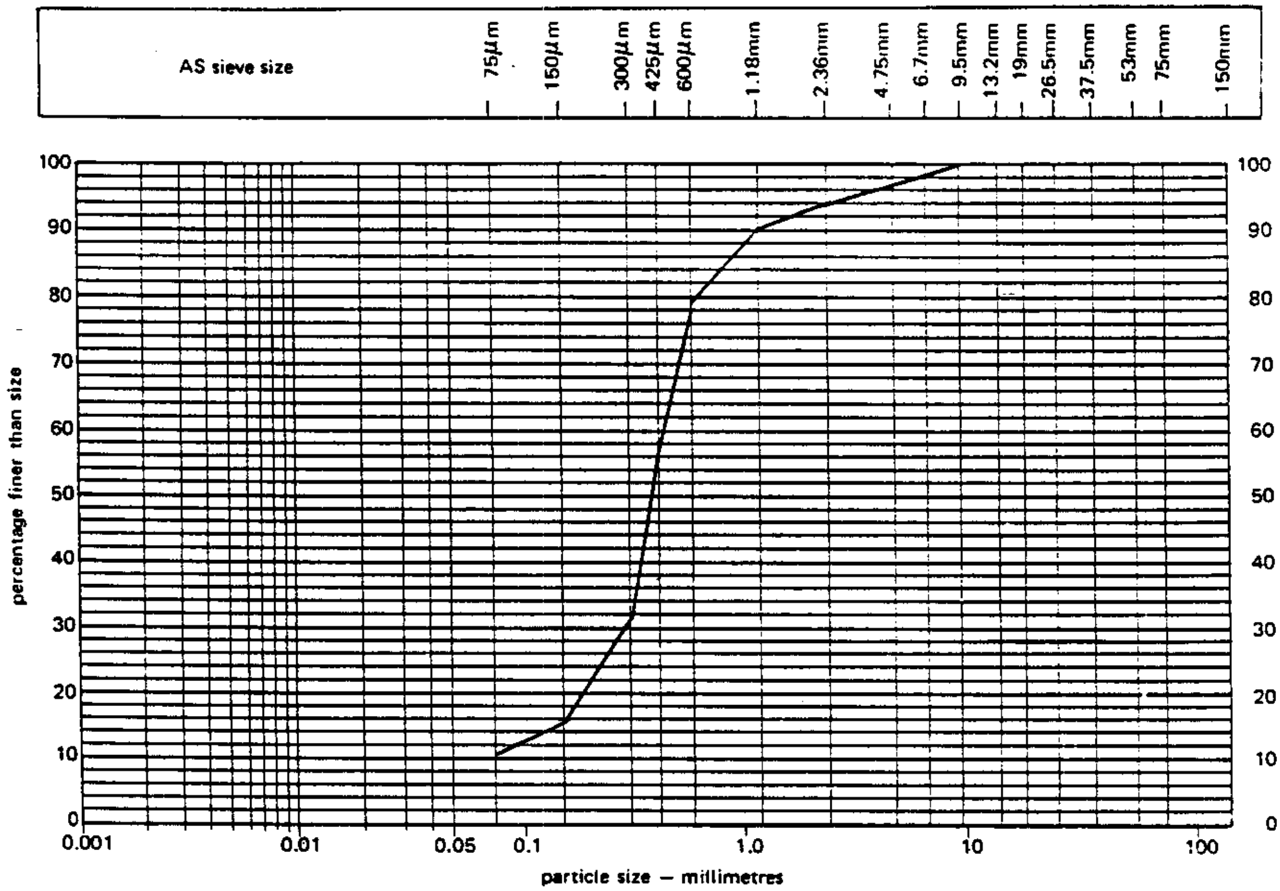
COFFEY

borehole no	BH6
sheet 1	of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

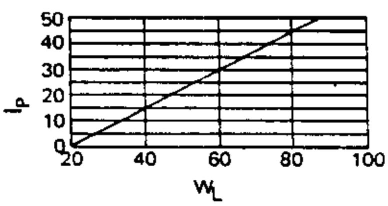
sample identification	BH6	depth	8.6-8.8m
test procedure	AS1289 C6.1 - 1977		



0.002			0.06			2.0			60	
clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

AS—1289

liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	—



classification

(SC/SP) SAND - fine to coarse, yellow brown, some fine to medium gravel, some fines (Gravel= cemented sands)

NATA

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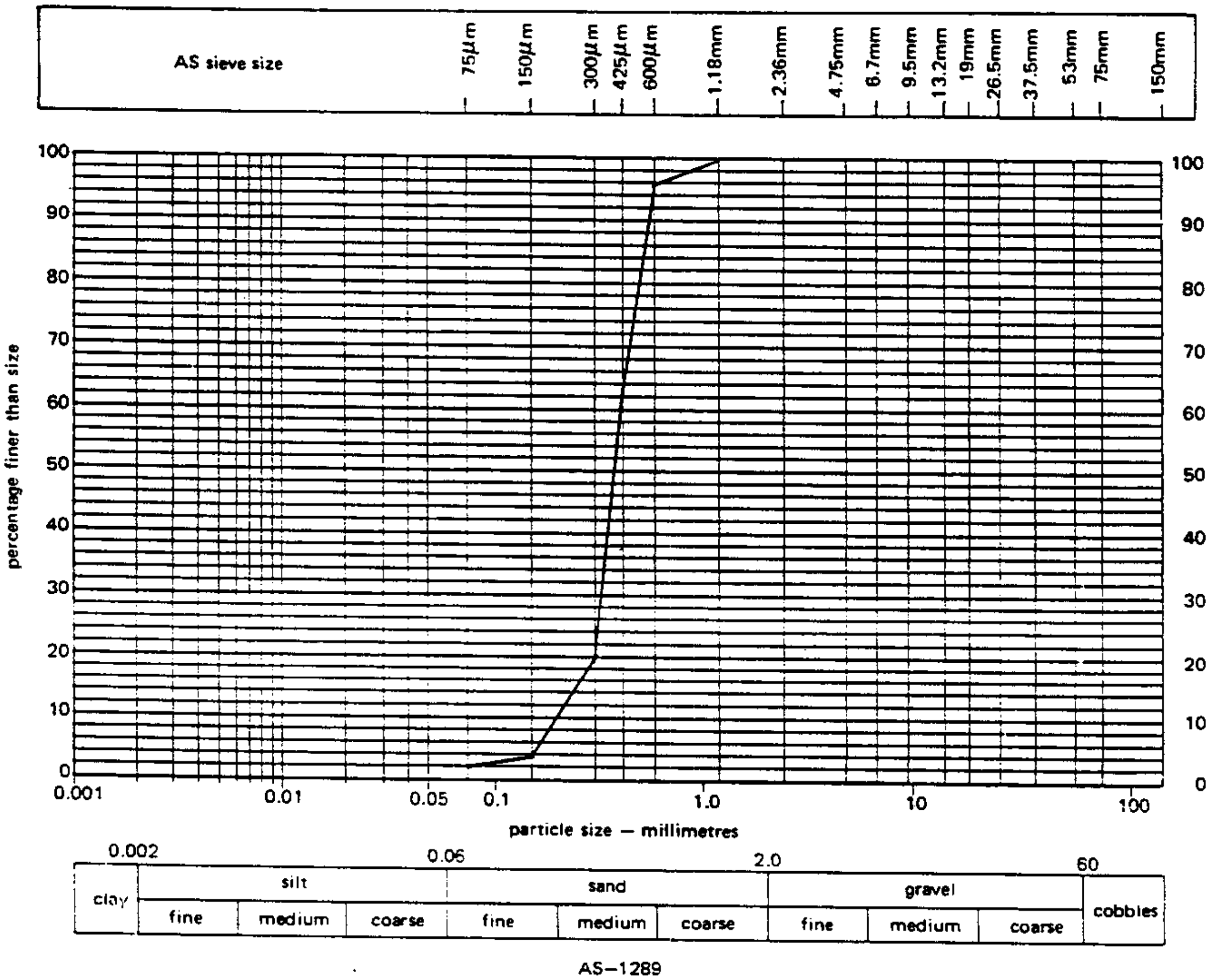
particle size distribution

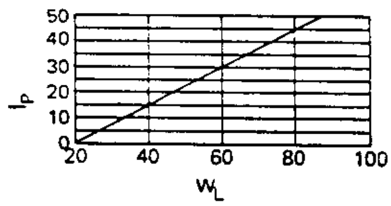
COFFEY

borehole no	BH7
sheet	1 of 1

		laboratory	SYDNEY
client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21-12-90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC
sample identification	BH7	depth	2.6 - 3.05m
test procedure	AS1289 C6.1 - 1977		



liquid limit %	-
plastic limit %	-
plasticity index %	-
linear shrinkage %	-
particle density t/m³	-
natural moisture %	-



classification

(SP) SAND, fine to coarse, yellow-brown, trace of fines.

NATA

This laboratory is registered by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with the terms of registration. This document shall not be reproduced except in full without the prior approval of the laboratory.

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Authorised Signature James Russell

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Incorporated in NSW ACN 003 692 019

particle size distribution

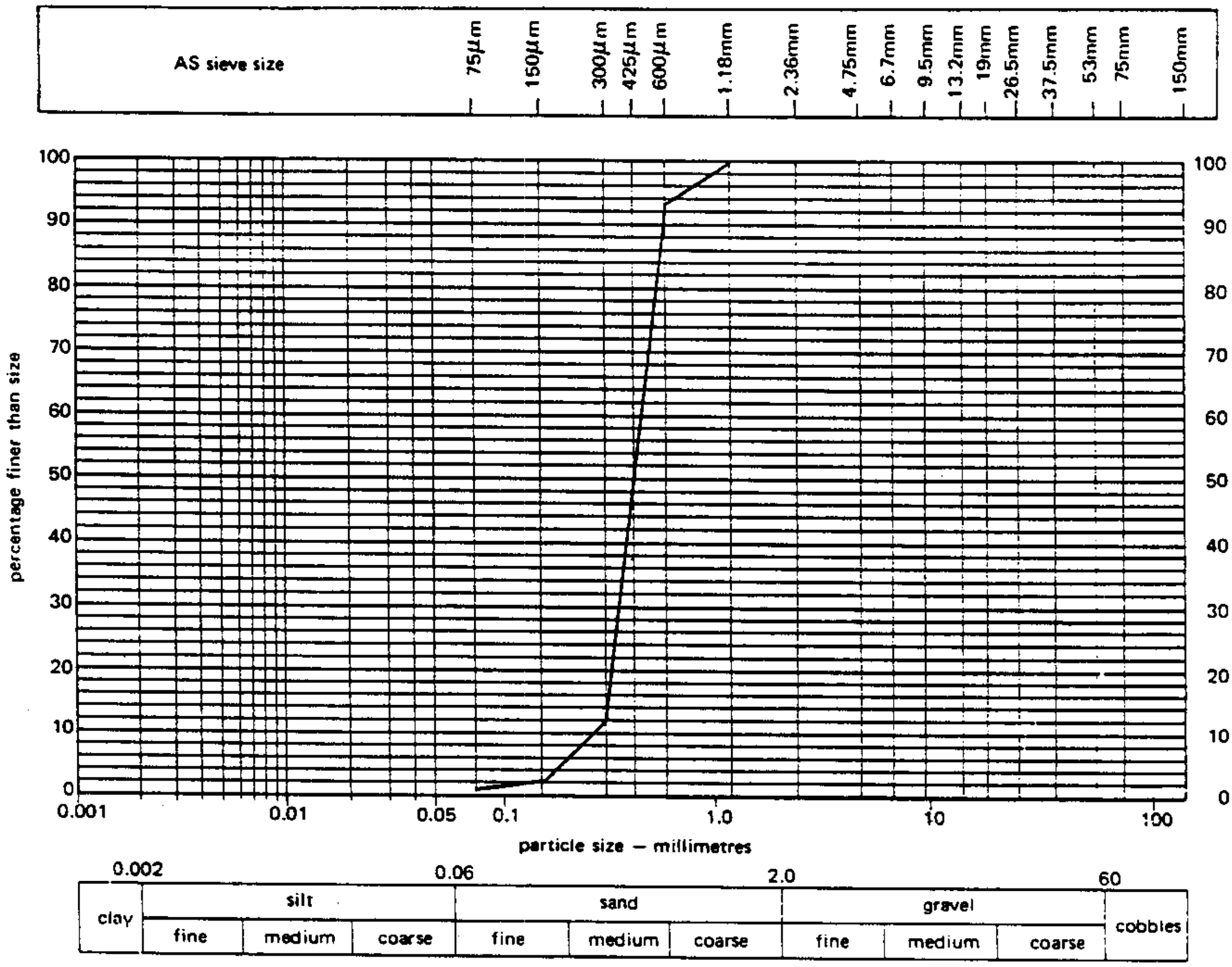
COFFEY

borehole no	BH7
sheet 1	of 1

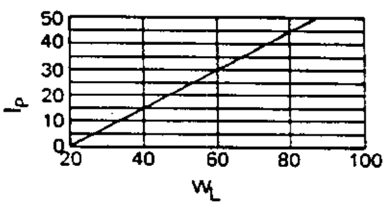
laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

sample identification	BH7	depth	7.1-7.55m
test procedure	AS1289 C6.1 - 1977		



liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SP) SAND - fine to coarse, yellow brown, trace of fines

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Authorised Signature James Russell

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Incorporated in NSW ACN 003 692 019

particle size distribution

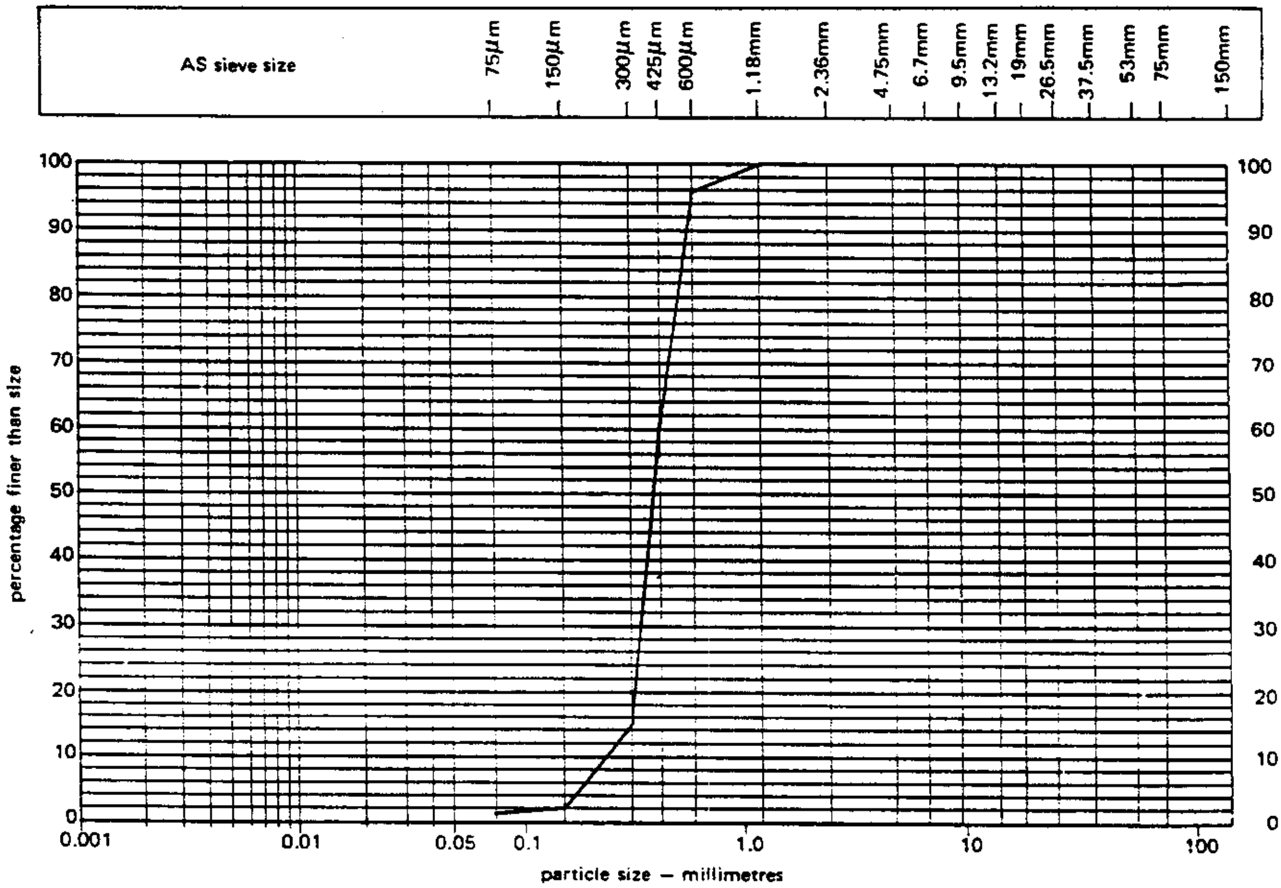
COFFEY

borehole no	BH 8
sheet	1 of 1

laboratory SYDNEY

client	GEOMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21-12-90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC & KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

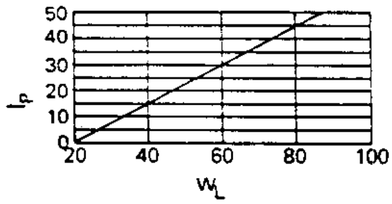
sample identification	BH8	depth	2.6 - 3.05m
test procedure	AS1289 C6.1 - 1977		



0.002				0.06			2.0			60
clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	

AS—1289

liquid limit %	–
plastic limit %	–
plasticity index %	–
linear shrinkage %	–
particle density t/m³	–
natural moisture %	–



classification

(SP) SAND, fine to coarse, yellow-brown, trace of fines.

8 / 1 / 91

Authorised Signature

Coffey Partners International Pty Ltd
Incorporated in NSW ACN 003 692 019

particle size distribution

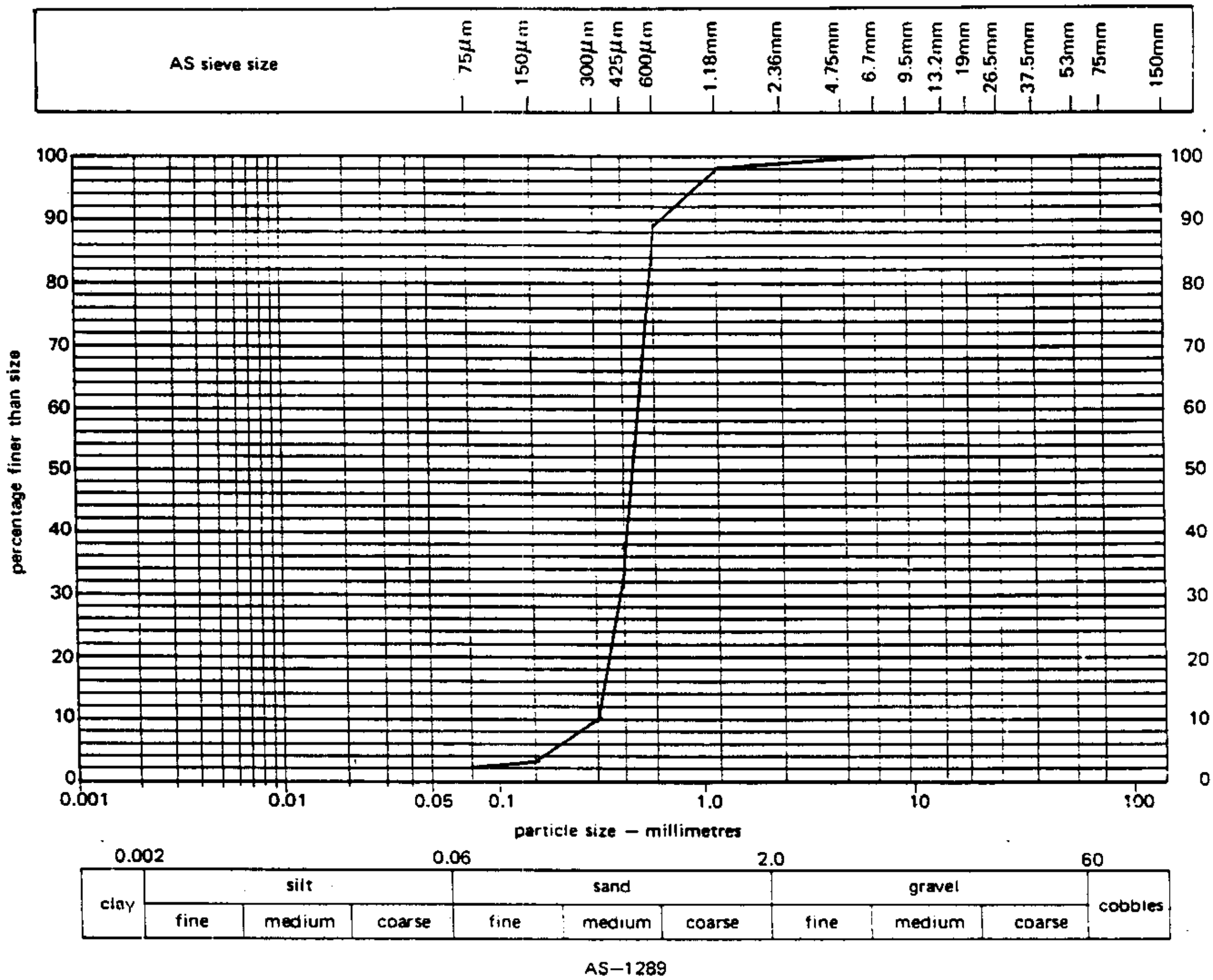
COFFEY

borehole no	BH8
sheet 1	of 1

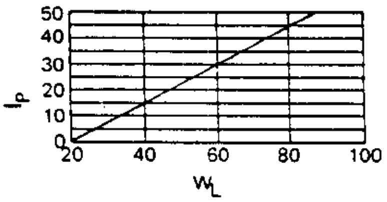
laboratory SYDNEY

client	GOEMARINE PTY LTD	job no	S9425/1
principal	WARRINGAH SHIRE COUNCIL	date	21/12/90
project	BEACH DEVELOPMENT DESIGN CRITERIA	tested by	GC &KK
location	NARRABEEN TO COLLAROY BEACH	checked by	GC

sample identification	BH8	depth	5.6-6.05m
test procedure	AS1289 C6.1 - 1977		



liquid limit %	
plastic limit %	
plasticity index %	
linear shrinkage %	
particle density t/m³	
natural moisture %	



classification

(SP) SAND - fine to coarse, yellow brown, trace of fine gravel, trace of fines

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Authorised Signature James Russell

Appendix D

References

BATTJES, J.A. (1974). *Computation of set-up, long shore currents, run-up and overtopping due to wind generated waves.* Report 74-2, Dept. of Civil Eng., Delft Uni. of Technology.

BURLAND, J.B., BURBRIDGE, M.C. (1985). *Settlement of foundations in sand and gravel.* Proc. Instn. Civ. Engrs., Vol. 78, No. 1, pp 1325-1381.

C.E.R.C. (1984). *Shore Protection Manual.* Fourth Edition. Coastal Engineering Research Centre. Waterways Experiment Station. US Army Corps of Engineers. US Govt. Printing Office, Washington, D.C. 20402. Two Volumes.

DAVIS, G.A., NIELSEN,P. (1988). *Field measurements of wave setup.* 21st International Conference on Coastal Engineering.

KASHEF, A-A.I. (1987). *Groundwater Engineering.* McGraw-Hill Book Co. Singapore. ISBN 0-07-100533-1.

GEOLOGICAL SURVEY OF N.S.W. (1982). *Quaternary sediment in coastal embayments Sydney metropolitan region.* Authors: P.S.ROY, I.L.WALSH. Dept. of Mineral Resources. Rpt. No. 1982/343. August, 1982.

GEOLOGICAL SURVEY OF N.S.W. (1985). *The Quaternary geology of the coast and inner shelf at Wooli, northern N.S.W.* Authors: D.L. SKENE, P.S.ROY. Dept. of Mineral Resources. Rpt. No. 1986/219. December, 1985.

GEOMARINE P/L (1988a). *Narrabeen-Collaroy-Fishermans Beach Nearshore Wave Parameters.* Report prepared for Warringah Shire Council. Rept No. 87020.01.004. March, 1988.

GEOMARINE P/L (1988b). *Coastal Processes Broken Bay N.S.W. relevant to an optic fibre cable crossing Broken Bay.* Report prepared for Unisearch Ltd. Rept No. 87021.01.001. September, 1988.

GODA, Y (1975). *Irregular wave deformation in the surf zone.* Coastal Eng. in Japan. 1975.

GOSFORD CITY COUNCIL (1989a). *Avoca Manual for Coastal Development.* Prepared by GEOMARINE P/L for Gosford City Council. April, 1989.

GOSFORD CITY COUNCIL (1989b). *Copacabana-Macmasters Beach Manual for Coastal Development.* Prepared by GEOMARINE P/L for Gosford City Council. July 1989.

GOSFORD CITY COUNCIL (1990a) *Forresters Beach Coastal Development Manual.* Prepared by GEOMARINE P/L for Gosford City Council. February, 1990.

GOSFORD CITY COUNCIL (1990b) *Pearl Beach Coastal Development Manual.* Prepared by GEOMARINE P/L for Gosford City Council. October, 1990 (unpublished at this date).

GOSFORD CITY COUNCIL (1990c) *Umina and Ocean Beaches Coastal Development Manual.* Prepared by GEOMARINE P/L for Gosford City Council. November, 1990 (unpublished at this date).

KISHIDA, H., NAKAI, S. (1977). *Large deflection of single pile under horizontal load.* Spec. Session No. 10, 9th Int. Conf. Soil Mechs. and Foundn. Eng. Divns., Vol 82, No. SM1, pp179.

LAMBE, T.W. & WHITMAN, R.V. (1969). *Soil Mechanics.* John Wiley & Sons. New York. ISBN 471-51193-5.

LAWSON, N.V. & TRELOAR, P.D. (1985). *Wave design criteria Wamberal and Avoca Beaches.* Rpt. prepared for P.W.D., N.S.W. on behalf of Gosford City Council. Rpt. No. 1067 Dec., 1984 (in P.W.D., 1985b).

M^c^GRATH, B.L. (1968). *Erosion of Gold Coast Beaches, 1967.* Jnl. Inst. Eng. Aust., July-August, 1968.

M^c^MONAGLE, C.J., FIDGE, B.L. (1981). *A study of extreme values of water level and wave height at Coffs Harbour.* Fifth Aust. Conf. on Coastal and Ocean Engineering. IEAust., Perth, W.A., 1981.

MEYERHOF, G.G. (1956). *Penetration tests and bearing capacity of cohesionless soils.* Proc. Amer. Soc. of Civ. Engrs. Jnl. of Soil Mechs. and Foundn. Eng. Divns., Vol. 82, No. SM1, pp 179.

NEW SOUTH WALES GOVERNMENT (1986). *Beach Dunes - their use and management.* Public Works Department, Soil Conservation Service. D. West Government Printer N.S.W. - 1986.

NIELSEN, P. (1988). *Wave setup: a field study.* Jnl of Geophysical Research. Vol. 93.

POULOS, H.G. (1989). *Pile behaviour - theory and application.* 29th Rankine Lecture, Geotechnique, Vol. 39, No. 3, pp365-415.

PUBLIC WORKS DEPARTMENT, N.S.W. (1977). *Dee Why Lagoon investigation of dredging proposal.* Authors: A.D. GORDON, R. COOK. Coastal Engineering Branch. Report No. PWD 77029. December, 1977.

PUBLIC WORKS DEPARTMENT (1984). *Gosford Council ATS Egger (Erosion at Lot D.P. 8854 Wamberal Beach in June, 1978).* author A.F. Nielsen. Coastal Engineering Branch Working Paper Contract No. 84145. March, 1985.

PUBLIC WORKS DEPARTMENT (1985a). *Boomerang Beach and Blueys Beach Coastal Engineering Advice.* author A.F. Nielsen. Civil Engineering Division. Rpt. No. PWD 85010. March, 1985.

PUBLIC WORKS DEPARTMENT (1985b). *Wamberal Beach and Avoca Beach Coastal Engineering Advice.* author A.F. Nielsen. Civil Engineering Division. Rpt. No. PWD 85040. May, 1985.

PUBLIC WORKS DEPARTMENT, N.S.W. (1985c). *Elevated Ocean Levels Storms affecting the N.S.W. coast 1880-1980.* prepared by Blain Bremner & Williams P/L in conjunction with Weatherex Meteorological Services P/L. PWD Coastal Branch Report No. 85041. December, 1985.

PUBLIC WORKS DEPARTMENT, N.S.W. (1986a). *Elevated Ocean Levels Coffs Harbour.* prepared by Blain Bremner & Williams P/L in conjunction with Weatherex Meteorological Services P/L. PWD Coastal Branch Report No. 86005. 1986.

PUBLIC WORKS DEPARTMENT, N.S.W. (1986b). *Elevated Ocean Levels Storms affecting the N.S.W. coast 1980-1985.* prepared by Lawson and Treloar P/L in conjunction with Weatherex Meteorological Services P/L. PWD Coastal Branch Report No. 86026. August, 1986.

PUBLIC WORKS DEPARTMENT, N.S.W. (1987). *Collaroy/Narrabeen Beaches coastal process hazard definition study.* authors: J. Hoffman & K. Hibbert. Coastal Branch. P.W.D. Rpt. No. 87040. 2 vols. ISBN 724027971. December, 1987.

PUBLIC WORKS DEPARTMENT, N.S.W. (1988). *Wave setup and the water table in a sandy beach.* author: P. Nielsen. Coasts and Rivers Branch. TM 88/1.

PUBLIC WORKS DEPARTMENT, N.S.W. (1990). *Coastal Engineering Advice to the Department of Planning in relation to Lots 11-14, Section 3, D.P. 1623, Childe Street, Byron Bay.* author: M. Moratti. Public Works Department. February, 1990.

SCHMERTMANN, J.H. (1970). *Static cone to compute settlement over sand.* Jnl. Soil Mechs. Foundn. Divn., Amer. Soc. of Civ. Engrs., Vol. 96, No. SM3, pp 1011-1043.

TERZAGHI, K & PECK, R.B. (1967). *Soil Mechanics in Engineering Practice.* second edition. John Wiley & Sons, New York. ISBN 0-471-85281-3.

TOMLINSON, M.J. (1986). *Foundation Design and Construction.* 5th Ed., Longman, England.

U.S. NATIONAL RESEARCH COUNCIL (1987). *Responding to Changes in Sea Level.* National Academy Press, Washington, D.C. 1987.

WARRINGAH SHIRE COUNCIL (1988). *Narrabeen-Collaroy-Fishermans Beach Coastal Management Strategy Phase One: Hazard Definition.* Report of the Coastal Management Steering Committee Prepared by Nielsen Lord Associates, GEOMARINE P/L Report No: 87020.01.003, April, 1988.

WARRINGAH SHIRE COUNCIL (1989). *Narrabeen-Collaroy-Fishermans Beach Coastal Management Strategy Management Options.* Report of the Coastal Management Steering Committee Prepared by Nielsen Lord Associates, GEOMARINE P/L and Travers Morgan P/L. Report No: 88013.01.001, February, 1989.

Appendix E

Technical Memorandum 88/02

GEOMARINE Pty Ltd (inc NSW)

· trading as Nielsen Lord Associates & Wavelength Press
426 Wilson Street Darlington NSW PO Box 67 Chippendale 2008 ph: (02) 699-1002

Technical Memorandum 88/02
Greenhouse Sea Level Rise

The conscensus of scientific opinion is that a global warming as a result of the *Greenhouse Effect* is occurring and this will impact on both sea level and the distribution of global weather patterns early next century. Further, it is argued that these changes should as far as possible be taken into account in coastal planning and development.

There are no clear guidelines put forward by The Institution of Engineers Australia* or by any of the New South Wales Government instrumentalities providing direction as to the manner and extent to which the *Greenhouse Effect* should be considered. Within this framework **GEOMARINE Pty Ltd** has adopted the following policy:

(1) In respect of coastal processes and coastal flooding, the values published for predicted sea level rise by the **U.S. National Research Council**** have been adopted. These present three scenarios of a high, medium and low rate of sea level rise as detailed by the curves in **Figure One** and the calculated values at **Table 1**.

(2) The appropriate sea level rise scenario to be adopted will be linked to the type of development according to the relationship presented in **Table 2**. The sea level rise to be considered will apply to the calculation of structure crest levels, design water levels, water levels for the computation of coastal flooding and in setting levels for floors of habitable structures, drainage and services.

(3) The additional storm erosion, foreshore recession and re-alignment of unconsolidated foreshores resulting from both a *Greenhouse* sea level rise and any associated increase in storminess will be accounted for as far as practicable in advice on coastal developments.

(4) The values adopted for a *Greenhouse* sea level rise will be reviewed as and when further information becomes available.

(5) The design values adopted for storm intensity (wind velocity, rainfall intensity, total rainfall) will be revised in accordance with sound engineering practice. Variations to the current design codes, standards and practices as endorsed by the Institution of Engineers Australia will be adopted.

*This GEOMARINE Technical Memorandum was issued first in February, 1988. In August, 1989 the Institution of Engineers Australia issued a Policy on The Greenhouse Effect (1/5/15). That policy has not resulted in revision of this Technical Memorandum.

****Responding to changes in sea level*. National Research Council (U.S.). National Academy Press. Washington, D.C. 1987.

(Modified from U.S. National Research Council, 1987)

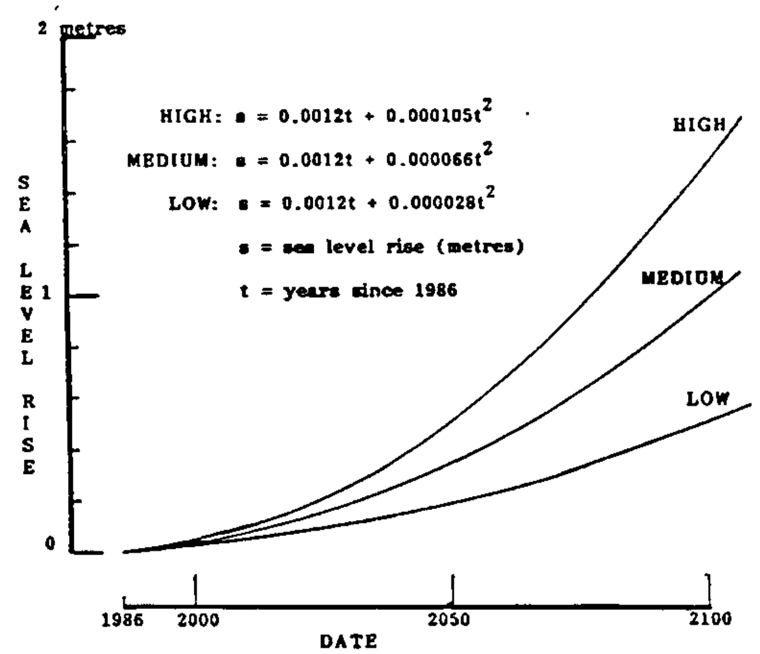

Table 1 - Greenhouse Sea Level Rise Scenarios

SCENARIO	25 YEARS	50 YEARS	100 YEARS
HIGH	0.10m	0.32m	1.17m
MEDIUM	0.07m	0.23m	0.78m
LOW	0.05m	0.13m	0.40m

(Modified from U.S. National Research Council, 1987)

Table 2 - Relating Development and Sea Level Rise

DEVELOPMENT	SEA LEVEL RISE	PLANNING PERIOD
Open space	Low	25 years
Residential	Medium	50 years
Intensive development	High	100years

Greenhouse Sea Level Rise

Technical Memorandum No. 2

Sea Level Rise Scenarios

Figure One

Nielsen Lord Associates

GEOMARINE P/L