JABATAN MINERAL DAN GEOSAINS MALAYSIA
MINERALS AND GEOSCIENCE DEPARTMENT MALAYSIA

GARIS PANDUAN

PEMETAAN GEOLOGI KEJURUTERAAN KAWASAN GAMBUT DAN TANIH LEMBUT

ENGINEERING GEOLOGICAL MAPPING IN PEAT AND SOFT SOILS

JMG.GP.07

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MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT

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PRAKATA

Garis panduan ini disediakan sebagai rujukan kepada kakitangan Jabatan Mineral dan Geosains Malaysia untuk melaksanakan kerja-kerja pemetaan geologi kejuruteraan kawasan gambut dan tanih lembut. Garis panduan ini bertujuan menyeragamkan prosedur kajian, pencerapan dan pengelasan bahan geologi dan persembahan data bagi membolehkan perbandingan dan korelasi maklumat litologi kawasan gambut di Malaysia. Garis panduan ini juga membincangkan semua aspek kajian daripada peringkat perancangan, cerapan lapangan dan penulisan laporan. Maklumat yang dihasilkan adalah berguna kepada ahli profesional seperti ahli geologi, jurutera dan perancang bandar, dan agensi berkaitan dalam penilaian cadangan pemajuan dan perancangan guna tanah.

Garis panduan ini disesuaikan daripada *Guide to Rock and Soil Descriptions (Geotechnical Engineering Office, Hong Kong, 1988), Guide to Site Investigation for Organic Soils and Peat, (Institut Kerja Raya Malaysia, 1995)* dan *A Manual of Quaternary Geology Methods (Suntharalingam* et al., 1987).

Usaha ini merupakan sebahagian daripada inisiatif untuk meningkatkan kualiti sistem penyampaian Jabatan. Daya usaha pegawai-pegawai yang terlibat dalam penyediaan garis panduan ini amatlah disanjung tinggi.

DATO' YUNUS BIN ABDUL RAZAK
Ketua Pengarah
Jabatan Mineral dan Geosains Malaysia

Julai 2010

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1.0 INTRODUCTION

Peat and soft soil commonly occur in extremely soft, wet, unconsolidated surficial deposits that are commonly found in the coastal flatland. Access to these deposits is usually very difficult as the water table will be near or above the ground surface. This makes pedestrian access a challenge and normal vehicular access impossible.

Peat and soft soil are different from inorganic firm clays and silts in that they require either modification to normal sampling or testing methods or in many situations a completely distinct method. As construction on these soils is often avoided, there tends to be an unfamiliarity and lack of experience with the methods needed to perform site investigations or to describe, classify and test them. This unfamiliarity produces uncertainty in the design of structures on these materials that in some instances leads to the production of very conservative and possibly uneconomic designs and construction methods.

2.0 EXTENT OF PEAT AND SOFT SOIL IN MALAYSIA

Peat and soft soil are integral component of the Quaternary deposits which are generally found in the coastal plains of Malaysia (Figures 1 and 2). Peat commonly occurs as the uppermost layer of these sediments.

There are 2,762,911 hectares of peat in Malaysia with 1,765,529 hectares in Sarawak (Table 1), 796,782 hectares in Peninsular Malaysia (Table 2) and 200,600 hectares in Sabah (Table 3).

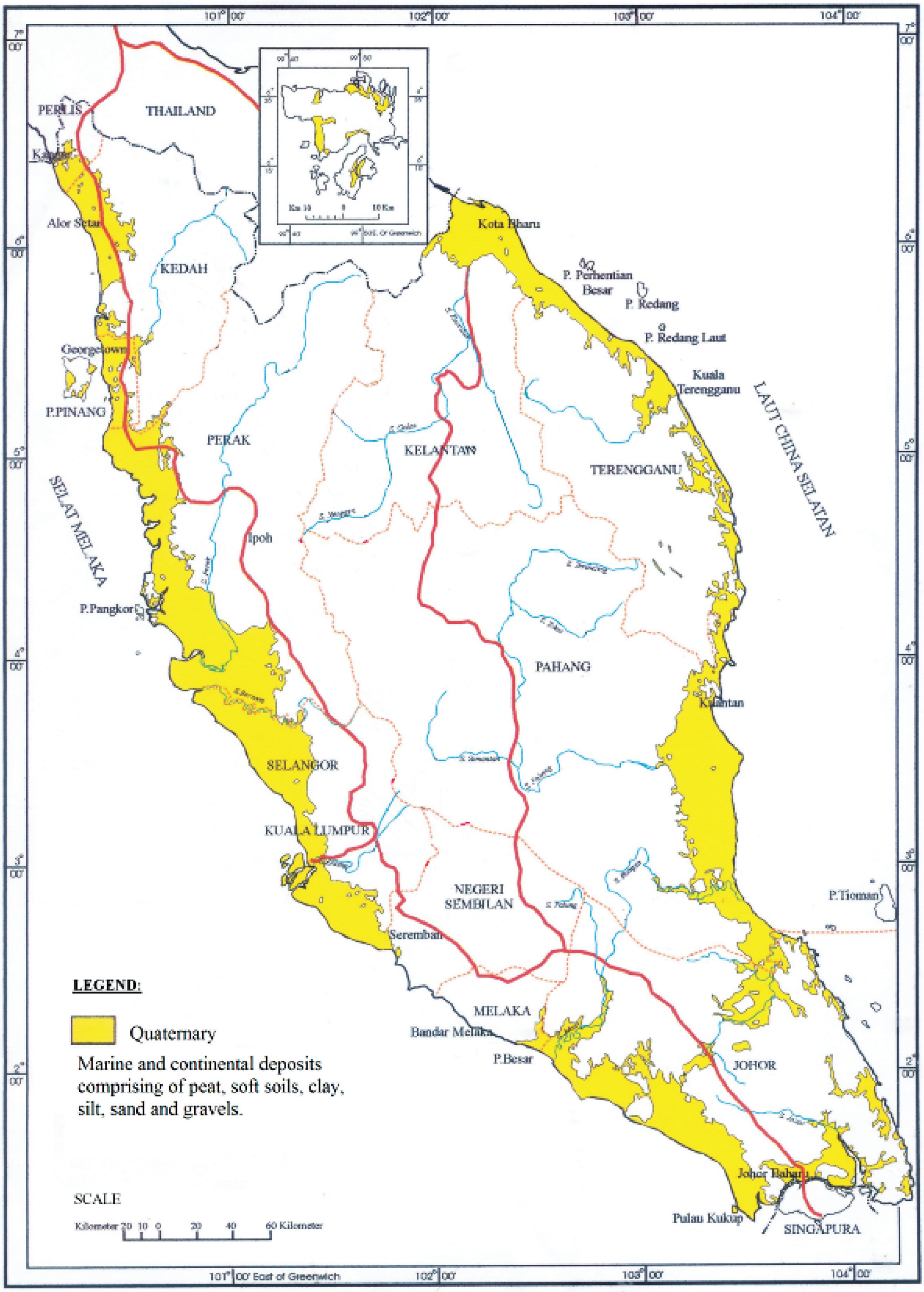


Figure 1 : General Distribution of Quaternary Deposits including Peat and Soft Soils in Peninsular Malaysia (modified after Quaternary Geological Map, Geological Survey of Malaysia, 1989)

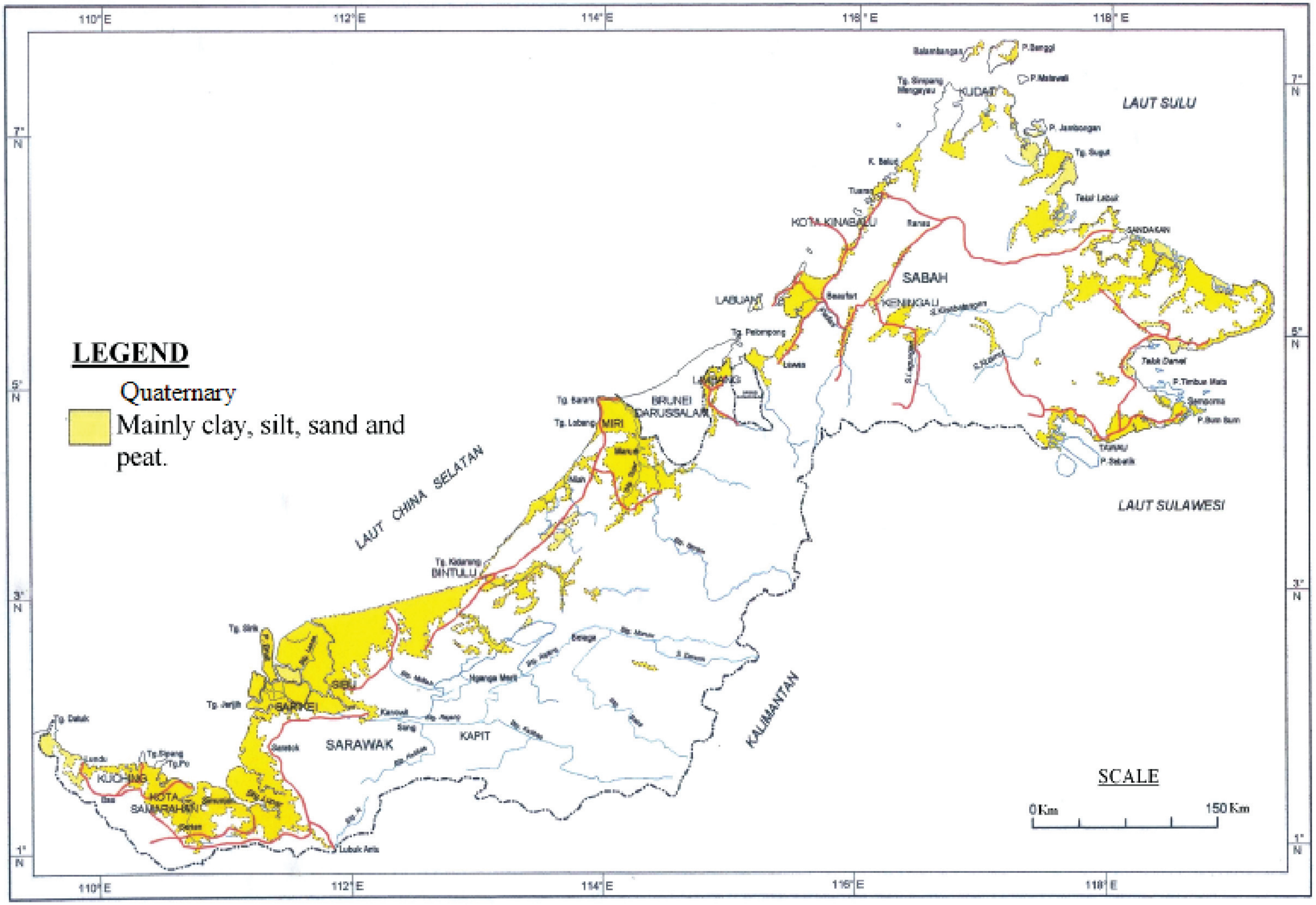


Figure 2 : General Distribution of Quaternary Deposits including Peat and Soft Soils in Sabah and Sarawak (modified after Geological Map Sabah and Sarawak, Geological Survey of Malaysia, 1992)

DIVISION	TOTAL AREA (Ha)	EXTENT OF PEAT AND ORGANIC SOILS	
		Ha	%
Kuching	455,955	26,827	0.2
Samarahan	496,745	205,479	1.7
Sri Aman	964,699	340,374	2.7
Sarikei	433,235	172,335	1.4
Sibu	1,527,590	502,466	4.0
Bintulu	1,216,621	168,733	1.4
Miri	2,677,707	314,585	2.5
Limbang	779,001	34,730	0.3
Kapit	3,893,447	-	-
Total:	**12,445,000**	**1,765,529**	**14.2**

Table 1 : Extent of Peat and Organic Soils in Sarawak (after Acres et al., 1975)

STATE	TOTAL AREA (Ha)	EXTENT OF PEAT AND ORGANIC SOILS	
		Ha	%
Johor	1,909,886	205,856	10.8
Kedah	937,712	-	-
Kelantan	1,497,351	7,880	0.5
Melaka	164,307	-	-
Negeri Sembilan	663,730	8,188	1.2
Pahang	3,584,758	228,644	6.4
Pulau Pinang / Seberang Perai	103,929	-	-
Perak	2,090,827	74,075	3.5
Perlis	80,974	-	-
Selangor	840,315	186,602	22.2
Terengganu	1,289,944	85,537	6.6
Total:	**13,163,733**	**796,782**	**6.1**

Table 2 : Extent of Peat and Organic Soils in Peninsular Malaysia (after Paramanathan et al., 2006)

STATE	TOTAL AREA (Ha)	EXTENT OF PEAT AND ORGANIC SOILS	
		Ha	%
Sabah	7,563,600	200,600	2.6

Table 3 : Extent of Peat and Organic Soils in Sabah (Acres et al., 1975)

3.0 DEFINITION

3.1 Peat

Peat is a naturally occurring highly organic substance derived primarily from plant materials. Peat is formed when organic (usually plant) matter accumulates more quickly than it humifies (decays). This usually occurs in wetlands where the organic matter is preserved below a high water table. Peat is distinguished from other organic soils by its higher organic content. The value of organic content that is used to define a peat varies throughout the world. The value often depends on the purpose for which the definition was originally created, e.g. construction, geology, agriculture, horticulture and fuel.

For the purpose of this guideline, a soil must have an organic content greater than 75% to be considered a peat. Integration of the definition of peat with the Unified Soil Classification System (USCS) requires the addition of an extra class of soil and a descriptive modifier to cover soils with significant organic content but less than 75%. This class of material lies between the peats and the purely inorganic silts and clays. This class is called Organic Soil. The numerical limits within the classification system for the organic content ranges for peat and organic soil and the descriptive modifier ‘slightly organic’ are presented in Table 4.

Basic Soil Type	Descriptor	Symbol	Organic Content (%)
Clay or Silt or Sand	Slightly Organic	o	3 - 20
Organic Soil	-	O	20 - 75
Peat	-	Pt	>75

Table 4 : Organic Content Ranges (Jarrett, 1995)

3.2 Soft Soils

Soft soils refers to geological materials of young sedimentary deposits consisting of clay, silt and organic soils usually Holocene in age. These sediments commonly show very low shear strength and very low Cone Penetration Test values, usually having a cone resistance of about 0.3 MN/m² (Lam, 1998a and 1998b).

4.0 DESKTOP STUDY

The investigation commences with literature survey and data collection, followed by preparation of base maps, topographical map study and remote sensing interpretation of the project area.

4.1 Literature Survey and Data Collection

Literature survey incorporates all information that is available, whether published or unpublished prior to an investigation. The information could be obtained from any source but should be properly acknowledged.

Literature on the site investigation results, even though from nearby surrounding areas, provides useful information about the soil profile.

Prospecting and mining records for tin and other minerals are available in the archives of the Department of Mineral and Geoscience Malaysia (JMG). Information on the lithology, thickness and nature of unconsolidated sediments could be obtained from these records.

Valuable data could also be obtained from Quaternary studies, hydrogeological, engineering or geophysical investigations that had been carried out in the proposed project area.

Another source of information is the soil map series of Malaysia published by the Soil Science Division, Department of Agriculture.

4.2 Topographical Map Study

Topographic maps (1:63,360 or 1:50,000) published by the Department of Survey and Mapping Malaysia (JUPEM) contain useful information on the geomorphology. The following features are generally depicted on these maps.

(i) Vegetation - primary and secondary forests, plantations (rubber, oil-palm, coconut and others) and paddy fields
(ii) Relief - contours and form lines
(iii) Drainage - rivers, lakes, canals, swamps, pools and reservoirs
(iv) Man-made - roads, railways, buildings, dams and others features
(v) Reference system - latitude and longitude, national grid system
(vi) Control - spot height, trigonometrical station, bench mark and others

4.3 Remote Sensing

Access in peat and soft coastal ground areas is a major problem. Remote sensing is therefore, the usual starting point for investigations. Ultimately however, interpretations made by remote sensing must be confirmed by ground truthing. An introductory review of remote sensing methods for peat land was given by Mollard (1986a).

4.3.1 Aerial Photography

Aerial photography interpretation and terrain analysis is very useful in delineating the extent of peat, organic soils and Holocene deposits, and can give indications of variations in the ground conditions. Terrain analysis of wetland commonly involves correlation between the surface vegetation and the subsurface materials, with the water table position effectively controls the form of vegetation. The methodology for aerial photography interpretation of peat land is provided by Mollard (1986b).

4.3.2 Satellite Imagery

LANDSAT imagery has been used for the delineation of wetland, peat and organic soil and Holocene deposits. LANDSAT TM images offer the highest quality available in terms of vegetation classification and landuse mapping. The images have a ground resolution of 30m and seven different spectral channels covering the whole range from the visible light to infrared and a thermal channel. Since the data are stored in a digital format it can be analysed by computer techniques.

The RADARSAT and LANDSAT TM images have useful information on the geology and hydrogeology, and hence, integration of these data sets can provide more information than is available from either image individually. RADARSAT and LANDSAT TM images can be used to map the wetland and peat deposits.

4.4 Preparation of Preliminary Maps

Several types of maps can be prepared depending on the amount of data available. Some of the maps that are of use in preliminary planning are as follows:-

4.4.1 Morphological Map

This map is prepared from topographic and aerial photographic information. This map gives a guide to the inland limit of swamps, peat land, marine sediments and also their distribution. The past and present fluvial pattern is also well displayed.

4.4.2 Sediment Thickness

The isopach map can be compiled from borehole data, Quaternary geological reports, prospecting and mining records that are available in the archives of the JMG, other government departments as well as from the private sector. This map gives an indication of the direction of thickening of sediments and the presence of former river direction or paleochannels.

4.4.3 Bedrock Topography and Geology

This map is also prepared from borehole data, prospecting and mining records. This map, besides indicating overburden thickness also indicates probable contact zones areas between granitic and sedimentary rocks.

4.5 Initial Fieldwork Planning

Prior to carrying out systematic mapping, it would be beneficial to carry out a reconnaissance field trip over the project area to study the accessibility, terrain and other landform features that have been observed in the topographic maps and remote sensing imagery.

It is most likely that the inspection will have to be done on foot, if vehicles cannot easily access the site. A decision concerning the applicability of heavier drilling equipment will be able to be made base on accessibility.

During the trip, the following data should be observed:

(i) Nature of access (metalled or laterite road or footpath). This will determine the type of drill and geophysical method to be used.
(ii) Ground conditions such as availability of campsite, potable water etc. which would probably determine if the survey may be conducted along grid lines.

5.0 FIELD INVESTIGATION

5.1 Surveying Methods

Surveying the position and elevation of sample locations in peat area is difficult. Theodolites and dumpy levels are commonly used. However, more sophisticated survey equipment like the Tellerumeter for Electronic Distance Measurement (EDM) and the Total Station are now being introduced. The set back is that in inaccessible areas, progress would be very slow and the work, arduous. In recent years, there is a switch to the use of gadgets like the Global Positioning System (GPS). The advent of GPS instruments for surveying purpose means that sampling positions may be quickly and effectively located. This technology is a great advance for use in wetlands especially where sight lines would be arduous to develop. It is also possible to use GPS systems to locate pre-selected sampling sites.

5.2 Geophysical Survey

Geophysical surveys are generally undertaken prior to drilling operations to:

(i) determine the thickness of the peat and the soft soils,
(ii) determine palaeochannels and other subsurface features,
(iii) indicate the different lithological units, and
(iv) guide the laying-out of the boreholes and type of drill to be used.

5.2.1 Seismic

The refraction technique is usually used for land surveys. In recent years the reflection method is also applied. The seismic technique is used to determine the thickness of the unconsolidated sediments, the different lithological units and to locate buried channels.

The refraction technique depends upon the refraction of longitudinal or primary waves at interfaces between lithological units with different seismic velocities and is based on Snell’s Law.

The limitations of the refraction technique are:

(i) If a layer has a seismic velocity less than that of the layer immediately above it, this layer cannot be detected by refraction.

(ii) If a particular layer is very thin and the seismic velocity of the layer immediately below is very much higher than the thin layer, the primary waves from the higher velocity layer may be detected by the geophones earlier than those from the thin layer. When this happens, the thin layer will not be detected.

(iii) For deep layers the shot spreads become very long and very high shot-energy is required.

5.2.2 Resistivity

By this method the apparent resistivity of the ground is determined by measuring the potential difference across two electrodes while introducing a current into the ground through two other electrodes. The main factor which contributes to the successful application of the resistivity method is the existence of contrast in the resistivity of the different rock types.

This method can be used to determine the thickness of the unconsolidated layers (i.e. depth to bedrock), the lithology of individual layers and to detect buried channels.

The limitation of this method is that its resolving power decreases very rapidly with depth when low resistivity layers are encountered near the surface. Since unconsolidated sediments can show a very wide range of resistivity, depending on thickness of layers, degree of saturation, groundwater composition and porosity, borehole control for such surveys is very necessary for effective interpretation of the measurements.

5.2.3 Gravity

The aim of gravity surveys is to detect subsurface structures by detecting the anomalies they produce in the earth's gravitational field. Gravity anomalies which are due to density differences could be used to determine overburden thicknesses and detect buried channels.

Gravity surveys can be carried out in conjunction with seismic surveys to obtain optimum results. The limitation is mainly that only broad scale features can be determined.

5.2.4 Electromagnetic

Electromagnetic methods of prospecting are based on the measurement of induced secondary electromagnetic fields associated with subsurface conductors in relation to the primary electromagnetic field. This method may be used to map for example a layer of sand of limited depth. However this technique has depth limitations.

5.3 Boring

Boring is carried out to determine the distribution, thickness and nature of the peat, organic soils and soft soils. This is accomplished by the augering of shallow holes and through the study of the bore logs. In more accessible areas, deep boreholes may be sunk to study the soil profile.

A borehole of less than 20m depth is a shallow hole (Suntharalingam et al., 1987). The equipment is generally light, operated by one to three persons and can be carried over large distances. A combination of more that one type of equipment is used for optimum results in terms of sample recovery and depth penetration. Sample recovery is generally good but is of small diameter.

A deep hole is considered as one with a depth greater than 20m. The deep holes are drilled in order to obtain the stratigraphy of the peat, soft soils and the underlying unconsolidated sediments down to the bedrock.

5.3.1 Shallow Holes

Hand augers are used on land to penetrate the upper layers between the ground surface and the water table. Some of the augers described here can also be used below the water table.

5.3.1.1 Edelman Auger

This auger is made up of a handle, rod and an attachment to the rod for cutting loose the unconsolidated material by turning the handle (Figure 3). The auger head is manufactured for use in clay, sand or gravel or combination of these soil types.The extension rods are of four sizes (length of 50cm, 75cm, 1m or 2m).

The auger head is 25cm long and recovery is generally good but disturbed. The auger is more effective above or slightly below water table in cohesive material such as clay but is unsuitable for loose sandy or gravelly material. Borings can be done to a depth of 10m with this auger.

5.3.1.2 Guts (Gouge) Auger

This auger is half of a pipe with sharp cutting edges in an axial direction (Figure 4). The cutting blade (head or bit) consists of a steel piece (50cm, 1m or 2m long) which has a diameter of 3cm (also available in 6 other diameters). This auger is suitable for investigation in soft marine clay and silty sediments.

Sampling is carried out by manually forcing the head into the ground and turning the cutting blade or head (by means of a handle) to cut out a relatively undisturbed cylindrical core. On pulling out, the core is contained within the head. Deeper cores may be obtained by the gradual addition of extension rods which are either screwed or hooked (bayonet connection) on to one another. The auger is suitable in soft marine clay and silty materials.

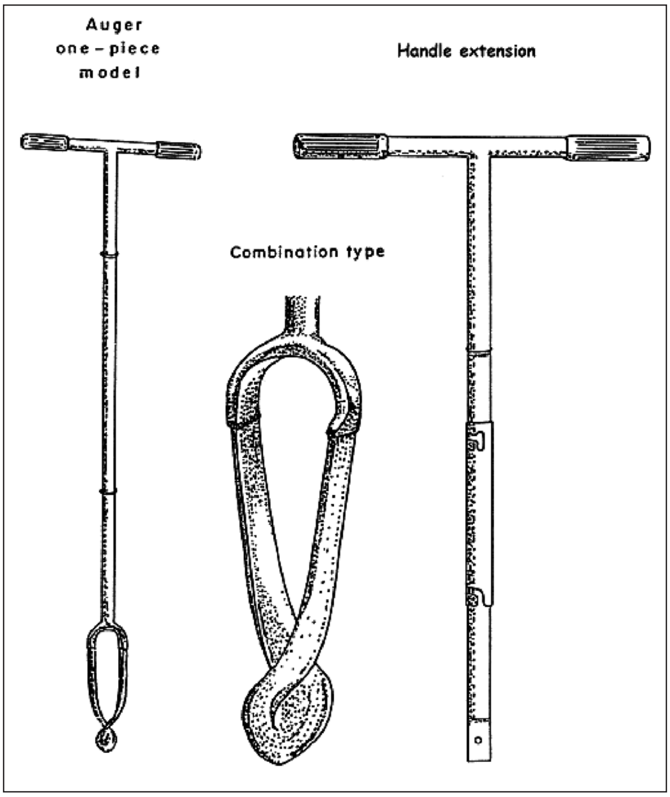


Figure 3 : The Edelman Auger

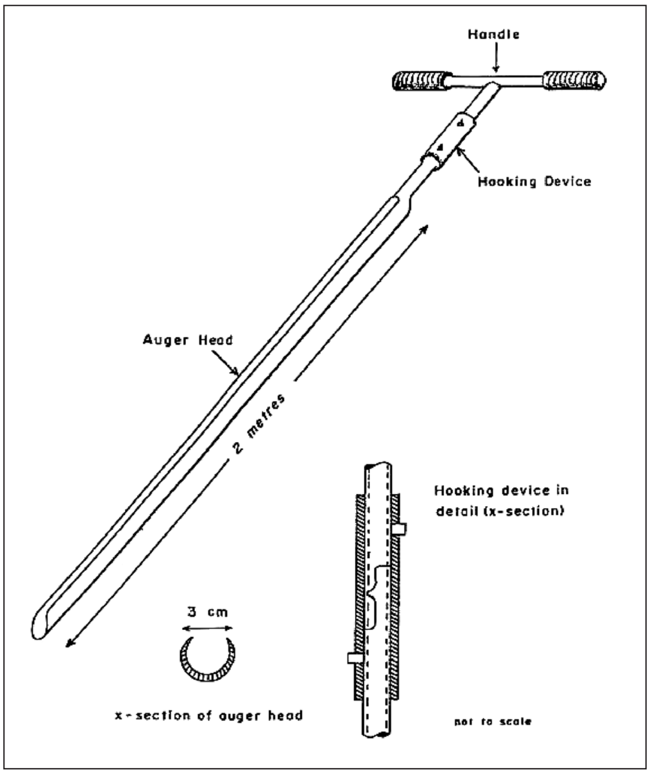


Figure 4 : Guts (Gouge) Auger

5.3.1.3 Peat Sampler

The peat or Russian-type sampler (Photo 1) described in Jowsey (1966), is mainly used for peat sampling. It consists of an anchored fin and a movable sampling chamber. The latter is a semi-circular cylinder measuring 50cm in length and 5cm diameter, with one end forming the sharp pointed edge that penetrates the peat sequence while the other end is connected to the T-shaped handle. Like the gouge auger, the peat sampler operates quite similarly, the difference being the latter is only rotated through a 180° turn during sampling. Before sampling proceeds, one needs to observe the alignment of the fin with regard to the sampling chamber so that when the sampler is rotated the required samples will be collected. There have been instances when the fin, which is supposed to be stationary, was forced to rotate. This could be due to incorrect fin and sampling chamber orientation when the sampler was rotated, or turning the auger more than 180°. This had unnecessarily incurred some damage to the sampler whereby the sampling chamber became skewed.

Samples collected using the peat sampler is not disturbed compared to those collected with the guts (gouge) auger. This is because the samples remain enclosed within the sampling chamber throughout the process of sampling.

Photo 1: Peat Sampler

5.3.2 Deep Holes

Two main techniques are employed for deep drilling i.e. percussion system and the flush method.

5.3.2.1 Percussion Drilling

The system consists of a casing, inside which a bailer can freely move in a vertical direction. The casing covers the drill hole over its entire depth. The bailer is lowered into the hole by drill rods (e.g. Hand Banka) or by a cable.

The bailer has an outside diameter slightly less than the casing's inner diameter and consists of a pipe with a flap valve or globe valve at its lower end. The valve opens when the bailer moves downwards and closes when it moves upwards. When the bailer is moved upwards and downward in short pulses it operates as a sand / mud pump. When the bailer is full, it is hauled to the surface. The lower end of the bailer is provided with a sharp edge that acts as a cutting shoe.

The pulsing motion can be generated by hand or by attaching the bailer cable to motor. The casing, which also has a cutting shoe at its lower end, generally sinks by its own weight (e.g. Hand Banka, Semi-mechanized Banka). However, an additional pull-down force (hydraulic unit) or rotating motion could be utilized if needed.

In order to overcome the problem of increased friction in deep holes, telescopic drilling is recommended. This implies that, when further penetration become difficult, drilling is continued with a smaller size casing that fits neatly in the large size casing already in place.

The following types of percussion drills are available in JMG.

(i) Hand Banka
It is a manually operated system with casings of 100mm (4 inch external diameter) which can go down to depths of 40m

(ii) Portable semi-mechanized Banka
It is a light portable drill where the bailer cable is operated by a motor. The external diameter of the casing is 127mm and it can go down to depths of 60m.

(iii) Semi-mechanized Banka
It is similar to (b) except that it is heavier and has more power. The external diameter of the casing's is 136mm and it can reach a maximum depth of 200m.

(iv) Fully Mechanized Drill Rig
The Conrad Pioneer (PP 350) is a fully mechanized drill rig which utilizes telescopic drilling of 150mm (6 inch) and 100mm (4 inch) casings to reach a maximum depth of 100m.

5.3.2.2 Flush Drilling

Flushing refers to a method by which the cut loose material is transported (flushed) to the surface by means of water circulation.

Essential for any flushing system is the simultaneous presence of a downward and upward water flow in the drill hole: both flows need to be kept separated except at the bottom of the drill hole where the downward flow changes into an upward flow (this is the spot where the loosened solids are entering the circulation system).

The separation of the downward and upward flows may be realized by either of the two methods:-

(i) Using a hollow drill rod in combination with a drill bit having a much larger outer diameter. One flow passes through the annular space between the open wall of the drill hole and the outer surface of the drill rod.

(ii) Using a dual-wall drill casing, combined with a drill-bit of the same diameter as the outer diameter of the casing.

With either method, two circulation patterns are possible, that is:

- Down-flow in the annular space and return flow in the central space, or
- Down-flow in the central space and return flow in the annular space.

In practice the following nomenclature is used:

(i) Straight Flush or Normal Flush Drilling
Down-flow is in the central channel and return flow in the annular space. This method applies to both drilling system using dual-wall casing and using hollow drill rods without casing.

(ii) Reversed Flush Drilling
This term applies only to drilling without casing: down-flow is in the annular channel, whereas the return flow is in the central channel inside the drill-rods.

(iii) Counter Flush Drilling
This term is used only in connection with dual wall drill casing; the annular space accommodates the down-flow and the central channel the return-flow.

Flush methods are often used in combination with rotary drilling (with or without casing) or vibracoring. Manufacturers nowadays build rigs with combinations of different drilling methods in which the percussion, flush and even diamond drilling system have been incorporated.

The department has a Conrad-Mini 200 drill which is a light weight mobile unit that incorporates a variety of drilling techniques i.e. auger drilling, percussion, straight-flush, counter-flush and diamond drilling. The maximum penetration possible depends, amongst others, on the drilling methods used. The maximum penetration depth up to 90m is achieved with straight flush drilling without casings.

6.0 FIELD TESTS

Field tests are conducted on water and soil to obtain their in-situ physical or chemical properties. Engineering tests are also conducted on soil to obtain their geotechnical parameters.

6.1 Engineering Tests

In-situ testing in areas underlain by peat, organic soil or soft soils includes a number of techniques such as dynamic probing with Mackintosh / JKR Probes, sounding test with a portable Dutch Cone Penetrometer, or shear tests with a portable shear vane. These are relatively inexpensive procedures that can be effective in delineating the boundaries of soft or weak materials and in the recording of general in-situ material condition.

6.1.1 Mackintosh / JKR Probe

The apparatus for this dynamic probing comprises a sectional rod fitted at the end with a cone whose base is of greater diameter than the rod. It is driven into the ground by a constant mass falling through a fixed distance. Probe results are very useful for making comparative qualitative assessments of ground characteristics. Probe results are reported as the number of blows per 30cm.

A description of the JKR Probe and its differences with the Mackintosh Probe is given in Appendix 1.

6.1.2 Vane Shear Test

A cruciform vane on the end of a solid rod is forced into the soil and then rotated and the torque required to rotate the vane can be related to the shear strength of the soil. The method of carrying out the test is described in BS: 1377; Part 9: 1990. Vanes can take the form of borehole vanes or penetration vanes, the latter being much more reliable. The test can be extended to measure the remoulded strength of the soil. This is done by turning the vane through ten complete rotations. A pause of not more than one minute is permitted to elapse and the vane test is then repeated in the normal way. The degree of disturbance caused by rotating the vane differs from that obtained by remoulding a sample of clay in the laboratory and the numerical value of the sensitivity of the clay determined by these procedures is not strictly comparable with the results obtained from laboratory trial tests.

The test is normally restricted to fairly uniform, cohesive, fully saturated soils and is used mainly for clay having undrained shear strength of up to about 75kPa. The results are questionable in stronger clays, or if the soil tends to dilate on shearing or is fissured.

The vane test is invaluable in marine sediments. However, some strata are sandy or contain shells, in which case vane shear results should be interpreted with caution. Marine clays are generally very soft, and it is often necessary to provide a separate support frame to carry out the vane test.

It should be noted that the undrained shear strength determined by in-situ vane test is, in general, not equal to the average value calculated at failure in the field, e.g. in the failure of an embankment on soft clay. The discrepancy between field and vane shear strengths generally increases as the clay becomes more plastic.

The testing procedure for a hand field vane shear test is given in Appendix 2.

6.1.3 Portable Dutch Cone

Several types of static probing equipment have been developed and are in use throughout the world (Sanglerat, 1972; De Ruiter, 1982). The basic principles of all systems are similar in that a rod is pushed into the ground and the resistance on the tip (cone resistance) is measured by a mechanical, electrical or hydraulic system. The resistance on a segment of the rod shaft (friction sleeve resistance) may also be measured.

There is no British Standard for cone penetration testing, but suitable recommendations are given by the International Society for Soil Mechanics and Foundation Engineering (ISSMFE, 1977) and the American Standard for Testing Materials (ASTM, 1985). Both of these test standards recognise a number of traditional types of penetrometers, and it is imperative that the actual type of instrument used is fully documented, as the interpretation of the results depends on the equipment used.

The testing procedure using a 1.6MPa Capacity Dutch Cone Penetrometer is described in Appendix 3.

6.1.4 Mounted Cone Penetration Test

A truck mounted Gemco drilling rig with hydraulic thrust is available in JMG for use as a thrust machine.

The Cone Penetration Test (CPT) system used is the mechanical type and as such, the quality of the data is operator dependent. For details of method, refer to the "Guidelines for Geotechnical Design Using the Cone Penetrometer Test and CPT with Pore Pressure Measurement" by Robertson and Camparella (1989).

6.1.5 Standard Penetration Test

The Standard Penetration Test (SPT) is a frequently used dynamic penetration test and is described in Test 19 of BS1377 (1975). A small disturbed soil sample (quality class 3) is normally obtained when the split barrel sampler is used. The test results have been related empirically to soil parameters and foundation conditions, especially in sands and gravels.

Minor variations from the specified equipment and procedures can seriously affect the results of the test (De Mello, 1971; Ireland et al, 1970; Nixon, 1982; Skempton, 1986). It is important that the test is carried out precisely as described in Test 19 of BS1377 (1975), except that the following modifications should be incorporated:

(i) An automatic release trip hammer should be used to drive the sampler
(ii) The weight of the hammer in the drive assembly should be 63.5kg
(iii) The diameter of the borehole should be between 60mm and 200mm
(iv) Drill rods with stiffness equal to or greater than type BW rods should be used to reduce energy dissipation

These modifications bring the test procedures into conformity with the proposed international standardization of the test (ISSMFE, 1977).

For details of the test, refer to Guide to Site Investigation (GCO, 1987a).

6.2 Physical Tests on Soil

6.2.1 Field Density

Almost all the methods use direct measurements of mass and volume, the choice of which depends on the type of materials. One of the methods uses gamma rays. Details of the testing procedure are given in MS 1056, Part 9:2005, page 2.

6.2.2 Field Moisture Content

Field moisture content of soil can easily be measured with the usage of field moisture kit.

6.2.3 Field In-situ Resistivity

This test is to assess the resistivity and indirectly the corrosivity of soil towards various metals. The resistivity of a soil indicates the relative capability of the soil to conduct electric currents. Generally the severity of corrosion decreases as the apparent resistivity rises. Details of the testing procedures are given in MS 1056, Part 9:2005, page 75.

6.2.4 Field In-situ Redox Potential

The test determines the redox potential of soil at a selected depth by measuring the electro-chemical potential between a platinum electrode. The test is to indicate the likelihood of microbiological corrosion of metals by sulphate reducing bacteria. Details of the testing procedures are given in MS 1056, Part 9:2005, page 78.

6.2.5 In-situ pH

There are three methods for in-situ determination of the pH of soil. They are indicator papers, Colorimetric (Kuhn's Method) and Electrometric Method. For details of the procedure, refer to BS 1377:1975, Test 11(A) and Test 11(B).

6.3 Physical Chemical Tests on Water

There are three methods for in-situ determination of the pH of water. They are indicator papers, Colorimetric (Kuhn's Method) and Electrometric Method. For details of the procedure, refer to BS 1377:1975, Test 11(A) and Test 11(B).

6.3.1 In-situ Water Quality

The objective of groundwater and surface water quality monitoring is to identify regional and seasonal variation and long-term changes of groundwater quality in the study area. In addition, surface water quality is measured for background information.

The parameters to be measured in-situ include temperature, turbidity, colour, pH, conductivity and dissolved oxygen. However, on site measurement can also be carried out other than for dissolved oxygen.

Groundwater and surface water quality analysis shall be conducted in-situ. Groundwater sampling should be done after the measurement of groundwater level to avoid the effect of sample taking on the groundwater level. All measured results for groundwater shall be recorded in Form E1 (Appendix 4) together with the result of groundwater level measurement and for surface water, in Form F1 (Appendix 5).

6.3.2 On Site Test for Water Quality

On-site test shall be conducted at the site or in the site office using sample water collected during the pumping for in-situ test. The following eight (8) parameters shall be analysed on-site:

(i) Biochemical Oxygen Demand (BOD),
(ii) Chemical Oxygen Demand (COD),
(iii) Manganese (Mn),
(iv) Iron (Fe),
(v) Total Iron (Fe-T),
(vi) Nitrate Nitrogen (NO_3-N),
(vii) Nitrite Nitrogen (NO_2-N), and
(viii) Phosphate (PO_4).

The procedure of measurement of each parameter is described in Water Testing Procedures (Appendix 6).

7.0 SAMPLING

Samples may have cost a considerable sum of money to obtain and should be treated with great care. The usefulness of the laboratory tests results depends on the quality of the samples at the time they are tested. It is therefore important to establish a satisfactory procedure for sampling and labelling the samples and also for their storage and transportation so that they do not deteriorate, and can readily be identified and drawn from the sample store when required.

The samples should be protected from excessive heat and temperature variation, which may lead to deterioration in the sealing of the sample containers and subsequent damage to the samples. The temperature of the sample store will be influenced by the climate, but it is recommended that the samples should be stored at the lowest temperature practicable within the range 20°C to 45°C. The daily temperature variation within the store should not exceed 20°C.

7.1 Disturbed Soil Samples

Disturbed soils samples that are required for testing should be treated as described below:

(i) Immediately after being taken from a borehole or excavation, the sample should be placed in a non-corrodible and durable container of at least 0.5kg capacity, which the sample should fill with the minimum of air space. The content of the sample can be maintained until tested in the laboratory. Large disturbed samples that are required for certain laboratory tests may be packed in robust containers or plastic sacks.

(ii) The sample containers should be numbered, and the tear-off slip or a label, should be placed in the container immediately under the cover. An identical label should also be securely fixed to the outside of the container under a waterproof seal (wax or plastics). The containers should be carefully crated to prevent damage during transit. During the intervals while the samples are on site or in transit to the sample store, they should be protected from excessive heat.

7.2 Undisturbed Soil Samples

The following recommendations are applicable to all undisturbed soil samples taken with tube samplers, except those taken with thick-walled samplers. The precautions for handling and protection of samples are to be regarded as a minimum requirement for samples taken by the usual methods. In special cases, it may be necessary to take more elaborate precautions.

7.2.1 Tube samples

Immediately after the tube samples has been taken from the borehole or excavation, the ends of the sample should be removed to a depth of about 25mm and any obvious disturbed soil in the top of the sampler should also be removed. Several layers of molten wax, preferably microcrystalline wax, should then be applied to each end to give a plug about 25mm in thickness. The molten wax should be as cool as possible. It is essential that the sides of the tube be clean and free from adhering soil. If the sample is very porous, a layer of waxed paper or aluminium foil should be placed over the end of the sample before applying the wax.

Any remaining space between the end of the tube or liner and the wax should be tightly packed with a material that is less compressible than the sample and not capable of extracting water from it and a close-fitting lid or screw-cap should then be placed on each end of the tube or liner. The lids should, if necessary, be held in position with adhesive tape.

For soft marine soil samples, the tube or liner should be held vertically, keeping the sample in the same direction as it left the ground, and extreme care should be taken during all stages of handling and transportation.

7.2.2 Block Samples

Samples that are not retained in a tube should be wholly covered with several layers of molten paraffin wax, preferably microcrystalline wax, immediately after being removed from the sampling tool, and then should be tightly packed with suitable material into a metal or plastic container. The lid of the container should be held in position with adhesive tape. If the sample is very porous, it may be necessary to cover it with waxed paper or aluminium foil before applying the molten wax.

A label bearing the number of the sample should be placed inside the container just under the lid. The label should be placed at the top of the sample. In addition, the number of the sample should be painted on the outside of the container, and the top or bottom of the sample should be indicated. The liners or containers should be packed in a way that will minimize damage by vibration and shock during transit.

7.3 Water Samples

The sample container used to collect and store the sample should be chosen after considering, for example, resistance to temperature extremes, resistance to breakage, ease of good sealing and reopening, size, availability, potential for cleaning and re-use. High density polyethylene is recommended for silica, sodium, total alkalinity, chloride, conductivity, pH, and hardness determinations in water. For light-sensitive materials, light-absorbent glass should be used. Stainless steel should be considered for samples of high temperature and / or pressure, or when sampling for trace concentrations of organic material. Glass bottles are suitable for organic chemical compounds and biological species, and plastic containers for radionuclide. Sample containers for microbiological examination should be able to withstand the high temperatures which occur during sterilization and not produce or release chemicals which could inhibit microbiological viability, release toxic chemicals, or encourage growth.

Waters are susceptible to changes as a result of physical, chemical or biological reactions which may take place between the time of sampling and the commencement of analysis. The nature and rate of these reactions are often such that, if precautions are not taken during sampling, transport and storage, the concentrations determined may be different to those existing at the time of sampling. Changes to particular constituents vary both in degree and rate, not only as a function of the type of water, but also, for the same water type, as a function of seasonal conditions. Preservation of water samples is necessary for these reasons.

The most common way of preserving waste-water samples is to cool to a temperature between 0°C and 4°C. When cooled to this temperature and stored in the dark, most samples are normally stable for up to 24 hours. When collecting samples during extended periods, preservation should be an integral part of the sampling operation. It may be necessary to use more than one sampling device, to allow both preserved and unpreserved samples to be taken. Sample preservation should be performed immediately upon sample collection. Preservation samples for multiple determinations may have to be split and preserved separately. The laboratory responsible for analyzing the samples should always be consulted with regard to the selection of the preservation method and subsequent transport and storage. Table 5 gives most common techniques generally suitable for the preservation of inorganic chemicals.

Complete preservation of water samples is a practical impossibility, where regardless of the sample nature complete stability for every constituent can never be achieved. Generally, preservation techniques only retard chemical and biological changes. As a general rule it is best to analyze the water samples as soon as possible after collection. This is especially true when the concentration is expected to be low.

Preservation	Volume / Container Type	Determinants
None	2 - 3 Litre / HDPE	pH, Colour, Conductivity, Total Dissolved Solids, Total Solids, Total Hardness, Turbidity, Alkalinity, F, Cl, SO_4, NO_2, Silica
Filtered and acidified with nitric acid 1ml 50% HNO_3 per 100ml sample pH < 2	1 Litre / HDPE	Ag, Al, As, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Ti, Zn
Filtered and acidified with sulphuric acid 1ml 20% H_2SO_4/ 100ml sample pH < 2	500ml / HDPE	NO_3, NH_4, Phosphorus
NaOH 1ml 20% NaOH / 100ml sample pH > 12.5	500ml / Amber Bottle	CN

Table 5 : Techniques Generally Suitable for The Preservation of Samples

7.4 Labelling

All soil samples should be labelled immediately after being taken from a borehole or excavation. If they are to be preserved at their natural moisture content, they will at the same time have to be sealed in an airtight container or coated in wax. The label should show all necessary information about the sample, and an additional copy should be kept separately from the sample; this latter is normally recorded on the daily field report. The label should be marked with indelible ink and be sufficiently robust to withstand the effect of its environment and of the transport of the sample. The sample itself should carry more than one label or other means of identification so that the sample can still be identified if one label is damaged.

The sample label should give the following information, where relevant:

(i) name or reference numbers of the site,
(ii) reference number, location and angle of hole,
(iii) reference number of sample,
(iv) date of sampling,
(v) brief description of the sample,
(vi) depth of top and bottom of the sample below ground level, and
(vii) location and orientation of the sample where appropriate (e.g. a sample from a trial pit).

8.0 FIELD DESCRIPTION

8.1 Peat and Organic Soils

For field description, slightly organic silts or clays will appear as inorganic fine grained soils, probably black or dark brown in colour, have an organic odour and possibly some visible organic remains. Their plasticity should be evaluated as is usual for fine grained soils. Peat on the other hand may well appear to be completely organic, contain many recognizable plant remains, have a low density and also be black or dark brown. Organic soil is difficult to define in the field lying as it does between the other two categories and with such a wide range of organic content. Definitive categorization can only be made after the organic content is measured in the laboratory.

For the purpose of resource environmental studies and some engineering investigations, the Modified Von Post Description is recommended.

8.1.1 Modified Von Post Description in the field

This method was derived by the Geological Survey of Finland and the Department of Natural Resources of the Province of New Brunswick, Canada (Table 6). A full description of the methodology was presented by Keys and Henderson (1983).

The peat material is described with reference to the following factors that are assessed in the field by visual inspection:

(i) Botanic Composition – The forms of plants from which the peat is composed is estimated to the nearest 10 percent. In listing the components the dominant species is listed last e.g. a shrubby – <u>*Carex-Sphagnum*</u> peat is predominantly <u>*Sphagnum*</u> with lesser amounts of <u>*Carex*</u> and shrubs. The term ‘ooze’ is used to describe subaqueous amorphous or gel-like humus. This parameter is not used in the classification system in this guideline.

(ii) Degree of Humification (H) – Use the Von Post Squeeze test and provide result between H1 and H10 (Table 6).

(iii) Wetness (B) – This is a relative estimate of moisture. The scale ranges as follows:

B1 – Dry
B2 – Low moisture content
B3 – Moderate moisture content
B4 – High moisture content
B5 – Very high moisture content

(iv) Fibers (F) – This is an estimate of the volumetric content of the material that is recognizably fibrous in nature but not woody. It varies as follows:

F0 – Nil
F1 – Low content
F2 – Moderate content
F3 – High content

In Key's system, fiber content is subdivided between coarse and fine fibers. For engineering site investigations this differentiation is not necessary.

(v) Woodiness (W) – This is an estimate of the volumetric content of the material that is recognizably woody. The scale varies as follows:

W0 – Nil
W1 – Low content
W2 – Moderate content
W3 – High content

These categories are used in the field to describe specimens in a symbolic or word form, for example a woody peat that is slightly decomposed, high water content, moderately fibrous, low wood peat could be symbolically represented as a woody peat H3 B4 F2 W1.

Degree of Humification	Description
H1	Completely undecomposed peat which releases almost clear water. Plants remain easily identifiable. No amorphous material present.
H2	Almost completely undecomposed peat which releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.
H3	Very slightly decomposed peat which releases muddy brown water, but for which no peat passes between the fingers. Plant remains still identifiable and no amorphous material present.
H4	Very slightly decomposed peat which releases muddy brown water, but for which no peat passes between the fingers. Plant remains still identifiable and no amorphous material present.
H5	Moderately decomposed peat which releases very “muddy” water with also a very small amount of amorphous granular peat escaping between the fingers. The structure of plant remains is quite indistinct, although it is still possible to recognise certain features. The residue is strongly pasty.
H6	Moderately strongly decomposed peat with a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The residue is strongly pasty but shows the plant structure more distinctly than before squeezing.
H7	Strongly decomposed peat. Contains a lot of amorphous material with a very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
H8	Very strongly decomposed peat with a large quantity of amorphous material and very dry indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibres that resist decomposition.
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed, almost all of the peat escapes between the fingers as a fairly uniform paste.
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.

Table 6 : Von Post Degree of Humification

8.2 Soft Soils

The recommendations in this section are generally applicable to all types of surficial deposits, including fill. Some of these recommendations are also applicable to soils derived from the in-situ weathering of rocks which however, is not in the purview of this guideline.

The main purpose of a soil description is to give an indication of the likely engineering properties of the soil. In this sense, soil descriptions in principle can be made using the same approach adopted for rock descriptions but there is one important difference. Unlike rocks, most soils can be easily disturbed during excavation, sampling or testing, and this may have a marked effect on engineering properties. Soil descriptions should include a note on the degree of sample disturbance, where this is considered to be important. The degree of disturbance ranges from the completely undisturbed, in-situ field condition to the fully disturbed, remoulded condition of a sample that has been completely broken down into its constituent grains. Additional geological information, such as the geological formation, age and type of deposit, should also be included in the description whenever possible, but these aspects may not readily determine without a detailed geological study of the area around a site.

In soil description, the main characteristics should be given in the following order:

(i) strength; i.e. compactness or consistency (material),
(ii) colour (material),
(iii) particle shape,
(iv) composition (material),
(v) sorting,
(vi) structure (mass),
(vii) soil name (in capital, e.g. SAND), grading and plasticity (material),
(viii) discontinuities (mass),
(ix) state of weathering, and
(x) additional geological information.

It should be noted that the term ‘structure’ as used in this chapter refers to macrostructure, i.e. structural features of a soil mass which can be identified by the naked eye. The description of soil microstructure is considered in section (8.2.10) which is on additional geological information.

8.2.1 Strength

The strength of a soil may be altered significantly by disturbance or remoulding during sampling and testing. Strength should therefore be described in the undisturbed field condition whenever possible; alternatively, the highest quality, least disturbed sample should be used.

The strength of cohesive soils is noticeably affected by moisture content. This is particularly the case for soils in the unsaturated zone above the water table, where significant short term and seasonal fluctuations in moisture content can occur. Strength descriptions of cohesive soils should therefore include an indication of the moisture condition. For example, possible moisture condition classes could be ‘dry’, ‘moist’ and ‘wet’. Any classes used should be defined in terms of simple field recognition criteria for particular soils and should be related to laboratory measured moisture contents where possible. As a general rule, soil strength in the field should be described at the natural field moisture content, and any samples taken should be kept at that same moisture content.

The recommended qualitative scales for strength assessment are given in Table 7. The strength of coarse and very coarse soils (sands, gravels, cobbles and boulders) is described in terms of compactness or relative density (e.g. ‘loose’ or ‘dense’). The strength of fine soils is described in terms of consistency (e.g. ‘soft’, ‘firm’, ‘stiff’, etc.). Equivalent quantitative scales of strength for these two groups of soils are also given in Table 7. Compactness and consistency terms cannot be applied easily to organic soils, which should be described as ‘compact’, ‘spongy’ or ‘plastic’.

The compactness terms for sands and gravels in Table 7 are based on N values measured in boreholes by the Standard Penetration Test (BS 1377; 1975), Mackintosh Probe (Terzaghi and Peck, 1967) and the JKR Probe. This scale is recommended for use only in transported soils. When used for engineering purposes, a correction factor is often applied to N values to account for overburden pressure, energy dissipation in the drill rods, and the effect of low permeability in fine sands and silty sands (Skempton, 1986). If the descriptive terms are based on corrected N values, this should be noted.

Soil Type	Descriptive Term for Compactness / Relative Density	SPT N Values (Blows / 30cm penetration)	JKR Probe (Blows / 30cm)
Sands and Gravels	Very loose Loose Medium dense Dense Very dense	0 – 4 4 – 10 10 – 30 30 – 50 > 50	< 10 10 – 30 30 – 80 80 – 110 > 110
Soil Type	**Descriptive Term for Consistency**	**Undrained Shear Strength (kPa or kN / m²)**	**JKR Probe (Blows / 30cm)**
Silts and Clays	Very soft Soft Firm Stiff Very stiff or hard	< 20 20 – 40 40 – 75 75 – 150 > 150	< 20 10 – 20 20 – 40 40 – 70 > 70

Table 7: Soil Strength in Terms of Compactness and Consistency

The consistency terms for fine soils in Table 7 are based on values of undrained shear strength. For descriptive purposes, a rapid approximate value of undrained shear strength can be obtained by using a small laboratory shear vane or hand penetrometer (Head, 1980).

The presence of mineral cement in the soil may have a significant effect on the soil strength. It appears that colluvial matrix material (Ruxton, 1987) and fine grained marine soils (Tovey, 1986; Yim and Li, 1983) can have relatively high strength and stiffness due to the presence of iron oxide, and possibly other, cementing agents. The presence of iron oxides in the soil is often indicated by a distinctive brown or reddish brown colouration. If mineral cement appears to be present, it is useful to note whether slaking occurs on immersion of a non saturated sample in water. Non cemented soils usually slake in water.

8.2.2 Colour

The Munsell Colour System is commonly used to describe the colour of soils. Alternatively, soil colour may be described according to the scheme as given in Table 8. It should be stated if the soil is wet or dry when described because it has a marked influence on the colour description.

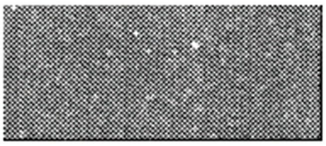
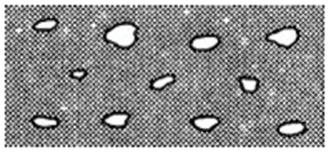
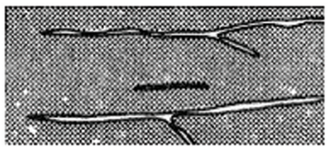
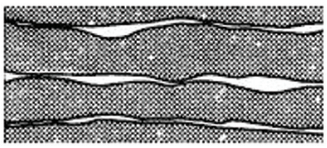
A Simplified Colour Chart is used to provide standard colour names and assist in correlation (Table 9). The chart also provides uniform and identifiable colour to others. Colour designations are optional, unless necessary for clarity, e.g. light brown (equivalent to 5YR 5/6 on the Munsell Colour System). Terms such as banded, streaked or mottled, speckled and stained may be used to further describe the colour. Also describe the colour of the bands.

Sample disturbance or remoulding may destroy some of the original soil colouring. Therefore, soil colours should be described in the undisturbed field condition whenever possible.

8.2.3 Particle Shape and Composition

Particle shape may be described by reference to the three dimensional form of the particles, their angularity (which indicates the degree of rounding at edges and corners) and their surface texture. In general, simple visual assessment of these characteristics is adequate for routine descriptions, but precise measurements may be required in some cases (e.g. assessment of granular soils as potential sources of aggregate, detailed assessment of texture and fabric, etc.).

Common terms for simple description of form and angularity are illustrated in Table 10 and Table 11 respectively. Common terms used to describe the surface texture of particles are ‘smooth’, ‘rough’, ‘glassy’, `honeycombed’, ‘pitted’ and ‘striated’.

Value	**Chroma**	**Hue**
Light	Pinkish	Pink
Dark	Reddish	Red
	Yellowish	Yellow
	Orangish	Orange
	Brownish	Brown
	Greenish	Green
	Bluish	Blue
	Purplish	Purple
	Whitish	White
	Greyish	Grey
	Blackish	Black
Colour Distribution		
Uniform	**Non uniform**	
	Spotted	
	Mottled	
	Dappled	
	Streaked	
	Striped	

Note: (1) For uniform colour distribution choose a hue and then supplement it if necessary with a value and / or chroma
(2) If the colour distribution is non-uniform, repeat this procedure for the two (or more) components of the distribution, employing the non uniform descriptor to indicate which component is dominant, e.g. light pinkish grey spotted with black.

Table 8 : Colour Description Scheme (GEO, 1988)

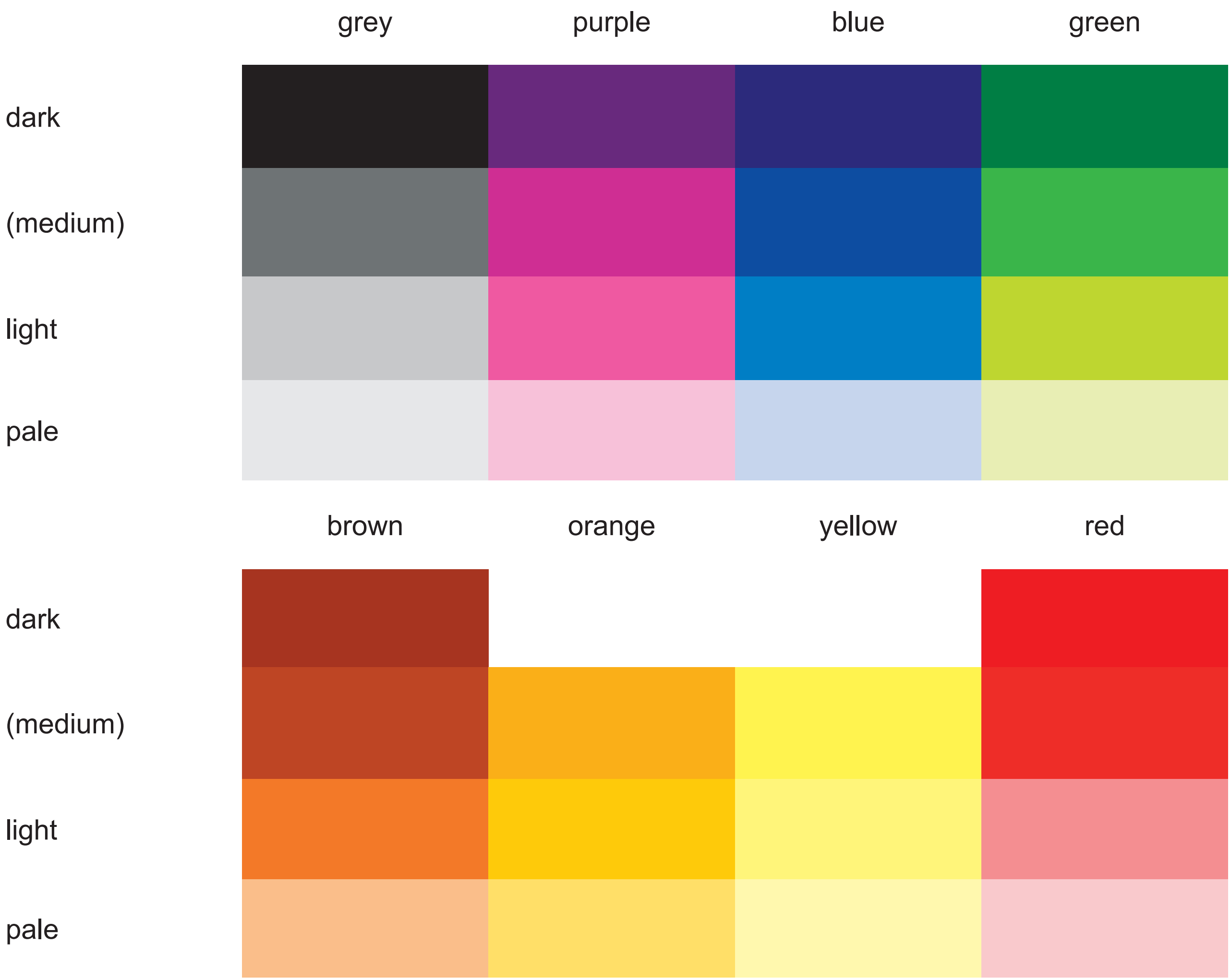


Table 9 : Simplified Colour Chart

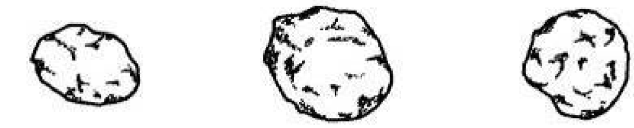
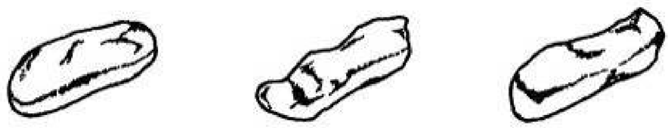
Descriptive Term	Illustration
Equidimensional	
Flat	
Elongate	
Flat and Elongate	

Table 10 : Particle Form

Descriptive Term	Illustration
Angular	
Subangular	
Subrounded	
Rounded	

Table 11 : Particle Angularity

8.2.4 Mineralogical and Lithological Composition

The composition of particles visible to the naked eye or under a hand lens may also be described. Gravel and larger particles are usually rock fragments (e.g. granite, tuff, schist). Sand and finer particles are generally individual mineral grains (e.g. quartz, mica, feldspar). Gravel and sand particles may be coated with specific minerals, such as limonite and other iron oxides, manganese or calcite. Concretions are considered as gravels and in cases in which concretions occur, the type of concretions must be indicated (e.g. iron oxide concretions, calcite concretions). Soil containing an appreciable proportion of shells or organic components may also be described as shelly (Table 12).

Shell Remains
(i) Identification of shells – bivalves, gastropods, others. *Nuculana* sp., *Anadara* sp., others. (ii) Disposition of shell – concentrated in layers or dispersed. Whether transported or in growth position. (iii) Condition and degree of morphology (e.g. surface of appearance) of shells – fragments, complete shells or in doublet form. Slightly, moderately or very worn to indicate transportation.
Detrital coral remains
(i) Disposition of corals – concentrated in layers or dispersed. Whether transported or in growth position. (ii) Condition of corals – slightly, moderately or very worn.

Table 12 : Shell Remains

8.2.5 Sorting

Sand is classified as well sorted, moderately sorted or poorly sorted. If more than two thirds of the grains are of one Wentworth size then the sand is “well sorted”; if of one to two Wentworth size grades then it is “moderately sorted”; if more than two Wentworth size grades the sand is “poorly sorted” (Table 13).

Another method of determining sorting is by reviewing the grain size distribution graph whereby sorting is the range of the distribution. The sorting or spread of the curve is measured by the coefficient of sorting (So), which is the square root of the quartiles Q3 / Q1 where Q3 > Q1 (Pettijohn, 1957). The quartiles are the size values associated with the intersection of the 25 and 75 per cent values with the cumulative curve. Perfectly sorted sediment has a coefficient of 1.0. According to Trask (1932), a So value of less than 2.5 indicates well-sorted sediment whereas a value of 3.0 is normal and a value of greater than 4.5 indicates poorly sorted sediment.

Millimetres	Microns	Wentworth Size Class	
		boulder	
256			
		cobble	GRAVEL
64			
		pebble	
4			
		granule	
2	2000		
		very coarse	
1	1000		
		coarse sand	
0.5	500		
		medium sand	SAND
0.25	250		
		fine sand	
0.125	125		
		very fine sand	
0.0625	62.5		
		coarse silt	
0.031	31		
		medium silt	SILT
0.0156	15.6		
		fine silt	
0.0078	7.8		
		very fine silt	
0.0039	3.9		
↓	↓	**CLAY**	

Table 13 : The Wentworth Size Scale

8.2.6 Structure

The important types of structure in soils are bedding in superficial deposits, and discontinuities in soils derived from in-situ rock weathering. General characteristics that should be considered in the description of bedding include the type of bedding, arrangement of the beds, and the spacing between bedding planes. Other characteristics that are relevant specifically to individual bedding planes are the orientation, surface texture, aperture, etc. Common types of bedding are illustrated in Figure 5.

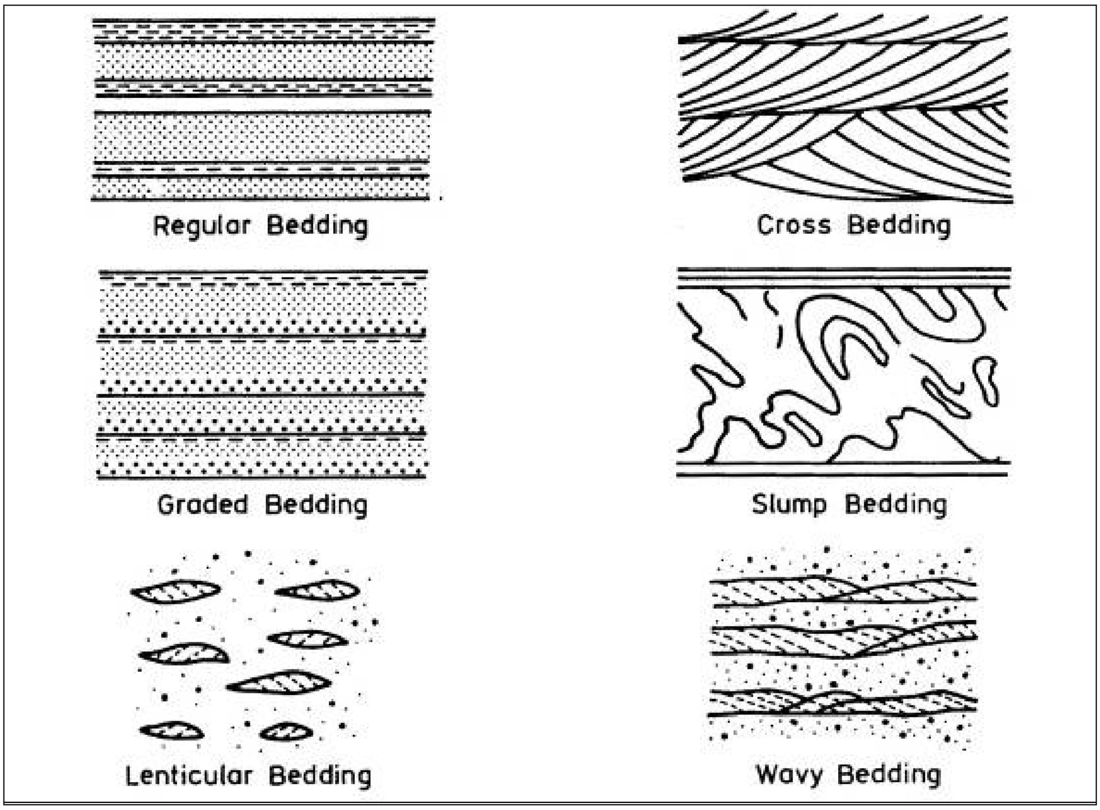


Figure 5 : Types of Bedding

The arrangement of beds may be described by reference to the degree of stratification and the spacing of the strata. Interstratified deposits are those in which there are layers of different types of material, which may be of constant thickness, or may thin out locally or occur as lenses. If beds of alternating soil types are too thin to be described individually, the soil may be described as 'interbedded' (e.g. SAND with interbedded CLAY), the first soil type mentioned being dominant or as ‘interlaminated' (e.g. thinly interlaminated SILT and CLAY). 'Partings' are bedding surfaces that separate easily, e.g. a thin layer of silt in more cohesive material. The nature of any parting material should be noted. Where two or more soil types are present in a deposit, arranged in an irregular manner, the soils may be described as intermixed, (e.g. SAND intermixed with CLAY). Thick beds which consist essentially of one soil type and show no significant variation in material can be described as 'homogeneous'.

Apart from variation in basic soil types, bedding features can also be identified by other sedimentary structures, such as shell bands and root holes. Knowledge of shell types and density within a bed may assist in stratigraphic correlations. Dominant shell types should be noted (by correct scientific name), sketched or photographed (Strange and Shaw, 1986; Wang and Yim, 1985).

Two other general structural terms commonly applied to sedimentary soils are fissured, if the soil is cracked or fragmented, and intact if no fissures are present. Fissures are most common in fine grained marine and alluvial soils, particularly where these soils have been exposed to air drying. Organic soils are commonly described as ‘fibrous’, or ‘amorphous'.

The spacing of bedding planes, fissures, shell bands and other sedimentary structures should be described using the terms given for planar structures and discontinuities as in Table 14 and Table 15 respectively.

8.2.7 Field Classification of Unconsolidated Sediments – Soil Name

In all the classifications currently being used for the description of sedimentary aggregates, the distinction of the components (gravel sand silt clay) is based entirely on particle size. The size scale most commonly used for defining the different size limits is that of Wentworth (1922) (Table 13). In the field, the distinction of the components on the basis of particle size is satisfactory in so far as only gravel or sand is concerned since gravel (particles more than 2mm in diameter) and sand (particles 62.5μm – 2mm in diameter) are visible to the naked eye. However, the same criteria cannot be used for the identification of silt (particles 3.9μm – 62.5μm in diameter) or clay (particles less than 3.9μm in diameter) as both are microscopic and are therefore not visible even with the aid of a hand lens. It is then obvious that all these classifications cannot be applied without a grain size analysis and are therefore not suitable for field usage. Furthermore, the major physical properties of silt and clay are related only indirectly to particle size and any distinction of the two based on particle size alone will not therefore be satisfactory.

It is highly desirable that silt and clay be recognized as and when they are encountered as both are included as components in all classifications of sedimentary aggregates. In addition, silt and clay possess different physical properties which must be taken into consideration in foundation engineering. Consequently, there is a need for a classification system such that silt and clay can be distinguished in the field and that the distinction of the two components be based on criteria other than particle size. The criteria in distinguishing clay from silt are given in Appendix 7.

The components which make up the present classification are the inorganic and the organic components. The inorganic components are gravel, sand, silt and clay. Organic components comprising plant, shell and detrital coral remains are included in the classification as these are commonly found associated with the unconsolidated sediments. Although not all organic components generally form deposits of regional extent, they are very often of local significance.

A sedimentary aggregate is classified by the type and the respective proportion of each of the components. The procedure is as follows:

(i) Determine if organic components predominate over inorganic components. If this is the case, then the sample will be referred to as peat, shell or coral depending on whether the organic component present is plant, shell or detrital coral remains.

(ii) If inorganic components dominate the sample, determine the amount (area percent) of gravel particles. A sample containing 50% or more of particle size greater than 2mm is referred to as gravel. If the sample contains less than 50% gravel the next step is to determine whether sand or fines predominate in the remaining portion of the sample. If sand is predominant, then the term sand is applied to the sample. However, if fines predominate, the sample is referred to as either silt or clay depending on the physical properties of the fines.

(iii) Having assigned a name to the sample, then it is necessary to determine the type and proportions of the subordinate components present. The nomenclature and class boundaries of the different proportions are summarized in Table 16.

Descriptive Term	Spacing
Very thick	> 2m
Thick	600mm - 2m
Medium	200mm - 600mm
Thin	60mm - 200mm
Very thin	20mm - 60mm
Thickly-laminated (sedimentary) Narrow (metamorphic and igneous) Thinly-laminated (sedimentary)	6mm - 20mm
Very narrow (metamorphic and igneous)	< 6mm

Table 14 : Spacing of Planar Structures

Descriptive Term	Spacing
Extremely widely-spaced	> 6m
Very widely-spaced	2m - 6m
Widely-spaced	600mm - 2m
Medium-spaced	200mm - 600mm
Closely-spaced	60mm - 200mm
Very closely-spaced	20mm - 60mm
Extremely closely-spaced	< 20mm

Table 15 : Discontinuity Spacing

<table>
<tr><th colspan="8">First remove material coarser than 60mm and record as cobbles (60mm to 200mm) or boulders (over 200mm)</th></tr>
<tr><th colspan="2" rowspan="2">Soil group
(See notes 1 & 2)</th><th colspan="5">Sub – group and laboratory identification</th><th rowspan="2">Field identification</th></tr>
<tr><th>Description</th><th>Group symbol
(See note 3)</th><th>Sub-group symbol</th><th>Fines
(% less than 0.06 mm)</th><th>Sub-group name</th></tr>
<tr><td rowspan="6">COARSE: INORGANIC SOILS
Less than 35% finer than 0.06 mm</td><td rowspan="3">GRAVELS
More than 50% of coarse material is of gravel size (coarser than 2 mm)</td><td>Slightly silty or clayey GRAVEL</td><td>G GW
GP</td><td>GW
GP GPu
GPg</td><td>0 – 5</td><td>Well graded GRAVEL
Poorly / uniformly / gap graded GRAVEL</td><td>Particles easily visible to naked eye. Particle shape and grading can be described.</td></tr>
<tr><td>Silty GRAVEL
Clayey GRAVEL</td><td>GF GM
GC</td><td>GWM GPM
GWC GPC</td><td>5 – 15</td><td>Well/poorly graded silty (clayey) GRAVEL</td><td rowspan="2">Particles easily visible to naked eye. Particle shape and grading can be described. A medium to high dry strength indicates that some clay is present. A negligible dry strength indicates the absence of clay.</td></tr>
<tr><td>Very silty GRAVEL
Very clayey GRAVEL</td><td>GF GM
GC</td><td>GM
GCL
GCI
GCH
GCV
GCE</td><td>15 – 35</td><td>Very silty GRAVEL sub-divide like GC Very Clayey GRAVEL (clay of low/intermediate / high / very high / extremely high plasticity)</td></tr>
<tr><td rowspan="3">SANDS
More than 50% of coarse material is of sand size (finer than 2mm)</td><td>Slightly silty or clayey SAND</td><td>S SW
SP</td><td>SW
SP SPu
SPg</td><td>0 – 5</td><td>Well graded SAND Poorly / uniformly / gap graded SAND</td><td rowspan="3">Majority of the particles visible to naked eye. Feels gritty when rubbed between the fingers.
A medium to high dry strength indicates that some clay is present. A negligible dry strength indicates the absence of clay.</td></tr>
<tr><td>Silty SAND
Clayey SAND</td><td>S-F S-M
S-C</td><td>SWM
SPM
SWC SPC</td><td>5 – 15</td><td>Well / poorly graded silty (clayey) SAND</td></tr>
<tr><td>Very silty SAND
Very clayey SAND</td><td>SF SM
SC</td><td>SM
SCL
SCI
SCH
SCV
SCE</td><td>15 – 35</td><td>Very silty SAND sub-divide like SC Very Clayey SAND (clay of low / intermediate / high / very high / extremely high plasticity)</td></tr>
</table>

Table 16 : Malaysian Soil Classification System for Engineering Purpose and Field Identification

Soil groups (See notes 1)		Sub – group and laboratory identification					Field identification
		Description	Group symbol (See note 3 & 4)	Sub-group symbol	Liquid limit %	Sub-group name	
FINE INORGANIC SOILS More than 35% finer than 0.06mm	Gravelly or sandy SILTS AND CLAYS 35% – 65% fines	Gravelly SILT Gravelly CLAY (see note 5)	MG FG CG	MG CLG CIG CHG CVG CEC	 <35 35-50 50-70 70-90 >90	Gravelly SILT (sub-divide like CG) Gravelly CLAY of low plasticity Gravelly CLAY of intermediate plasticity Gravelly CLAY of high plasticity Gravelly CLAY of very high plasticity Gravelly CLAY of extremely high plasticity	Coarse particle visible to naked eye. Silt fraction dries moderately quickly and can be dusted off the fingers. Clay fraction can be rolled into threads when moist; smooth to touch and plastic; sticks to fingers and dries slowly.
		Sandy SILT Sandy CLAY (See note 5)	MS FS CS	MS CLS etc		Sandy SILT Sandy CLAY : sub-divide like CG	Sandy silts and sandy clays feel gritty when rubbed between the fingers. Silts and sandy silts dry quickly and can be dusted off the fingers; exhibit marked dilatancy. Dry lumps have some cohesion but can be powdered easily in the fingers.
	SILTS and CLAYS 65% - 100% fines	SILT (M-SOIL) CLAY (See notes 6&7)	M F C	M CL CI CH CV CE	 <35 35-50 50-70 70-90 >90	SILT sub-divide like C CLAY of low plasticity CLAY of intermediate plasticity CLAY of high plasticity CLAY of very high plasticity CLAY of extremely high plasticity	Clays, silty clays, sandy clays are plastic and can be readily rolled into threads when moist. Dry lumps can be broken but not powdered but they disintegrate under water. They stick to fingers and dry slowly. Clays feel smooth to touch.

Table 16 (continued)

Soil groups (See notes 1)		Sub – group and laboratory identification						Field identification
		Description	Group symbol	Sub-group symbol	Liquid limit %	Degree of Humification	Sub-group name	
ORGANIC SOILS and PEATS	SLIGHTLY ORGANIC SOILS Organic content 3% - 20%	Slightly Organic SILT Slightly Organic CLAY	Mo Fo Co	Mo CLo CIo CHo CVo CEo	 <35 35-50 50-70 70-90 >90		Slightly Organic SILT (Sub-divide like Co) Slightly Organic CLAY of low plasticity Slightly Organic CLAY of intermediate plasticity Slightly Organic CLAY of high plasticity Slightly Organic CLAY of very high plasticity Slightly Organic CLAY of extremely high plasticity	Usually very dark to black in colour, small amount of organic matter may be visible. Often has distinctive organic smell.
	ORGANIC SOILS Organic Content 20%-75%	ORGANIC SOIL	0				Subdivision of Organic Soils is difficult, as neither the plasticity test nor the humification tests are reliable for them. As such a "best attempt" is the probable outcome of subdivision leading to descriptions such as "Fibrous ORGANIC SOIL" or "Amorphous ORGANIC SOIL of Intermediate Plasticity".	
	PEATS Organic Content more than 75%	PEAT	Pt	Ptf Pth Pta		H1-H3 H4-H6 H7-H10	Fibric or Fibrous Peat Hemic or Moderately Decomposed Peat Sapric or Amorphous Peat	Dark brown to black in color. Material has low density so seems light. Majority of mass is organic so if fibrous the whole mass will be recognizable plant remains. More likely to smell strongly if highly humified.

NOTES

NOTE 1. The name of the soil group should always be given when describing soils, supplemented, if required, by the group symbol, although for some additional applications (e.g. longitudinal sections) it may be convenient to use the group symbol alone.

NOTE 2. Gravel and Sand my be qualified as Sandy GRAVEL and Gravelly SAND where appropriate.

NOTE 3. The group symbol or sub-group symbol should be placed in brackets if laboratory methods have not been used for identification. e.g.(GC).

NOTE 4. The designation FINE SOIL or FINES, F, may be used in place of SILT, M, or CLAY, C, when it is not possible or not required to distinguish between them.

NOTE 5. GRAVELLY if more than 50% of coarse material is of gravel size. SANDY if more than 50% of coarse material is of sand size.

NOTE 6. SILT, M, is material plotting below the A-line on the plasticity chart and has a restricted plastic range in relation to its liquid limit, and relatively low cohesion. Slightly organic soils also usually plot below the A-line on the plasticity chart, when they are designated SLIGHTLY ORGANIC SILT, Mo.

NOTE 7. CLAY, C, is material plotting above the A-line on the plasticity chart, and is fully plastic in relation to its liquid limit.

Table 16 (continued)

8.2.8 Discontinuities

Soil discontinuities are individual bedding planes, lamination planes and fissures in transported soils such as alluvium. Faults and shear planes may also occur in the transported soils but generally much less common.

If a full description of discontinuities in a soil mass is required, the same procedures and terms given for rock discontinuity description should be used. However, with regard to strength, deformation, permeability and other engineering characteristics, the influence of discontinuities on mass behaviour is generally much less marked in a soil mass than in a rock mass. Therefore, a full description of soil discontinuities may only be required in particular circumstances (e.g. discontinuities which influence slope instability). Descriptions of discontinuities include the following:

(i) Location and Orientation

It is important to record the location of each individual discontinuity described. This is often stated as the relative position along a fixed datum line, or ground co ordinates plus elevation in an exposure. Information should preferably be recorded on a map or plan.

The orientation of a discontinuity is described by the dip direction, the compass bearing of the maximum inclination measured clockwise from true north, and by the dip, the maximum inclination of the discontinuity measured from horizontal. Dip directions and dips are normally measured with a compass and clinometer, and should be expressed to the nearest degree. In order to differentiate clearly between dip direction and dip, the dip direction value should always be given with three digits and the dip with two digits (e.g. dip direction/dip 025/60).

(ii) Spacing

Recommended terms for the description of discontinuity spacing are given in Table 15. They may be used to describe the spacing of discontinuities in a single set or for the average spacing of all discontinuities measured along a traverse line.

(iii) Persistence

Persistence refers to the areal extent or size of a discontinuity within a plane. It is one of the most important items in discontinuity description; unfortunately, however, it is difficult to quantify accurately because it is rarely possible to see the three-dimensional extent of a discontinuity. For most practical purposes, persistence can only be assessed very approximately by measuring the discontinuity trace length on the surfaces. A discontinuity set often tends to have a characteristic range of persistence which differs from that of other sets within the same study site.

For the description of individual discontinuities, it is recommended that the measured maximum persistence dimension should always be used where possible. The description should also state whether the discontinuity extends outside the exposure, or terminates against other discontinuities. In the case of general descriptions of different discontinuity sets, relative terms should be used. For example, in a study site with three discontinuity sets, the most persistent set could be described as ‘persistent’, the intermediate set as ‘sub-persistent' and the least persistent set as ‘non - persistent'.

(iv) Roughness

The roughness of a discontinuity is made up of two components: large scale waviness, and small scale unevenness (Table 17). Waviness refers to undulations of the surface of the discontinuity over distances of typically tens of metres. Unevenness refers to the bumps, asperities and small ridges on the surface of the discontinuity over distances of typically one centimetre to a few metres. Other general terms which are used quite commonly are ‘first-order’ roughness for waviness and ‘second-order’, roughness for the smaller scale superimposed unevenness.

Roughness may be measured quantitatively by using linear profiling, a compass and disc clinometer or a photogrammetric method. A clear introduction to these three methods has been given by ISRM (1978). The most commonly used is the compass and disc clinometer, which involves measuring discontinuity dip direction and dip angles on a series of circular plates of different diameter (GEO, 1987). The results are usually presented and analysed stereographically.

For general descriptive purposes, waviness should be assessed by estimating dimensions of wave length and wave amplitude. These could be single values for a single discontinuity or characteristic values for a discontinuity set. Unevenness should be described using two terms, the first referring to lengths of several centimetres and the second to lengths of up to several metres. Nine classes of unevenness are formed by combinations of these two terms, as illustrated and defined in Table 17. The term slickenside, should only be used if there is clear evidence of previous shear displacement along the discontinuity such as striations in the direction of inferred movement.

(v) Aperture

Aperture is the perpendicular distance between adjacent walls of an open discontinuity, in which the intervening space is filled by air or water. It should be distinguished from the width of an unfilled discontinuity. Apertures are caused by a number of factors, such as tensile opening, washing out of infilling materials, solution or shear displacement of discontinuities with significant roughness. Description of aperture size is important because it has a marked effect on the shear strength and hydraulic conductivity of a discontinuity.

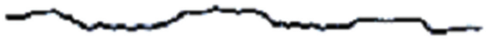
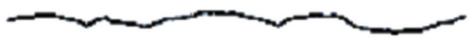
Aperture size should be described using the terms given in Table 18. If the discontinuity is closed, with zero aperture, it should be described as 'tight'. The use of these terms may not provide a reliable indication of the hydraulic properties of discontinuities, particularly where the discontinuities have been disturbed by surface weathering.

(vi) Infilling

Infilling is the term for the material that separates the adjacent walls of a discontinuity. This term is preferred to filling, which is normally used to describe the placement of fill materials. It should be noted, however, that not all infill materials are necessarily transported into the discontinuity at a later stage; some can form in-situ, e.g. by the action of intense weathering along a discontinuity.

(vii) Seepage

Seepage along discontinuities is often of great engineering importance and deserves very careful assessment. Seepage aspects of unfilled discontinuities should be described using one of three basic terms, that is dry, damp / wet (but with no free water) and seepage present. For the last category, the quantity of water flowing at the point of observation should be noted in litres / second or litres / minute either by estimation or approximate measurement. Unless the study site is completely dry, it is often difficult to select characteristic values of seepage for discontinuity sets, in which case supplementary description of seepage variability within the mass should be given. The date of observation should always be noted when seepage is described, so that the seepage amount can be related to the wet and dry seasons. If possible, subsequent observations should be made during the wet and dry season in order to give an indication of maximum and minimum seepages.

Class	First Term	Second Term	Illustration
1	Rough	Stepped	
2	Smooth	Stepped	
3	Slickensided	Stepped	
4	Rough	Undulating	
5	Smooth	Undulating	
6	Slickensided	Undulating	
7	Rough	Planar	
8	Smooth	Planar	
9	Slickensided	Planar	

Notes *(1) Length of the illustrated profiles is in the range 1 to 10 meters*
(2) Vertical and horizontal scales are equal

Table 17 : Unevenness (Small-Scale Roughness) of Discontinuities

Descriptive Term	Aperture Distance Between Discontinuity Walls (mm)
Wide	> 200
Moderately wide	60 – 200
Moderately narrow	20 – 60
Narrow	6 – 20
Very Narrow	2 – 6
Extremely narrow	< 2
Tight	Zero

Table 18 : Aperture Size (GEO, 1988)

8.2.9 State of Weathering

A clear distinction must be made between the weathering of surficial deposits (i.e. transported soils) and the weathering of rocks in situ which has led to the formation of engineering soils.

It is highly likely that the transported soils are generally much younger than the soils derived from in-situ rock weathering (Bennett, 1984). Also, the transported soils, unlike the igneous and pyroclastic rocks, have not formed under conditions of high temperature and pressure, which means that their susceptibility to weathering processes in general is much lower. Therefore, the degree and extent of weathering in the transported soils is generally much less marked than in the thick zones of intensely weathered rock. Nevertheless, the changes brought about by weathering can still have a significant effect on the engineering properties of transported soils.

The occurrence of weathered transported soils is generally limited to the older colluvial and alluvial deposits. Most of the marine deposits show no obvious signs of weathering, but some weathered marine soils can be found in areas where they have been exposed previously during periods of lower sea level.

In fine soils, where individual mineral and rock fragments cannot be identified by eye, the most distinctive aspect of weathering is discolouration caused by decomposition of the soil particles and precipitation of various oxides. Discolouration is most noticeable in alluvial sediments. A non uniform colour distribution (Table 9), often comprising mottled yellow, red and brown colours, can be a distinctive feature in these soils (Shaw et al., 1986). In offshore sedimentary sequences, there is often a marked contrast between mottled, weathered alluvial sediments and the overlying unweathered marine muds.

In coarse soils, or composite soils containing coarse fragments, the weathered state of individual gravel and larger sized rock fragments can also be described, in addition to discolouration of the whole soil.

Common weathering features are decomposition of individual mineral grains or whole rock fragments, and cracking or disintegration, which may show up as concentric layering approximately parallel to the fragment boundary.

Weathering features in soils may be destroyed by sample disturbance or remoulding. These features should therefore be described in the field whenever possible; alternatively, the highest quality undisturbed sample should be used.

8.2.10 Additional Geological Information

It is often difficult to make a full description of the mass characteristics of soils because of sample disturbance or inadequate sample size. Even in a field exposure, very careful and detailed inspection may be necessary for accurate identification of structural features. Additional information should be added to the description if the sample is not considered to be representative of the soil mass, or if it shows signs of significant disturbance.

One other group of features which should always be described if present in the soil is voids. The most important types of void are pipes and tunnels caused by subsurface erosion, but other features such as animal burrows and root holes should also be noted if they are likely to have a significant effect on the mass properties of the soil. The geometry and seepage aspects of void should be recorded where possible.

The microstructure in a soil can be important for engineering purposes, e.g. soils with pronounced small scale fabrics, such as very thin laminations in marine clays, etc. Partial assessment of these features by eye may be possible, depending on their spacing and continuity, but, if the soil microfabric is of particular importance to an engineering project, the use of a microscope is recommended. A general introduction to the study of soil microfabric, using optical microscopy, electron microscopy and x-ray diffraction techniques, is given by Tovey (1986).

8.3 Extended Malaysian Soil Classification System

The soil classification system presently in use in Malaysia is the British Soil Classification System (BS 5930:1999). This suggested development of that system, which amplifies the coverage of peat and organic soils, does not change it all for inorganic soils. Rather, based on the organic content, it more precisely defines organic soil and peat and gives limits to when inorganic soil classes should be described as slightly organic. The symbol for the added descriptor slightly organic is changed from ‘O’ in the British Classification to ‘o’ to allow use of the symbol ‘O’ for the organic soil class. To use this system the organic content must be measured and if the soil is a peat then the Degree of Humification is estimated. Malaysian Soil Classification System is outlined in Table 16.

9.0 LABORATORY TESTS

Disturbed and undisturbed samples collected in the field are to be sent to the Engineering Geology Laboratory and Geochemistry Laboratory in JMG for tests to determine the physical, chemical and engineering characteristics of the peat, organic soils and soft soils. Likewise, groundwater and surface water have to be also analysed (Table 19). Some of the tests which could not be carried out in-house would have to be sent to private laboratories.

The type of tests to be carried out depends on the judgement of the investigating officer bearing in mind the objectives of the investigation. For example, the amount of carbonaceous material which is determined by the Loss on Ignition (LOI) Test is carried out in peat and organic soils, but it may be also carried out in soft soils if there are minor amounts of the material (3 - 20%).

A list of the laboratory tests which need to be carried out is shown in Appendix 8. However, this list is by no means exhaustive and the investigating officer may include other tests mentioned in this guideline as and when necessary.

9.1 Chemical Tests for Water Samples

9.1.1 Inorganics

Some of the inorganic parameters to be analysed in the laboratory include Total Dissolved Solids (TDS), Total Solids (TS), Chloride (Cl), Anionic Detergent (MBAS), Ammonium Nitrogen (NH_3-N), Fluoride (F), Carbonate (CO_3), Hydrogen Carbonate (HCO_3), Total Hardness ($CaCo_3$), Sodium (Na), Calcium (Ca), Potassium (K), and Aluminium (Al). These tests can be carried out in the JMG Geochemistry Laboratory except for Anionic Detergent (MBAS) and Ammonium Nitrogen (NH_3-N).

9.1.2 Heavy Metals and Others

The heavy metals to be analysed include Magnesium (Mg), Mercury (Hg), Cadmium (Cd), Selenium (Se), Arsenic (As), Silver (Ag), Copper (Cu), Zinc (Zn), Sulphate (SO_4), Silica (SiO_2), Phosphorus (P), Lead (Pb), Chromium (Cr) and Cyanide (CN). Those tests can be carried out in the JMG Geochemistry Laboratory.

9.1.3 Synthetic Organic Chemicals

Synthetic organic chemicals include chloroform and phenol. Those chemicals cannot be analysed in the JMG Geochemistry Laboratory and have to be sent to some private laboratories.

9.1.4 Petroleum Products / Oil and Grease

Oil and grease and Total Petroleum Hydrocarbon (TPH) have to be analysed in some private laboratories.

9.1.5 Volatile Organic and Semi-volatile Components

Volatile organic compounds include chemicals like trichlorobenzene, benzene vinyl chloride etc and semi-volatile organic compounds have to be analysed in some private laboratories.

9.1.6 Biocides

Biocides include organochlorine pesticides and organophosphorus pesticides and have to be analysed in some private laboratories.

9.1.7 Organics

Organics like Total Coliform Bacteria and E-Coli (*Escherichia Coli*) have to be analysed in some private laboratories.

Category	Parameters to be Analysed	Test Location
Group I (Physical)	Temperature	In-situ / On-site
	Turbidity	In-situ / On-site
	Colour	In-situ / On-site
	pH	In-situ / On-site
	Conductivity	In-situ / On-site
Group II (Inorganic)	Dissolved Oxygen (DO)	In-situ
	Biochemical Oxygen Demand (BOD)	On-site
	Chemical Oxygen Demand (COD)	On-site
	Manganese (Mn)	On-site
	Iron (Fe)	On-site
	Total Iron (Fe-T)	On-site
	Nitrate Nitrogen (NO_3-N)	On-site
	Nitrite Nitrogen (NO_2-N)	On-site
	Total Dissolved Solids (TDS)	Laboratory
	Total Solids (TS)	Laboratory
	Chloride (Cl)	Laboratory
	Anionic Detergent (MBAS)	Laboratory
	Ammoniacal Nitrogen (NH_3-N)	Laboratory
	Fluoride (F)	Laboratory
	Carbonate (CO_3)	Laboratory
	Hydrogen Carbonate (HCO_3)	Laboratory
	Total Hardness ($CaCO_3$)	Laboratory
	Sodium (Na)	Laboratory
	Calcium (Ca)	Laboratory
	Potassium (K)	Laboratory
Group III (Heavy metals and others)	Aluminium (Al)	Laboratory
	Magnesium (Mg)	Laboratory
	Mercury (Hg)	Laboratory
	Cadmium (Cd)	Laboratory
	Selenium (Se)	Laboratory
	Arsenic (As)	Laboratory
	Cyanide (CN)	Laboratory
	Lead (Pb)	Laboratory
	Chromium (Cr)	Laboratory
	Silver (Ag)	Laboratory
	Copper (Cu)	Laboratory
	Zinc (Zn)	Laboratory
	Sulphate (SO_4)	Laboratory
	Silica (SiO_2)	Laboratory
	Phosphorus (P)	Laboratory

Table 19 : List of Parameters for Groundwater and Surface Water Quality Analysis

Group IV (Biocides and others)	Organochlorine Pesticides	Laboratory
	Organophosphorus Pesticides	Laboratory
	BTEX	Laboratory
Group V (Organic)	Total Coliform Bacteria	Laboratory
	E. Coli (*Escherichia Coli*)	Laboratory
Group VI (Volatile and Semi-volatile organic)	VOC (Volatile Organic Components)	Laboratory
	SVOC (Semi – Volatile Organic Components)	Laboratory
Group VII Petroleum products / oil and grease	Oil and Grease Total Petroleum Hydrocarbon (TPH)	Laboratory
	Total Petroleum Hydrocarbon (TPH)	Laboratory
Group VIII Synthetic Organic Chemicals	Chloroform	Laboratory
	Phenol	Laboratory

Table 19: List of Parameters for Groundwater and Surface Water Quality Analysis (Continued)

9.2 Tests on Disturbed and Undisturbed Soil / Peat Samples

Described below are tests which are commonly carried out on disturbed and undisturbed soil samples, inclusive of peat.

9.2.1 Mineral Composition

The major mineral compositions of the estuarine / deltaic soft sediments or organic soil are determined. The composition may be quartz, feldspar and clays like kaolin, illite, vermiculite, chlorite or montmorillonite in varying amounts.

9.2.2 Chemical Composition

The chemical compositions of the estuarine / deltaic soft sediments or organic soils are determined. The compositions to be analyzed include SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O and Loss on Ignition (LOI).

9.2.3 Chemical Properties

The chemical properties of peat to be analyzed include pH, N, C, S, ash, volatile matter, gross calorific value and net calorific value.

9.2.4 Natural Moisture Content

The moisture content of a sample is the ratio of the weight of water present in the sample to the oven-dry (105°C – 110°C) weight of the solid particles. The natural moisture content serves as one of the most useful index properties of fine-grained sediments since it influences the strength and consolidation, and may indicate the need for special drainage during construction.

The peat deposits are usually waterlogged and have high water content. The moisture content, expressed as percentage of dry weight, may range from 260% to 1600%. The sediments above the water table have much lower moisture content than those underlain by peat. The moisture content of the estuarine / deltaic sediments usually range from about 40% to 95%.

9.2.5 Density

The bulk or wet density of a soil is the weight of that soil per unit volume. It is determined on soils in their natural state and includes the effect of voids, whether filled with air or water. The dry density is the weight of the dry materials contained in the unit volume of moist materials after drying to a constant weight at a temperature of 105°C – 110°C. The bulk density is one of the important physical properties of a soil. It is required for computing earth pressure or overburden pressure.

Peat has a low bulk and dry density. The bulk and dry densities generally increase with depth due to compaction and presence of elastic sediments.

9.2.6 Atterberg Limits

Atterberg limits of cohesive soils are founded on the concept that they can exist in any of four states depending on their water content. These limits are also influenced by the amount and character of the clay mineral content. In other words, a cohesive soil is solid when dry but as water is added, it first turns to a semi solid, then to a plastic, and then finally to a liquid state. The water content at the boundaries between these states are referred to as the shrinkage limit (SL), the plastic limit (PL) and the liquid limit (LL) respectively. The difference in moisture content between PL and LL defines the range over which the material is plastic and is called the plasticity index (PI). The plasticity index has been divided into five classes which are as follows:

Class	Plasticity Index (%)	Description
1	< 1	Non-plastic
2	1 - 7	Slightly plastic
3	7 - 17	Moderately plastic
4	7 - 35	Highly plastic
5	> 35	Extremely plastic

The liquid limit and the plasticity index together constitute a measure of the plasticity of a soil. Soils possessing large values of LL and PI are classified to be highly plastic or fat. Those with low values are slightly plastic or lean. The interpretation of liquid and plastic limit tests is greatly facilitated by the use of the plasticity chart developed by Casagrande, 1932 (Figure 6).

The relation of moisture content (W) to liquid limit (LL) and plastic limit (PL) is a useful index property. Those sediments having moisture content close to their liquid limit are usually much softer than those with moisture content close to the plastic limit.

The consistency index (CI) is the ratio of the difference between the liquid limit and natural moisture content to the plasticity index.

$$CI = \frac{LL - W}{PI}$$

Consistency index can be used to classify the different types of cohesive soils.

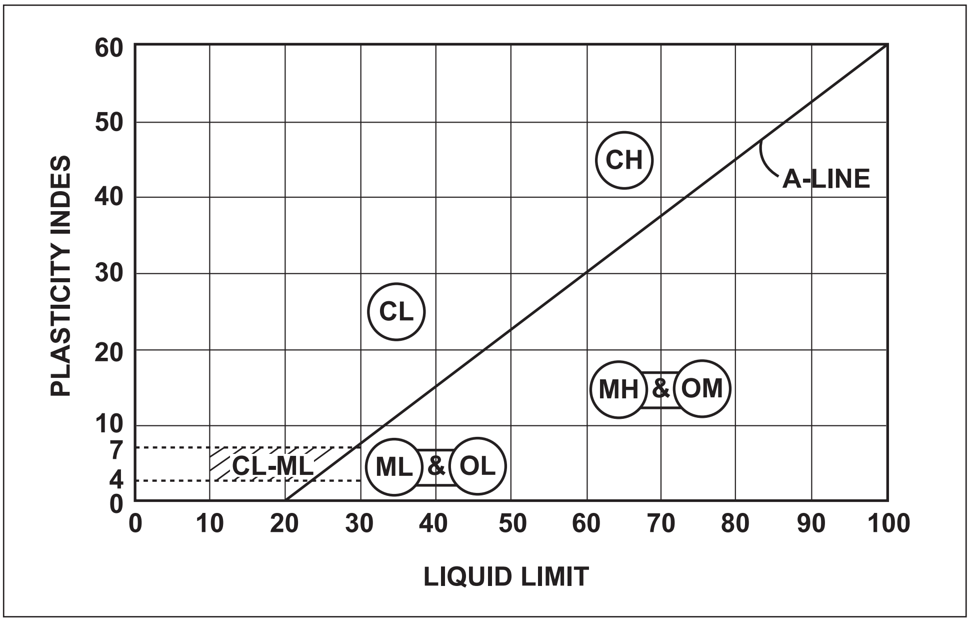


Figure 6 : Chart A-line

9.2.7 Specific Gravity

The specific gravity (G) of solid constituents is defined as:

$$G = Y_S / Y_W$$

Where Y_S = Unit weight of solid constituent

Y_W = Unit weight of water (1g / cc)

9.2.8 Organic Matter Content

The amount of organic matter in a soil has a strong influence on its index properties such as moisture content, density, plasticity and others. Hence it affects the engineering behaviour of a soil and is therefore, useful for engineering works as well as the ceramic industry.

9.2.9 Sulphate Content

The sulphate content of soil is an important parameter because excessive sulphate will attack concrete structures and cause deterioration of foundation concrete. In general, water or soil containing more than 0.1% sulphates is likely to attack concrete (Terzaghi and Peck, 1948). Therefore, sulphate content of soil should be determined even if there is no reason to suspect the presence of this substance because contamination may take place at some later date. The test results can serve as a documentary proof of the sulphate content at the time of construction. If sulphates are high in the soil, the designer should specify sulphate-resistant cement for concreting of foundation structures.

9.2.10 pH Value

The pH value needs to be measured for soil and water sample.It is important parameter in engineering designing especially for foundation concrete because acidic water attacks Portland cement concrete aggressively by dissolution of calcium hydroxide and calcium carbonate.

9.2.11 Grain Size Analysis

Grain size analysis is carried out for sand and gravels to check the field classification. When more than 5% fines are present, the wet sieving method is used. Otherwise, the dry sieving method is applied.

9.2.12 Firing Tests

Firing tests are conducted on clay to determine their physical properties when fired at temperatures of 1000°C, 1100°C, 1200°C and 1250°C. Parameters on drying shrinkage, modulus of rupture, water absorption, fired shrinkage and fired colour are obtained.

9.2.13 Pollen Analyses

Pollen analyses is carried out on peat and soft soil samples which may give an indication of the paleo-environment.

9.2.14 Radiocarbon Dating

Radiocarbon dating is carried out to determine the age of the sediments. The amount of samples collected should be sufficient and the recommended amount is 8-10gm for charcoal, 15-20gm for wood, 15-25gm for peat and 40-50gm for shells. The samples should be packed properly and tightly for shipment to a competent laboratory to conduct this test.

9.2.15 Permeability

Permeability tests are conducted on undisturbed samples to determine the ease in which groundwater permeates through the pores.

9.2.16 Consolidation

Consolidation tests are conducted on undisturbed clay samples to determine the rate of subsidence of an area when there is loading over it.

9.2.17 Triaxial Tests

Triaxial tests are conducted on undisturbed samples to determine their shear strengths. The shear strength is an important parameter in the design of stable slopes and cuttings.

9.2.18 Botanic Composition

This test carried out mainly to estimate the forms of plants from which the peat is composed.

9.2.19 Fibre Content

This is an estimate of the volumetric content of the material that is recognizably fibrous in nature but not woody. The test is based on ASTM D1997-91(2001).

9.2.20 Acidity

The acidity of a peat is carried out based on ASTM D2976-71 (1998).

9.2.21 Absorbency

The absorbency of a peat is carried out based on ASTM D2980-71 (1996).

9.2.22 Ash content

The ash content of peat after firing is determined based on ASTM D2974-87 (1994).

10.0 RESULTS

10.1 Figures and Thematic Map

The results of the investigation should come up with data, figures and thematic maps which are useful and comply with the objectives. However, the list is by no means exhaustive. In addition, a report should be compiled. The following figures and thematic maps should be produced;

10.1.1 Figures

i) Location map
ii) Geological map
iii) Location map for boreholes, geophysical lines, sampling points etc.
iv) Remote sensing interpretation
v) Variation of Cone Resistance (Dutch Cone Penetration Tests) against depth of ground profile.
vi) Variation of Local Friction (Dutch Cone Penetration Tests) against depth of ground profile.
vii) Variation of number of blows per foot from JKR / Mackintosh Probes / SPT against depth of ground profile.
viii) Variation of shear strength against depth of ground profile.
ix) Cross sections of lithology profile from borehole logs.

10.1.2 Thematic Maps

i) Thicknesses of peat or soft soil map
ii) Isopach map of Cone Resistance (Dutch Cone Penetration Tests)
iii) Isopach map of Local Friction (Dutch Cone Penetration Tests)
iv) Isopach map of shear strengths
v) Isopach map of JKR / Mackintosh Probe results
vi) Isopach map of ground settlement rates / compressibility
vii) Ground water level contour map
viii) Geohazard map

10.2 Report Writing

This report should present results of the investigation, highlight the geological constraints which may be encountered and also provide recommendations on the development potential of the area. The report may contain the following list of contents to be presented or discussed, but the author is encouraged to exercise his own discretion in either leaving out or adding certain contents. A typical template for the report is shown in Appendix 9. General instructions on the report writing are shown in Appendix 10. Generally, the contents to be included in the report are as follows:

10.2.1 Executive Summary

Present a brief account of the objectives and scope of study, the findings of the project, and recommendations.

10.2.2 Introduction

Explain the purpose for conducting the investigation and when it was carried out and completed.

10.2.3 Objectives

Explain the objectives of the investigation.

10.2.4 Physiography

a) Write briefly on the location, accessibility, size of the project area and its location with respect to well-documented landmarks.
b) Write a short paragraph on the main access and other secondary access routes within the study area.
c) Write on the topography and relief.
d) Discuss on the drainage system and surface hydrology.

10.2.5 Geology

Give a brief account of the various rock types present. Discuss on the weathering profile and the characteristics of the soil.

10.2.6 Previous Investigations

Write briefly on work, such as geological or engineering geological investigations conducted previously in the project area or in nearby areas.

10.2.7 Scope of Study / Methodology

Present facts on the processes involved such as desktop studies, field investigations, analysis and preparation of maps.

10.2.8 Results

Write on the outcome of the investigation on the peat and soft soils detailing their characteristics and the various types of thematic maps.

10.2.9 Geotechnical Considerations

Write on geotechnical constraints as imposed by the various geomorphological and geological factors pertaining to peat and soft soils.

10.2.10 Geohazards

Write on the severity of ground settlement, flooding, combustion of peat and discuss their risks.

10.2.11 Recommendations

Present ideas on how the area should be utilised for development and highlight mitigation measures to reduce geohazard risks.

10.2.12 Conclusion

State whether the objectives of the investigation have been met. Present ideas on how the area should be utilised for development and highlight mitigation measures to reduce geohazard risks.

10.2.13 References

State the books or articles referred to in the report.

10.2.14 Appendices

The appendices should contain information or data which do not fit into the main text or related investigations in the area which are of interest to the readers.

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APPENDIX 1

Description of JKR Probe and Mackintosh Probe

1.1 DESCRIPTION OF APPARATUS

The JKR probe has been developed based on the principles outlined by Hvorslev (1948) for drive rods for sounding and sampling and the recommended methods for static and dynamic sounding by the European Group Subcommittee (1968). The probe consists of a cased harden steel pointer of 25mm diameter and 60° cone. The pointer is screwed onto the lower end of the rod. The rods are of 12mm diameter HY55 steel each of length 120cm. The rods are connected to each other by 22mm outer diameter coupling. These couplings provide the lateral support to the rods so as to prevent buckling during driving. The rods are threaded at the ends after it has been built up to 14mm by welding. Heating of the rod before welding is necessary to ensure that brittle failure due to welding stresses does not occur. Driving is executed with a small hammer of 5kg in weight and falling through a fixed height of 28cm along a guide rod. In operations, the total number of blows required for the pointer to penetrate a distance of 30cm (1ft) is recorded and used as a measure of the consistency of cohesive soil and the packing of granular soil. The apparatus can be used down to depths of 15m (50ft) if the ground condition permits. The rods and pointer can be withdrawn by jacking against the extractors. Figure 1.1 shows a typical arrangement of the apparatus.

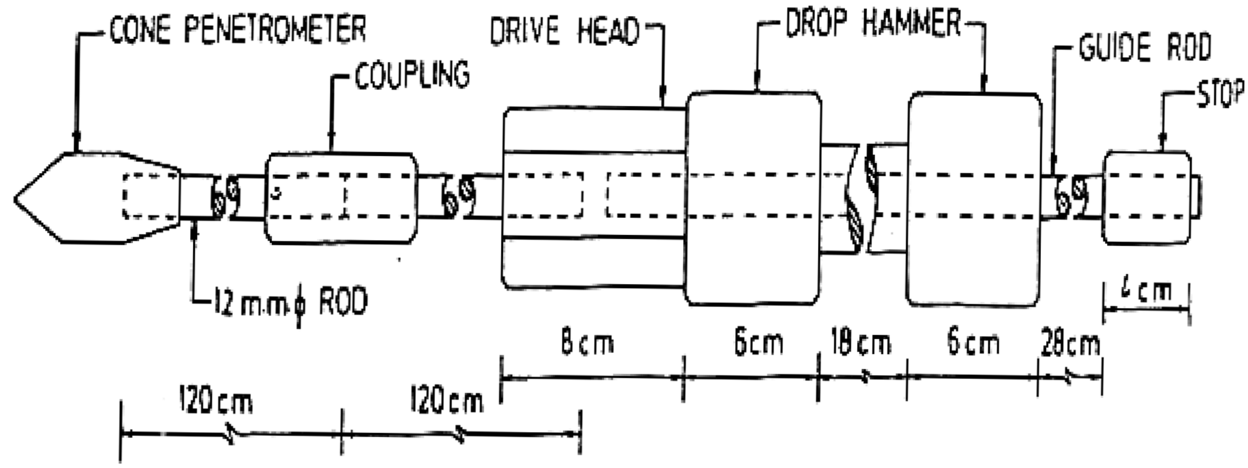


Figure 1.1. General Arrangement of JKR Probe

Figure 1.2(a) gives the features of the JKR Probe pointer. The recommended hammer weight was not adopted because its weight is too heavy for a man to handle comfortably. Figure 1.2(b) shows the pointer of the Mackintosh probe, it can be seen that the geometry of the pointer does not conform to the recommended features. Chin et. al. (1970) modified the Mackintosh Probe pointer to 60° cone in their study of residual soils in the laboratory as it was argued that the cone angle of 60° is easily reproduced. Comparison between the JKR Probe and Mackintosh Probe is shown in Table 1.1.

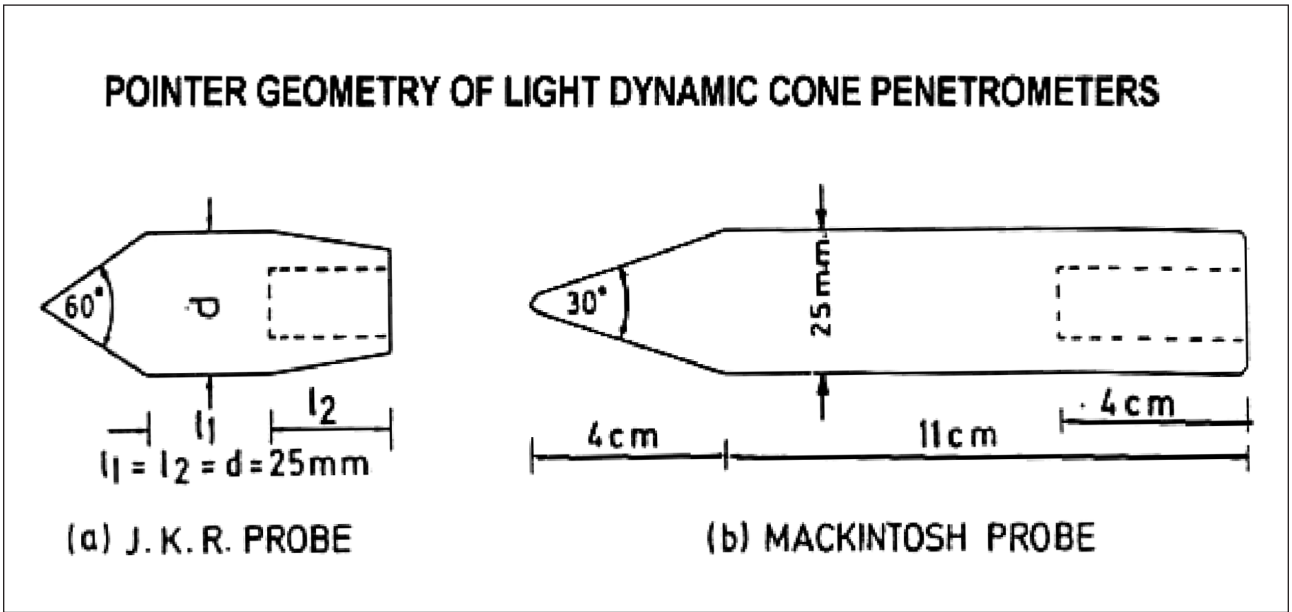


Figure 1.2. Features of JKR Probe and Mackintosh Probe Pointers

Type of penetrometer	Cone			Diameter of rod (mm)	Diameter of Coupling (mm)	Weight of hammer (Kg)	Height of fall (cm)	Measured value (Blows/ cm)
	Diameter (mm)	Cross-section (sq. cm)	Angle (degree)					
JKR Probe	25	5	60	12	22	5	28	N=30
Mackintosh Probe	25	5	30	13	24	4.5	30	N=30

Table 1.1. Comparison between JKR Probe and Mackintosh Probe.

APPENDIX 2

Testing Procedure for a Hand Field Vane Shear Test
(TEST METHOD NO. Q152A-1978)

2.1 SCOPE

This method describes the procedure for the measurement of the shear strength (i.e. undrained cohesion) of undisturbed or remoulded cohesive soils in the field using a vane of cruciform section, which is subjected to a torque of sufficient magnitude to shear the soil. The test is suitable for very soft to stiff non-fissured saturated cohesive soils.

2.2 APPARATUS

Pilcon hand vane shear apparatus (Photo 2.1) consisting of:

(i) Torque head – capable of reading shear strengths in tonnes / square meter for either a 19mm vane or a 33mm vane. (Notes on method 2.5 (iii)).
(ii) 19mm diameter shear vane
(iii) 33mm diameter shear vane
(iv) Several 300mm extension rods
(v) Several 1.5m extension rods
(vi) Pointed end attachment to fit an extension rod
(vii) Two joint spanners
(viii) Field vane shear recording sheet (Form 23 CZ (Table 2.1))

2.3 PROCEDURE

There are two possible ways of carrying out the test:

2.3.1 Method A – Test at the bottom of a borehole:

(i) The vane, together with its extension rods, shall be lowered into a previously bored vertical hole which shall normally be cased for its whole depth. Care shall be taken that the rod couplings remain tight while the vane is lowered.

(ii) With the vane resting at the bottom of the borehole and with the rods located centrally at the top of the borehole, the vane shall be pushed steadily, without twisting, for a distance of not less than three times the diameter of the borehole into the undisturbed soil.

(iii) The torque head shall be coupled to the upper extension rod and the measuring point set to zero.

The vane shall then be rotated clockwise (by rotating the torque head) until the soil has sheared. The gauge shall be read at maximum deflection which indicates the peak shear strength of the soil. The rate of turning the vane throughout the test shall be slow and smooth. The maximum rate shall not be more than one vane revolution per minute, i.e. the same speed as the second hand of a watch.

(iv) After recording the peak shear strength, the vane shall be rotated at least two complete revolutions.

(v) The measuring point on the gauge shall then be set to zero. The vane shall then be rotated and the gauge read at maximum deflection which indicates the residual shear strength of the soil. (Notes on method 2.5(iv)).

2.3.2 Method B – Hand Driven Testing

(i) The vane, together with its extension rods, shall be pushed by hand into soft ground to the depth at which the shear strength is required to be measured. (Notes on method 2.5(v)).

(ii) Steps (iii) to (v) of Method A shall be carried out.

(iii) Measurements at the required depths shall be made as in Method A.

(iv) After all peak and residual shear strength measurements have been made at the required depths, the vane and extension rods shall be withdrawn by hand and the vane detached from the rods.

(v) Measurements shall then be repeated, in accordance with step (iii) of Method B, at an adjacent location approximately 0.5m from the first position, using the pointed end attachment instead of the vane.

The measurements made indicate the rod resistance component of the measured peak and residual shear strengths. For each reading it is essential that the pointed end attachment be as near as possible in elevation to the corresponding vane test.

2.4 REPORTING

The following readings are recorded on the Form 23 CZ (Table 2.1).

(i) Depth at which reading was taken

(ii) Peak, residual and Rod shear resistance

(iii) Corrected readings calculated by subtracting the rod reading from the corresponding peak and residual readings

(iv) The corrected readings converted to Shear Strength in kPa by multiplying by a factor 9.8

(v) The clay sensitivity calculated from the ratio of Peak to Residual Shear strengths

2.5 NOTES ON METHOD

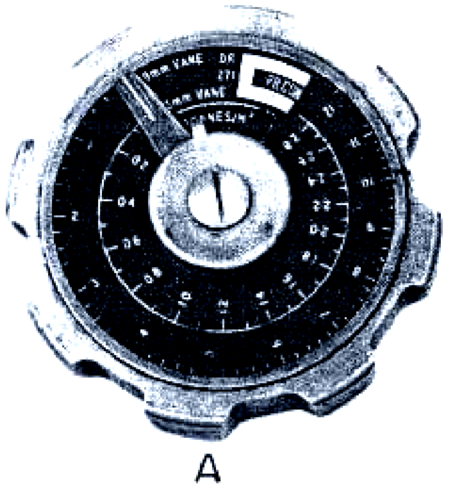
(i) With adequate care, shear strength measurements may be made in undisturbed tube samples while inside the tube sampler. Only the 19mm vane is to be used for a sample of at least 50mm diameter. The sample being tested in this case is slightly disturbed and, in addition, tube edge effects could affect shear strength readings. Hence results obtained in this manner must be treated with appropriate caution.

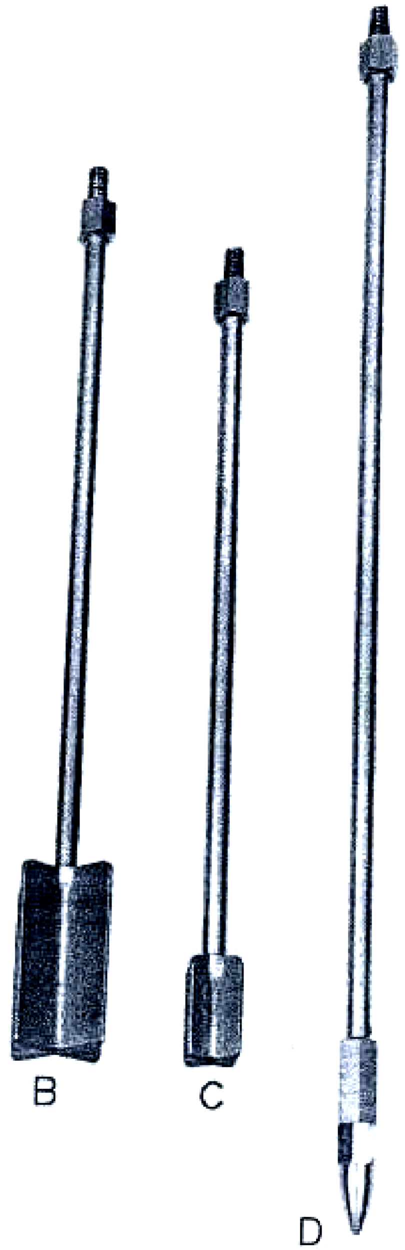
(ii) Cohesion of clay may also be measured from a lump which shall essentially be undisturbed and large enough to ensure that no boundary effects will affect measurements.

(iii) The 33mm vane is used for testing in very soft and soft cohesive soils. The 19mm vane is appropriate for testing firm to stiff soils, as well as for tube sample testing as in Note (i).

(iv) A faster rate of rotation than that specified is allowable while the soil is being brought to the residual strength condition. However, the specified standard rate must be used when measuring the residual shear strength.

(v) Care must be taken to ensure that all screw couplings between extension rods are fully tightened, using the spanners provided.





PILCON HAND VANE SHEAR APPARATUS

A. Torque Head
B. 33mm Vane
C. 19mm Vane
D. Pointed End Attachment
(300mm and 1.5m extension rods not shown)

Photo 2.1. Pilcon Hand Vane Shear Apparatus

Q 152A -1978
FORM 23 CZ
(- / 9 / 77)

MAIN ROADS DEPARTMENT
FIELD VANE SHEAR RESULTS

PROJECT: **ROCKLEIGH BRIDGE SOUTHERN APPROACHES** **VANE SIZE:** **33mm**
LOCATION: **CH. 1550 A, on** **HOLE NO:** **S5JOB**
NO.: **145 / 10H /9** **PROJECT NO.:** **CDI – 162** **GROUND SURFACE:** **RL2.419**

Depth (m)	Intrumental reading (t/m2)			Corrected Reading (t/m^2)		Shear Strength (kPa)		Reak Residual Ratio
	Peak	Residual	Rod	Peak	Residual	Peak	Residual	
0.6	2.12	0.32	0.04	2.08	0.28	20.40	2.80	7.30
0.9	1.90	0.40	0.07	1.83	0.33	18.00	3.20	5.60
1.2	1.15	0.40	0.10	1.05	0.30	10.30	2.90	3.50
1.5	1.57	0.50	0.16	1.41	0.34	13.80	3.30	4.20
1.8	2.08	0.60	0.20	1.88	0.40	18.40	3.90	4.70
2.1	2.16	0.60	0.20	1.96	0.40	19.20	3.90	4.90

REMARKS: ____________________

OPERATOR: R. SMITH
ENGINEER: E. BARRON
DATE: 1/12/1977
FIGURE 1

Table 2.1. Form 23 CZ

APPENDIX 3

Testing Procedure using a 1.6MPa Capacity Dutch Cone Penetrometer (TEST METHOD NO. Q151A-1978)

3.1 SCOPE

This method describes the procedure for the determination of the end bearing penetration resistance developed during the steady slow penetration of a steel rod and cone into soil. The method supplies data on the engineering properties of soil for the design of earthworks and foundations. The data can be used as a measure of in-situ strength, and also as an aid in identification of material type.

The apparatus referred to in this method is most suited for sounding in very soft to firm clayey alluvial deposits, or very loose saturated sand deposits. The capacity of the equipment is relatively low as it will reach full scale readings in firm to stiff clay, or loose to medium dense sand.

The test gives a continuous record of cone resistance (i.e. soil shear strength) from the ground surface to the maximum depth reached. The scope of this Test Method does not include measurement of friction sleeve resistance.

3.2 APPARATUS

The following apparatus comprises the Barentsen Dutch Cone Penetrometer equipment which has a thrust capacity of 1.6 MPa. (Photo 3.1).

(i) Thrust head and 2 handles

(ii) Drive collar with two handles

(iii) Push rod / inner rod combinations (1m long)

(iv) End rod consisting of a 1m push rod and 1.1m inner rod with the 60° angle cone attached at the bottom end, having a base diameter of 35.7mm (Note on method 3.5 (i)).

(v) 2 x Stillson wrenches

(vi) Thrust mandrel

(vii) Thrust machine capable of providing upwards and downwards thrust at a constant controllable rate (Note on method (ii)).

(viii) Tape, chalk, Penetrometer Log Sheets (Form 23 CY (Table 3.1))

3.3 PROCEDURE

(i) The thrust machine shall be set up at the required test position and levelled to provide a thrust direction as near to vertical as practicable. The thrust mandrel shall be attached to the drive head in the thrust machine.

(ii) The penetrometer end rod shall be marked with chalk at 150mm intervals from the cone tip, and spudded in vertically below the thrust mandrel. The rod shall be advanced to the required first test depth, with the cone retracted, by pushing on the outer push rods by means of the drive collar and thrust mandrel.

(iii) The thrust head shall be located on the top of the inner rod, which projects above the outer push rod approximately 90mm. The cone shall be extended 75mm, at a constant rate of 10mm/sec (Note on method 3.5(iii)) by applying thrust through the head and mandrel. The cone resistance, from the thrust head gauge, shall be recorded on Form 23 CY as the average resistance reading during the downward movement of the inner rods relative to the stationary outer push rods. (Note on method 3.5(iv)).

(iv) The drive collar shall then be located on the top of the outer push rods, and thrust applied to advance the rods 150mm to the next test depth (Note on method 3.5(v)). As this occurs, the cone and inner rods will resume the retracted position.

(v) Section 3.3(iii) and 3.3(iv) shall be repeated continually to provide cone resistance reading at 150mm intervals. Extreme care shall be taken at all times to ensure that the capacity of the thrust head gauge is not exceeded when the cone is being advanced. Over-capacity resistance at test depths should be so noted on the recording sheet.

(vi) Further extension push rod/inner rod combinations shall be screwed onto the rod string as required, and the chalk depth marking at 150mm intervals extended onto the new rod. The test shall continue until the specified depth is reached or prior absolute refusal is obtained.

(vii) The rod string shall be withdrawn by means of the drive collar, thrust mandrel and thrust machine. The cone shall be inspected, and a description of soil adhering to the cone recorded on the recording sheet.

3.4 REPORTING

All information, data and remarks as indicated on Form 23 CY shall be recorded (Table 3.1).

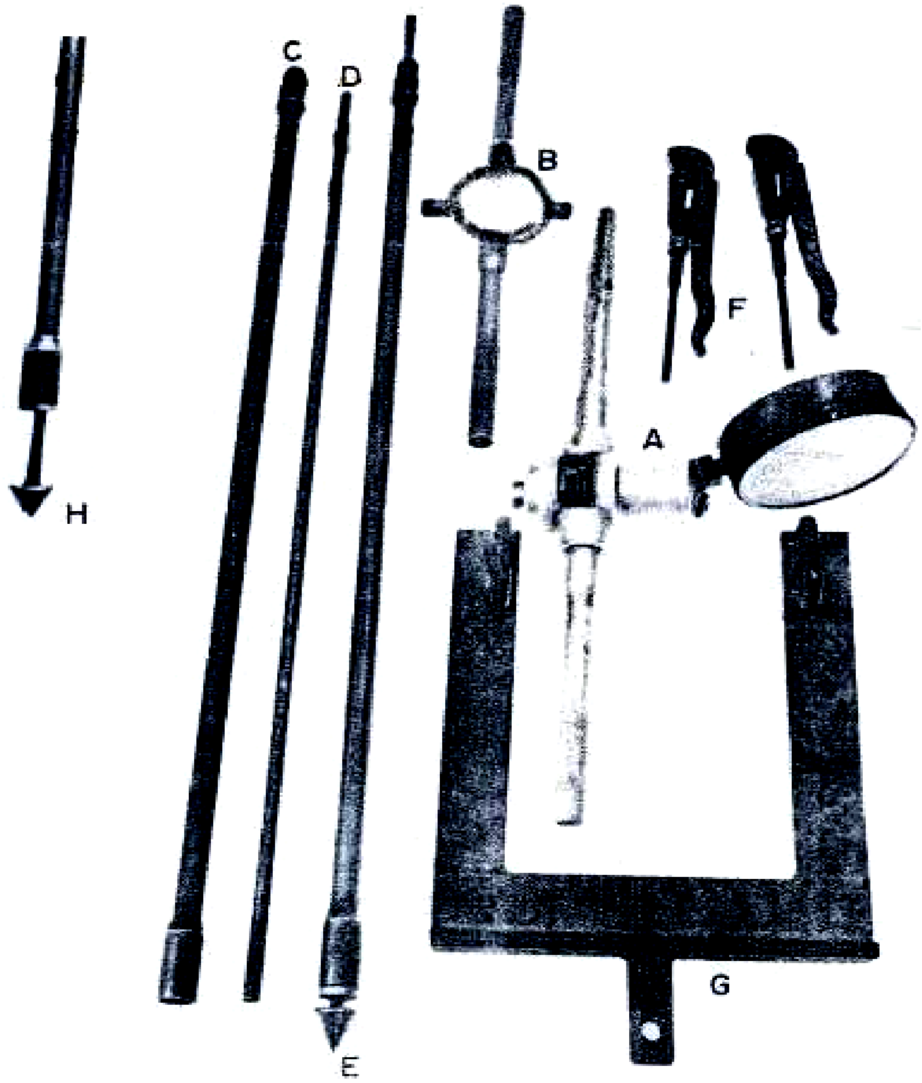
3.5 NOTES ON METHOD

(i) The “Dutch Cone Penetrometer” or “Static Cone Penetrometer” is a standard international sounding device. The cone has standardized geometry, with the diameter so chosen to provide a projected end area of $1000mm^2$.

(ii) It is important to maintain a rate of penetration of the cone as constant as possible, and as close to 10mm / sec as possible. This rate is standard internationally and must be maintained if resistance results are to be comparable with international experience. It is also a convenient rate to allow the operator sufficient time to properly read and record the resistance values during the drive interval.

(iii) While this test is primarily designed to measure average in-situ strength over the test interval, it is also particularly suited, when testing soft soils, to identifying thin lensing of material showing markedly different granulometry, consistency or density from the norm over the drive interval. Care should be taken to accurately record the depth and nature of such anomalies. A typical example would be a sudden peak value in the midst of an essentially constant resistance value over the drive interval. This could represent a thin silt or sand lens within a soft clay deposit, whose identification is vital to a more complete understanding of drainage path characteristics for expelled pore water during the consolidation process.

(iv) The standard test interval is 150mm. Other test intervals may be used if required. However, test intervals less than 150mm are not advisable in normal operation, and if used, the resistance values must be interpreted with appropriate caution because of the disturbance effects from the preceding test. Of course, test intervals cannot be less than the specified 75mm drive interval.



BARENTSEN DUTCH CONE PENETROMETER EQUIPMENT CAPACITY 16 kg/cm sq.

A. Thrust Head
B. Push Rod, pushing and lining filling
C. Push Rod
D. Inner Rod
E. Push / Inner Rod Combination with cone attached to Inner Rod
F. Joint Sellsen
G. Thrust Mandrsi
H. Extended position of cone

Photo 3.1. Barentsen Dutch Cone Penetrometer

Q 152A -1978
FORM 23 CY
(- / 9 / 77)

MAIN ROADS DEPARTMENT

PENETROMETER LOG

PROJECT: TRIAL EMBANKMENT
PENETROMETER NO.: AB
LOCATION: 2m left of Line A - A
DATUM: AHD
JOB NO.: 98 / 10H / 66
PROJECT NO.: 2-22 SURFACE RL 2.50M

Depth (m)	DIAL READING kgf/cm²	DEPTH (m)	DIAL READING kgf/cm²	DEPTH (m)	DIAL READING kgf/cm²
0.00-0.07	Pushed through Sand ↓	4.20-4.27	5.5	8.40-8.47	2.2
0.15-0.22		4.35-4.42	2.6	8.55-8.62	1.9
0.30-0.37		4.50-4.57	1.6	8.70-8.77	2.8
0.45-0.52		4.65-4.72	2.0	8.85-8.92	2.8
0.60-0.67		4.80-4.87	1.4	9.00-9.07	2.8
0.75-0.82		4.95-5.02	1.8	9.15-9.22	2.0
0.90-0.97	2.6	5.10-5.17	1.7	9.30-9.37	8.0
1.05-1.12	1.7	5.25-5.32	1.5	9.45-9.52	> 16.0
1.20-1.27	1.1	5.40-5.47	1.2	9.60-9.67	
1.35-1.42	0.9	5.55-5.62	1.6	9.75-9.82	
1.50-1.57	1.2	5.70-5.77	1.8	9.90-9.97	
1.65-1.72	1.4	5.85-5.92	1.8	10.05-10.12	
1.80-1.87	1.3	6.00-6.07	1.8	10.20-10.27	
1.95-2.02	1.7	6.15-6.22	1.7	10.35-10.42	
2.10-2.17	1.4	6.30-6.37	1.8	10.50-10.57	
2.25-2.32	1.3	6.45-6.52	2.0	10.65-10.72	
2.40-2.47	1.0	6.60-6.67	2.0	10.80-10.87	
2.55-2.62	1.0	6.75-6.82	1.7	10.95-11.02	
2.70-2.77	1.8	6.90-6.97	2.2	11.10-11.17	
2.85-2.92	1.8	7.05-7.12	2.2	11.25-11.32	
3.00-3.07	1.8	7.20-7.27	2.2	11.40-11.47	
3.15-3.22	1.8	7.35-7.42	2.5	11.55-11.62	
3.30-3.37	1.6	7.50-7.57	2.3	11.70-11.77	
3.45-3.52	3.2	7.65-7.72	2.5	11.85-11.92	
3.60-3.67	2.0	7.80-7.87	2.5	12.00-12.07	
3.75-3.82	4.8	7.95-8.02	2.4	12.15-12.22	
3.90-3.97	3.0	8.10-8.17	2.5	12.30-12.37	
4.05-4.12	5.5	8.25-8.32	2.0	12.45-12.52	

SOIL DESCRIPTION REFUSAL GREENISH GREY BROWN SILTY CLAY: ____________

REMARKS: ____________
OPERATOR: JR
DATE: 8 / 7 / 77

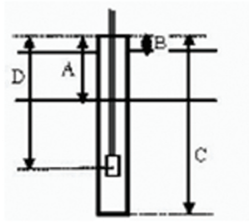
Table 3.1. Form 23 CY

APPENDIX 4

Form E1 for In-situ Groundwater Measurements and Sampling for Regular Monitoring

<u>FORM E1</u>

(1) Basic Information

PROJECT NAME:				
Date		Time		
Location Name		Location No.		
A: G.W.L	m	C: Well Depth	m	
B: Height of collar	m	D: Depth of Sub. Pump	m	
Start of Pumping Time		Start of sampling Time		
Accompany				

(2) Measurement Results in the well before Pumping

Parameters	unit	H = m	H = m	H = m	H = m	
Temperature	ºC					
Conductivity	µs / m					
Turbidity	NTU					
pH-value	pH					
0_2-contents	mg / ℓ					
0_2-Saturation	%DO					
Water Colour						
Remarks						

(3) Measurement Results after Pumping

Parameters	unit	H = m	H = m	H = m	H = m	
Temperature	ºC					
Conductivity	µs / m					
Turbidity	NTU					
pH-value	pH					
0_2-content	mg / ℓ					
0_2-Saturation	%DO					
Water Colour						
Remarks						

APPENDIX 5

Form F1 for In-situ Surface Quality Measurement and Sampling for Regular Monitoring

PROJECT NAME:													
Date													
Time													
Location Name													
Location No													
Coordinates													
Accompany													
Temperature	°C												
Conductivity	µs/m												
Turbidity	NTU												
pH-value	pH												
0_2-content	mg / ℓ												
0_2-Saturation	%DO												
Water Colour													

APPENDIX 6

On-site Water Testing Procedures

On-site Test (Chemical Analysis) of Water Quality for Regular Monitoring

FORM – 3

Page ____________ of

NAME:		DATE:	
ADDRESS:			

Sample Number			On-site test						
Date of sampling	Time	Sampling No.	BOD	COD	Mn	Fe	Fe-T	NO_3-N	NO_2-N
			mg / ℓ	mg / ℓ	mg / ℓ	mg / ℓ	mg / ℓ	mg / ℓ	mg / ℓ

Plate C2. Form 23 CY

APPENDIX 7

Criteria in Distinguishing Clay and Silt

7.1 Present Classification

The present classification is designed for use in the field and can easily be applied with the aid of simple field equipment such as a handlens, grain size comparator, area estimation chart and a pail of water. The classification is based mainly on the texture and physical properties of the sediments as determined by visual inspection and feel.

In the present classification, a major boundary is set at 62.5μm. The size parameter is applied only to particles coarser than 62.5μm comprising gravel (particles >2mm in diameter) and sand (grains 62.5μm – 2mm in diameter). Particles less than 62.5μm in size are referred to as fines comprising either silt or clay and recognized as such on the basis of certain physical properties other than particle size, manifested by the sediments. In this respect, the present classification is similar to the scheme as outlined by Kruse (1982). The physical properties are those of plasticity, lustre, cohesion, adhesion (stickiness) and dilatancy.

The following is a brief description of the physical properties and their applications in the recognition and distinction of silt and clay.

7.2 Plasticity

The property of plasticity is characteristic of clay and may be used as the basis for a simple field test to distinguish clay from silt which is non-plastic (Table 7.1 and Table 7.2). Being plastic means that clay, at certain moisture content can be deformed and remoulded in the hand without disintegration. Thus a lump of moist to wet clay can be manipulated between the palms of the hands and fingers and rolled into a long thin thread. As moisture is lost during continued manipulation, the clay approaches a non-plastic condition and crumbles. Just before the crumbly state is reached, highly plastic clay can be rolled into a long thread with a diameter of approximately 3mm which has sufficient strength to support its own weight. Silt, on the other hand, can seldom be rolled into a thread with a diameter as small as 3mm without severe cracking and is completely lacking in tensile strength unless small amounts of clay are present.

7.3 Lustre

Wet or moist clay shows a greasy lustre when rubbed between the fingers while moist silt gives a silky, satin-like lustre.

7.4 Cohesion

Both silt and clay are cohesive materials but clay has a much greater cohesion than silt by virtue of its greater surface contacts and more moisture films. When a lump of clay is held under water, particles will not detach from it whereas fine particles will detach from a lump of silt and slowly settle in the water.

7.5 Adhesion (Stickiness)

The property of stickiness or adherence to foreign objects is exhibited by wet clay but is not present in silt. This sticky consistency in wet clay is the result of water being attracted to the surface of a foreign object to form connecting films between it and the clay. The value of the adhesion is equivalent to the surface area of these films and the tension within them. The force of adhesion or stickiness of a sedimentary mixture to a foreign object is therefore dependent upon the clay content which determines the number of films and the amount of water that regulates the thickness of these films.

7.6 Dilatancy Reaction (Shaking Test)

The dilatancy or shaking test may also be used to distinguish clay from silt. In this test, a small amount of fines is mixed with water to a very soft consistency in the palm of the hand. The back of the hand is then lightly tapped. If the test material is silt, water rises quickly to the surface to give it a shining or glistening appearance. Then if the material is deformed by squeezing or stretching the water flows back into it and leaves the surface with a dull appearance. Usually, the greater the amount of clay in the sample, the slower the reaction to the test. Clay itself has no reaction to the test.

Descriptive Term for Plasticity	Range of Liquid Limit (%)
Low plasticity	< 35
Intermediate plasticity	35 - 50
High plasticity	50 - 70
Very high plasticity	70 - 90
Extremely high plasticity	> 90
Note: Classification in terms of plasticity is based on Liquid Limit, in accordance with BS 5930 (1999).	

Table 7.1. Plasticity Terms Based on Liquid Limit

Physical Properties / Nomenclature	Plasticity	Lustre	Cohesion	Stickiness (Adhesion)	Dilatancy Reaction
Clay	plastic	greasy	no detachment of fine particles under water	sticky	none
Silty Clay	plastic	satin - like	detachment of fine particles under water	sticky	slow to none
Clayey Silt	slightly plastic	satin - like	detachment of fine particles under water	slightly sticky	rapid to slow
Silt	non plastic	satin - like	detachment of fine particles under water	not sticky	rapid

Table 7.2. Differentiation between Clay and Silt

APPENDIX 8

List of the Laboratory Tests

Peat / Organic soil	
(i) Organic matter (ii) Radiocarbon dating (iii) Acidity (iv) Absorbency (v) Ash content (vi) Botanic composition	(i) Fibre content (ii) LOI (iii) Moisture content (iv) Chemical properties (pH, N, C, S, ash, volatile matter, gross calorific value and net calorific value) (v) The bulk and dry density
Soft soils	
(i) Moisture content (ii) PSD (iii) Atterberg limit (iv) Dry and bulk density (v) Mineral composition - XRD	(i) SG (ii) Consolidation Test (iii) Shear Strength (iv) Chemical composition (SO_4, pH) (v) Permeabilty
Water	
(i) Iron (Fe) (ii) Sulphate (SO_4) (iii) Chloride (Cl) (iv) Manganese (Mn) (v) Total Iron (Fe-T) (vi) Nitrate Nitrogen (NO_3-N) (vii) Nitrite Nitrogen (NO_2-N) (viii) Total Dissolved Solids (TDS) (ix) Total Solids (TS) (x) Fluoride (F) (xi) Carbonate (CO_3) (xii) Hydrogen Carbonate (HCO_3) (xiii) Total Hardness ($CaCO_3$) (xiv) Sodium (Na) (xv) Calcium (Ca) (xvi) Potassium (K)	(i) Aluminium (Al) (ii) Magnesium (Mg) (iii) Mercury (Hg) (iv) Cadmium (Cd) (v) Selenium (Se) (vi) Arsenic (As) (vii) Cyanide (CN) (viii) Lead (Pb) (ix) Chromium (Cr) (x) Silver (Ag) (xi) Copper (Cu) (xii) Zinc (Zn) (xiii) Silica (SiO_2) (xiv) Phosphorus (P)

APPENDIX 9

Typical Format for Engineering Geological Mapping in Peat and Soft Soils Report

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APPENDIX 10

General Instructions on Report Format
(Format Penyediaan Laporan)

1. **Pendahuluan**

Format laporan perlu seragam bagi memudahkan kerja-kerja pemantauan dan penyelarasan. Format laporan kajian yang telah dilakukan perlu disesuaikan mengikut keperluan projek, tujuan / objektif, maklumat yang dikutip dan terkumpul.

2. **Format Laporan**

Perkara berikut perlu diberi perhatian semasa menulis laporan kajian:

i) **Bahasa**

Laporan boleh ditulis dalam Bahasa Melayu atau Bahasa Inggeris.

ii) **Teks**

Laporan perlu ditaip menggunakan komputer dan perisian pemprosesan perkataan (*word processor*) yang dipersetujui oleh Jabatan. Contohnya MS Word untuk teks dan perisian lain yang sesuai.

iii) **Kertas**

Warna putih, saiz A4.

iv) **Saiz huruf**

Untuk teks – saiz *font* digunakan adalah 12-*point*.
Untuk jadual – saiz *font* yang digunakan adalah mengikut kesesuaian. Walau bagaimanapun, digalakkan menggunakan font 10-*point*.

v) **Jenis font**

Jenis *font* adalah Arial.

vi) **Birai**

Birai yang digunakan adalah seperti berikut dan *full justification*.

Birai Kiri	:	30mm
Birai Kanan	:	25mm
Birai Atas	:	25mm
Birai Bawah	:	25mm

vii) Langkau baris (spacing)

Langkau baris bagi keseluruhan teks adalah langkau 1.5 baris.

Langkau 1 baris (*single spacing*) pula boleh digunakan semasa membuat jadual yang panjang dan senarai Rujukan / Bibliografi.

viii) Penomboran halaman

Untuk muka surat sebelum bab Pendahuluan, gunakan angka Roman kecil secara berturutan selepas kulit laporan iaitu bermula dengan ii, iii, iv dan seterusnya. Untuk muka surat teks kandungan laporan, Rujukan, Bibliografi dan Apendiks diberi nombor biasa iaitu 1,2,3,4 dan seterusnya. Contoh nombor muka surat adalah seperti -30-.

ix) Kedudukan nombor halaman

Semua nombor muka surat hendaklah dicetak di tengah bahagian bawah muka surat dengan *font* Arial bersaiz 12-*point*.

x) Header / Footer

Semua muka surat laporan, bermula daripada muka surat "Kandungan". "Tajuk laporan" perlu diletakkan di bahagian atas sebelah kanan di atas garisan sebagai *header* dan nama *Jabatan Mineral dan Geosains Malaysia* di bahagian bawah sebelah kiri di bawah garisan sebagai *footer*. Jenis *font* yang digunakan ialah Arial dengan saiz 8-*point*. Tema warnanya adalah *White, Background 1, Darker 50%.*

xi) Jadual

Setiap jadual mestilah mengandungi nombor rujukan dan keterangan yang dicetak pada sebelah atas di bahagian tengah jadual tersebut dan ditulis sebagai Jadual No. Bil. Jadual: Keterangan.

xii) Rajah

Setiap rajah (termasuk peta) mestilah mengandungi nombor rujukan dan keterangan yang dicetak pada sebelah bawah di bahagian tengah rajah tersebut dan ditulis sebagai Rajah No. Bil. Rajah: Keterangan. Khas untuk peta, di dalamnya mesti dimasukan logo Jabatan, rujukan peta, tarikh disediakan dan nama pegawai yang menyediakan selain daripada petunjuk, skala dan arah mata angin.

xiii) Foto

Setiap foto / gambar mestilah mengandungi nombor rujukan dan keterangan yang dicetak pada sebelah bawah di bahagian tengah foto tersebut dan ditulis sebagai Foto No. Bil. Foto: Keterangan.

xiv) Keterangan (Caption)

Keterangan bagi Rajah, Jadual dan Foto hendaklah menggunakan *Font* Arial bersaiz 12-*point*. Panjang keterangan seelok-eloknya tidak melebihi 2 baris. (Contoh, Jadual 3: Taburan hujan di Pontian, Johor).

xv) Ringkasan Eksekutif / *Executive Summary*

Ringkasan mesti tidak melebihi 300 perkataan atau satu muka surat A4, dan dicetak di bahagian hadapan laporan iaitu selepas halaman judul. Penulisan mesti disediakan dalam dua bahasa iaitu Bahasa Melayu dan Inggeris. Sekiranya laporan ditulis dalam Bahasa Melayu, *Executive Summary* ditulis dalam Bahasa Inggeris (*italic*). Sebaliknya, jika laporan ditulis dalam Bahasa Inggeris, Ringkasan Eksekutif ditulis dalam Bahasa Melayu (*italic*). Ia hendaklah langkau satu baris.

xvi) Penghargaan

Penghargaan merupakan satu kenyataan ringkas bagi menyampaikan ucapan terima kasih / penghargaan kepada mereka yang banyak memberi sumbangan dan terlibat dalam menjayakan projek yang dilaporkan. Ianya dicetak selepas tajuk Kesimpulan.

xvii) Rujukan

Senarai penerbitan yang dirujuk hendaklah mengikut Sistem Harvard. Setiap rujukan di dalam teks perlu dinyatakan nama pengarang, tahun penerbitan dan tajuk buku / laporan. Jika menggunakan maklumat dari laman web, nyatakan keseluruhan alamat URL serta tarikh laman web tersebut dirujuk.

xviii) Bibliografi

Meliputi bahan-bahan penerbitan yang berkaitan dengan projek tetapi tiada rujukan secara langsung dalam teks, juga perlu disenaraikan mengikut Sistem Harvard.

xix) Apendiks

Apendiks merupakan lampiran bagi jadual, ilustrasi dan sebagainya yang tidak sesuai dimuatkan ke dalam teks kerana ianya boleh mengganggu kesinambungan teks. Apendiks boleh dibahagikan kepada beberapa apendiks yang berasingan iaitu Apendiks A, B, C dan sebagainya. Tiap-tiap apendiks serta tajuknya hendaklah disenaraikan secara berasingan di dalam Senarai Isi Kandungan.

xx) Kulit Laporan

Kulit laporan hendaklah menggunakan kertas kulit yang telah disediakan oleh Jabatan. Tajuk laporan yang ditulis pada kulit laporan hendaklah mengikut seperti mana yang ditetapkan *Font* Arial *Bold* dengan saiz huruf 16-*point* (contoh seperti di Format Kulit Laporan).

xxi) Nombor Laporan

Nombor laporan hendaklah mengikut format berikut:

JMG.kod cawangan / negeri / bahagian (kod bidang) bil laporan / tahun
Contoh : JMG.PRK (SGR) 01/2007
(laporan yang dikeluarkan oleh JMG Perak)

xxii) Format Belakang Kulit Laporan

Halaman ini mengandungi penyataan di mana laporan ini boleh diperolehi dan ia diletakkan pada sebelah belakang kulit laporan seperti yang ditunjukkan di Format Kulit Belakang Laporan.

xxiii) Format Muka Dalam / Muka Surat Tajuk

Format muka dalam atau surat tajuk mengandungi tajuk laporan beserta nama penulis laporan (seperti di Format Muka Dalam / Mukasurat Tajuk)

xxiii) Unit SI:

Semua unit mesti diselaraskan mengikut *International System of Units* (SI).

Format Kulit Laporan

JABATAN MINERAL DAN GEOSAINS MALAYSIA
Minerals and Geoscience Department Malaysia

PROJEK
PEMETAAN GEOLOGI KEJURUTERAAN
KAWASAN GAMBUT
BATANG BERJUNTAI, SELANGOR

NO. LAPORAN: JMG.SWP (GS) 03/2010

KEMENTERIAN SUMBER ASLI DAN ALAM SEKITAR
Ministry of Natural Resources and Environment

Format Kulit Belakang Laporan

Lampiran ini dicetak pada sebelah belakang kulit laporan

Laporan ini boleh diperoleh daripada:

Jabatan Mineral dan Geosains Malaysia
Lantai 20, Bangunan Tabung Haji
Jalan Tun Razak
50658 Kuala Lumpur

Tel:03-21611033
Faks:03-21611036
http://www.jmg.gov.my

atau

Jabatan Mineral dan Geosains Malaysia, Selangor / W.Persekutuan
Tingkat 6 & 7, Bangunan Darul Ehsan
No. 3, Jalan Indah, Seksyen 14
40000 Shah Alam
Selangor

Tel: 03-55101833
Faks: 03-55101918
Emel: jmgselwp@jmg.gov.my

Harga : RM50.00

Format Muka Dalam / Muka Surat Tajuk

JABATAN MINERAL DAN GEOSAINS MALAYSIA
Minerals and Geoscience Department Malaysia

PROJEK PEMETAAN KEJURUTERAAN KAWASAN GAMBUT BATANG BERJUNTAI, SELANGOR

Oleh

(Nama Penulis Laporan)

NO. LAPORAN: JMG.SWP (GS) 03/2010

KEMENTERIAN SUMBER ASLI DAN ALAM SEKITAR
Ministry of Natural Resources and Environment

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