VOLUME 5 CONTRACT DOCUMENTS FOR SPECIALIST ACTIVITIES

SECTION 3 GROUND INVESTIGATION

PART 4

SPECIFICATION

SUMMARY

Specification for ground investigation.

INSTRUCTIONS FOR USE

This is a new document to be inserted into the manual.

1. Insert this Specification into Volume 5, Section 3.

2. Archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from the Stationery Office Ltd.

THE HIGHWAYS AGENCY

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
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THE DEPARTMENT OF THE ENVIRONMENT FOR NORTHERN IRELAND

Ground Investigation
Part 4: Specification

Summary: Specification for ground investigation.

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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VOLUME 5 CONTRACT DOCUMENTS FOR SPECIALIST ACTIVITIES

SECTION 3 GROUND INVESTIGATION

PART 4

SPECIFICATION

Contents

1. INFORMATION

1.1 General

Information and requirements specific to the particular ground investigation Contract are given in the following Schedules which form part of the Specification.

1.2 Schedules

The following information is provided in Schedule 1:

1.2.1 Schedule 1.1 - The scope and object of the Contract.

Schedule 1.2 - A description of the route or development.

Schedule 1.3 - A list of Drawings referred to in the tender. The Drawings are of a confidential nature and the details contained in these Drawings shall not be divulged to anyone outside the Contractor's organisation or to those not directly concerned with the tender itself.

Schedule 1.4 - A general description of the Site Operations including Ancillary works.

Schedule 1.5 - The geological formations likely to be encountered.

Schedule 1.6 - The list of affected landowners, tenants and occupiers together with appropriate landplans.

Schedule 1.7 - Form of Monthly Statement if required (Conditions of Contract clause 60).

Schedule 1.8 - Particular general requirements (Section 3).

Schedule 1.9 - Particular borehole requirements (Section 4).

Schedule 1.10 - Particular rotary drilling requirements (Section 5).

Schedule 1.11 - Particular pit and trench requirements (Section 6).

Schedule 1.12 - Particular sampling requirements (Section 7).

Schedule 1.13 - Particular in situ testing requirements (Section 8).

Schedule 1.14 - Particular instrumentation and monitoring requirements (Section 9).

Schedule 1.15 - Particular laboratory testing requirements (Section 11).

Schedule 1.16 - Particular reporting requirements (Sections 10 and 12).

Schedule 1.17 - Particular requirements relating to potentially contaminated land.

1.2.2 The following information is provided in Schedule 2: A list of exploratory holes including details of location, depth, minimum diameter, etc.

1.2.3 The following information is provided in Schedule 3: The requirements for the Engineer's office, office equipment, transport, protective clothing and survey equipment.

1.2.4 The following information is provided in Schedule 4: Amendments to clauses of the Specification.

1.2.5 The following information is provided in Schedule 5: Additional clauses to the Specification.

2. DEFINITIONS

2.1 General

These definitions refer to the Specification, Drawings, Schedules, Conditions of Contract and Bill of Quantities of this Ground Investigation Contract only.

2.2 Geotechnical and environmental personnel

Geotechnical and environmental personnel shall be competent to undertake the work required. Categories of personnel who may be required by the Contract are as follows:

(a) Technician.

(b) Incorporated Engineer.

(c) Graduate Engineer/Geologist/Environmental Scientist.

(d) Graduate Engineer/Geologist/Environmental Scientist with at least 3 years of relevant experience since graduation.

(e) Chartered Engineer/Geologist/Environmental Scientist with at least 5 years of relevant experience.

(f) Principal Chartered Engineer/Geologist/ Environmental Scientist with at least 10 years of relevant experience.

Recognised qualifications and experience from states of the European Economic area which are equivalent to one of the above categories will be satisfactory.

2.3 Topsoil

The word 'topsoil' shall mean the top layer of material, that contains humus and can also support vegetation.

2.4 Soil

The word 'soil' shall include any natural or artificial material not classified herein as topsoil, hard material or hard stratum.

2.5 Hard stratum and obstruction

2.5.1 The words 'hard material', 'hard stratum' and 'obstruction' shall mean natural or artificial material, including rock, which cannot be penetrated except by the use of chiselling techniques, rotary drilling, blasting or powered breaking tools.

2.5.2 The terms 'hard stratum' and 'obstruction' shall apply whilst boring where it is demonstrated by the Contractor that condition (1) and either condition (2) or condition (3) below are fulfilled provided that the boring rig is in good working order and is fully manned.

2.5.3 Condition (1) - cable percussion boring cannot proceed at a rate greater than 0.5m/hour through the hard stratum/obstruction being penetrated.

2.5.4 Condition (2) - 100 mm diameter undisturbed sample tubes cannot be driven more than 300 mm.

2.5.5 Condition (3) - A Standard penetration resistance test shows a resistance in excess of 35 blows/75mm.

2.5.6 The term 'hard material' shall apply only to excavation of pits and trenches and shall mean one of the following:

(a) natural or artificial material, including rock, in masses in excess of 0.20 cubic metres, which cannot be penetrated except by the use of chiselling techniques or powered breaking tools;

(b) existing pavements, footways, paved areas (but excluding unbound materials) and foundations in masses in excess of 0.20 cubic metres.

2.6 Fill

The word 'fill' shall mean any deposits or construction which have been formed by persons, as distinct from geological agencies.

2.7 Exploratory hole

The words 'exploratory hole' shall mean any hole or in situ test hole formed for the purpose of ground investigation.

2.8 Boring

The term 'boring' shall include percussion boring and auger boring.

2.9 Drilling

The term ‘drilling’ shall include rotary drilling techniques.

2.10 Borehole

The term ‘borehole’ shall mean an exploratory hole put down by boring or drilling techniques.

2.11 Inspection pit

The term ‘inspection pit’ shall refer to a hand excavated hole for the purpose of investigating the possible presence of underground services at the location of an exploratory hole.

2.12 Trial pits and trenches

The terms ‘trial pit’ and ‘trial trench’ shall refer to exploratory holes for which personnel entry is not required.

2.13 Observation pits and trenches

The terms ‘observation pit’ and ‘observation trench’ shall refer to exploratory holes requiring geotechnical or environmental personnel entry.

2.14 Potentially contaminated land

The term ‘potentially contaminated land’ shall mean that land designated as such on the Drawings. This land may contain substances which could give rise to hazards likely to affect human health, the natural environment or the proposed highway.

2.15 Contamination ground investigation

The term ‘contamination ground investigation’ shall mean those parts of the Investigation that are undertaken on potentially contaminated land to obtain information on the contamination of the ground.

2.16 Hygiene facility

The term ‘hygiene facility’ shall mean designated washing and other specific facilities (as described in Schedule 1.8).

2.17 Sampling Well

The term ‘sampling well’ shall mean groundwater sampling standpipes and combined gas and groundwater sampling standpipes from which groundwater samples are taken for the contamination ground investigation.

3. GENERAL REQUIREMENTS

3.1 Mutual Recognition

Work, goods and materials shall comply with the standards specified in the Contract.

Except where the specified standard implements or is technically equivalent to a Harmonised European Standard or to a European Standard adopted for use after 31 December 1985, any requirement for goods or materials to comply with the specified standard shall be satisfied by compliance with:

(i) a relevant standard or code of practice of a national standards body or equivalent body of any state of the European Economic Area, or

(ii) a relevant international standard recognised for use in any state of the European Economic Area, or

(iii) a technical regulation of any state of the European Economic Area, or

(iv) traditional procedures of manufacture of any state of the European Economic Area where these are the subject of a written technical description sufficiently detailed to permit assessment of the goods for the use specified, or

(v) a European Technical Approval (ETA) issued in accordance with the Construction Products Directive 89/106/EEC (or, until procedures are available for the issue of ETAs, a specification sufficiently detailed to permit assessment) for goods or materials of an innovative nature or subject to innovative processes of manufacture and which fulfil the purpose provided for by the specified standard,

provided that the proposed standard, code of practice, regulation, specification, technical description or European Technical Approval provides, in use, levels of safety, suitability and fitness for purpose equivalent to those required by the specified standard in so far as they are not inconsistent with the 'Essential Requirements' of the Construction Products Directive (89/106/EEC). This clause applies also to investigations only in so far as the means of carrying out such investigations are indivisibly associated with the goods or materials for which an alternative standard, code of practice, technical specification or technical description is proposed.

The requirement for any goods or materials to be manufactured or supplied subject to a quality management scheme or product certification scheme respectively shall be satisfied by compliance with an equivalent quality management scheme or product certification scheme of any state of the European Economic Area, provided that the proposed scheme is designed to ensure in use levels of safety, suitability and fitness for purpose equivalent to those provided for by the scheme specified. This paragraph applies also to investigations only in so far as the means of carrying out such investigations are indivisibly associated with the goods or materials for which an alternative quality management scheme or product certification scheme is proposed.

The requirement for types of goods or materials to have a British Board of Agrement Roads and Bridges Certificate shall be satisfied by goods or materials having an equivalent Agrement certificate issued in any state of the European Economic Area, provided that the goods or materials covered by such certificate offer in use levels of safety, suitability and fitness for purpose equivalent to those incorporated in the British Board of Agrement Roads and Bridges Certificate. This paragraph applies also to investigations only in so far as the means of carrying out such investigations are indivisibly associated with the goods or materials for which an alternative Agrement certificate is proposed.

Where there is a requirement for work, goods or materials to have Departmental type approval/ registration this will be granted by the Overseeing Department where the work, goods or materials have an equivalent approval/registration of the national highway authority of any state of the European Economic Area, provided that such approval/registration offers in use levels of safety, suitability and fitness for purpose equivalent to those incorporated in the Departmental type approval/registration.

Where required tests and associated sampling shall be undertaken only by laboratories accredited in accordance with BS7502 by the United Kingdom Accreditation Services (UKAS) laboratory accredited for such tests and sampling.

Where testing is carried out in another state of the European Economic Area such tests shall be undertaken by an appropriate organisation offering suitable and satisfactory evidence of technical and professional competence and independence.

3.2 Work not required

Any clauses of this Specification which relate to work or materials not required in the Contract, shall be deemed not to apply.

3.3 Statutory undertakers, public authorities and privately owned services

The positions of mains, services, drains, sewers, tunnels and pipelines owned by statutory undertakers and public authorities, where shown on the Drawings have been based on information extracted from the records of the various organisations and shall be regarded as approximate only. Services to individual properties are likely to exist but are not shown on the Drawings. The Contractor shall make his own enquiries of the statutory undertakers and public authorities and satisfy himself as to the exact position of such apparatus and the depth, size and gradient thereof. The Contractor shall also make enquiries as to the presence and location of any privately owned tunnels, services or land drains and satisfy himself as to their exact location. Where the presence of underground services is suspected, exploratory holes shall be started by means of a hand-excavated inspection pit.

3.4 Notice of entry and access routes

3.4.1 Before making entry on to the Site with any equipment the Contractor shall give the Engineer at least 14 days' written notice or in the case of Statutory Undertakers' land at least 28 days' written notice of his intended date of entry together with the names of leaders of the survey parties concerned, the number of persons in the party and details of any equipment which may be taken on the Site. The Contractor shall also give 48 hours' notice of his intended date of entry to the owners and occupiers both at the site of each exploratory hole and on the access routes thereto and shall submit to the Engineer a copy of this notice. Access routes to and between exploratory holes and which walls, gates, fences hedges etc will need to be removed or displaced by the Contractor, are shown on the Drawings. Only the agreed access routes shall be used.

3.4.2 Taking down and re-erection of motorway safety fences for the purposes of access, shall only be carried out by the Agent for the Highway Authority. The Contractor shall give the Engineer 14 days' written notice of locations where safety fences are to be taken down.

3.5 Re-entry for further Site Operations

Should the Contractor require to re-enter any part of the Site to carry out further Site Operations he shall, unless he is able to make the entry arrangements himself, again give notice to the Engineer as specified in clause 3.4 above.

3.6 Care in executing the Site Operations

The Contractor shall carry out all Site Operations with the least possible damage or disturbance. Particular care should be taken to avoid unnecessary damage to standing crops on farmland. On potentially contaminated land the Contractor shall ensure that the formation and backfilling of exploratory holes, and the handling and storing of arisings, including any groundwater arisings, does not cause or spread contamination.

3.7 Security of Site

All walls, fences, hedges, etc breached or otherwise disturbed during the progress of the Site Operations shall be immediately repaired by the Contractor with stockproof barriers irrespective of whether stock is occupying the land or not; and in the case of gates, an equivalent replacement shall be used.

3.8 Working areas

3.8.1 General

The Contractor shall confine his Site Operations to the minimum area of ground required. On completion of each exploratory hole the site and access routes thereto shall be left in a clean and workmanlike condition. The Contractor shall remove any excess spoil and shall make good damage, whether in the vicinity of a hole or on the access route thereto, to the satisfaction of the Engineer. He shall be responsible for damage to crops, stock or property due to his failure to carry out such restoration. Paving slabs and blocks shall be removed at the site of each exploratory hole and stored separately for reuse. Paving slabs and blocks which are liable to be damaged by the operations shall either be removed and stored as above or otherwise protected from damage. Other paved areas shall be broken out to the minimum

extent necessary for each exploratory hole. Reinstatement shall be as described in clause 3.9.

3.8.2 Working on potentially contaminated land

3.8.2.1 The Contractor shall take the necessary precautions to control and secure the Site Operations on potentially contaminated land. Access to and egress from such land shall be via a single designated point where a hygiene facility for personnel and a wheel wash facility for equipment may be required as defined in Schedule 1.8. The main site office and messing facilities shall be located outside the potentially contaminated land.

3.8.2.2 Arisings from exploratory holes shall be placed on heavy gauge polyethylene sheeting and covered in wet or windy weather so as to prevent the spread of contamination, or placed in covered skips.

3.8.2.3 At the end of the working day any exploratory hole not backfilled shall be securely covered and fenced so as to prevent human or animal access.

3.8.2.4 The Contractor shall dispose of all surplus excavated material in accordance with current waste disposal legislation.

3.9 Backfilling and reinstatement of exploratory holes

3.9.1 Backfilling

3.9.1.1 Exploratory holes shall be backfilled as soon as practicable after the hole is completed, unless otherwise directed by the Engineer. The Contractor shall backfill and compact all exploratory holes in such manner and using such materials that no subsequent depression is formed at the ground surface due to settlement of the backfill. Where required by the Engineer, the Contractor shall return during the Period of Maintenance to fill any subsequent depression or to remove any surplus soil which has failed to settle sufficiently, without reducing the original depth of topsoil at the ground surface. Exploratory holes which are required for subsequent Ancillary Work shall be backfilled in the appropriate manner.

3.9.1.2 Where concrete infilling to exploratory holes is specified in Schedule 2 it shall be in accordance with clause 2602 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments) unless otherwise described in the Contract. Where cement/bentonite grout backfill is required it shall consist of equal portions by weight of Ordinary Portland cement and bentonite mixed by machine or hand to a uniform colour and consistency before placing, with a moisture content not greater than 250%. The grout shall be introduced at the bottom of the hole by means of a tremie pipe, which shall be raised but kept below the grout surface as the filling proceeds.

3.9.1.3 Where directed by the Engineer, in addition to the requirements of clauses 3.9.1.1 and 3.9.1.2, a precast concrete slab, having minimum dimensions of 600 mm square and 50 mm thick shall be provided and placed centrally over the exploratory hole and the top of the slab shall be at least 500 mm below ground level. The remaining depression shall be backfilled and the surface made good with topsoil or turf, as described in clause 3.9.3, or the surface made good as described in the Contract.

3.9.1.4 Highway reinstatement shall be in accordance with the New Roads and Streetworks Act 1991 and the Specification for the Reinstatement of Openings in Highways (1992).

3.9.2 Particular requirements on potentially contaminated land

Unless specified otherwise, backfill to pits and trenches on potentially contaminated land shall comprise of the solid arisings being replaced at the same depth and location from which they originated. Any deficit in material at a particular level shall be made up with inert material having a coefficient of permeability of less than 10^{-5}m/sec as placed. Backfill to other exploratory holes on potentially contaminated land shall comprise cement/bentonite grout as specified in clause 3.9.1.2.

3.9.3 Turf and topsoil

Turf and topsoil shall be stripped at the site of each exploratory hole and stockpiled separately for reuse. Turf and topsoil adjacent to the exploratory hole which may be damaged by the operations shall either be removed and stockpiled as above, or otherwise protected from damage. After completion of the holes the topsoil shall be spread evenly over the area to its original thickness or to the thickness required in the Contract. It shall be reduced to a fine tilth free from stones and other debris with any dimension greater than two thirds the thickness of the topsoil layer. When turf is relaid, it shall be laid so as to match the original profile of the ground and shall be well bonded and lightly tamped. Where new turfing is required the turves shall comply with BS 3969.

3.10 Compensation for unavoidable damage

Any claims for compensation by owners or occupiers for damage to crops, ground surface, hedges or fences which are considered by the Contractor to be unavoidable under Clause 22 of the Conditions of Contract shall be referred to the Engineer for decision.

3.11 Engineer's facilities

3.11.1 The Contractor shall supply and maintain accommodation, furnishings, services, and equipment for the sole use of the Engineer all in accordance with Schedule 3. All accommodation, furnishings, services, office and survey equipment and vehicles shall be ready for occupation and use by the Engineer on the Date for Commencement of the Site Operations, and shall be removed at the end of the Site Operations unless otherwise directed by the Engineer.

3.11.2 The Contractor shall provide plain coloured transport as described in Schedule 3, for the exclusive use of the Engineer for any purpose in connection with the Site Operations. The vehicles shall be delivered and maintained in good roadworthy condition. They shall be licensed and insured for use on the public highway and shall have comprehensive insurance cover for any qualified driver authorised by the Engineer together with any authorised passengers and the carriage of goods or samples. The Contractor shall provide fuel, oil, and maintenance in conformity with the vehicle manufacturer’s recommendation and shall clean the vehicles inside and outside as required. A suitable replacement shall be provided for any vehicle out of service for more than 24 hours.

3.12 Professional attendance on Site

3.12.1 The Contractor shall provide professional attendance of experience as described in Schedule 1.8 full time on site. The professional attendant shall be approved in writing by the Engineer which approval may be withdrawn at any time, and shall be responsible for the technical direction and output of the Site Operations.

3.12.2 In addition to the requirements of the Conditions of Contract, and of clauses 3.12.1, 4.4.2, 5.3.6, 5.4.2, 6.5 and 7.14 of this Specification, the Engineer may require the services of geotechnical and environmental personnel for advice, assistance and/or the preparation of interpretative reports as defined in Schedule 1.8. The Contractor shall submit adequate records of time and expenses to the Engineer. If required by the Engineer, details of the qualifications and experience of the personnel shall be supplied.

3.13 Written instructions to site staff

3.13.1 The Contractor shall give written instructions to his site staff on all relevant aspects in the Specification. A copy of these instructions shall be provided to the Engineer prior to the commencement of the Site Operations.

3.13.2 The instructions shall include a description of the nature of any potential hazards and the details of appropriate precautionary measures in handling and disposing of material on potentially contaminated land.

3.14 Location of exploratory holes

The Engineer will provide the Contractor with the National Grid coordinates of each exploratory hole in Schedule 2 together with adequate bench marks, permanent ground markers and/or other information sufficient for the Contractor to set out the whole of the Site Operations in accordance with Clause 17 of the Conditions of Contract.

The Contractor shall establish the position of each exploratory hole, and shall confirm this position with the Engineer prior to commencing any Site Operations at that location. Each position shall be reported to the nearest 0.5 m using National Grid coordinates.

3.15 Ground elevation of exploratory holes

The Contractor shall establish the elevation of each exploratory hole prior to commencing any Site Operations at that location. Ground elevations shall be related to Ordnance Datum and shall be established to the nearest 0.05m.

3.16 Exploratory work

The location and depth of each exploratory hole shall be as described in Schedule 2. The Engineer may, after consultation with the Contractor, vary the location and depth of any exploratory hole and the sequence or quantity of in situ testing depending on the actual ground conditions encountered. When the position of an exploratory hole has been varied, the Contractor shall take all necessary measurements and shall inform the Engineer of the revised coordinates and ground elevation or other measurements required to locate the exploratory hole. This data shall be submitted in the same format as stated in Schedule 2 to locate the original position.

The Contractor shall obtain the Engineer's prior approval before commencing any exploratory hole and before moving his equipment from each location and backfilling each exploratory hole.

3.17 Methods of investigation

The Engineer may require investigation to be carried out by all or any of the methods described in the Specification.

3.18 Mine workings

The positions of any known mine workings, mineral extractions, quarries, shafts or similar works within the area and at a depth likely to affect the Site Operations are shown on the Drawings as far as available records will permit. If evidence of further mining activity is revealed, the Contractor shall inform the Engineer immediately and await his further instructions.

3.19 Potentially contaminated land

3.19.1 General

The presence and nature of the known areas of potentially contaminated land are noted in Schedule 1.17 and shown on the Drawings as far as available records permit. If evidence of further potentially contaminated land is encountered the Contractor shall cease work and inform the Engineer immediately. The Contractor shall agree a revised method of working appropriate to the nature and level of hazards encountered with the Engineer and any concerned regulatory authority.

3.19.2 Statement of working methods

In accordance with the requirements of Clause 14 of the Conditions of Contract, and not less than 14 days before the commencement of Site Operations on potentially contaminated land the Contractor shall provide a statement describing in full the arrangements and methods he proposes to adopt in carrying out the Site Operations including full details of safety precautions.

The Contractor shall not subsequently amend the statement or any working practice or procedure contained therein, except as provided for in clause 3.19.3, without the consent of the Engineer.

3.19.3 Liaison with authorities

Not less than 14 days prior to the commencement of the Site Operations on potentially contaminated land the Contractor shall liaise with the authorities listed in Schedule 1.17 and agree actual working practices and procedures to be adopted on potentially contaminated land. The Contractor shall, if necessary, subsequently amend and re-submit the statement of working methods to the Engineer to take account of any variation agreed with the authorities. The Contractor shall advise the Engineer when any meeting with the authorities to discuss working practices is to be held.

3.19.4 COSHH assessment

Not less than 7 days prior to the commencement of the Site Operations on potentially contaminated land the Contractor shall submit a copy of his COSHH Statement relating to these Site Operations to the Engineer for information, together with any revised statement of working methods resulting from clause 3.19.3.

3.19.5 General safety precautions

On potentially contaminated land, the Contractor shall comply with the safety requirements of "Protection of Workers and the General Public During the Development of Contaminated Land" (1991) and follow the safety guidance in Appendix A of DD175:1988 - "Code of Practice for the identification of potentially contaminated land and its investigation" (Draft for Development) and Section 7 of the Site Investigation Steering Group publication "Guidelines for the safe investigation by drilling of landfills and contaminated land" (1994). The following minimum requirements shall apply in addition to any requirements stipulated in Schedule 1.17:

(i) Site personnel shall wear protective overalls, safety hat, safety boots, gloves and/or barrier cream and eye protection where appropriate. Any protective clothing and footwear shall be removed at the hygiene facilities before leaving the potentially contaminated land.

(ii) Dust masks of suitable efficiency and artificial respiratory equipment shall be available on site for the duration of the Site Operations on potentially contaminated land.

(iii) Instructions for use of safety equipment shall be prominently displayed and at least one member of staff who is conversant with the use of the safety equipment shall be on site at all times during working hours.

(iv) An adequate range of appropriate first aid facilities shall be provided.

(v) Adequate washing facilities shall be provided at the hygiene facilities.

(vi) Activities which involve hand to mouth contact, such as eating and smoking, shall not be permitted on potentially contaminated land.

(vii) No naked flames or other ignition sources shall be allowed on potentially contaminated land.

(viii) Only suitably trained personnel shall be permitted to work in confined spaces or in excavations. Health and Safety Executive Guidance Note GS5 shall be strictly adhered to.

(ix) The Contractor shall make adequate provision of both personnel and equipment for rescue should an incident occur. The Contractor shall inform the local hospital of the type of work in progress and the potential type of injuries.

The above list is not exclusive and does not remove from the Contractor any obligations to conform with Statutes etc under Clause 26 of the Conditions of Contract.

3.19.6 Safety plan

The statement of working methods shall include a safety plan presenting details including, but not limited to, the following:

1. Specification for personal protective equipment to prevent ingestion of, inhalation of and skin contact with contaminated materials.

2. Details of decontamination facilities.

3. Statement of safe working practices which will be employed to avoid or minimise contact with contaminated materials.

4. Details of health and safety training undertaken by all levels of the work force.

5. A schedule for each potentially contaminated area giving the name, organisation, specialism, availability, location and proximity of specialist health and safety expertise within the Contractor's organisation and externally.

3.20 Anomalous conditions

Where anomalous or unexpected features are revealed the Contractor shall inform the Engineer immediately.

3.21 Surface water control

Surface water or other water shall be prevented from entering the exploratory hole from at or above ground surface level, except as permitted in clause 4.2.

3.22 Traffic safety and management

3.22.1 When planning and undertaking work on highways open to traffic the Contractor shall take account of the recommendations contained in the following:

(a) for work on motorways - "Planning for safety Guidance Notes for the Health and Safety of Workers at In-Service Motorway Roadworks Sites", issued jointly by the Department of Transport, the Welsh Office, the Scottish Office Industry Department and the Federation of Civil Engineering Contractors;

(b) for works on all highways - "Safety at Roadworks: Notes for Guidance (1993)" issued jointly by the Department of Transport and the County Surveyors' Society.

3.22.2 When planning traffic safety and management measures the Contractor shall take into account the information contained in Schedule 1.8.

3.22.3 The Contractor shall, unless otherwise stated in Schedule 1.8, after consultation with any statutory, police or other authority concerned prepare and submit traffic safety and management proposals within the timescale described in Schedule 1.8 to the Engineer for consent. These shall show the proposed traffic safety and management measures, including provision of safety zones, which he proposes for carrying out the Site Operations. If stated in Schedule 1.8, the proposals shall include the provision of running lanes for the use of emergency vehicles within the Site. If required by the Engineer the Contractor shall make such changes to his proposals as may be necessary, in the opinion of the Engineer, to meet the requirements of the Contract and to obtain the Engineer's consent. Thereafter the Contractor shall furnish such details and information as may be necessitated by the Site Operations or as the Engineer may require.

3.22.4 Central reserve crossovers shall not be permitted.

3.22.5 If stated in Schedule 1.8, the Contractor shall undertake the maintenance functions described therein and to the extent there described, on the lengths of highway there specified, until the issue of the appropriate Certificate of Completion.

3.22.6 Nothing in clause 3.22.5 shall relieve the Contractor from his obligations under Clause 22 of the Conditions of Contract to the extent that they require the Contractor to indemnify and keep indemnified the Employer against losses and claims for injuries or damage to any person or property, which may arise out of or in consequence of a failure on the part of the Contractor adequately to maintain a highway described in Schedule 1.8.

3.22.7 The Contractor shall, unless otherwise stated in Schedule 1.8, provide, erect, maintain, reposition, cover and uncover and finally remove traffic signs as required by the Site Operations. In so doing, such other measures shall be taken by the Contractor as may be necessitated by the Site Operations in accordance with any special requirements in Schedule 1.8, recommendations in Chapter 8 of the Traffic Signs Manual published by the Stationery Office Ltd or any amendments thereto, or other instructions of the Overseeing Organisation listed in Schedule 1.8. Where the circumstances of any particular situation are not covered by the recommendations or described in Schedule 1.8, the Contractor shall submit proposals for dealing with that situation to the Engineer for consent.

3.22.8 Traffic signs shall comply with the appropriate Clauses in Series 1200 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments). The Contractor shall unless otherwise stated in Schedule 1.8 keep traffic signs clean, secure and legible and ensure that all signs required to be lit, whether by external or internal lighting, are so lit during periods when road vehicles are required to display lights.

3.22.9 Where the Contract provides that the Contractor shall not erect, maintain or reposition traffic signs, the Contractor shall not change in any manner the permanent or temporary traffic signs except with the consent of the Engineer and shall give the Engineer such notice as is stated in Schedule 1.8 to indicate when signs should be moved compatible with the progress of the Site Operations.

3.22.10 All traffic safety and management measures necessitated by the Site Operations shall be fully operational and shall have been approved by the Engineer before the Contractor commences any work which affects the public highway or the use of it.

3.22.11 Any area of highway which has been closed because of the Site Operations shall not be re-opened until the Engineer is satisfied that all appropriate traffic safety and management measures have been completed and the highway is in a suitable condition for public use.

3.22.12 Where work is carried out on, or adjacent to a highway open to traffic the Contractor shall ensure that vehicles and equipment under his control operating frequently or regularly on or adjacent to that highway in the execution of the Site Operations shall be painted in a conspicuous colour and shall have sign boards reading “Highway Maintenance” or where appropriate “Motorway Maintenance”, fixed at the rear. The lettering shall be 150 mm x height for vehicles and plant except that for light vans and cars it shall be the largest x height that can be accommodated out of the following heights: 37.5, 50, 62.5, 75 or 100 mm. The lettering shall be in black capital letters from the “Transport heavy alphabet”, described in The Traffic Signs Regulations and General Directions 1981 Schedule 7 Part V, on a yellow non-reflectorised background in accordance with BS 381C lemon yellow No 355. In addition each such vehicle or item of plant shall be provided with a roof mounted amber flashing distinctive lamp. The lamp shall be switched on:

(i) when the vehicle or plant is manoeuvring into or out of the Site or operating at low speed on a carriageway or hard shoulder open to vehicles and;

(ii) when the vehicle or plant is standing on a carriageway or hard shoulder open to vehicles, unless Schedule 1.8 permits hazard warning lights to be switched on and they are.

3.22.13 Temporary lighting shall be provided in accordance with Clause 1405 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments) where required by Schedule 1.8, or by the Contractor in the execution of the Site Operations with the consent of the Engineer.

3.22.14 The Contractor shall provide and suitably sign points of entry to and exit from the Site, for vehicles and equipment engaged on the Site Operations. Such provision shall be subject to the agreement of the Engineer. The Contractor shall ensure that when any vehicle or item of equipment is reversing within the Site on or adjacent to a highway open to traffic, it does so only under the supervision of a person designated for the purpose of regulating traffic within the Site who shall be readily distinguishable from the remainder of the work force.

3.22.15 Where work is carried out on or adjacent to a highway open to traffic the Contractor shall ensure that the workforce, the site supervising staff and visitors at all times wear high visibility garments appropriate to the assessed level of risk. For work on motorways and high speed dual carriageways, high visibility clothing complying with BSEN471:1994 Class 3 should be worn outside protected areas. Where workers are protected by a safety zone, garments to BSEN471:1994 Class 2 may be adequate. In accordance with Clause 104.2 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments), garments complying with other specifications may be used where they offer equivalent levels of performance. The Contractor shall ensure that the person in charge of the workforce is readily distinguishable from the person designated in clause 3.22.14 and from the remainder of the workforce.

3.22.16 Where required in Schedule 1.8, the Contractor shall appoint a Traffic Safety and Control Officer who shall make all arrangements necessary for traffic safety and control. The Traffic Safety and Control Officer shall have one or more nominated deputies. The Contractor shall provide the Engineer with the names of this Officer and his nominated deputies and with telephone numbers or details of other means by which they or one of them can be contacted at any time. The Traffic Safety and Control Officer or his nominated deputy shall be on the Site at all times when work is proceeding and shall be readily available to deal with matters related to traffic safety and control.

3.22.17 If an accident or breakdown occurs on a carriageway or hard shoulder open to traffic within or in the vicinity of the Site, the Contractor shall act as requested by the police but subject to any instructions or contrary directions by the Engineer.

3.22.18 Headlamps shall not be used when facing oncoming traffic whilst in a closed-off section of carriageway.

3.22.19 The storage of plant and materials or the mixing of materials will not be permitted on any part of the carriageway or hardshoulder.

3.22.20 The Contractor shall not display any advertisement on the highway site without the written consent of the Engineer.

3.23 Quality management

Where required in Schedule 1.8, all work shall be carried out in accordance with a quality management system established in accordance with BS EN ISO 9001. Records to indicate compliance with quality management shall be made available to the Engineer on request.

3.24 Accreditation of drillers

3.24.1 All drillers employed on the Contract shall hold a certificate of competence for percussion boring or rotary drilling applicable to the work on which they are engaged, as issued by the British Drilling Association Limited under the Ground Investigation Driller's Accreditation Scheme or an equivalent body in a State of the European Economic Area.

3.24.2 Alternatively, non-accredited drillers may be employed, provided each rig is supervised by an engineer or geologist meeting the requirements of clause 2.2 item (e), except for investigations on potentially contaminated land where an accredited driller shall be engaged. This supervision shall be on the basis of one full time engineer or geologist for each rig.

3.25 Laboratory accreditation

The schedule of tests specified in Appendix 5 shall be carried out in laboratories that are currently accredited for those tests by UKAS (the United Kingdom Accreditation Service) or equivalent EU bodies.

3.26 Photographs

3.26.1 Where required in the Contract, colour photographs shall be taken and supplied by the Contractor. Each photograph shall clearly show all necessary details and shall contain a graduated scale which shall be the same in every photograph of a particular type. A standard colour chart and monochrome step wedge shall also be included in each photograph.

3.26.2 A single gloss colour enprint (minimum size 150mm x 100mm) copy of each photograph shall be submitted to the Engineer for his approval and retention within 2 working days of the photography. In the event that the photographs are of a quality unacceptable to the Engineer they shall be retaken.

3.26.3 On acceptance of the quality of the photograph two complete sets of enprints of all the approved photographs shall be presented, annotated and submitted in bound volumes together with the photograph negatives with the Factual Report. A bound volume shall comprise of one complete set of prints of approved photographs. A copy of the standard colour chart and monochrome step wedge shall be included in each bound photographic volume.

3.26.4 Particular requirements for photographs of cores and pits and trenches are given in clauses 5.8 and 6.9.

4. BOREHOLES

4.1 Method and diameter

4.1.1 The method of advancement and the diameter of a borehole shall be such that the boring can be completed and logged to the scheduled depth, and samples of the specified diameter can be obtained, in situ testing carried out and instrumentation installed as described in the Contract.

4.1.2 The following methods may be employed for advancement of a borehole unless otherwise stated in Schedule 1.9.

Percussion boring
Auger boring
Rotary drilling

4.2 Addition of water to the borehole

Water shall not be used to assist the advance of the borehole except where approved by the Engineer. Where the borehole penetrates below the water table and disturbance of the soils is likely, a positive hydraulic head shall be maintained in the borehole at all times during sampling and boring.

4.3 Percussion boring

4.3.1 Hard stratum or obstruction in percussion boring

In borings using percussion boring techniques where hard strata or obstructions are encountered the Contractor shall continue boring using a chisel or similar approved tool for a minimum time of 1 hour in an attempt to penetrate the hard strata or obstructions. Upon completion of the above requirement the Contractor shall consult with the Engineer who shall instruct the use of one or more of the following procedures:-

4.3.1.1 Continue boring using a chisel or similar approved tool to penetrate the hard strata or obstruction, or to break it up sufficiently for fragments to be recovered and identified until otherwise instructed by the Engineer. If, in the Engineer's opinion, insufficient progress is being made he may instruct the Contractor to change to rotary drilling as in clause 4.3.1.2, or abandon the boring as in clause 4.3.1.4.

4.3.1.2 Continue the exploratory hole by rotary core drilling to the required depth of the hole unless otherwise instructed by the Engineer. The equipment used shall be capable of producing cores of not less than the minimum diameter stated in Schedule 2.

4.3.1.3 Should the hard strata or obstruction prove to be a thin ledge of rock, boulder or other object underlain by soil, by penetrating it, the Engineer will instruct the Contractor to either break out the hard strata or obstruction to allow boring, in situ testing and sampling to proceed, or to continue with rotary drilling as in clause 4.3.1.2.

4.3.1.4 Abandon the boring and commence a further boring nearby to obtain the required samples.

4.3.2 Use of clay cutters

Clay cutters shall not be used for advancing the boring in soft alluvial soils or where the undrained shear strength of the soil is less than 40kN/m^2 as measured by the vane test (BS 1377: Part 9, clause 4.4). Where clay cutters are permitted they shall be of a pattern approved by the Engineer, and the combined weight of clay cutter and any sinker bar shall not exceed 150kg in the case of 150mm diameter borings and 180kg in the case of 200mm diameter borings.

4.3.3 Use of shell and casing

Care shall be taken at all times to avoid disturbing or loosening of the soil or loss of ground. When using a shell and casing, in order to keep disturbance of the ground to a minimum, the Contractor shall operate the equipment in such a way as to allow the shell to proceed before the casing only the minimum distance necessary to advance the boring. The casing shall not be advanced by reciprocating action of the cable, but by driving, rotation or self-weight.

4.4 Augering

4.4.1 Hand auger

Where hand augering is specified in the Contract the equipment shall be used to auger and recover samples to a maximum depth of 4m. The minimum diameter shall be 100mm.

4.4.2 Continuous flight augering

Where continuous flight augering is required it shall be carried out under the full time supervision of an engineer or geologist meeting the requirements of clause 2.2 item (d) who shall produce, as augering proceeds, a record of the material and groundwater encountered.

4.4.3 Hollow stem flight augering

Where hollow stem flight augering is required the equipment used shall be such as to auger and recover samples as specified in Schedule 1.9. Sampling shall be carried out through the hollow stem.

4.5 Rotary drilling in soils

Where rotary drilling is employed the work shall be carried out in accordance with Section 5, Rotary drilling.

4.6 Percussion boring with tube window sampling

Where specified in Schedule 2, boring shall be carried out by driving tubes with longitudinal window slots. The equipment shall comprise one or more tubes mounted on a cutting shoe suitable for the purposes of recovering a continuous soil sample. The equipment shall be driven into the ground by pneumatic, mechanical or hydraulic percussive methods. The minimum sample diameter shall be 30mm. The soil recovered shall be logged by an engineer, geologist or environmental scientist, as appropriate, meeting the requirements of clause 2.2 item (d), before removal from the sampling tube.

4.7 Backfilling

The Contractor shall backfill boreholes with arisings except on potentially contaminated land or where special infilling is required by the Engineer. On potentially contaminated land backfill shall comprise cement/bentonite grout (as specified in clause 3.9.2) unless other special infilling is described in Schedule 1.9 or otherwise required by the Engineer.

4.8 Artesian water

Where artesian water is encountered the Contractor shall immediately inform the Engineer and shall attempt to contain the artesian head by extending the casing above the existing ground surface by a maximum of 1m. Where an artesian head greater than 1m above ground surface is encountered the Contractor shall cap the boring and fit a pressure gauge and by-pass to measure the pressure head of the artesian water.

On completion of boring, the exploratory hole shall be grouted up. A suitable grout tube shall be lowered to the bottom of the exploratory hole and an approved sand/cement grout mix pumped down the tube, the lower end of which shall always remain below the level of grout in the hole until grouting is completed. If it is not possible to extract the casing it shall be left in the hole permanently.

5. ROTARY DRILLING

5.1 General

5.1.1 Rotary drilling may be required starting from ground level, or to extend borings which cannot penetrate further, or to prove rock in borings prior to breaking it out. Open hole drilling may be carried out where core drilling is not required.

5.1.2 Where required by clause 5.3.3, or where requested by the Engineer, SPTs as specified in clause 8.3.1.4 shall be carried out.

5.2 Drilling fluid

5.2.1 The drilling fluid shall normally be clean water, air or air mist. However, with the agreement of the Engineer non-toxic drilling muds, additives or foam may be used.

5.2.2 On potentially contaminated land the Contractor shall take all necessary precautions to contain the drilling fluid returns in order to prevent surface contamination.

5.3 Rotary drilling with core recovery

5.3.1 Types of equipment

Unless otherwise stated in Schedule 1.10 rotary core drilling shall be carried out by a double or triple tube coring system incorporating a removable inner liner. The triple tube system may be effected by use of a double tube barrel with an approved semi-rigid liner. Rotary core drilling shall normally be carried out with diamond or tungsten carbide tipped bits which shall be suitable for the percentage core recovery and diameters required. Where rotary drilling is ordered within weathered rock strata which include friable or soft layers, softer lenses within solid rock, or other than solid continuous strata, the Contractor shall use suitable well maintained equipment to produce cores in such strata to meet the recovery requirements. All bits, core barrels, and casing shall conform to BS 4019: Part 3.

5.3.2 Core recovery

Rotary core drilling shall produce cores of circular cross section not less than the specified diameter (Schedule 1.10) throughout the core length. The type and state of drill bit, feed rates and management of the drill shall be such that 100% core recovery in any single run can be obtained where the condition of the rock permits. Core recovery less than 90% in any drill run will not normally be acceptable unless the Engineer is satisfied that a greater recovery than 90% is impractical under the prevailing conditions. Where core recovery is less than 90% or the rate of coring indicates a core recovery of less than 90%, a standard penetration test shall be carried out in the rotary core hole.

5.3.3 Drill runs

The first drill run in each hole shall not exceed 1m in length. Subsequent drill runs shall not normally exceed 3.0m in length and the core barrel shall be removed from the drill hole as often as is required to obtain the best possible core recovery. When any recovery is less than 90% from a drill run then the next drill run shall be reduced to 50% of the previous length, unless otherwise directed by the Engineer, and so on down to a minimum length of 0.5 m. The Engineer may specify in situ testing between drill runs.

5.3.4 Removal of cores and labelling of liners

5.3.4.1 All operations entailed in recovering the cores from the ground after completion of drilling shall be carried out in a manner such as to minimise disturbance to the cores.

5.3.4.2 Core barrels shall be held horizontally while the innermost liner containing the core is removed without vibration and in a manner to prevent disturbance to the core. The core should be rigidly supported at all times while it is being extruded and during subsequent handling, and the liner containing the core must not be allowed to flex.

5.3.4.3 Immediately after removing the liner the top and bottom shall be marked in indelible ink. Liners shall be cut to the length of the enclosed core. The ends of the liners shall be capped and sealed using adhesive tape.

5.3.4.4 Where the length of core recovered from any single core run is such that it cannot be accommodated in one channel of the core box, the liner shall be cut to coincide, if possible, with existing fractures. The liner either side of the cut shall be marked ‘cut’ and the ends capped as above.

5.3.4.5 Each section of liner shall be marked with the Contract title, exploratory hole reference number, date and the depths of the top and bottom of the drill run.

5.3.4.6 Core obtained without a liner and that from within the core catcher but not inside the liner shall be wrapped in two layers of plastic cling film and labelled to indicate the depth and exploratory hole reference number.

5.3.5 Core boxes, packing, labelling, storing

5.3.5.1 Core boxes shall be soundly constructed and fitted with stout carrying handles, fastenings and hinged lids. The total weight of the cores and box shall together not exceed 60kg.

5.3.5.2 Cores shall be rigidly and securely packed at the site of drilling and during all subsequent handling and storage the cores shall remain packed unless required for examination or testing. Cores shall be placed in the box, in their liners where used, with the shallowest core to the top left hand corner, the top being considered adjacent to the hinged section. Cores from the core catcher shall also be placed in the core boxes at the correct relative depth.

5.3.5.3 Depth shall be indicated on the core box by durable markers of a type approved by the Engineer at one metre intervals and at all significant changes of strata and at the end of each drill run. Where there has been failure to achieve 100% recovery, core spacer pieces of appropriate size clearly indicating the missing lengths, shall be placed in the boxes. The location, exploratory hole number and the depth of coring relating to the contents of each box shall be clearly indicated in indelible ink on labels, inside the box, on the top and on each end of the box. All markers and labels shall be such as to facilitate subsequent photography. All core boxes other than those to be retained by the Employer shall remain the property of the Contractor.

5.3.5.4 Core boxes containing core shall be kept horizontal and moved and handled with care at all times. Core shall be protected to ensure that their temperature does not fall below 2°C and rise above 25°C. They shall also be protected from direct heat and sunlight. At the end of each day's work, core boxes shall be stored secure from interference and protected from the weather.

5.3.6 Preparation of cores for examination

5.3.6.1 Cores shall be prepared for examination by the removal of sealing materials and splitting of liners in such a way as not to damage the cores. Plastic liners shall be cut lengthwise such that at least half the core circumference is exposed.

5.3.6.2 Prior to examination of the core the Contractor shall photograph the cores as specified in clause 5.8. The time between commencement of preparation and the examination of the prepared and photographed cores shall be minimised to prevent loss of moisture from the core samples.

5.3.6.3 The cores shall be examined and described on site by an engineer or geologist meeting the requirements of clause 2.2 item (d). Logging shall be in accordance with BS 5930 and the recommendations of the Engineering Group of the Geological Society Working Party Report 'The logging of rock cores for engineering purposes' (1970). Access for the inspection of the cores by the Engineer shall be provided by the Contractor for the duration of the Contract.

5.3.7 Retention of core sub-samples

When the examination of the cores has been completed, the Contractor may be required to retain separately specified core sub-samples for possible laboratory testing. The Contractor shall cut the liner and cap and seal the core sub-samples in such a way as to prevent loss of moisture and sample disturbance. They shall be clearly labelled so that the location, depth and origin of the sub-samples can be readily identified. Cores in their liners remaining after the specified sub-samples have been removed shall be end-capped and resealed and replaced in the original core box location. Rigid spacers shall be placed in the spaces in the core boxes previously occupied by the core sub-samples to prevent movement of adjacent cores and these shall be labelled identically to the core sub-samples that they replace. The core sub-samples shall be retained in separate core boxes clearly marked to indicate the origin of the cores contained within.

5.3.8 Protection and transportation of cores

The Contractor shall be responsible for the protection of all cores and for their transport (including loading and unloading):

(a) to the Contractor's laboratories, or

(b) to a store or laboratory as stated in Schedule 1.10.

5.3.9 Retention and disposal of cores

Retention and disposal of cores shall be in accordance with Clause 20(2) of the Conditions of Contract, with the report referred to in Clause 20(2) being that defined in Schedule 1.10. However, in addition, the Engineer may instruct that some cores be sent elsewhere. The disposal of core samples from potentially contaminated land shall be in accordance with current waste legislation.

5.4 Rotary drilling without core recovery

5.4.1 Rotary open hole or rotary percussive drilling may be used to advance a hole. The hole diameter shall be as stated in Schedule 1.10.

5.4.2 When used for the purpose of locating mineral seams, mineworkings, adits, shafts, other cavities or anomalous conditions, drilling shall be under the full-time supervision of an engineer or geologist meeting the requirements of clause 2.2 item (d). As drilling proceeds a systematic record shall be made of the drilling methods, rate of penetration, loss of flushing medium, the material penetrated and any cavities or broken ground encountered.

5.5 Backfilling

5.5.1 Except where otherwise specified the Contractor shall backfill rotary drillholes with a cement bentonite grout as defined in clause 3.9.1.2.

5.5.2 Where artesian water conditions or voids make normal grouting impractical the Contractor shall consult and agree with the Engineer a procedure for sealing the drillhole.

5.6 Artesian water

Where artesian water is encountered the Contractor shall follow the requirements of clause 4.8.

5.7 Proving hard strata

Where it is necessary to prove hard strata by open hole drilling from ground level or by rotary core drilling, then the hard strata shall be proved to 1.5 m depth or as otherwise instructed by the Engineer.

5.8 Photographs

In addition to the requirement of clause 3.26 the Contractor shall photograph cores where required in a fresh condition prior to logging preferably on the day of recovery, but always within a maximum of 72 hours of recovery and ensure that the following criteria are fulfilled.

(a) A graduated scale in 10mm intervals is provided.

(b) Labels and markers are clearly legible in the photograph.

(c) A clearly legible reference board identifying the project title, exploratory hole number, date and depth of drill runs shall be included in each photograph.

(d) Core boxes are evenly and consistently lit.

(e) The length of the core box in each photograph fills the frame.

(f) The core fills a minimum of 50% of the frame.

(g) The focal plane of the camera and the plane of the core box are parallel.

(h) The camera is placed in the same position with respect to the core box in every photograph.

5.9 Borehole closed circuit television surveys

Borehole closed circuit television surveys shall be carried out where directed by the Engineer. The camera equipment shall be capable of entering a 100 mm diameter exploratory hole and shall have adequate lighting, forward and lateral viewing capabilities. The survey shall be seen live on a TV monitor. Depth and inclination of the camera and azimuth shall be recorded on to the video tape at all times, and a facility for recording general reference information at selected positions on to the tape for permanent record purposes shall be available. The closed circuit television camera shall be of a suitable type which can be used in exploratory holes containing a mixture of potentially explosive gases. The Contractor shall be responsible for presenting a report describing features observed and giving the depth of each feature described. Preliminary results of the closed circuit television surveys consisting of all video tape recordings (in VHS format) and report shall be submitted to the Engineer in duplicate within 7 calendar days of the completion of the work to which they refer.

6. PITS AND TRENCHES

6.1 Inspection pits

The Contractor shall start all exploratory holes located within the boundaries of public highways and elsewhere where the presence of underground services or field drains is expected by means of a hand excavated inspection pit not less than 1.0m^2 in base plan area and 1.2m deep. Hand-operated power tools may be used to assist excavation where hard strata such as road pavements cannot be broken out without the use of such tools. Exploratory holes shall not begin until the presence or otherwise of all such services has been established. The positions, depths and dimensions of all services encountered shall be measured and recorded in the daily report with other information as required by clause 10.2.

6.2 Trial pits and trenches

6.2.1 Trial pits and trenches shall be excavated to enable visible examination and sampling from outside the pit or trench. They shall be excavated by hand to a maximum depth of 1.2m or by machine to the required depth.

6.2.2 Trial pits and trenches on potentially contaminated land shall be excavated by machine only.

6.3 Observation pits and trenches

6.3.1 Observation pits and trenches shall be excavated by hand or machine, and shall be adequately supported at all times to enable personnel to enter and work safely and to permit in situ examination, soil sampling and testing as required. The supports shall be placed so as to minimise interference with the taking of samples or inspection of the faces. The Contractor shall make available at the site of each observation pit or trench, a ladder of adequate length to permit access to the base of the excavation.

6.3.2 Observation pits and trenches on potentially contaminated land shall be excavated by machine, unless specified to be dug by hand in Schedule 2. All safety precautions as required under clause 3.19 shall be followed before and during personal entry into observation pits and trenches.

6.4 Pit and trench dimensions

Unless otherwise required in Schedule 1.11,

(a) trial pits and observation pits shall have a minimum base plan area of 1.5m^2.

(b) trial trenches and observation trenches shall have plan base dimensions of 1.0m wide and not less than 5.0m long.

6.5 Description

Pits and trenches shall be examined and described by an engineer or geologist meeting the requirements of clause 2.2 item (d). Ground from potentially contaminated land shall be described by an environmental or geotechnical specialist, as appropriate, meeting the requirements of clause 2.2 item (d).

6.6 Groundwater

The Contractor shall keep all pits and trenches free of surface water run-off. Groundwater shall be controlled by pumping from a sump to permit continuous work in so far as the rate of inflow of groundwater can be controlled by use of a 50mm outlet diameter pump and the excavation remains stable.

6.7 Backfilling

Backfilling of the pits and trenches shall be carried out in accordance with clause 3.9 with material replaced at similar depth as encountered. In open land any surplus shall be heaped proud over the pit site. In paved areas reinstatement shall be as specified in Schedule 2.

6.8 Protection to pits and trenches left open

Where pits and trenches are required to be left open for a period of several days the Contractor shall provide fencing in accordance with Clause 303.1(3) of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments) or other fencing approved as suitable for the purpose, together with all necessary lighting and signing required under Clause 19 of the Conditions of Contract. Precautions shall be taken to protect the pits and trenches from the adverse effects of weather during this period.

6.9 Photographs

The Contractor shall photograph and supply colour prints of all pits and trenches and their arisings. In addition to the requirements of clause 3.26 photographs shall clearly show details of the ground conditions in the pit and trench with any support in place and shall contain a graduated scale. Unless otherwise required in Schedule 1.11, artificial lighting appropriate to the colour balance of the film shall be used where necessary. Photographs will generally be required at the rate of three for every pit or as directed by the Engineer.

7. SAMPLING

7.1 Small disturbed samples

Small disturbed samples shall weigh not less than 1.0kg. They shall be placed immediately in airtight containers, which they should sensibly fill.

7.2 Bulk disturbed samples

7.2.1 Bulk disturbed samples shall be taken from borings, pits or trenches in both cohesive and non-cohesive soils and shall weigh not less than 25kg. They shall be representative of the zone from which they have been taken, care being taken to retain the fines of water bearing granular soils.

7.2.2 For bulk samples from a particular zone of a trial or observation pit or trench, all the recovered soil shall be placed on a suitable tray, mixed by shovel and quartered until the required amount of soil is obtained.

7.3 Open tube and piston samples

7.3.1 Open tube and piston samples shall be taken using the sampling equipment and procedures as described in BS5930 except that detachable inner liners shall not be used in open tube samplers. The diameter shall be at least 100mm unless otherwise required in Schedule 1.12. The minimum length of open tube samples shall be 450mm. The maximum area ratio of open tube samples shall be 30%.

7.3.2 Before an open tube or piston sample is taken, the bottom of the hole shall be carefully cleared of loose materials and where a casing is being used the sample shall be taken below the bottom of the casing. Following a break in the work exceeding one hour, the borehole shall be advanced by 250mm before open tube or piston sampling is resumed.

7.3.3 Where an attempt to take an open tube or piston sample is unsuccessful the hole shall be cleaned out for the full depth to which the sampling tube has penetrated and the recovered soil saved as a bulk disturbed sample. A fresh attempt shall then be made from the level of the base of the unsuccessful attempt. Should this second attempt also prove unsuccessful the Contractor shall agree with the Engineer alternative means of sampling.

7.3.4 The samples shall be sealed with paraffin wax immediately to preserve their natural moisture content and in such a manner as to prevent the wax from entering any voids in the sample.

7.3.5 Soil from the cutting shoe of an open tube shall be retained as a small disturbed sample.

7.4 Thin-walled tube samples

Thin walled tube samples shall be taken using the sampling equipment and procedures described in BS5930. The minimum sample diameter shall be 75mm. The Contractor shall ensure that the least possible disturbance occurs to the samples during sampling, storage and transport.

7.5 Undisturbed block samples

The Contractor may be required to recover undisturbed block samples in cohesive soils from trial pits. The exact dimensions of each sample, which shall be cuboid, shall be as directed by the Engineer. The weight of each sample after trimming shall be not less than 50kg. In taking the sample every care should be taken in handling to avoid damage. No water shall be allowed to come into contact with the samples which shall be sealed with an approved wax to preserve the natural moisture content and labelled and marked with their orientation.

7.6 Standard penetration test samples

When a standard penetration test (SPT) is carried out the sample from the split barrel sampler shall be retained as a small disturbed sample. Where a sample is not retained in the split barrel or when the cutting shoe is replaced by a solid cone, a bulk disturbed sample shall be taken from the test zone.

7.7 Solid samples for contamination ground investigation

7.7.1 Solid samples for the contamination ground investigation may be of any of the types covered by clauses 7.1 to 7.6 and be taken from boreholes, trial pits, observation pits and trenches.

7.7.2 Sample tubes and split spoon samplers used for recovering material for contamination testing shall be washed with clean water immediately before use to minimise the potential for cross contamination.

7.7.3 Small disturbed samples shall be taken with clean stainless steel hand tools and placed in rigid containers made of a material that is non-reactive with the likely contaminants. The containers shall be filled to the brim to effectively exclude air.

7.8 Groundwater samples

7.8.1 Samples from exploratory holes

Groundwater samples shall be taken from each exploratory hole where groundwater is encountered. Where more than one groundwater level is found, each one shall be sampled separately. Where water has been previously added, the hole shall be baled out before sampling so that only groundwater is present. The sample volume shall be not less than 1.0 litre.

7.8.2 Samples for contamination testing from sampling wells

7.8.2.1 Water samples shall be taken from sampling wells as instructed by the Engineer. Samples shall only be taken after purging standing water from the installation. The water level shall be measured prior to purging.

7.8.2.2 A minimum of three times the volume of water in the well shall be purged from sampling wells, unless otherwise specified by the Engineer. Purging shall occur from the upper part of the water column. During purging pH and conductivity levels shall be monitored when the following approximate well volumes of water have been removed: 0.5, 1.0, 2.0 and 3.0 times well volume.

7.8.2.3 The sampling equipment and procedures used shall allow discrete depth sampling and shall cause minimum disturbance to the physical or chemical condition of the groundwater.

7.8.2.4 Field tests and measurements as described in clause 8.11 shall be carried out on all samples.

7.8.2.5 Depending on the suite of chemical or biological laboratory tests to be undertaken, several sub-samples of groundwater may be required to be placed in different types and sizes of container, and chemically fixed with an appropriate agent where necessary. Specific requirements are detailed in Schedule 1.17.

7.8.2.6 Unless otherwise specified by the Engineer, water samples for metal analysis shall be filtered through a 0.45 micron membrane filter on site before any preservation fixing agents or techniques are applied.

7.8.2.7 Care shall be taken to ensure that no cross-contamination occurs either during extraction of the sample from the sampling well or whilst stored and handled prior to analysis.

7.8.3 Surface water samples

7.8.3.1 Water samples shall be taken from water courses or surface sources as instructed by the Engineer.

7.8.3.2 If chemical or biological tests are to be carried out the procedures described in clauses 7.8.2.5 to 7 shall apply.

7.9 Undisturbed sampling and testing frequency

The Contractor shall take samples as follows:

7.9.1 Borings

At each change in soil type or change in consistency, a small disturbed sample shall be taken. Immediately following this an open tube sample shall be taken in cohesive soils, a ‘bulk disturbed’ sample or standard penetration test in granular soils. Further small disturbed samples shall be taken at intervals in the same stratum midway between successive standard penetration tests, open tube samples or bulk disturbed samples. In addition the maximum distances between open tube samples, bulk disturbed samples or standard penetration tests measured centre to centre shall be as follows:

Structures: 1.0m for the first 8.0m below road profile level or existing ground level, whichever is the lower, and at 1.5m thereafter. Generally in cohesive soils alternate open tube samples and standard penetration tests shall be taken.

Embankments: 1.0m for the first 5.0m below existing ground level and at 1.5m thereafter. Generally in cohesive soils open tube samples shall be taken. If the soil becomes very stiff, penetration resistance tests shall be taken.

Cuttings: 1.0m throughout the depth of the exploratory hole. Generally in cohesive soils open tube samples shall be taken. If the soil becomes very stiff, penetration resistance tests shall be taken.

7.9.2 Inspection Pits, Trial Pits, Observation Pits and Trial Trenches

A small disturbed sample shall be taken at each change in soil type or change in consistency. Immediately following this a bulk disturbed sample shall be taken or an in situ test carried out as stated in Schedule 1.12. Further small disturbed samples shall be taken at intervals in the same stratum midway between successive bulk disturbed samples. Thin walled tube samples and undisturbed block samples shall be taken in cohesive soils where instructed by the Engineer.

7.10 Special sampling

The Engineer may require special sampling. This shall be carried out in accordance with BS5930 or as described in Schedule 1.12 of this specification.

7.11 Samples for the contamination ground investigation

7.11.1 Solid and liquid samples for contamination testing shall be taken under the supervision of an environmental scientist meeting the requirements of clause 2.2 item (d).

7.11.2 The size and type of sample and container, method of sampling and time limitations for carrying out specific analyses shall be commensurate with the range of tests to be carried out or as described in Schedule 1.17.

7.11.3 The Contractor shall take all steps necessary to avoid cross contamination of sampling points.

7.11.4 The Contractor shall take samples which are representative of each of the materials encountered. As a minimum samples shall be taken as follows unless specified differently in Schedule 1.17:

Solid Samples:

(i) The first sample shall be taken at 0.15m below existing ground level and at 1.0m intervals thereafter as required.

(ii) A sample shall also be taken where colour, odour or consistency indicate a change in the nature of the strata.

Groundwater Samples:
Samples of groundwater shall be taken from each exploratory hole in accordance with clause 7.8.1, and from groundwater sampling and combined gas and groundwater sampling standpipes in accordance with clause 7.8.3.

Gas Samples:
Gas samples shall be taken from gas monitoring standpipes and exploratory holes in accordance with the procedures given in clauses 7.12 and 8.10.

7.11.5 Handling, containment, preservation and transport of samples shall be in accordance with Section 6.4 of DD175:1988 and Sections 4.8 and 4.9 of "General Principles of Sampling and Accuracy of Results (1980).

7.12 Gas sampling

7.12.1 Samples of gas for chromatographic analysis shall be obtained from exploratory holes or standpipes, as specified in Schedule 1.12 or as directed by the Engineer. The sampling method shall relate to the volume of gas available and the type of laboratory analysis and shall be in accordance with Section 8 of CIRIA Report 131 (Crowhurst and Manchester, 1993). The sampler receptacle shall be airtight and may include lockable syringes, PTFE lined bags and gas bombs, or alternatives fit for the purpose.

7.12.2 Gas samples shall be not less than 0.075 litres in volume and shall be taken at the same time as in situ gas concentration monitoring, gas emission rate and pressure measurements in accordance with the procedure described in clause 9.11.3.

7.13 Recording depths of samples

The depths below ground level at which samples are taken shall be recorded. For open tube and piston samples the depth of the top and bottom of the sample, and the length of sample obtained shall be given. For bulk samples the limits of the sampled zone shall be recorded.

7.14 Description of samples

All solid samples shall be examined and described by a geotechnical specialist meeting the requirements of clause 2.2 item (d) in accordance with BS 5930. Solid and liquid samples taken on potentially contaminated land shall be described by an environmental or geotechnical specialist meeting the requirements of clause 2.2 item (d) and descriptions shall include colour and smell with reference to specific inclusions.

7.15 Labelling, protection and transportation of samples

7.15.1 Samples shall be clearly labelled in accordance with BS 5930. Solid, liquid or gas samples suspected to be toxic or hazardous shall be tagged with a red label (HMSO, 1984).

7.15.2 Samples other than those referred to in 7.15.5 and 7.15.6 below shall be protected to ensure that their temperature does not fall below 2°C or rise above 25°C. They shall also be protected from direct heat and sunlight.

7.15.3 Samples shall be transported to the Contractor's premises. Where required, selected samples shall be delivered to the address given in Schedule 1.12. The Contractor shall be responsible for the protection of all samples and for their transport (including loading and unloading).

7.15.4 All samples taken as part of the contamination investigation shall be placed in rigid, air tight, clean containers and labelled to indicate the site, exploratory hole, depth, date and time o'clock of sampling. The containers shall be made of a material suitable for the purpose, and in accordance with "General Principles of Sampling and Accuracy of Results" (1980). Containers for water samples shall be opaque, robust enough to avoid being damaged during handling and transportation, and shall not react with the sample. Containers for bacteriological sample collection shall be sterile.

7.15.5 All groundwater samples pertaining to the contamination ground investigation shall be stored in the dark and protected at all times from temperatures below 2°C and above 4°C

7.15.6 All solid samples pertaining to the contamination ground investigations and which are to be used for bacteriological analysis shall be stored in the dark and protected at all times from temperatures below 2°C and above 4°C.

7.16 Retention and disposal of samples

7.16.1 The Contractor shall be responsible for the protection of all samples and for their transport (including loading and unloading):

(a) to the Contractor's laboratories, or

(b) to a store or laboratory as stated in Schedule 1.10.

7.16.2 Retention and disposal of samples shall be in accordance with Clause 20(2) of the Conditions of Contract with the report referred to in Clause 20(2) being that defined in Schedule 1.16. However, in addition, the Engineer may instruct that some samples be sent elsewhere.

7.16.3 All samples from potentially contaminated land shall be disposed of in accordance with current waste legislation.

8. IN SITU TESTING

8.1 Calibration of measuring instruments

Where load, displacement or other measuring equipment is used which necessitates regular calibration then this shall be carried out in accordance with the manufacturer's instructions. Evidence of calibrations and copies of calibration charts shall be supplied to the Engineer prior to commencing work and when otherwise requested.

8.2 Testing: general

8.2.1 The following information shall be submitted for each test record to be included in the daily report, preliminary log and factual report.

(a) date of test

(b) project name, exploratory hole number and location

(c) depth and location of test or depths covered by test, as appropriate, together with reduced levels on preliminary logs and in the factual report

(d) information on water levels in exploratory hole during testing

(e) original ground level at test site (not required for daily report)

(f) soil type and description as identified from the sample.

8.2.2 Unless otherwise specified, all results shall be reported in SI units.

8.2.3 Contractor's staff who undertake in situ testing shall be trained and experienced in the equipment's use.

8.3 Tests in accordance with BS 1377

The following in situ tests shall be carried out and reported in accordance with BS 1377:

(1) In situ density test
(2) Static cone penetration test (CPT).
(3) Dynamic probing (DPH or DPSH).
(4) Standard penetration test (SPT).
(5) Plate loading test.
(6) California Bearing Ratio (CBR).
(7) Vane shear strength.
(8) Apparent resistivity of soil.
(9) Redox potential.

8.3.1 Tests

8.3.1.1 In situ density test

Equipment and procedure:

In situ density testing shall be carried out by the large pouring cylinder method as described in Part 9, Clause 2.2.

Information to be submitted:

The information to be submitted shall be as described in Part 9, Clause 2.2.7.

8.3.1.2 Static cone penetration test (CPT).

Equipment and procedure:

Electric recording static cone penetrometer tests shall be carried out where indicated by the Engineer and shall comprise the measurement of the end bearing and side friction components of resistance, and the porewater pressures at the penetrometer tip, determined during the penetration into the ground of a pointed steel cone. The equipment and procedure shall be as described in Part 9, Clause 3.1. The capacity of the equipment shall suit scheduled depths unless otherwise stated in Schedule 1.13. A continuous electric recording of the cone resistance, the skin friction of the sleeve and the porewater pressure at the tip shall be obtained.

Information to be submitted:

1. The information submitted shall be as described in Part 9, Clause 3.1.6.
2. In addition the dimensions of probe head including diameter and cone angle, and an estimation of soil types shall be submitted.

8.3.1.3 Dynamic probing (DPH or DPSH)

Equipment and procedure:

1. The equipment and procedure shall be as described in Part 9, Clause 3.2.
2. The type of probing apparatus shall be as described in Schedule 1.13.

Information to be submitted:

The information to be submitted shall be as described in Part 9, Clause 3.2.5.

8.3.1.4 Standard penetration test (SPT)
Equipment and procedure:

1. The test equipment and procedure shall be as described in Part 9, paragraph 3.3. The drive hammer shall be of the type incorporating an automatic trip mechanism to ensure free fall.
2. When tests are performed in coarse granular soils the driving shoe of the split barrel sampler shall be replaced by a solid 60 degree cone, or the split barrel sampler with solid cone may be replaced by an identically dimensioned solid test rod.
3. Where required by the Engineer these tests shall be extended to record 'N' values to a maximum of 100 blows.
4. Where a solid cone is used or where no soil is recovered in the split sampler, a bulk disturbed sample shall be obtained from the position of the test.

Information to be submitted:

1. The information to be submitted shall be as described in Part 9, paragraph 3.3.5.
2. In addition the following information shall be submitted.
   (a) The number of blows for each successive 75 mm penetration or penetration produced by a maximum of 100 blows.
   (b) Information on added water.

8.3.1.5 Plate loading test
Equipment and procedure:

1. The equipment, procedure and information to be submitted shall be as described in Part 9, Clause 4.1, except as detailed below:
2. The test shall be carried out in a trial pit carefully excavated to the depth stated in Schedule 1.13 and shall be of sufficient plan area to accommodate the specified size of plate. The sides of the excavation shall be supported where necessary. The test area and apparatus should be protected against weather effects.
3. The test plate shall be carefully bedded onto the soil to be tested using sand/cement mortar, or quick setting gypsum plaster.
4. The diameter of the plate, maximum load to be applied and the method of loading are detailed in Schedule 1.13.
5. In the case of incremental load tests the load shall be applied and maintained until movement of the plate has ceased or has slowed to a rate not exceeding that stated in Schedule 1.13, or until continual settlement denoting failure has occurred.
6. The movement of the plate under load shall be measured by not less than three dial gauges capable of reading to 0.02 mm. The gauges shall be attached to a rigid reference beam supported on a stable base which is not influenced by the load test.
7. For incremental plate load tests the plate dial readings shall be taken at ¼, ½, 1, 2, 4, 8, 12, 16, 20, 30, 45, 60 minutes and 2, 4, 8 and 24 hours after the application of the load, unless otherwise stated in the Contract. For constant rate of penetration plate tests the applied load shall be recorded at equal time intervals detailed in Schedule 1.13.

Information to be submitted:

1. The information to be submitted shall be as described in Part 9, Clause 4.1.8.
2. In addition the following information shall be submitted.
   (a) Location of test.
   (b) Description of soil at test depth.
   (c) Plate displacement dial gauge readings (individual and average) at times given in sub-paragraph 7 above for each increment of incremental loading.
   (d) Applied load at times given in sub-paragraph 7 above for each constant rate of penetration test.
3. The results of the tests shall be presented graphically as follows:
   for incremental loading
   (a) average settlement (mm) against time (mins);
   (b) total average settlement (mm) against pressure under plate (kN/m^2);
   for constant rate of penetration tests:
   (c) average penetration (mm) against pressure under plate (kN/m^2).
4. A record of air temperature at the test site during the period of the test.

8.3.1.6 In situ California Bearing Ratio (CBR)
Equipment and procedure:

1. The equipment and procedure shall be as Described in Part 9, Clause 4.3.
2. After the penetration test has been completed, a sample of the soil (approx 350 gm weight) shall be taken immediately below the penetrated surface and its moisture content determined in accordance with Part 2, Clause 3.

Information to be submitted:

1. The information to be submitted shall be as described in Part 9, Clause 4.3.6.

8.3.1.7 In situ vane shear strength
Equipment and procedure:
1. The equipment and procedure shall be to the approval of the Engineer and as described in Part 9, Clause 4.4. An apparatus in which the torque is applied through a worm and pinion mechanism shall be used.
2. Where vane tests are being performed close to the position of a previously excavated exploratory hole the distance from the test position to the perimeter of the previous hole shall be not less than 1.5 m measured from the perimeters of the holes.
3. After the peak vane shear strength has been determined, the vane shall be rotated through at least five revolutions. The test shall then be repeated in order to determine the remoulded shear strength.
4. For tests in borings or trial pits a small disturbed sample representative of the ground from where the test was performed shall be obtained.

Information to be submitted:
1. The information submitted shall be as described in Part 9, Clause 4.4.6.
2. In addition the following information shall be submitted:
   (a) Peak and remoulded vane shear strengths in kN/m² expressed to two significant figures.
   (b) Dimensions of the vane and relevant constants.
   (c) Maximum reading of torque scale in degrees.
   (d) Time taken to reach maximum torque.
   (e) The sensitivity of the soil.

8.3.1.8 In situ apparent resistivity test
Equipment and procedure:
1. The Contractor shall carry out resistivity tests on undisturbed ground in trial pits or other locations as directed by the Engineer.
2. The equipment and procedure shall be as described in Part 9, Clause 5.1.

Information to be submitted:
1. The information to be submitted shall be as described in Part 9, Clause 5.1.5.
2. In addition the following information shall be submitted:
   (a) Location of each test site
   (b) The orientation of electrodes
   (c) The actual resistance measured.

8.3.1.9 In situ redox potential test
Equipment and procedure:
1. The Contractor shall measure the in situ redox potential of the undisturbed ground in trial pits or other locations as directed by the Engineer, by measuring the potential of a platinum electrode with respect to a saturated calomel reference electrode.
2. The equipment and procedure shall be as described in Part 9, Clause 5.2.

Information to be submitted:
The information to be submitted shall be as described in Part 9, Clause 5.2.5.

8.4 Tests in accordance with BS 5930

The following in situ tests shall be carried out and reported in accordance with BS 5930:
(1) Constant head permeability test.
(2) Variable head permeability test.
(3) Packer permeability test.

8.4.1 Tests

8.4.1.1 Constant head permeability test
Equipment and procedure:
1. The Contractor shall carry out constant head permeability tests in standpipes or standpipe piezometers and exploratory holes as required by the Engineer. The Contractor shall demonstrate that the results obtained in each test are reproducible.
2. The apparatus for the constant head test shall consist of an arrangement of the following apparatus which shall be approved by the Engineer:
   (i) A suitable reservoir to maintain a constant head of water, with a minimum surface area of 0.75 square metre.
   (ii) A suitable approved system to maintain constant head during flow measurements.
   (iii) A suitable connecting tube with leakproof joints between the constant head reservoir, the measuring devices, and the cased borehole or piezometer.
3. All measuring devices shall be adequately protected against changes in temperature.
4. The head of water shall be applied in the minimum time possible. The flow shall be

recorded at sufficient time intervals to obtain a representative plot of flow against $1/\sqrt{t}$ where t denotes time.

Information to be submitted:

1. Hole location and number.
2. Ground level.
3. Soil and/or rock profile.
4. Type of piezometer and permeability of tip (if applicable).
5. Groundwater table before test.
6. Diameter of hole.
7. Depth to base of hole or bottom of piezometer filter.
8. Depth to base of casing or top of piezometer filter.
9. Quality of water used, eg fresh water, sea water etc.
10. Excess head of water applied by apparatus.
11. Method used to determine flow.
12. Plot of flow against $1/\sqrt{t}$.
13. Value of coefficient of permeability of material tested reported in m/sec together with calculations.

8.4.1.2 Variable head permeability test

Equipment and procedure:

1. The Contractor shall carry out falling head or rising head tests in standpipe and standpipe piezometers and exploratory holes as required by the Engineer. The Contractor shall demonstrate to the satisfaction of the Engineer that the results obtained in each test are reproducible.
2. In falling head tests the water level in each hole, standpipe or piezometer shall be raised by adding water to a level agreed by the Engineer. It may be necessary to raise the water level above the ground surface and sufficient length of casing or tubing shall be provided to project above ground level.
3. In rising head tests, the water level in each hole, standpipe or piezometer shall first be lowered by baling to a level agreed by the Engineer.
4. The water level shall be recorded at 10 second intervals during the early stages of the test and at less frequent intervals in the latter stages in order that a representative record of the fall or rise in the water level relative to time can be obtained.

Information to be submitted:

1. Hole location and number.
2. Ground level.
3. Soil and/or rock profile.
4. Type of piezometer and permeability of tip (if applicable).
5. Groundwater table before test.
6. Diameter of hole.
7. Depth to base of hole or bottom of piezometer filter.
8. Depth to base of casing or top of piezometer filter.
9. Quality of water used, eg fresh water, sea water, etc.
10. Level of water at start of test.
11. Level of water at end of test.
12. Plot of head of water divided by initial head of water (log scale) against time.
13. Value of coefficient of permeability of material tested reported in m/sec together with calculations.

8.4.1.3 Packer permeability test

Equipment and procedure:

1. The equipment and procedure shall be in accordance with BS5930, Clause 21.5.
2. The Contractor shall perform Packer tests at selected depths in selected rotary drill holes as required by the Engineer. Tests may be required in which packers are used individually or in pairs and will necessitate the injection of clean water. The Contractor shall demonstrate to the satisfaction of the Engineer that an effective seal has been obtained with each packer and that a steady flow rate has been attained at every stage in any test. Each test shall comprise not less than three equally spaced increments of head and two decrements of head which shall be agreed with the Engineer. The results of all tests shall be presented graphically.
3. The Contractor shall allow for the provision of a suitable monitoring system for water flows not exceeding 0.3 litres/second and suitable monitoring system for flows not exceeding 30 litres/second, a gauge suitable for pressures not exceeding 200 kPa and an approved pump and hydraulic system. The length of any packer shall not be less than 1.0 m. The Contractor will be required to test strata of varying thicknesses, which will necessitate variable test lengths between packers.

Information to be submitted:

1. Location and reference number of hole in which the test is performed.
2. Depth to the upper packer.
3. Spacing of packers.
4. Length of packers.
5. Inflation pressure of packers.
6. Three readings of the steady flow rate at 5 min

intervals per test pressure.
7. Check readings on the apparatus, made to prove the seal of the packers during the test.
8. Calibration data for test equipment.
9. Quality of water used, eg fresh water, sea water, etc.
10. Level of water at start of test.
11. Level of water at end of test.
12. Plot of head of water divided by initial head of water (log scale) against time.
13. Value of coefficient of permeability of material tested reported in m/sec together with calculations.

8.5 Other routine in situ tests

The following in situ tests shall be carried out and reported in accordance with the details given below:

(1) Hand dynamic probing
(2) Hand penetrometer for shear strength
(3) Hand penetrometer for CBR

8.5.1 Tests

8.5.1.1 Hand Dynamic Probing
Equipment and procedure:

The hand probing equipment shall be 25mm nominal diameter such as the Mackintosh Boring and Prospecting Tool or similar approved as fit for the purpose.

Information to be submitted:
1. Dynamic probing daily report as required by specification clauses 10.1 and 10.2.
2. Dynamic probing logs as required by specification clauses 12.1 and 12.2.
3. Dimensions of probe head, including diameter and cone angle.
4. Weight of hammer, drop height and method of operation.

8.5.1.2 Hand Penetrometer for Shear Strength
Equipment and procedure:
1. Hand penetrometer tests shall be carried out where required to give a preliminary estimate of undrained shear strength of the soil tested.
2. Hand (or pocket) penetrometer equipment shall be of an approved proprietary make with stainless steel tip of end area 31mm^2 with an engraved penetration line 6mm from the tip. The scale shall be suitably graduated. The procedure for the test shall be in accordance with the manufacturer's instructions.
3. The reported shear strengths for the hand penetrometer shall be the average of 3 tests in close proximity. Tests giving inconsistent results shall be reported and comments on the relevance of the tests noted.

Information to be submitted:
1. Location of test
2. Depth of test or sample details
3. Unconfined compressive strength
4. Estimated shear strength.

8.5.1.3 Hand Penetrometer for CBR (Vicksburg or MEXE)
Equipment and procedure:
1. Hand penetrometer tests shall be carried out where indicated by the Engineer.
2. The equipment shall be a penetrometer of a type recognised or proved by demonstration to be fit for the purpose with a CBR cone.
3. The procedure for the tests shall be in accordance with the manufacturer's instructions.

Information to be submitted:
1. A description of the test location
2. The CBR values of the soil tested
3. Type of hand penetrometer used.

8.6 Geophysical methods of investigation

8.6.1 The requirements for geophysical testing are described in Schedule 1.13. The Contractor shall submit to the Engineer a full description of equipment and procedure for each geophysical method required.

8.6.2 The equipment and procedure, and information to be submitted for the following land geophysical methods of investigation, shall be as described in BS 5930, BS 7022, the Geological Society Engineering Group Working Party Report on Engineering Geophysics and Schedule 1.13.

1. Electrical resistivity method.
2. Seismic refraction and reflection methods.
3. Magnetic method.
4. Gravity method
5. Electromagnetic methods
   (a) ground electrical conductivity
   (b) transient electromagnetic
   (c) ground probing radar.
6. Borehole geophysical logging.
7. Cross-hole and down-hole seismic method.
8. Echo-sounding (marine geophysics only).
9. Continuous seismic reflection profiling (marine geophysics only).
10. Side scan sonar (marine geophysics only).

8.6.3 Other geophysical investigation techniques may be required, such as infra-red thermographic surveys for investigation of potentially contaminated land.

8.7 Special in situ testing

Special in situ testing shall be carried out as described in Schedule 1.13.

8.8 Self-boring pressuremeter

8.8.1 The requirements for pressuremeter testing are described in Schedule 1.13.

8.8.2 The equipment, procedure and information to be submitted shall be as described in Appendix 3 unless otherwise specified in Schedule 1.13.

8.9 Gas concentrations using a portable gas meter

8.9.1 The Contractor shall carry out in situ measurements of gas concentration in gas monitoring standpipes and during the advancement of those exploratory holes designated in Schedule 2. Where measurements are required during the advancement of exploratory holes these shall be at 1m intervals over the depth range specified in Schedule 2, or as otherwise directed by the Engineer.

8.9.2 Measurements taken in gas monitoring standpipes shall be taken by an environmental scientist meeting the requirements of clause 2.2 item (d). Measurements during the advancement of exploratory holes shall be taken by a person experienced in the use of the appropriate specialised equipment.

8.9.3 Concentrations of the following gases shall be measured:
Flammable Gases
Hydrogen Sulphide
Carbon Dioxide
Oxygen

8.9.4 The equipment shall be capable of measuring gas concentrations to the following degrees of accuracy:

GAS TYPE	UNITS	DEGREE OF ACCURACY
Flammable Gases	%LEL	1.0
	%v/v	0.1
Hydrogen Sulphide	ppm	0.5
Carbon Dioxide	%v/v	0.1
Oxygen	%v/v	0.1

8.9.5 The selection of equipment and the method of testing shall be in accordance with the guidance given in Sections 7, 8, 9 and 10 of CIRIA Report 131 (CIRIA 1993).

8.9.6 Gas concentration measurements in gas monitoring standpipes shall be undertaken in association with measurements of barometric pressure, differential pressure, gas emission rate and gas sampling as specified in clause 9.11.3.

8.9.7 The information to be submitted shall be:

(a) location and reference number of hole

(b) depth of gas concentration measurement

(c) weather conditions during gas concentration measurement

(d) installation details (eg depth of casing, pit supports, etc)

(e) depth to water

(f) equipment used

(g) operator name and responsibility

(h) gas concentrations in the units described in clause 8.9.4.

8.10 Soil gas surveys

8.10.1 The Contractor shall undertake a soil gas survey in the area(s) specified in Schedule 1.17 and on the Drawings, or as instructed by the Engineer.

8.10.2 The Equipment required shall be supplied by the Contractor and shall comprise a hollow metal probe with a minimum length of 2m, a device for driving the probe into the ground and equipment for analysing gas.

8.10.3 The probe shall be driven into the ground to the depth specified in Schedule 1.17 or as instructed by the Engineer. Alternatively, a pilot hole shall be made prior to inserting the probe. Air ingress into the probehole shall be minimised by sealing at the surface.

8.10.4 Soil gas shall be taken from within the probe before it is removed from the ground. The gas shall be taken using a vacuum pump, and drawn either directly into monitoring equipment or into an inert receptacle for immediate analysis. Monitoring equipment shall be as specified in clause 8.9. Measurements shall be taken by an environmental scientist meeting the requirements of clause 2.2 item (d).

8.10.5 If directed by the Engineer, the Contractor shall, upon removal of the probe, insert a tube a distance of at least 150mm into the probehole. The tube shall be of uPVC, metal or other approved material and shall be sealed at ground surface. An isolating valve shall be fitted at the top of the tube from which subsequent gas analyses can be undertaken.

8.10.6 The Contractor shall record and report the position of each probehole as required by clause 3.14.

8.10.7 The information to be submitted shall be:

(a) location and reference number of probehole
(b) depth of probehole
(c) equipment used
(d) environmental scientist's name
(e) gas concentrations in the units specified in clause 8.9.4 or as specified in Schedule 1.17.

8.11 Field tests on groundwater samples

8.11.1 The following field tests and measurements shall be carried out on groundwater samples obtained for the contamination ground investigation from standpipes and piezometers:

1. pH. The test equipment and procedure shall be in accordance with "The Measurement of Electrical Conductivity and the Laboratory Determination of the pH value of Natural Treated and Waste Waters" (1978).
2. Temperature. The test equipment and procedure shall be in accordance with "Standard Methods of the Examination of Water and Waste-Water" 18th Edition (1992) Section 2550. The ambient temperature at the time of testing shall be measured and recorded.
3. Dissolved oxygen. The test equipment and procedure shall be in accordance with "Dissolved Oxygen in Natural and Waste Waters" (1980) - Method B - Instrumental Method.
4. Electrical conductivity. The test equipment and procedure shall be in accordance with "The Measurement of Electrical Conductivity and the Laboratory Determination of the pH Value of Natural, Treated and Waste Waters" (1978) Method A.
5. Redox potential. In accordance with clause 3.19.2 the Contractor shall submit to the Engineer for his consent, a statement detailing the proposed procedure for the measurement of Redox Potential of groundwater.

8.11.2 The information shall be submitted as follows:

TEST	UNITS	DEGREE OF ACCURACY
pH	pH units	$\pm$0.1
Temperature	°C	$\pm$0.1
Dissolved oxygen	$mgO_2/1$	$\pm$0.1
Electrical conductivity	µS/cm	$\pm$2.1
Redox potential	mV	$\pm$0.1

The time o' clock of sampling and of carrying out the field tests and measurements shall also be submitted.

9. INSTRUMENTATION AND MONITORING

9.1 Groundwater measurement records

9.1.1 Encountering groundwater

9.1.1.1 On each occasion when groundwater is encountered in exploratory holes, the depth from ground level of the point of entry shall be recorded together with depth of any casing. Exploratory hole operations shall be stopped and the depth from any ground level to water level recorded with an approved instrument at 5 minute intervals for a period of 20 minutes. If at the end of the period of 20 minutes the water level is still rising, unless otherwise instructed by the Engineer, this shall be recorded together with the depth of water below ground level and the exploratory hole shall then be continued. If casing is used and this forms a seal against the entry of groundwater, the Contractor shall record the depth of casing at which no further entry or only insignificant infiltration of water occurred. Where applicable, every effort shall be made to seal off each water strike. The time that the Equipment is standing shall be agreed with the Engineer.

9.1.1.2 An exception to clause 9.1.1.1 above is where groundwater occurs as a slow seepage into the exploratory hole. In this case the point of entry of the seepage shall be recorded and the exploratory hole continued.

9.1.2 Recording groundwater levels

9.1.2.1 Water levels shall be recorded at the beginning and end of each shift or other rest periods during the work and as required by clause 9.11.1.

9.1.2.2 On each occasion when groundwater is recorded, the depth of the exploratory hole, the depth of any casing and the time on a 24 hour clock shall also be recorded.

9.1.2.3 The Engineer may require exploratory holes to be left open for 24 hours after completion and the water level recorded at the end of this time.

9.2 Standpipes and piezometers

9.2.1 Standpipes

Standpipes for monitoring groundwater levels and changes in groundwater levels shall be installed in exploratory holes where indicated in Schedule 2, or as instructed by the Engineer. They shall be as described in clause 9.3 and Specification Appendix 1, Drawing 1.1.

9.2.2 Standpipe piezometers

Standpipe piezometers for monitoring groundwater levels and changes in groundwater levels at a particular depth in exploratory holes shall be installed where indicated in Schedule 2, or as instructed by the Engineer. They shall be as described in clause 9.4 and Specification Appendix 1, Drawing 1.2.

9.2.3 Piezometers

The Contractor shall install piezometers of the hydraulic, electrical, pneumatic or vibrating wire type where indicated in Schedule 2, or as instructed by the Engineer. Specification details for the piezometers are given in clause 9.8 and in Schedule 1.14. The typical installation details are given on Specification Appendix 1, Drawing 1.3.

9.2.4 Groundwater sampling standpipes

Standpipes for sampling groundwater as well as for monitoring groundwater levels and changes in groundwater levels shall be installed in exploratory holes where indicated in Schedule 2 or as instructed by the Engineer. They shall be as described in clause 9.5 and Specification Appendix 1, Drawing 1.4.

9.2.5 Gas monitoring standpipes

Standpipes for monitoring gas concentration, pressure and emission rate shall be installed in exploratory holes where indicated in Schedule 2, or as instructed by the Engineer. They shall be as described in clause 9.6 and Specification Appendix 2, Drawing 2.1. All as-installed dimensions and depths shall be recorded.

9.2.6 Combined gas and groundwater sampling standpipes

Standpipes to allow both gas monitoring and groundwater sampling shall be installed in exploratory holes where indicated in Schedule 2, or as instructed by the Engineer. They shall be as described in clause 9.7 and Specification Appendix 2, Drawing 2.2.

9.2.7 Installation details

9.2.7.1 Whereas the piezometer and standpipe installations shall be generally as shown in the drawings in Appendix 1 and Appendix 2, the final details of any piezometer or standpipe installation will be decided by the Engineer and will be dependent upon the actual soil and groundwater conditions found.

9.2.7.2 All dimensions and depths shall be recorded at the time of installation.

9.3 Standpipes

9.3.1 The standpipe shall consist of unplasticised polyvinyl chloride (uPVC) tubing according to BS 3506 Class 6 or high density polyethylene (HDPE) tubing according to BS 6437 Class 10.0 and not less than 19mm internal diameter.

9.3.2 The base of the tubing shall be capped and the tubing perforated by holes not greater than 5mm in diameter at intervals of approximately 75mm or by an equivalent area of slots not greater than 5mm width for the full depth of groundwater investigation.

9.3.3 The filter shall be rounded (pea) gravel, or similar material, as approved by the Engineer, 6-10mm in diameter.

9.3.4 Where the depth of the exploratory hole is greater than the depth to which the filter and tubing are to be installed then the exploratory hole shall be backfilled with cement/bentonite grout in accordance with clause 9.4.4 to the base of the filter and allowed to sufficiently harden before placing the gravel filter to prevent the filter sinking into the grout.

9.3.5 The gravel filter shall be placed in the exploratory hole up to the level of the proposed base of the tubing.

9.3.6 The tubing with centralising devices attached at 2m intervals over the perforated section shall be lowered carefully down the exploratory hole to the level of the filter material, and the exploratory hole backfilled to within 1.0m of ground level with filter gravel or other materials approved by the Engineer. The elevations of the base of the tubing and top and base of the filter shall be recorded.

9.3.7 The top of the tubing shall be covered by a plastic cap or similar, as approved by the Engineer. An air vent shall be provided as indicated on Appendix 1, Drawing 1.1.

9.3.8 Arrangements to prevent the ingress of surface water and to protect the top of the tubing shall use a steel water barrel of 75mm diameter with lockable cover, a 150mm lockable stopcock cover, or an alternative as agreed with the Engineer. The protective cover shall be set in concrete mix ST2 in accordance with Clause 2602 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments) and as shown on Appendix 1, Drawing 1.1.

9.3.9 Each standpipe shall be permanently labelled with a metal stamp or tag indicating the exploratory hole number. Where a stop cock cover is used it shall be painted with a lead free paint of an approved colour. Where required a timber post 100mm diameter and 2.0m long shall be erected adjacent to the cover to stand 1.5m above ground level. Protective fencing, where required shall be as shown on Appendix 1, Drawing 1.5.

9.3.10 The groundwater level shall be recorded immediately before and after installation and the standpipe shall be filled with water and its correct functioning shall be demonstrated to the Engineer before readings are commenced.

9.4 Standpipe piezometers

9.4.1 The final details of any standpipe piezometer installation will be decided by the Engineer.

9.4.2 The piezometer tip shall consist of a porous ceramic element or other suitable element not less than 150mm long with a diameter not less than 35mm, and shall be protected at each end by uPVC or HDPE fittings. The ceramic shall have a pore diameter of the order of 60 microns and a permeability of the order of 3 x 10^{-4}m/s.

9.4.3 The uPVC or HDPE tubing shall be according to BS 3506 Class 6 or BS 6437 Class 10.0 as applicable, nominal size 19mm and shall be supplied and installed in not less than 3m lengths, except for one shorter length

as required to suit the total standpipe dimensions. The tubes shall be jointed together and to the porous element with approved couplings and glue in such a manner that the joints remain leakproof under the anticipated head of water.

9.4.4 Where the depth of the completed exploratory hole is greater than the depth at which the porous element and sand filter are to be installed then the lower part of the exploratory hole shall be grouted.
A grout consisting of cement and bentonite in the proportions of 1:1 by weight shall be prepared by thorough mixing with approved equipment and with only sufficient water to form a pumpable mix.

Where the exploratory hole is dry, sufficient grout shall be placed in the hole using a tremie reaching to the bottom of the hole, such that the top of the grout shall just reach its interface with the sand filter. Where there is water in the exploratory hole the top of the grout shall finish 1m below the proposed grout/filter interface. A similarly proportioned mixture of cement/bentonite shall then be prepared but having just sufficient water to form a cohesive paste. This mix shall be formed into balls of approximately 75mm diameter and placed in porous canvas bags or other suitable porous bags. These bags shall be placed in the exploratory hole and punned with a suitably shaped punner to form a homogenous plug to the exploratory hole without significant voids between adjacent bags. The top of this plug shall be at the interface with the sand filter. Compressed bentonite pellets may be used as an alternative to the grout balls where the inflow of water into the piezometer is sufficient for immediate saturation.

9.4.5 If water in the exploratory hole becomes contaminated by grout it shall be replaced by clean water, the method being to the approval of the Engineer.

9.4.6 The sand filter surround to the porous elements shall be clean and fall wholly between the limits of grading 1200 and 210 microns, and the volume of the sand filter placed shall be recorded. This filter shall not be placed until the underlying grout is sufficiently hardened to prevent the sand sinking into it.

9.4.7 That portion of the sand filter below the porous elements shall be placed first, and methods such as tremie pipe shall be used to ensure that no sand adheres to the soil in the sides of an unlined exploratory hole. Where there is water in an exploratory hole the Contractor shall allow sufficient time for all the sand to settle. The final elevation of the top of this sand shall be recorded. The porous element shall be placed in the hole with the vertical axis of the porous element co-incident with the vertical axis of the exploratory hole. The remaining sand filter shall then be added as described above.

9.4.8 Further grout balls or compressed bentonite pellets shall be placed on top of this sand filter to form a plug not less than 0.5m thick. The remainder of the exploratory hole shall be filled with grout to within 1.0m of ground level according to the procedure described in clause 9.4.4 above.

9.4.9 The top of the uPVC or HDPE tubing shall be covered by a plastic cap or similar as approved by the Engineer. An air vent shall be provided as shown on Appendix 1, Drawing 1.2.

9.4.10 Arrangements to prevent the ingress of surface water and to protect the top of the tubing shall use a steel water barrel of 75mm diameter with lockable cover, a 150mm lockable stopcock cover or an alternative as agreed with the Engineer. The protective cover shall be set in concrete mix ST2 in accordance with Clause 2602 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments) and as shown on Appendix 1, Drawing 1.2.

9.4.11 The groundwater level shall be recorded immediately before and after installation of the standpipe piezometer.

9.4.12 Before readings commence the standpipe piezometer shall be filled with water and its correct functioning demonstrated to the Engineer. Each standpipe piezometer shall be clearly and permanently labelled with a metal stamp or tag giving the exploratory hole number. Where a stop cock cover is used it shall be painted with a lead free paint of an approved colour. Where required a timber post 100mm diameter and 2.0m long shall be erected adjacent to the cover to stand 1.5m above ground level. Protective fencing, where required shall be as shown on Appendix 2, Drawing 1.5.

9.5 Groundwater sampling standpipe

9.5.1 The final details of any groundwater sampling standpipe will be decided by the Engineer.

9.5.2 The standpipe shall consist of uPVC or HDPE tubing according to BS 3506 Class D or BS 6437 Class 6.0, as applicable and not less than 50mm internal diameter.

9.5.3 The base of the tubing shall be capped.

9.5.4 The lower section of the tubing shall be slotted with slots not greater than 2mm wide over the depth of investigation decided by the Engineer. The slots shall provide an open area of between 5% and 10% of the surface area of the tubing.

9.5.5 The slotted section shall be wrapped in a sewn sleeve or stocking having a pore size of between 100 and 250 microns. The fabric wrapping material shall be to the approval of the Engineer.

9.5.6 The slotted and wrapped section of pipe shall be surrounded by an inert filter material which shall be either pea gravel or washed sand depending upon the actual subsoil and groundwater conditions found. Pea gravel shall be 6-10mm in diameter. Sand filter material shall meet the grading requirements of clause 9.4.6.

9.5.7 Where the depth of the exploratory hole is greater than the depth to which the filter and tubing are to be installed then the exploratory hole shall be backfilled with cement/bentonite grout and cement/ bentonite paste in bags, or compressed bentonite pellets, in accordance with clause 9.4.4 to the base of the filter.

9.5.8 The gravel or washed sand filter shall be approved by the Engineer and placed in the exploratory hole up to the level of the base of the tubing.

9.5.9 The tubing with centralising devices attached at 2m intervals over the slotted section shall be lowered carefully down the exploratory hole to the level of the filter material, and the exploratory hole backfilled with additional filter gravel or sand material either to within 1.0m of ground level or to the base of an upper bentonite plug and cement/bentonite grout backfill installed in accordance with clause 9.4.8 . The elevations of the base of the tubing and top and base of the filter shall be recorded.

9.5.10 The top of the tubing shall be covered by a plastic cap or similar, as approved by the Engineer. An air vent shall be provided as indicated on Appendix 1, Drawing 1.4.

9.5.11 Arrangements to prevent the ingress of surface water and to protect the top of the tubing shall use a steel water barrel of 75mm diameter with lockable cover, a 150mm lockable stopcock cover, or an alternative as agreed with the Engineer. The protective cover shall be set in concrete mix ST2 in accordance with Clause 2602 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments) and as shown on Appendix 1, Drawing 1.4.

9.5.12 Each groundwater sampling standpipe shall be permanently labelled with a metal stamp or tag indicating the exploratory hole number. Where a stop cock cover is used it shall be painted with a lead free paint of an approved colour. Where required a timber post 100mm diameter and 2.0m long shall be erected adjacent to the cover to stand 1.5m above ground level. Protective fencing, where required shall be as shown on Appendix 1, Drawing 1.5.

9.5.13 The groundwater level shall be recorded immediately before and after installation. No water shall be added to the groundwater sampling standpipe.

9.5.14 Within 3 days of installation and before readings are commenced the Contractor shall bale out the tubing with a clean baler or pump to demonstrate current functioning of the installation to the Engineer.

9.6 Gas monitoring standpipe

9.6.1 The standpipe shall consist of uPVC or HDPE tubing according to BS 3506 Class D or BS 6437 Class 6.0, as applicable, and shall be not less than 50mm in diameter.

9.6.2 The base of the tubing shall be capped and the tubing perforated or slotted to provide an open area of between 10% and 15% of the surface area of the tubing. Holes shall not be greater than 5mm in diameter and slots shall not be greater than 5mm width.

9.6.3 The filter shall be pea gravel, or similar material, as approved by the Engineer, 6-10mm in diameter.

9.6.4 Where the depth of the exploratory hole is greater than the depth to which the filter and tubing are to be installed then the exploratory hole shall be backfilled below the base of the filter with cement/ bentonite grout and a 1m plug of cement/bentonite paste in bags, or compressed bentonite pellets, in accordance with clause 9.4.4. If compressed bentonite pellets are used as an alternative to grout balls they shall be partially saturated before adding to the borehole, and further clean water added to the borehole to complete saturation.

9.6.5 The tubing with centralising devices attached at 2m intervals shall be lowered carefully down the exploratory hole to the level of the filter material, and the exploratory hole backfilled to within 1.2m of ground level with pea gravel.

9.6.6 The top of the tubing shall be covered with a screw threaded plastic cap having two tap valves as indicated on Appendix 2, Drawing 2.1. One of the two tap valve assemblies shall have a quick fit compression fitting to enable a 5mm internal diameter tube to be suspended on the underside of the tap valve assembly. The 5mm ID tube shall be hung to within 1m of the groundwater level or base of the standpipe, whichever is the higher.

9.6.7 The upper 1.2m of the uPVC or HDPE tubing shall be unperforated and the borehole backfilled by a 0.5m plug of cement/bentonite paste in bags, or compressed bentonite pellets, in accordance with clause 9.4.4 and 0.7m of concrete in accordance with clause 9.6.8. If compressed bentonite pellets are used as an alternative to the grout balls, they shall be partially saturated before adding to the borehole, and further clean water added to the borehole to complete saturation.

9.6.8 Arrangements to prevent the ingress of surface water and to protect the top of the tubing and tap valves shall use a 150mm lockable stop cock cover which shall be set in concrete mix ST2 in accordance with Clause 2602 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments) as shown on Appendix 2, Drawing 2.1. Each gas standpipe shall be permanently labelled with a metal stamp or tag indicating the exploratory hole number. The stop cock cover shall be painted with a lead free paint of an approved colour. Where required a timber post 100mm diameter and 2.0m long shall be erected adjacent to the cover to stand 1.5m above ground level. Protective fencing, where required, shall be as shown on Appendix 1, Drawing 1.5.

9.6.9 The installation of gas standpipes shall be completed in a single day.

9.6.10 Where groundwater is anticipated over the depth of ground under investigation the gas monitoring standpipe shall be constructed as a combined gas and groundwater sampling standpipe as described in clause 9.7.

9.7 Combined gas and groundwater sampling standpipe

9.7.1 The final details of any combined gas and groundwater sampling standpipe will be decided by the Engineer.

9.7.2 The standpipe shall consist of uPVC or HDPE tubing according to BS 3506 Class D or BS 6437 Class 6.0, as applicable and not less than 50mm internal diameter.

9.7.3 The base of the tubing shall be capped.

9.7.4 The lower section of the tubing shall be slotted with slots not greater than 2mm over the depth of investigation decided by the Engineer. The slots shall provide an open area of between 5% and 10% of the surface area of the tubing.

9.7.5 The slotted section shall be wrapped and surrounded as specified in clauses 9.5.5 and 9.5.6.

9.7.6 Installation of the tubing and backfilling shall be as specified in clauses 9.5.7, 9.5.8, 9.5.9 and 9.6.5, 9.6.7 and 9.6.8.

9.7.7 The top of the tubing shall be covered with a screw threaded plastic cap as specified in clause 9.6.6.

9.8 Pneumatic and vibrating wire piezometer

9.8.1 The final details of any piezometer installation will be decided by the Engineer and will be dependent upon the actual subsoil and ground water conditions found. Only proprietary products specifically designed as piezometers by specialist contractors shall be used.

9.8.2 The piezometer tip shall consist of a porous ceramic low air entry element. The element shall be not less than 100 mm long and 38 mm outside diameter, and shall be protected by brass fittings. The ceramic shall have a pore diameter of the order of 60 microns and a permeability of the order of 3×10^{-4} m/s. The complete piezometer unit shall be capable of recording pore water pressures over the range -5 m to 25 m head of water to an accuracy of ±100 mm.

9.8.3 Piezometer tubing for pneumatic piezometers shall consist of twin nylon tubing, with outside diameters of not more than 4 mm, sheathed in polythene at least 1 mm thick. The minimum burst pressure shall be

10 MN/m². The tubes shall be jointed together and to the porous element with brass couplings. Each tube shall be identifiable with a colour code over its entire length. All joints shall be leak-proof under the anticipated head of water.

Conductor cable for vibrating wire piezometers shall have a braided screen and PVC outer sheath suitable for direct burial. The length of cable attached to the tip shall be sufficient to reach the readout location without splicing.

9.8.4 The exploratory hole, into which the pneumatic or vibrating wire piezometer is to be installed, shall be formed in soils using percussion boring techniques and in rocks with rotary drilling. The exploratory hole shall have a maximum diameter of 200 mm. Piezometers shall not be driven into soft soils, without the formation of an exploratory hole beforehand, unless approval is given by the Engineer.

9.8.5 Where the depth of the completed exploratory hole is greater than the depth at which the porous element and sand filter are to be installed then the bottom of the exploratory hole shall be grouted.

A grout consisting of cement and bentonite in the proportions of 1:1 by weight shall be prepared by thorough mixing with approved equipment and with just sufficient water to form a pumpable mix.

Where the exploratory hole is dry, sufficient grout shall be placed in the hole using a tremie reaching to the bottom of the hole, such that the top of the grout will just reach its interface with the sand filter. Where there is water in the exploratory hole the top of the grout shall finish 1 m below the proposed grout/filter interface. A similarly proportioned mixture of cement/bentonite shall then be prepared but having just sufficient water to form a cohesive paste. This mix shall be formed into balls of approximately 100 mm diameter and placed in porous canvas bags or other suitable porous bags. These balls shall be placed in the exploratory hole and punned with suitably shaped punner to form a homogeneous plug to the exploratory hole sensibly without voids between adjacent bags. The top of this plug shall be at the interface with the sand filter. Compressed bentonite pellets may be used as an alternative to the 100 mm diameter grout balls where the inflow of water into the piezometer is sufficient for immediate saturation.

9.8.6 If water in the exploratory hole is contaminated by grout it shall be replaced by clean water, the method being to the approval of the Engineer.

9.8.7 The sand filter surround to the porous element shall be clean and falling wholly between the limits of grading 1200 and 210 microns and the volume of the sand filter to be placed shall be recorded. During placement of the sand filter a head of water of 1 metre above its upper surface shall be maintained in the exploratory hole.

9.8.8 That portion of the sand filter below the porous element shall be placed first, and all the Contractor's arrangements shall ensure that no sand adheres to the soil in the sides of an unlined exploratory hole. Where there is water in the exploratory hole, the Contractor shall allow sufficient time for all the sand to settle. The final elevation of the top of this sand shall be recorded. The porous element shall be maintained so as to be completely saturated when it is installed. It shall be placed in the hole with the vertical axis of the porous element co-incident with the vertical axis of the exploratory hole. The remaining sand filter shall then be added as described above.

9.8.9 Further 100 mm diameter grout balls or compressed bentonite pellets shall be placed on top of this sand filter as described in clause 9.8.5 above to form a plug not less than 0.5 m thick. The remainder of the exploratory hole shall be filled with grout to ground level according to the procedure described in clause 9.8.5.

9.8.10 The top of the nylon tubing or cable shall be protected by a terminal duct with a secure cover plate or a 150 mm stop cock cover set in concrete mix ST2 in accordance with Clause 2602 of the Specification for Highway Works, (1991 with August 1993 and August 1994 amendments). For pneumatic piezometers the cover plate shall incorporate individual terminations for the twin tubing and quick release couplings to connect with a pneumatic readout unit. For vibrating piezometers the cover plate shall incorporate a pair of rubber insulated black and red jack sockets suitable for connection to a readout unit.

9.8.11 The ground water level shall be recorded immediately before installation of the piezometer. The operation of the piezometer shall be verified before use (where possible) by measuring the water pressure it records as it is installed in the borehole. Immediately after installation of the piezometer a water pressure

reading shall be recorded. Each piezometer shall be permanently labelled with a metal stamp or tag indicating the exploratory hole number.

9.8.12 For vibrating wire piezometers, the Contractor shall record with his water pressure readings the atmospheric pressures at the time and shall correct his reading to allow for atmospheric pressure.

9.9 Covers

The top of each standpipe, standpipe piezometer, piezometer, groundwater sampling standpipe, gas monitoring standpipe and combined gas and groundwater sampling standpipe shall be protected by a cover of one of the types shown in Appendices 1 or 2 of this Specification as appropriate. The type of protective cover shall be agreed with the Engineer.

9.10 Fencing

When instructed by the Engineer, the Contractor shall install a timber protective fence around the top of a standpipe or piezometer. The fence shall be as shown on Appendix 1, Drawing 1.5.

9.11 Readings

9.11.1 Groundwater level and pressure readings

Groundwater level and pressure readings shall be made by the Contractor with an approved instrument during the Site Operations period as directed by the Engineer.

9.11.2 Gas readings

Gas measurements shall be made by the Contractor at a range of depths during construction of exploratory holes and in gas monitoring standpipes as described in clauses 8.9 and 9.11.3.

9.11.3 Gas pressure and emission rate measurement

9.11.3.1 The Contractor shall carry out gas pressure and emission rate measurements in all gas monitoring standpipes. Gas concentration measurements as described in clause 8.9 shall also be carried out in association with these measurements. Gas samples in accordance with clause 7.12 shall be taken as directed by the Engineer.

9.11.3.2 Measurements of atmospheric pressure and differential pressure in gas monitoring standpipes shall be taken with instruments capable of achieving the degrees of accuracy described in clause 9.11.3.5. Emission rate measurements shall be taken with a hot wire anemometer. Concentrations of methane and carbon dioxide shall be measured using infra-red monitoring equipment.

9.11.3.3 Each gas pressure and emission rate measurement shall be undertaken in accordance with the following procedure:

1. Measure initial barometric pressure and differential gas pressure in the standpipe.
2. Take initial gas concentration measurement in accordance with paragraph 8.9 from each tap valve with portable gas monitoring equipment.
3. Circulate standpipe gas from top of standpipe through the portable gas monitoring equipment and back into the standpipe via the tap valve with the suspended sampling tube taking readings of gas concentrations at one minute intervals until steady values are achieved.
4. If specified in Schedule 2, or instructed by the Engineer, take a gas sample for subsequent laboratory analysis in accordance with paragraph 7.12 via the tap valve with the suspended sampling tube.
5. Remove the top cap and twin valve assembly and fit the hot wire anemometer assembly to the top of the standpipe. Carry out gas flow velocity measurements at 1 minute intervals for a period of not less than 15 minutes, unless gas flow is exhausted. Replace top cap assembly and ensure both valves are closed.
6. If there is an initial gas flow velocity above 0.1m/s which is exhausted within 15 minutes, remove flowmeter and replace top cap assembly. Attach displacement suction pump to one of the tap valves (with the other tap valve closed) and run pump until theoretical volume of standpipe has been displaced then measure gas concentrations from each tap valve in accordance with paragraph 8.9.
7. Measure the atmospheric pressure at the end of the procedure.

9.11.3.4 A further test shall be carried out 24 to 72 hours later if step (6) above has been required.

9.11.3.5 The information to be submitted shall be:

(a) All of the gas flow velocity measurements in units of m/sec. The detection limit shall be 0.01.
(b) Differential gas pressure measurement in units of mm water gauge. The sensitivity shall be 0.5.
(c) All of the gas concentration measurements in accordance with paragraph 8.9.
(d) The atmospheric pressure in units of millibars.
(e) Weather conditions during testing.

9.12 Removal of piezometers and standpipes

Unless otherwise described in the Contract, all types of piezometer and standpipe and their protection shall not be removed from the site.

9.13 Frequency of monitoring

Monitoring shall be carried out as described in Schedule 1.14.

10. DAILY REPORTS

10.1 General

The Contractor shall prepare for each exploratory hole a daily report which shall be of a form to be approved by the Engineer and shall be submitted to the Engineer in duplicate at the beginning of the next working day. Information shall be recorded as work proceeds and shall include the following where relevant.

10.2 Information for daily reports

✓means information required; (✓) means information required if applicable.

	Borehole	Rotary drilling	Pit and trench	Static and dynamic probing
1. Contract title and site location	✓	✓	✓	✓
2. Contractor's and operator's name	✓	✓	✓	✓
3. British Drilling Association (or similar) registration number or name of supervising person if not registered	✓	✓		
4. Exploratory hole reference number and grid reference	✓	✓	✓	✓
5. Day and date	✓	✓	✓	✓
6. Type and depth of any services or drains encountered	✓	✓	✓	✓
7. Equipment and technique in use	✓	✓	✓	✓
8. Diameter and depth of holes and casing	✓	✓		
9. The depths at which any water was added	✓			
10. Depth of each change of stratum	✓	✓	✓	(✓)
11. Description of each stratum	✓	✓	✓	
12. The types of samples, the depths from which they were taken and length of open tube sample or core sub samples recovered; the method used and the number of blows required to drive open tube samples	✓	(✓)	✓	(✓)
13. The depths and details of all in situ tests including the depth of casing when each open tube, piston and thin-walled sample, and SPT test was taken, as applicable.	✓	✓	✓	(✓)
14. Depths of hard strata and times o'clock spent on penetration	✓		✓	

	Borehole	Rotary drilling	Pit and trench	Static and dynamic probing
15. Records of groundwater	✓	✓	✓	(✓)
16. Installation details of any standpipes, piezometers and other instrumentation	✓	✓	✓	(✓)
17. Water level readings in previously installed standpipes and piezometers	✓	✓	✓	
18. Details of backfilling and/or infilling	✓	✓	✓	
19. Details of times o'clock spent other than in advancing the borehole, including details and duration of any periods of standing time	✓	✓	✓	✓
20. Inclination and direction relative to grid North of non-vertical drillholes		✓		
21. Type of drilling fluid		✓		
22. Type of core barrel and bit used		✓		
23. Depth and times of start and finish of each core run		✓		
24. Core diameters and depths of changes in core diameter		✓		
25. Colour and condition of the return drilling fluid and cuttings		✓		
26. The depth and/or extent of any loss of return of drilling fluid		✓		
27. Total core recovery with information as to possible location of core losses, if any, for each core run		✓		
28. The dimensions of the pit or trench in plan and orientation relative to grid North			✓	
29. The method of support and comments on stability			✓	
30. Sketches of the strata and any foundations or other feature encountered on each face of the pit or trench as appropriate			✓	
31. Estimate of the quantity of water, if any, pumped from the pit or trench, the type of pump and time spent on pumping			✓	

	Borehole	Rotary drilling	Pit and trench	Static and dynamic probing
32. Details of photographs taken			✓	
33. Type of cone used, results of blow count, cone and friction resistance, friction ratio and piezometric pressure as appropriate plotted against depth, rate of penetration				✓
34. Gas concentration measurements during advancement	✓		✓	

10.3 Special in situ testing and instrumentation reports

The information to be recorded and submitted shall be as described in Schedule 1.16.

11. LABORATORY TESTING

11.1 Schedule of tests

Either Option A or Option B below shall apply, but not both, depending upon whose responsibility for providing the Schedule of Laboratory Tests is specified in Schedule 1.15.

A The Engineer will decide the laboratory tests required and will provide the Contractor with one or more schedules of Laboratory Tests. It may be necessary to specify additional testing after the results of the original testing are available. Schedules for tests other than for contamination testing will not be prepared until the Engineer has received the relevant preliminary logs as detailed in clause 12.1. The Contractor shall inform the Engineer within 7 calendar days from the receipt of the testing schedule if the sample is not available for all the tests specified. An initial schedule for contamination testing will be provided by the Engineer within 7 calendar days from receipt of the daily report (clause 11.5.1.3).

B The Contractor shall inspect all the samples and decide upon the laboratory tests required, and shall submit a proposed laboratory testing schedule to the Engineer for his approval.

11.2 Testing procedures

11.2.1 All storing, preparation, testing and reporting shall be where applicable in accordance with the relevant British Standards and this Specification. Where tests are not covered by British Standards they shall be performed in accordance with the procedures in the references or as described in Schedule 1.15.

11.2.2 Calibration of load-displacement or other measuring equipment shall be carried out in accordance with the appropriate British Standards and the manufacturer's recommendations. Evidence of current calibrations shall be supplied to the Engineer when requested.

11.2.3 Prior to undertaking any geotechnical testing on samples from potentially contaminated land a safe method of working shall be agreed with the Engineer. It should be noted that this will include but is not limited to the safe storage, and handling of all material.

11.3 Soil testing

The following soil testing shall be carried out as specified in clauses 11.3.1.1 to 11.3.1.48:

(1) Moisture content
(2) Moisture Condition Value (MCV)
(3) Liquid limit, plastic limit, plasticity index.
(4) Particle density
(5) Particle size distribution
(6) Organic matter content
(7) Total sulphate content of soil
(8) Sulphate content of groundwater and aqueous soil extracts
(9) pH value
(10) Carbonate content - standard method
(11) Carbonate content - simplified method
(12) Chloride content
(13) Dry density/moisture content relationship
(14) Dry density
(15) California Bearing Ratio (CBR)
(16) One-dimensional consolidation
(17) Consolidation test in a hydraulic cell
(18) Unconfined compressive strength
(19) Undrained triaxial compression without the measurement of pore water pressure (single stage)
(20) Undrained triaxial compression without the measurement of pore water pressure (multi stage)
(21) Undrained shear strength for remoulded cohesive soil
(22) Consolidated undrained triaxial compression with the measurement of pore water pressure (single stage)
(23) Consolidated undrained triaxial compression with the measurement of pore water pressure (multi stage)
(24) Consolidated drained triaxial compression with measurement of volume change
(25) Consolidated undrained triaxial compression without the measurement of pore water pressure
(26) Isotropic triaxial consolidation
(27) Anisotropic consolidation in triaxial cell
(28) Permeability in triaxial cell
(29) Small shearbox test
(30) Large shearbox test
(31) Drained strength and residual strength shearbox tests
(32) Laboratory vane test

(33) Residual strength determination using small ring shear apparatus
(34) 10% fines value
(35) Frost heave test
(36) Chalk crushing test
(37) Hand vane test
(38) Total sulphur content
(39) Initial consumption of lime
(40) Available lime content
(41) Laboratory lime addition value
(42) Moisture content for lime stabilisation studies
(43) Moisture condition value for lime stabilisation studies
(44) Dry density/moisture content relationship for lime stabilisation studies
(45) CBR for lime stabilisation studies
(46) Swelling test for lime stabilisation studies
(47) Frost heave test for lime stabilisation studies
(48) Aggressive carbon dioxide

11.3.1 Tests

The presence of tests in this Clause does not preclude them from also being specified for use on site or on rock samples.

11.3.1.1 Moisture content
Equipment and Procedure:
The equipment and procedure shall be as described in BS 1377:Part 2, Clause 3.2.
Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 2, Clause 3.2.5.

11.3.1.2(a) Moisture Condition Value (MCV) [England, Wales and N Ireland]
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 1377: Part 4, Clause 5.
2. The MCV shall be determined at the field moisture content.
3. The relationship between MCV and moisture content shall be determined for each major soil type.

Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 4, Clause 5.

11.3.1.2(b) Moisture Condition Value (MCV) [Scotland]
Equipment and procedure:
The equipment and procedure shall be as described in SH7/83 (DMRB 4.1.5)
Information to be submitted:
The information to be submitted shall be as described in SH7/83 (DMRB 4.1.5)

11.3.1.3 Liquid limit, plastic limit, plasticity index
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 2, Clauses 4 and 5.

Information to be submitted:
1. The information to be submitted shall be as described in BS 1377:Part 2, Clauses 4 and 5.
2. The natural moisture content of each specimen.

11.3.1.4 Particle density
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 2, Clause 8.
Information to be submitted:
1. The information to be submitted shall be as described in BS 1377:Part 2, Clause 8.
2. Method of testing.

11.3.1.5 Particle size distribution
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 1377:Part 2, Clause 9.2. The number of sieve sizes shall be increased accordingly to match those given in Table 6/2 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments).
2. When a particle size distribution is carried out on a sample and where 15% or more of the soil sample passes the 63 micron sieve, testing in accordance with BS 1377:Part 2, Clause 9.4 shall be required.

Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 2, Clauses 9.2 and 9.4 giving both tabular results and a semi logarithmic chart of the type shown in Form 2N of BS 1377:Part 2 but including the additional sieves.

11.3.1.6. Organic matter content
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 3, Clause 3.
Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 3, Clause 3.6.

11.3.1.7 Total sulphate content of soil
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 3, Clause 5.2 and 5.5. If the total sulphate content exceeds 0.2% of the dry weight of soil a 2:1 water : soil extract must be prepared and the sulphate content redetermined in accordance with Clause 11.3.1.8.
Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 3, Clause 5.5.5, and the total sulphate content expressed as SO_3.

11.3.1.8 Sulphate content of groundwater and aqueous soil extracts
Equipment and procedure:
1. The equipment and procedure for the preparation of the water extract shall be as described in BS 1377:Part 3, Clause 5.3.
2. The equipment and procedure for the remainder of the test shall be as described in BS 1377:Part 3, Clauses 5.4, 5.5 and 5.6.

Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 3, Clause 5, and the total sulphate content expressed as SO_3.

11.3.1.9 pH value
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 3, Clause 9.
Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 3, Clause 9.6.

11.3.1.10 Carbonate content - standard method
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 3, Clause 6.4.
Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 3, Clause 6.4.5.

11.3.1.11 Carbonate content - simplified method
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 3, Clause 6.3.
Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 3, Clause 6.3.7.

11.3.1.12 Chloride content
Equipment and procedure:
The equipment and procedure shall be as described in BS 1377:Part 3, Clause 7 for soils and BS 2690 for groundwater.
Information to be submitted:
The information to be submitted shall be as described in BS 1377:Part 3, Clause 7 for soils and BS 2690 for groundwater.

11.3.1.13 Dry density/moisture content relationship
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 1377:Part 4, Clause 3 using whichever test is specified in Schedule 1.15.
2. There shall be at least two measured points either side of the optimum.

Information to be submitted:
1. The information to be submitted shall be as described in BS 1377:Part 4, Clause 3, whichever test is carried out.
2. Relevant zero air voids line based on measured or assumed particle density.

11.3.1.14 Dry density
Equipment and Procedure:
The equipment and procedure shall be as described in BS 1377:Part 2, Clause 7.
Information to be submitted:
1. The information to be submitted shall be as described in BS 1377:Part 2, Clause 7.
2. Bulk density of soil to nearest 0.01 Mg/m^3.

11.3.1.15 California Bearing Ratio (CBR)
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 1377:Part 4, Clause 7.2.4.4 (Method 5 Rammer compaction with specified effort).
2. Compaction of the samples shall normally be to an intermediate value.
3. The surcharge weight to be used (up to a maximum of 20kg) and compaction moisture content will be specified by the Engineer.
4. Laboratory vane tests in accordance with Clause 11.3.1.32 may be required for the measurement of the shear strength of compacted cohesive soils in CBR moulds normally when the CBR is 3% or less. Subsequent to carrying out the CBR test, the vane shall be pushed into the specimen from one end only at three locations around the imprint of the CBR plunger to measure the shear strength of the soil at the mid-height of the sample. After

each vane test has been carried out, the vane shall be rotated through at least five revolutions in order to determine the remoulded shear strength.

5. Testing shall be carried out on the top and bottom of the specimen.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1377:Part 4, Clause 7.6.
2. The mass of surcharge employed.
3. The initial sample density and the dry density reported to 0.01Mg/m^3 and moisture content.
4. If soaked, dry density before and after soaking reported to 0.01 Mg/m^3.
5. If soaked, moisture content before compaction; also after test at top, middle and bottom of specimen.
6. For multiple CBRs on the same sample a plot of moisture content (vertical axis) against the logarithm of CBR.

11.3.1.16 One dimensional consolidation

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 5, Clause 3.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1377:Part 5, Clause 3.7.
2. Final moisture contents.
3. Final voids ratio.
4. The Plastic Limit and Liquid Limit on soil from which the consolidation test specimens were taken as described in Clause 11.3.1.3.
5. A plot of coefficient of consolidation against the logarithm of applied pressure.
6. Mass of specimen after test.
7. The coefficient of volume compressibility for each decrement of unloading shall be reported to two significant figures.
8. All information shall be based on five increments and two decrements of loading. Loading increments and decrements shall be as specified by the Engineer.

11.3.1.17 Consolidation test in a hydraulic cell

Equipment and procedure:

1. The equipment and procedure shall be as described in BS 1377:Part 6, Clause 3.
2. Calculate the voids ratio.
3. Derive the coefficient of secondary compression.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1377:Part 6, Clause 3.
2. Calculated voids ratio shall be tabulated and plotted.
3. Derived coefficient of secondary compression.

11.3.1.18 Unconfined compressive strength

Equipment and procedure:

1. The equipment and procedure shall be as described in BS 1377:Part 7, Clause 7.
2. Alternatively a triaxial compression apparatus shall be employed as described in Clause 11.3.1.19 but without the use of a rubber membrane on the sample or the introduction of water into the cell or any other lateral restraint.

Information to be submitted:

The information to be submitted shall be as described in BS 1377:Part 7, Clause 7.

11.3.1.19 Undrained triaxial compression without the measurement of pore water pressure

Equipment and procedure:

1. The equipment and procedure shall be as described in BS 1377:Part 7, Clause 8.
2. The test shall be carried out on either a set of 3 x 38 mm diameter test specimens or a single 102 mm diameter specimen.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1377:Part 7, Clause 8.6.
2. Mohr circle diagrams required if principal stress differences vary more than 10% (for set of 3 test specimens only).
3. The stress-strain curve plotted with the axial strain as abscissa and the principal stress difference as ordinate.

11.3.1.20 Undrained triaxial compression without the measurement of pore water pressure (multistage test on a single specimen)

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 7, Clause 9.

Information to be submitted:

The information to be submitted shall be as described in BS 1377:Part 7, Clause 9.6.

11.3.1.21 Undrained shear strength for remoulded cohesive soil

Equipment and procedure:

The equipment and procedure shall be as described in Clause 633 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments).

Information to be submitted:

The information to be submitted shall be as described in Clause 633 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments).

11.3.1.22 Consolidated undrained triaxial compression with pore water pressure measurement

Equipment and procedure:

1. The equipment and procedure shall be as described in BS 1377:Part 8, Clause 7.
2. The test shall be carried out on either a set of 3 x 38 mm diameter specimens or a single 102 mm diameter specimen.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1377:Part 8, Clause 7.6.
2. Pore pressure parameter A.
3. Final dry density.
4. Coefficient of permeability k for the consolidation stage reported in m/s.

11.3.1.23 Consolidated undrained triaxial compression with pore water pressurement measurement (multistage test on a single specimen)

Equipment and procedure:

The equipment and procedure shall be as described in Manual of Soil Testing by K H Head: Vol 3, Ch. 19.2.2, or recognised equivalent fit for the purpose.

Information to be submitted:

1. The information to be submitted shall be as described in K H Head: Vol 3, Ch. 19.2.3, and 18.7.5.
2. Pore pressure parameters.
3. Final moisture content.
4. Final dry density.
5. Coefficient of permeability k for the consolidation stage reported in m/s.

11.3.1.24 Consolidated drained triaxial compression with measurement of volume change

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 8, Clause 8.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1377:Part 8, Clause 8.6.
2. Final dry density.

11.3.1.25 Consolidated undrained triaxial compression without the measurement of pore water pressure

Equipment and procedure:

The equipment and procedure shall be as described in Manual of Soil Laboratory Testing by K H Head: Vol 3, Ch. 19.3.3, or recognised equivalent fit for the purpose.

Information to be submitted:

The information to be submitted shall be as described in K H Head: Vol 3, Ch 19.3.3.

11.3.1.26 Isotropic triaxial consolidation

Equipment and procedure:

1. The equipment and procedure shall be as described in BS 1377:Part 6, Clause 5.
2. Calculate the voids ratio.
3. Derive the coefficient of secondary compression.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1377:Part 6, Clause 5.7.
2. The calculated voids ratio shall be tabulated and plotted.
3. The derived coefficient of secondary compression.

11.3.1.27 Anisotropic consolidation in triaxial cell

Equipment and procedure:

The equipment and procedure shall be as described in The Triaxial Test by Bishop and Henkel: Part IV.5, or recognised equivalent fit for the purpose.

Information to be submitted:

The information to be submitted shall be as described in Bishop and Henkel: Part IV.5.

11.3.1.28 Permeability in triaxial cell

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 6, Clause 6.

Information to be submitted:

The information to be submitted shall be as described in BS 1377:Part 6, Clause 6.10.

11.3.1.29 Small shearbox test

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 7, Clause 4.

Information to be submitted:

The information to be submitted shall be as described in BS 1377:Part 7, Clause 4.7.

11.3.1.30 Large shearbox test

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 7, Clause 5.

Information to be submitted:

The information to be submitted shall be as described in BS 1377:Part 7, Clause 5.7.

11.3.1.31 Drained strength and residual strength shearbox tests

Equipment and procedure:

The equipment and procedure shall be as described in Manual of Soil Laboratory Testing by K H Head: Vol 2, Ch. 12.7, or TRRL Report LR 515, whichever is specified in Schedule 1.15, or recognised equivalent fit for the purpose.

Information to be submitted:

1. Preparation of sample(s) ie undisturbed, compacted, orientation etc.
2. Initial dimensions.
3. The normal pressure kN/m².
4. Peak shear stress kN/m².
5. Strain at peak shear stress %.
6. Initial voids ratio.
7. Effective shear strength parameters both peak and residual c' kN/m², Ø' degrees and c'_r kN/m², $Ø'_r$ degrees.
8. Voids ratio, dry density and moisture content after test.
9. Dimensions after consolidation and after test.
10. Graphs of volume change against time during consolidation.
11. Graph of effective shear stresses against effective normal stress.
12. Strain in % at residual shear stress.
13. Graph of effective shear stress against strain.

11.3.1.32 Laboratory vane test

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 7, Clause 3.

Information to be submitted:

The information to be submitted shall be as described in BS 1377:Part 7, Clause 3.5.

11.3.1.33 Residual strength determination using small ring shear apparatus

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 7, Clause 6.

Information to be submitted:

The information to be submitted shall be as described in BS 1377:Part 7, Clause 6.6.

11.3.1.34 10% fines value

Equipment and Procedure:

The equipment and procedure shall be as described in Clause 635 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments).

Information to be submitted:

The information submitted shall be as described in BS 812:Part 3, 1975.

11.3.1.35 Frost heave test

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 5, Clause 7 and BS 812:Part 124 as amended in sub-clause 705.5 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments).

Information to be submitted:

The information submitted shall be as described in BS 1377:Part 5, Clause 7 and BS 812:Part 124 as amended in sub-clause 705.5 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments).

11.3.1.36 Chalk crushing value

Equipment and procedure:

The equipment and procedure shall be as described in BS 1377:Part 4, Clause 6.

Information to be submitted:

The information submitted shall be as described in BS 1377:Part 4, Clause 6.4.3.

11.3.1.37 Hand vane test

Equipment and procedure:

1. The portable hand vane tester shall comprise a torque head with a direct reading scale which is turned by hand. Vanes shall be either 19mm or 33mm diameter (range 0-120 kN/m² and 0-28kN/m² respectively) mounted on extension rods screwed into the rear of the torque head.
2. The vane shall be pushed into the soil.
3. The vane shall then be rotated at a rate of turning in accordance with the manufacturer's instructions, until the soil has sheared. The maximum torque shall be recorded.
4. The vane shall then continue to be turned through 5 complete revolutions so as to remould the soil in the sheared zone. Without further delay the vane shall be rotated as in sub-clause 3 above until the soil has sheared again and the maximum torque shall be recorded as a remoulded value.

Information to be submitted:

1. Date of test.
2. Sample reference.
3. Type of vane test apparatus.
4. Size of vane.
5. Rate of turning the vane.

6. The peak vane shear strength of the soil.
7. The remoulded vane shear strength of the soil.

11.3.1.38 Total sulphur content
Equipment and procedure:
The equipment and procedure shall be as described in BS 1047. Appendix B. Method B2.
Information to be submitted:
The total percentage of sulphur (S%) calculated in accordance with BS 1047. Appendix B. Method B2 and then expressed as SO_3% using the formula:

$$S\% \times \frac{80}{32} = SO_3\%.$$

11.3.1.39 Initial consumption of lime
Equipment and procedure:
The equipment and procedure shall be in accordance with BS 1924: Part 2, Clause 5.4.
Information to be submitted:
The information to be submitted shall be as described in BS 1924: Part 2, Clause 5.4.9.

11.3.1.40 Available lime content
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 6463:Part 1.
2. The available lime content shall be determined as calcium oxide in accordance with BS 6463:Part 2, Method 20.

Information to be submitted:
The results shall be reported as:
Available lime (as CaO) = ...% by mass.

11.3.1.41 Laboratory lime addition value
Equipment and procedure:
1. The laboratory lime addition value shall be determined from the CBR for lime stabilisation studies (Clause 11.3.1.45) and the swelling test for lime stabilisation studies (Clause 11.3.1.46).
2. The Initial Consumption of Lime test shall be used as the starting value for lime addition subject to a minimum value of 2.0% by weight of available lime expressed as a percentage of dry weight.

Information to be submitted:
The Laboratory Lime Addition Value shall be reported as the percentage by weight of available lime, expressed in terms of the dry weight, which when mixed with the soil produces an average 7day CBR strength greater than 15% (no individual specimen less than 8%) and an average swelling of 5mm or less (no individual specimen more than 10mm).

11.3.1.42 Moisture content for lime stabilisation studies
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 1924: Part 2, Clause 1.3 except that the material samples shall be mellowed in sealed containers for a period of 24 to 72 hours after the addition and mixing of lime.
2. All the material for a particular test shall be mellowed prior to measurement for a similar period of time as the dry density/moisture content relationship.
3. Testing shall be carried out at the laboratory lime addition value and for each major soil type.

Information to be submitted:
The information to be submitted shall be as described in BS 1924: Part 2, Clause 1.3.8.

11.3.1.43 Moisture condition value for lime stabilisation studies
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 1924: Part 2, Clause 2.2 except that the material samples shall be mellowed in sealed containers for a period of 24 to 72 hours after the addition and mixing of lime.
2. All the material for a particular test shall be mellowed prior to measurement for a similar period of time as the dry density/moisture content relationship.
3. The relationship between MCV and moisture content shall be determined.
4. Testing shall be carried out at the laboratory lime addition value and for each major soil type.

Information to be submitted:
The information to be submitted shall be as described in BS 1377: Part 4.

11.3.1.44 Dry density/moisture content relationship for lime stabilisation studies
Equipment and procedure:
1. The equipment and procedure shall be as described in BS 1924: Part 2, Clause 2.1 except that the material samples shall be mellowed in sealed containers for a period of 24 to 72 hours after the addition and mixing of lime and prior to compaction.
2. All the material samples for a particular test shall be mellowed for a similar period of time prior to moisture content measurement and compaction.
3. The method of compaction using a 2.5kg rammer shall be used unless otherwise agreed by the Engineer.
4. Testing shall be carried out at the laboratory lime addition value and for each major soil type.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1924: Part 2, Clause 2.1.3.6.2.
2. The mellowing period for each test specimen.
3. The 0% and 5% air voids lines based on measured particle density using the procedure specified in BS1377: Part 2 Method 8.2 (Gas Jar method) except that water shall be replaced with either white spirit or paraffin oil (kerosene).
4. The moisture content at the intercept of the 5% air voids line and the compaction curve.

11.3.1.45 CBR for lime stabilisation studies

Equipment and procedure:

1. The equipment and procedure shall be as described in BS 1924: Part 2, Clause 4.5, except as detailed below:
2. After addition of lime and prior to compaction in the moulds the material samples shall be mellowed in sealed containers for a period of 24 to 72 hours.
3. The 2.5kg rammer shall be used for compaction of stabilised material into the mould.
4. After allowing the sealed test sample to cure for a 3 day period at 20±2°C, the sample shall be soaked for 4 days, at the same temperature, after which the CBR is measured.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1924: Part 2, Clause 4.5.8.
2. The moisture content and dry density at which the specimens were prepared (i.e. at the end of the mellowing period) and the moisture content and dry density at which the specimens were tested shall both be reported.
3. Lime addition value at which the specimens were prepared.

11.3.1.46 Swelling test for lime stabilisation studies

Equipment and procedure:

1. The equipment and procedure shall be as described in Clause 11.3.1.44 (CBR for lime stabilisation studies), except as detailed below:
2. After allowing the test sample to cure in air for a 3 day period at 20±2°C the sample shall be soaked for 28 days, at the same temperature.
3. Measurements of swell shall be taken during the soaking period as described in BS 1924LPart 2, Clause 4.5.5. At least 2 measurements per day shall be taken during the first 3 days. Daily measurements shall be taken between 4 and 28 days.
4. If swelling is still occurring at 28 days but the total swell is less than 10mm then the soaking period shall be extended for a further 28 days. Daily swell measurements shall be taken unless 3 consecutive measurements indicates that swelling has ceased. Subsequent measurements may be taken at 3 day intervals, or the soaking period curtailed, at the direction of the Engineer.

Information to be submitted:

1. The information to be submitted shall be as described in BS 1924: Part 2, Clause 4.5.8.
2. The moisture content and dry density at which the specimens were prepared (i.e. at the end of the mellowing period) and the moisture content and dry density at which the specimens were tested shall both be reported.
3. A plot of swell displacement in mm versus time in days.
4. Lime addition value at which the specimens were prepared.
5. If water reaches the top of the specimen, the time this takes to occur.

11.3.1.47 Frost heave test for lime stabilisation studies

Equipment and procedure:

The equipment and procedure shall be as described in BS1924: Part 2, Clause 4.8 and BS 812: Part 124 as amended in Sub-clause 705.5 of the Specification for Highway Works (1991with August 1993 and August 1994 amendments), and to be carried out at the laboratory lime addition value.

Information to be submitted:

The information submitted shall be as described in BS 1924: Part 2, Clause 4.8 and BS 812: Part 124 as amended in Sub-clause 705.5 of the Specification for Highway Works (1991 with August 1993 and August 1994 amendments).

11.3.1.48 Aggressive carbon dioxide

Procedure:

The procedure shall be as described in The Chemistry of Cement and Concrete (Lea, 1970) pg 342.

Information to be submitted:

1. Temporary hardness of water sample in mg/l $CaCo_3$.
2. Aggressive CO_2 as free CO_2 in mg/l CO_2.
3. The volumes of the samples used in the titrations.

11.4 Rock testing

Rock testing shall be carried out and reported in accordance with the following references and as described in Schedule 1.15.

11.4.1 Classification

11.4.1.1 Natural water content - Brown (1981)

11.4.1.2 Porosity/density - Brown (1981)

11.4.1.3 Void index - Brown (1981)

11.4.1.4 Carbonate content - BS 1881: 1971

11.4.1.5 Petrographic description - Brown (1981)

11.4.2 Durability

11.4.2.1 Slake durability index - Brown (1981)

11.4.2.2 Soundness by solution of magnesium sulphate - BS 812:1989

11.4.3 Hardness

11.4.3.1 Shore sclerometer - Brown (1981)

11.4.3.2 Schmidt rebound hardness - Brown (1981)

11.4.4 Aggregates

11.4.4.1 Aggregate crushing value - BS 812: 1989

11.4.4.2 Ten percent fines - BS 812: 1989

11.4.4.3 Aggregate impact value - BS 812: 1989

11.4.4.4 Aggregate abrasion value - BS 812: 1989

11.4.4.5 Polished stone value - BS 812: 1975

11.4.4.6 Aggregate frost heave - BS 812: 1989

11.4.5 Strength

11.4.5.1 Uniaxial compressive strength - Brown (1981)

11.4.5.2 Deformability in uniaxial compression - Brown (1981)

11.4.5.3 Tensile strength - Brown (1981)
Direct tensile strength
Indirect tensile strength by Brazilian method

11.4.5.4 Undrained triaxial compression without measurement of porewater pressure - Brown (1981)

11.4.5.5 Undrained triaxial compression with measurement of porewater pressure - ASTM:SP 402

11.4.5.6 Direct shear strength - Brown (1981)

11.4.5.7 Swelling pressure - Brown (1981)
Swelling pressure index under conditions of zero volume change.
Swelling strain index for a radially confined specimen with axial surcharge.
Swelling strain developed in an unconfined rock specimen.

11.4.5.8 Point load test - IRSM Commission on Testing Methods (1985).

11.4.6 Geophysical

11.4.6.1 Seismic velocity - Brown (1981).

11.5 Testing for contamination

Laboratory testing for contamination shall be carried out on soil, water and gas samples.

11.5.1 General

11.5.1.1 The Engineer will decide the laboratory tests required and will provide the Contractor with one or more schedules of laboratory tests from the range of analyses given in Schedule 1.17. It may be necessary to specify additional testing after the results of the original tests are available.

11.5.1.2 At least 2 working days in advance of the programmed start of each exploratory hole for the contamination investigation, the Engineer will provide the Contractor with a provisional schedule of tests which may be required. The Contractor shall provide suitable containers and undertake the sampling in such a manner to ensure that the samples are suitable for the provisional schedule of tests provided by the Engineer.

11.5.1.3 The Engineer will specify the initial schedule of contamination testing for each exploratory hole on the basis of the daily report as detailed in Clause 10.1 within 7 calendar days of receipt of the daily report.

11.5.2 Laboratory accreditation

11.5.2.1 The schedule of contamination tests specified in Appendix 6 shall either be carried out to the methods

listed in Appendix 4 in laboratories that are currently accredited for those tests by UKAS or equivalent bodies in states of the European Economic Area; or be undertaken in laboratories demonstrating proficiency in carrying out the specified tests. Proficiency shall be determined by satisfying the performance score specified in Appendix 6 in a proficiency testing scheme such as CONTEST or other equivalent scheme.

11.5.3 Solids testing

11.5.3.1 Samples shall be examined for characteristics such as colour, odour, and any non-soil materials, and the findings recorded.

11.5.3.2 The percentage volume of the following categories of matter in the sample shall be estimated and each category described:

(i) 'Inert' material, less than 2mm (eg clay, sand)
(ii) 'Inert' material, greater than 2mm, (eg stones, glass, pottery, etc).
(iii) Organic material - non-putrescible
(iv) Organic material - putrescible.

11.5.3.3 Testing and reporting shall be carried out as specified in Appendix 4 or in Schedule 1.17 to the detection limits specified in Schedule 1.17. Alternatively, an in-house analytical method may be used provided that the laboratory has demonstrated that the in-house method satisfies the performance score specified in Appendix 6 and the detection limits specified in Schedule 1.17

11.5.3.4 Unless otherwise specified, the preparation of the sample shall be as in Part B "The sampling and initial preparation of sewage and water works, sludges, soils, sediments, plant materials and contaminated wildlife prior to analysis", (1987), except that the milled sample should pass through a maximum sieve size of 2mm.

11.5.4 Water testing

11.5.4.1 Samples shall be prepared in accordance with Section 4, "General principles of sampling and accuracy of results", (HMSO,1980). Each sample shall be thoroughly mixed to ensure that aliquots taken from it for analysis are representative of the whole sample.

11.5.4.2 Testing and reporting shall be as specified in Appendix 4 or Schedule 1.17 to the level of detection specified in Schedule 1.17. Alternatively, an in-house analytical method may be used provided that the laboratory has demonstrated that the in-house method satisfies the performance score specified in Appendix 6 and the detection limits specified in Schedule 1.17

11.5.5 Gas testing

11.5.5 Preparation testing and reporting shall be carried out in accordance with "The analysis of sludge digester gas", (1979), and as specified in Appendix 4.

11.6 Testing on site

When required in Schedule 1.13 tests listed under laboratory testing shall be carried out on site.

11.7 Special laboratory testing

11.7.1 The equipment, procedure and information to be submitted for the following special laboratory soil tests shall be all as described in the relevant reference documents or recognised equivalent.

Test	Reference
(a) Permeability Test in a Hydraulic Consolidation Cell.	BS 1377:Part 6, Clause 4.
(b) Linear Shrinkage.	BS 1377:Part 2, Clause 6.5.
(c) Swelling and Collapse Characteristics.	BS 1377:Part 5, Clause 4.
(d) Erodibility (Pinhole Test).	BS 1377:Part 5, Clause 6.2.
(e) Erodibility (Crumb Test).	BS 1377:Part 5, Clause 6.3.
(f) Erodibility (Dispersion Test).	BS 1377:Part 5, Clause 6.4.
(g) Relative Density (Cohesionless Soil)	ASTM D 2049.

11.7.2 Other special laboratory testing shall be carried out as described in Schedule 1.15.

12. REPORTING

12.1 Preliminary logs

The Contractor shall prepare a preliminary log of each exploratory hole using an agreed pro forma or as shown in Schedule 1.16. For trial pits a simplified version of a log and elevations showing each face of the pit shall be provided as appropriate. Preliminary logs shall be submitted to the Engineer in duplicate within seven working days of completion of the explorations to which they refer and shall contain the information required for the exploratory hole logs.

12.2 Exploratory hole logs

12.2.1 General

The exploratory hole logs shall be in the same form as the preliminary logs, presented to a suitable vertical scale, and shall include all the information that follows, such information having been updated as necessary in the light of laboratory testing and further examination of samples and cores.

12.2.2 Information for exploratory hole logs

✓means information required; (✓) means information required if applicable.

	Borehole	Rotary drilling	Pit and trench	Static and dynamic probing
1. All the information set out in Clause 10.2	✓	✓	✓	✓
2. National grid coordinates	✓	✓	✓	✓
3. Ground level related to Ordnance Datum	✓	✓	✓	✓
4. Elevation of each stratum referred to Ordnance Datum	✓	✓	✓	(✓)
5. Description of each stratum in accordance with BS 5930 and initials and surname of person who carried out the logging (and responsible Supervisor if under training)	✓	✓	✓	(✓)
6. Details of groundwater observations	✓	✓	✓	(✓)
7. Symbolic legend of strata in accordance with BS 5930	✓	✓	✓	(✓)
8. Solid core recovery as percentage of each core run		✓		
9. Rock Quality Designation RQD (Deere et al, 1967)		✓		

12.3 Preliminary laboratory test results

12.3.1 Laboratory test results shall be submitted to the Engineer in batches at the completion of each week's testing. A summary sheet, together with legible photocopies of laboratory test data and calculation forms are acceptable.

12.3.2 An example of the calculation of each type of test result shall be submitted to the Engineer.

12.4 Digital data

12.4.1 Format

12.4.1.1 The Contractor shall provide exploratory hole, in situ test, groundwater monitoring and laboratory test data in digital form in ASCII format on 3½ inch double sided virus free high-density disks or other transmission media as agreed by the Engineer formatted to be compatible with MS-DOS version 3.2 or higher. The files shall not be compressed.

12.4.1.2 Where exploratory hole, in situ test, groundwater monitoring and laboratory test data is required to be contained in the Factual Report, it shall also be supplied in digital form provided that there is an appropriate field/group within Appendices 2 and 3 of the Association of Geotechnical Specialists publication 'Electronic Transfer of Geotechnical Data from Ground Investigations' (2nd Edition, 1994) (hereinafter referred to as AGSP 1994) together with the amendments and additions set out in Schedule 1.16.

12.4.1.3 The digital data files shall comply with the Rules for Creating Data Files, Appendix 1 of the AGSP 1994 and incorporating the amendments and additions set out in Schedule 1.16. Each data file shall only contain one AGSP 1994 data group. The key data groups, common data groups and additional data groups or fields to be included shall be prepared in accordance with Appendices 2 and 3 of AGSP 1994 and incorporating the amendments and additions set out in Schedule 1.16.

12.4.1.4 Any new or amended groups or fields shall only be created with the Engineers's prior approval.

12.4.2 Method statement

12.4.2.1 The Contractor shall use an appropriate system of hardware and software in order that information common to the Factual Report and the Digital Data Report can be prepared from the same system. In accordance with Clause 14 of the Conditions of Contract, within 14 days after the acceptance of his Tender, the Contractor shall provide the Engineer with a written description of the procedure and methods which the Contractor proposes to adopt for producing and checking the digital data prior to submission to the Engineer. This information shall include details of the proposed hardware and software and how the proposed system has been validated.

12.4.3 Dummy data

12.4.3.1 Within 14 days of the Date for Commencement of the Investigation the Contractor shall submit to the Engineer a dummy set of data on disk in the required format. The dummy set of data shall be prepared using the same system referred to in Clause 12.4.2 to which the Engineer has given his consent. The extent of the dummy set of data shall be sufficient to cover the proposed scope required by the investigation and to demonstrate that it meets the requirements of the Investigation.

12.4.4 Preliminary data

12.4.4.1 When required in Schedule 1.16 the Contractor shall issue to the Engineer copies of digital data disks containing all available preliminary data in order to demonstrate the continuing application of the Contractor's procedures and methods.

12.4.4.2 In addition to the labelling given in 12.4.5 the preliminary disks shall be labelled "PRELIM".

12.4.4.3 Preliminary digital data shall be updated as necessary in the light of laboratory testing and the further examination of samples and cores.

12.4.5 Security and indexing

12.4.5.1 All disks or other agreed transmission media shall be securely labelled and clearly marked with:-

The title 'AGS Format ASCII Data';
The unique project identification (PROJ_ID);
The date of issue to the Engineer;
The name of the Employer;
The name of the Contractor;
The name of the Engineer;
The unique issue sequence number;
The relevant AGSP 1994 Data Group(s);
Status of the disk (PRELIM, DRAFT, FINAL etc).

If more than one disk, or other agreed transmission medium, is required, then the Contractor shall label them clearly to indicate the order in which the Engineer should read the data. The split of the data into separate files shall be decided by the Contractor. The unique sequence number shall run sequentially from the start of the Contract. Where more than one disk is required for a particular issue of digital data, this fact shall be clearly identified on the labels in that issue.

12.4.5.2 The Contractor shall keep, until the completion of the Period of Maintenance, an identical copy of each disk issued and an index detailing:

The heading 'AGS Format ASCII Data';
The title 'Media index record';
The unique project identification (PROJ_ID);
The unique issue sequence number;
The date of issue to the Engineer;
The name of the Contractor issuing the transmission medium;
The name of the Engineer to whom the transmission medium was issued;
A general description of the data transferred.

For each data file, the index shall detail:

The filename, including the extension '.AGS';
The date the file was created;
The time the file was created;
The file size in bytes;
A general description of the data contained in each file.

A copy of this index sheet shall be included in the Digital Data Report and with each issue of the digital data disk.

12.4.5.3 The Contractor shall make the requisite number of identical copies of the digital data disks required by the Contract and a further additional copy which shall remain the property of the Contractor and shall be kept by the Contractor until the expiry of the maintenance period.

12.4.6 Units of measurement

12.4.6.1 The units of measurement shall be those given in Appendices 2 and 3 of the AGSP 1994, unless other units of measurement for digital data are required by the Contract, in which case the format of the digital data files shall comply with Item 18 of Rules for Creating Data Files in Appendix 1 of the AGSP 1994.

12.4.7 Digital Data Report

12.4.7.1 The Contractor shall provide the Draft Digital Data Report with the draft Factual Report.

12.4.7.2 The final Digital Data Report shall contain the following information:

(i) Copies of the final digital data disk(s) or other agreed transmission medium containing data specified in the Contract to be in digital form. The final digital data shall be complete and a total replacement of any previous preliminary data and incorporate all the amendments instructed by the Engineer.The disk(s) or other agreed transmission medium shall be secure within the Digital Data Report but allow ready access. In addition to the labelling given in 12.4.5 the final disks shall be labelled "FINAL";

ii) A copy of the final index of digital data highlighting amended or new data fields or groups incorporated;

iii) A paper copy of the descriptive account of the Investigation from the Factual Report;

iv) A paper copy of the exploratory hole location plans from the Factual Report.

12.4.7.3 The Digital Data Report shall contain all of the contents required by 12.4.7.2 which shall be firmly bound in a single hard backed document.

12.4.7.4 The Digital Data Report shall clearly indicate where data are included as a paper record but are not included in digital form.

12.5 Form of Report

12.5.1 The Report shall comprise the Factual Report, Digital Data Report, and where required by Schedule 1.16 the Interpretative Report each as separate volumes.

12.5.2 The Factual Report shall be bound into loose leafed hard backed multiple ring binders with not more than 50 mm thickness of content in each, or as otherwise directed by the Engineer.

12.5.3 Each volume of the Report shall begin with a cover page showing the name of the Contract and the names of the Employer, Engineer and Contractor. Report pages shall be numbered consecutively.

12.6 Contents of Factual Report

12.6.1 The Factual Report shall contain the following information where applicable, in the format required by Schedule 1.16:

i) A brief factual description of the Investigation, stating the aim of the Investigation, the numbers and types of exploratory holes, time of year and weather conditions encountered, a brief description of the Site Operations, list of laboratory tests and a summary of general geology and revealed strata.

ii) Exploratory hole records including probe logs.

iii) All in situ test records and results.

iv) Standpipe and piezometer records, including permeability test reading and plots, any other relevant groundwater records.

v) All laboratory test records and results, including all information described in BS1377:Part 1, Clause 9.1.

vi) Summary sheets of all test results.

vii) Site plans showing locations of all exploratory holes and areas covered by the Investigation, including the Scale and North sign.

viii) Longitudinal Sections showing existing ground level and proposed road profile. The exploratory holes shall be identified and the revealed strata marked on the section at the appropriate location and at the same vertical scale. The scale shall be suitable for reading the data. Cross sections showing similar details shall be provided if required by Schedule 1.16.

ix) Gas standpipe records, including results of gas monitoring.

12.6.2 Exploratory hole records shall be of the form given in Schedule 1.16, or shall contain the same information on a similar form to be approved by the Engineer. The records shall include all the information set out in Clause 12.2.2, such information having been updated as necessary in the light of laboratory testing. Laboratory and in situ test results shall be recorded in the exploratory hole records or presented in tabular or graphical form as required in Schedule 1.16.

12.6.3 Summaries of laboratory tests shall be presented in tabular form as shown in Schedule 1.16, suitably grouped for aggregation for statistical purposes.

12.6.4 The Engineer will provide suitable negatives of the site plans, longitudinal section and other sections for the plotting of exploratory holes.

12.6.5 Test results for the contamination ground investigation shall be accompanied by an unambiguous description of sample preparation, extraction and analysis method used.

12.7 Contents of Interpretative Report

12.7.1 The Interpretative Report shall contain the following information:

(a) the brief agreed with the Employer
(b) reference to the desk study information
(c) a written appraisal of the ground and water conditions
(d) analyses and recommendations as indicated in Schedule 1.16.

12.7.2 Where required in the Contract the Contractor shall supply the calculations and analyses on which recommendations are based.

12.8 Approval of Report

Two draft copies of the Factual Report, Digital Data Report, and where specified in Schedule 1.16 the Interpretative Report shall be submitted to the Engineer for approval before submission of the final Report.

The Contractor shall allow three weeks in his Programme of Investigation for the Engineer to grant this approval and he shall include amendments, if any, as required by the Engineer, in the final Report.

12.9 Confidentiality

The Contractor should treat the information contained in the Factual and Interpretative Reports as confidential and shall not make their contents available to anyone who is not a party to the Contract.

13. ENQUIRIES

Approval of this document for publication is given by the undersigned:

The Quality Services Director
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J A KERMAN
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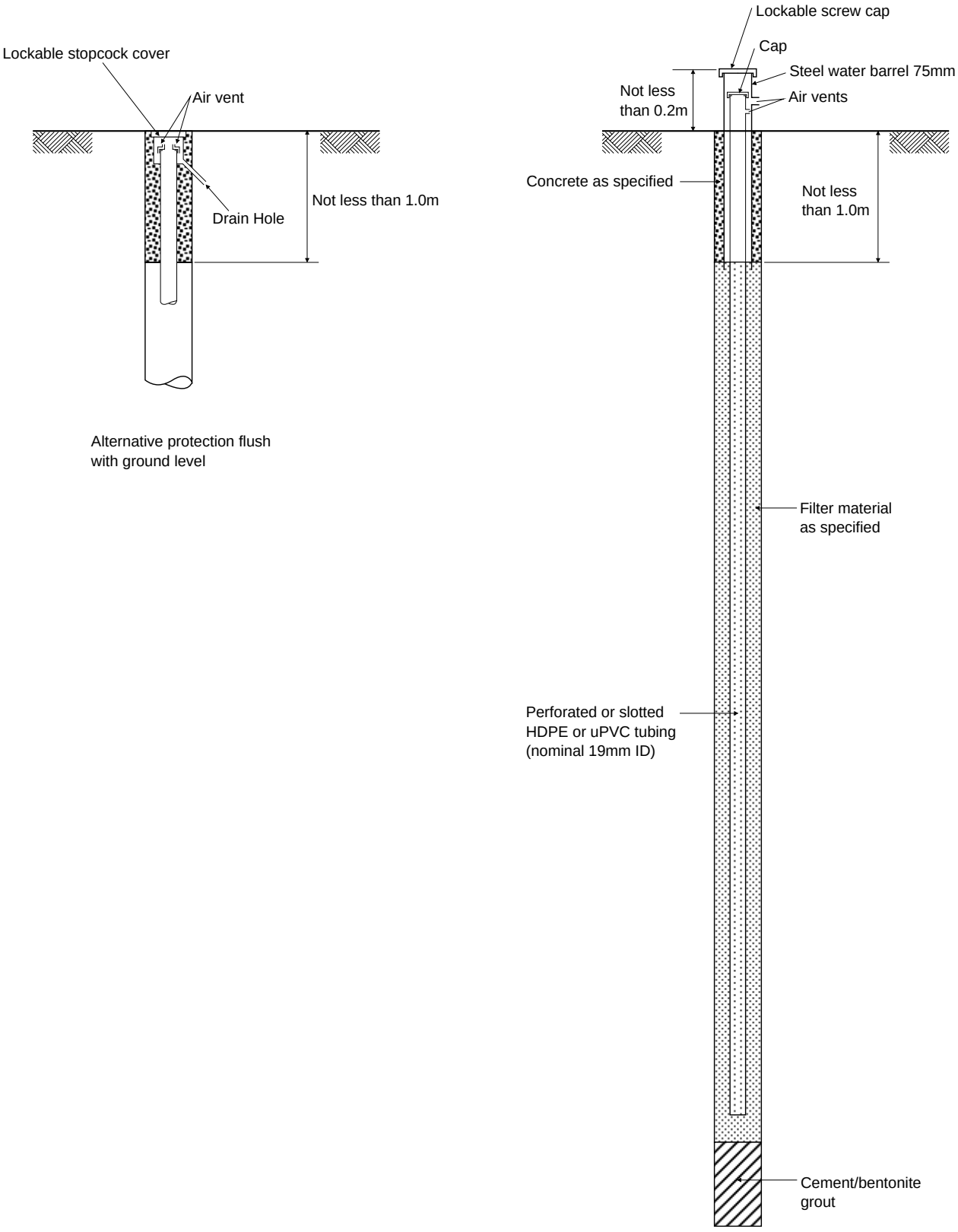
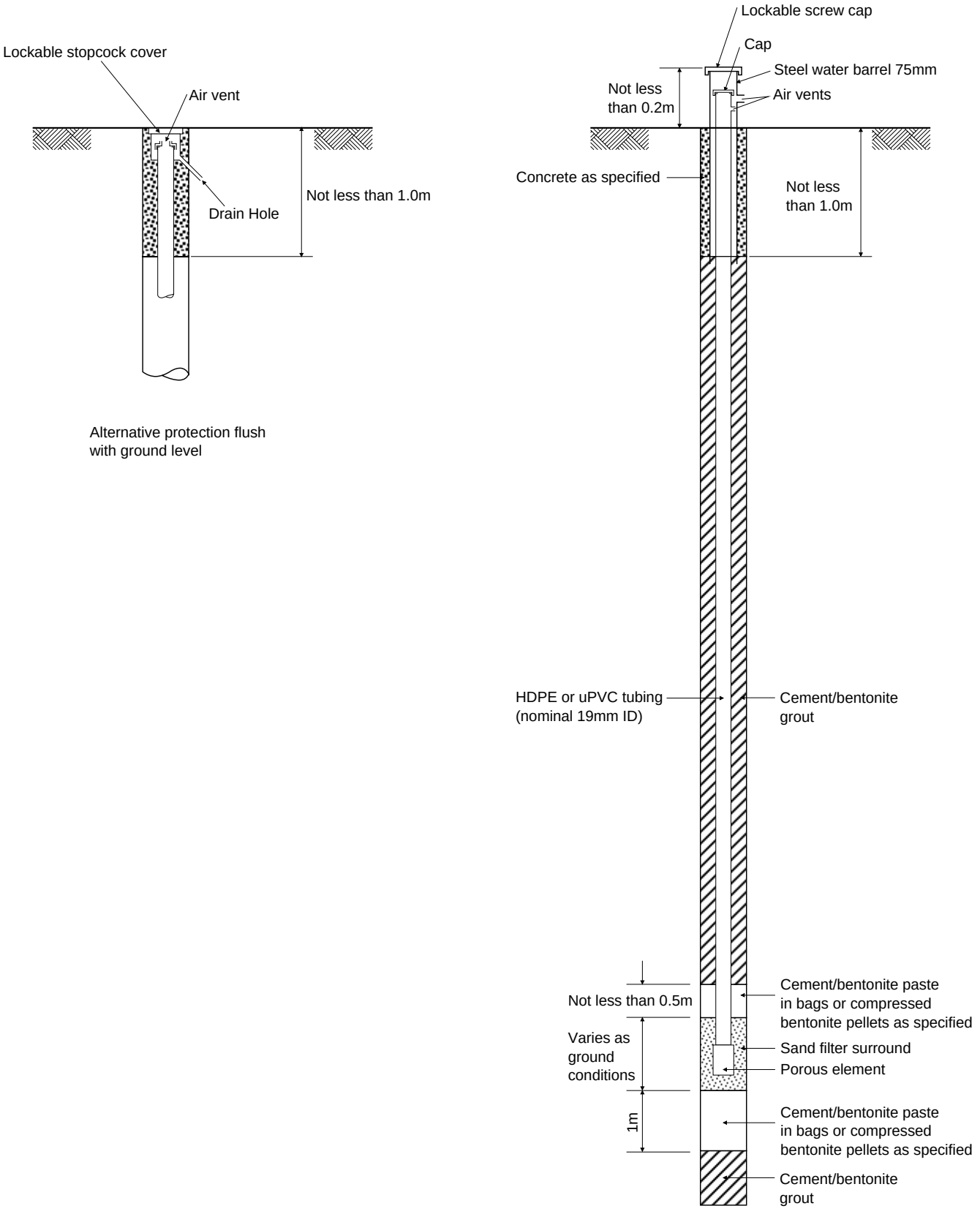
All technical enquiries or comments on this document should be sent in writing as appropriate to the above.

APPENDIX 1

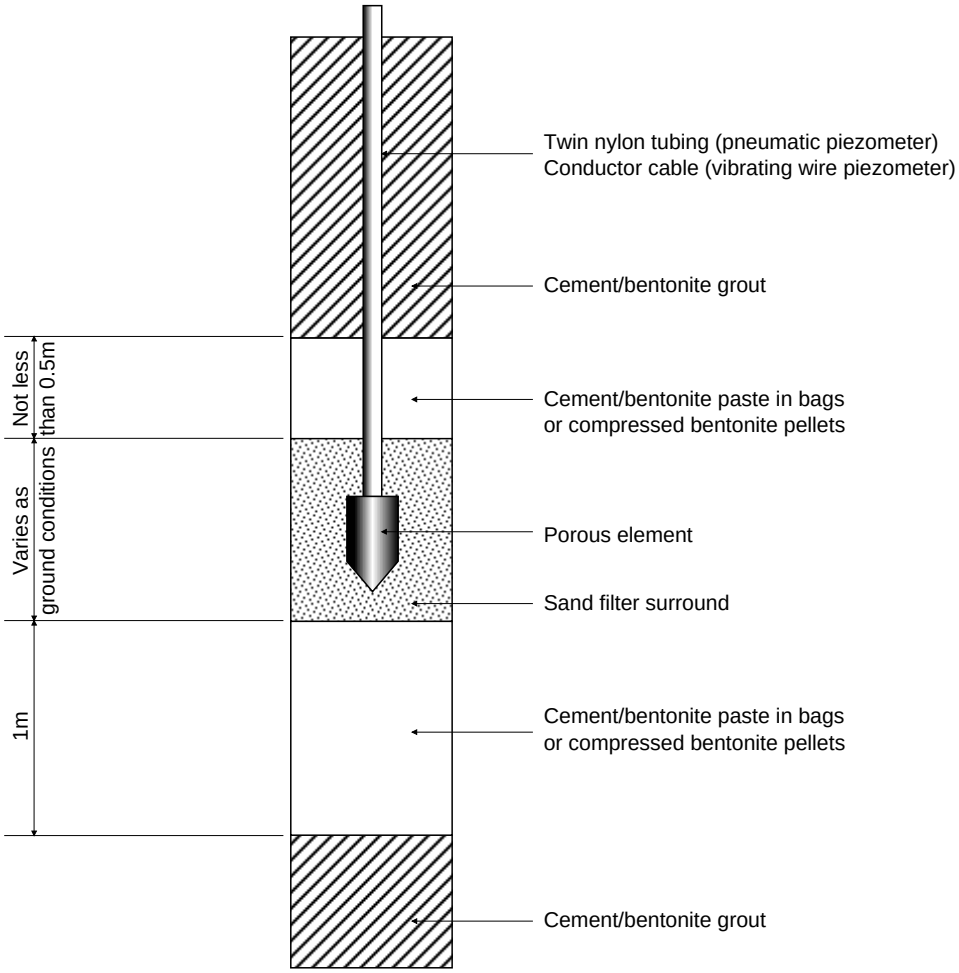
STANDPIPE AND PIEZOMETER DETAILS



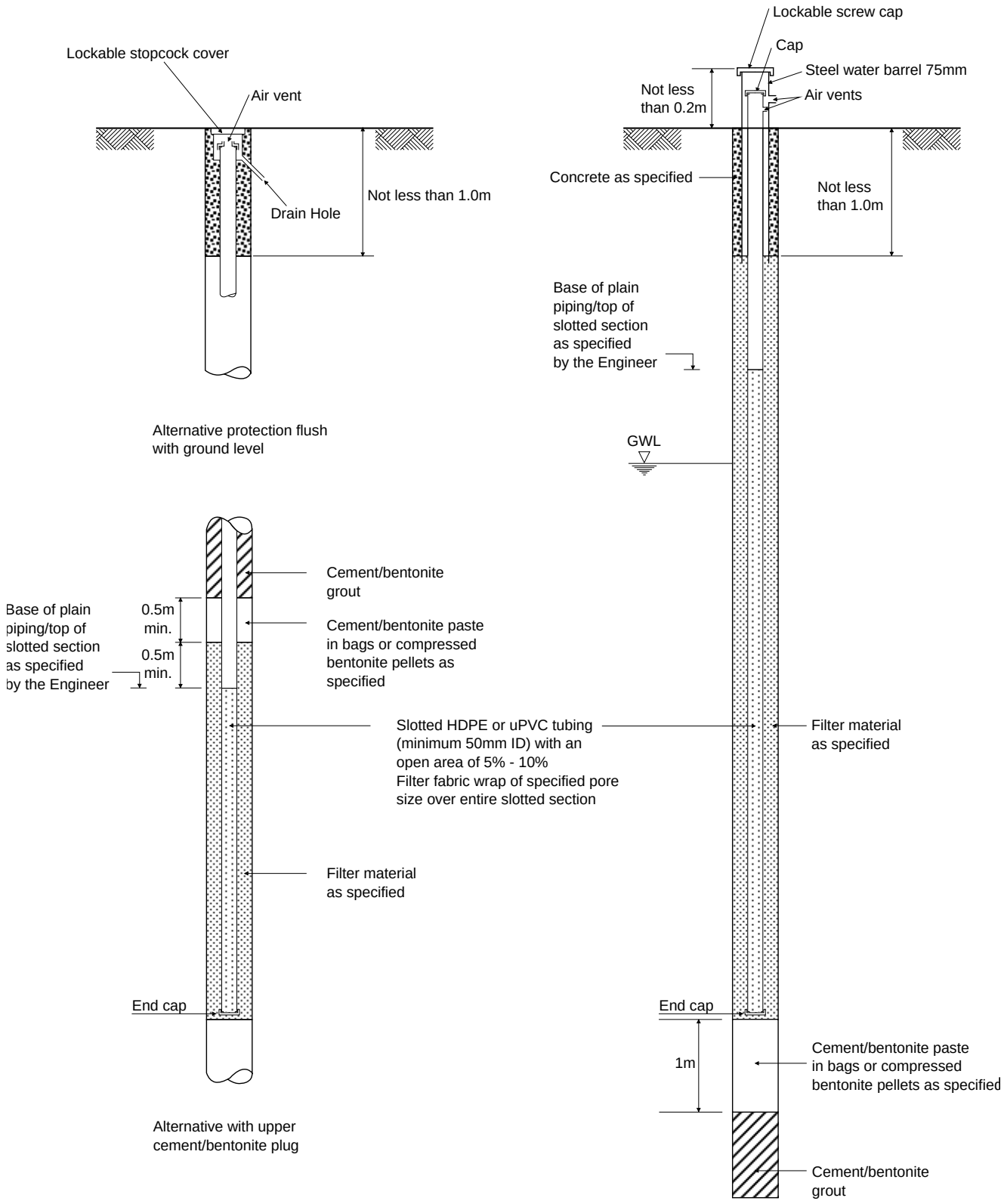
Drawing 1.1 Standpipe details



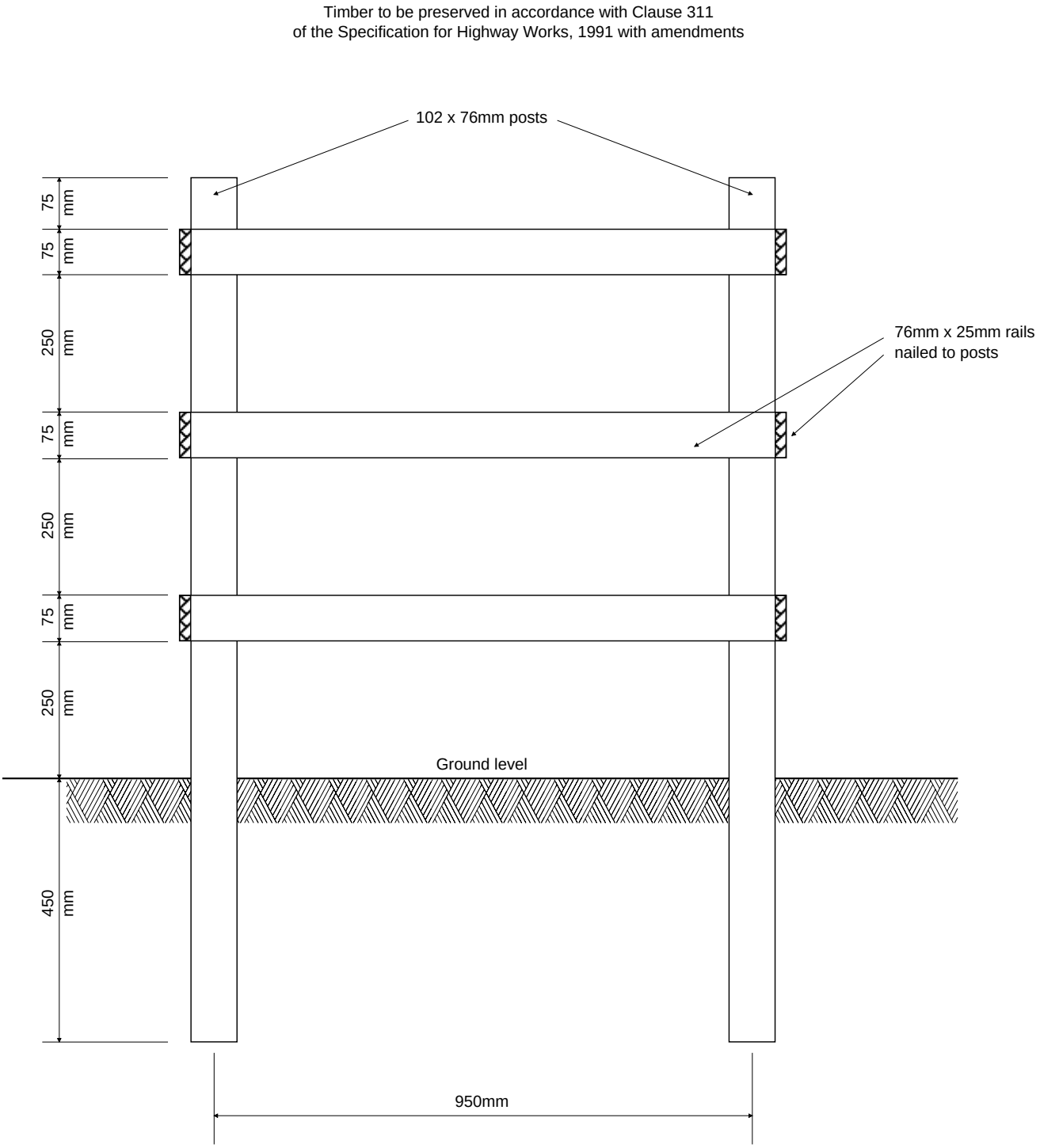
Drawing 1.2 Standpipe piezometer details



Drawing 1.3 Pneumatic and vibrating wire piezometer tip details



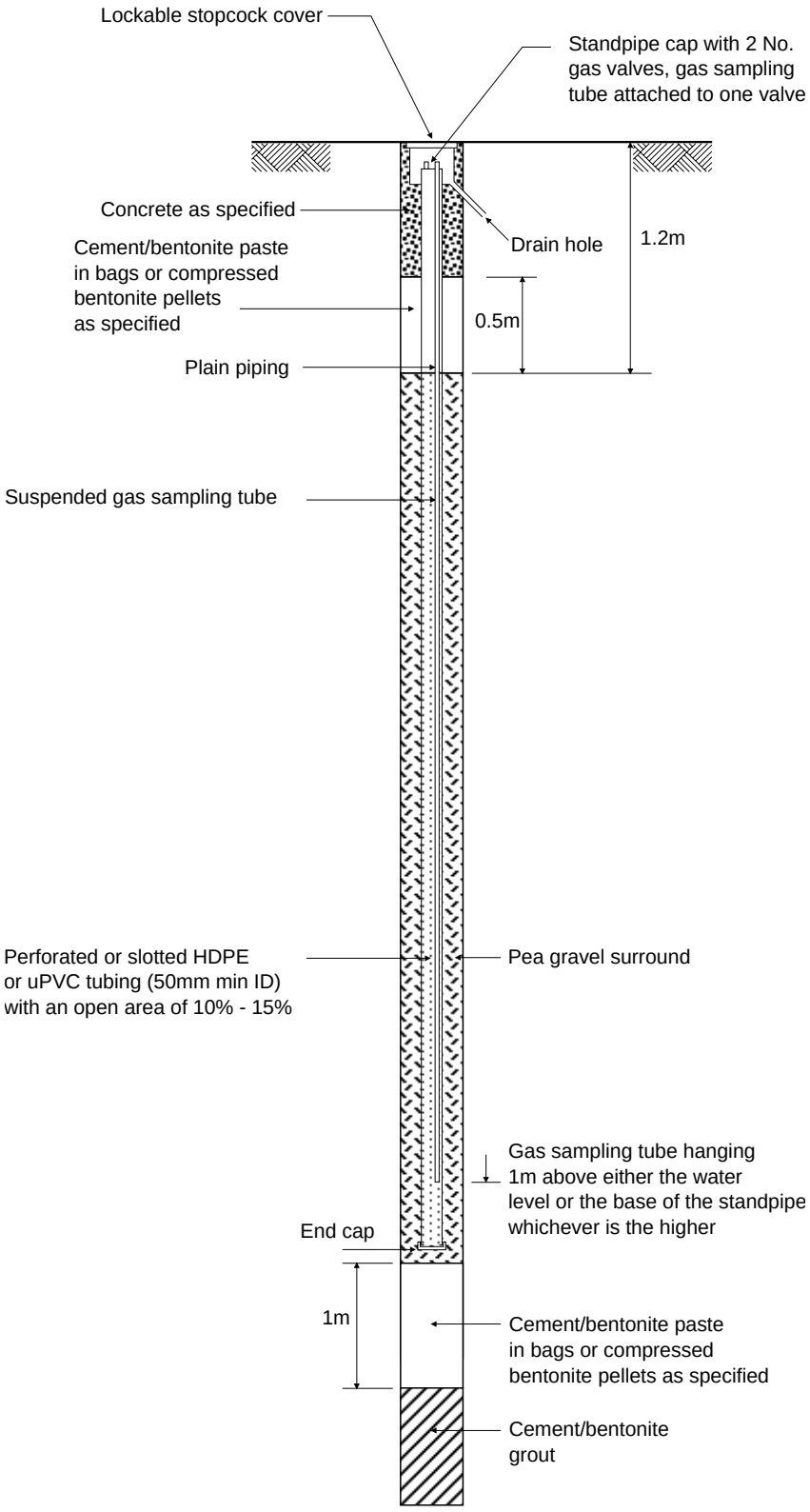
Drawing 1.4 Groundwater sampling standpipe



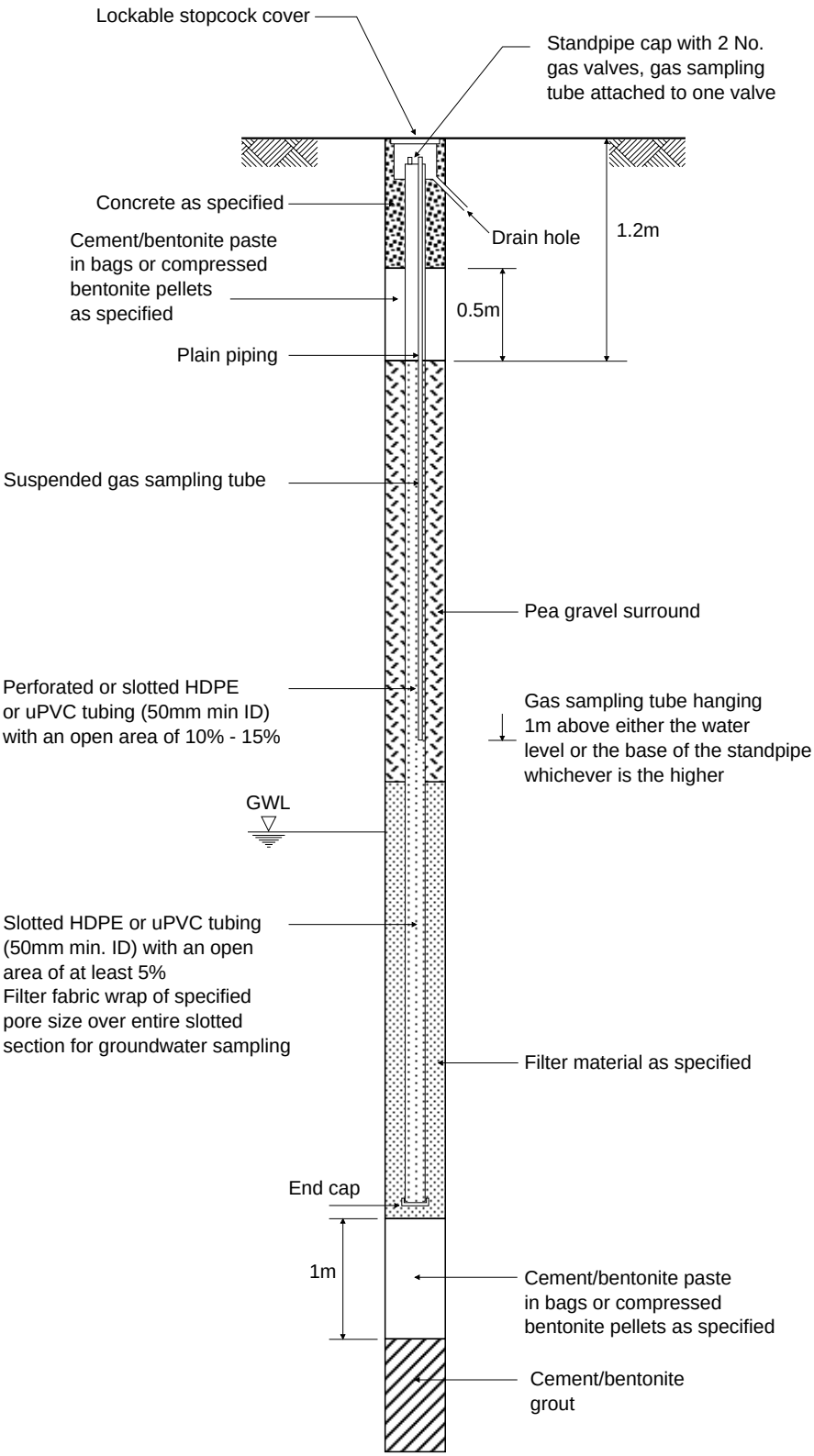
Drawing 1.5 Protective fencing

APPENDIX 2

GAS MONITORING AND STANDPIPE DETAILS



Drawing 2.1 Gas monitoring standpipe details



Drawing 2.2 Combined gas and groundwater sampling standpipe

APPENDIX 3

PRESSUREMETER TESTING

Equipment and Procedure:

A3.1 Instruments

A3.1.1 The pressuremeter shall be self boring and be a cylindrical device designed to apply uniform pressure to the walls of the exploratory hole by means of a flexible membrane. The length to diameter ratio of the membrane shall be greater than five. The vertical axis of the pressuremeter shall be straight to within 1 mm per metre over the length of the major diameter. Displacement shall be measured directly at the mid point of the membrane at three or more equidistant points around the circumference by displacement transducers mounted within the instrument. The sensitivity to external pressure of the displacement transducers shall not be greater than 4 mm per GPa. The total pressure shall be measured by a transducer within the instrument and shall have a working range less than or equal to the maximum capacity of the instrument. The resolution of the transducers mounted within an instrument shall be to within 0.05% of their full working range. The data acquisition system used with the instrument shall be capable of recording the transducer outputs to that resolution.

A3.1.2 The type(s) of self-boring pressuremeter used shall be such that they comply with the requirements for installation and testing. In addition they shall be of suitable capacity and sensitivity to achieve satisfactory data to enable the analysis required in clauses A.3.6.1 to A.3.6.4 of 'Equipment and Procedure' to be carried out. An indication of the strength and characteristics of the ground to be tested is given in Schedule 1.13.

A3.1.3 The self-boring pressuremeter shall be self-bored into the ground using an integral cutting head at its lower end such that the instrument replaces the material it removes. The self-boring techniques and flushing medium shall be consistent with achieving minimum disturbance to the ground surrounding the instrument such that a direct assessment of the in situ total horizontal stress can be made.

A3.2 Calibration

A3.2.1 Where required in Schedule 1.13, a statement from the manufacturer shall be given that the instrument meets the requirements of the specification for straightness and sensitivity.

A3.2.2 Calibrations shall be carried out where required in this clause and Schedule 1.13, and in shaded clean dry conditions. The record of each calibration shall include the ambient temperature at which the calibration was carried out and a description of the location where it was carried out.

A3.2.3 Calibrations for each instrument shall be kept in a register for that instrument and be available for inspection. The mean and standard deviation for the correlations of each transducer shall be given.

A3.2.4 The output from the transducers shall be read to within 0.05% of the output over the full working range. The data for each transducer shall be tabulated and presented as a graph of measured displacement against corresponding output. Regression analysis shall be used to determine the correlation between output and displacement or pressure and the coefficient shall be expressed to at least three significant figures. The coefficient of determination (r^2) for each calibration shall be greater than 0.95. The correlation coefficient for each calibration shall be within 5% of the mean correlation given in the register. Calibrations which do not meet these criteria will not be acceptable without the approval of the Engineer. All calibrations shall be traceable to National Standards.

A3.2.5 The procedures for calibrating the instrument shall be carried out as described below.

(a) Type 1. Displacement transducer:

The calibration of displacement transducer shall be the change in output from the transducer against the movement of the transducer measured by a micrometer. The micrometer shall read to 0.01 mm. The displacement shall be continuously increased up to the maximum working range of the transducer and then reduced to zero at increments of displacement of no greater than 0.5 mm. Each transducer shall be calibrated independently.

(b) Type 2. Total pressure transducer:

The instrument shall be placed in a cylinder strong enough to restrain the expansion safely at full working pressure. The pressure in the instrument shall be continuously increased in equal increments, such that there are 20 to 40 increments up to the total working capacity of the installed pressure transducer. The pressure in the instrument shall be reduced by the same number of increments used for pressurisation. The pressure at the end of each increment or decrement shall be held constant until the readings from the transducer remain substantially constant, readings being recorded at 10 second intervals throughout. The calibration of a pressure transducer shall be the change in output from the transducer against the pressure applied to the transducer measured by a calibrated Bourdon gauge. The maximum capacity of the Bourdon gauge shall be between 100% to 120% of the maximum capacity of the transducer and shall read to within 0.25% of the maximum capacity of the gauge.

(c) Type 3. Pore pressure transducer:

The procedure and equipment for calibrating the pore pressure transducers shall be the same as that for Type 2. If the pore pressure is measured relative to the pressure within the instrument then the transducer shall be calibrated by internally pressurising the instrument within a cylinder strong enough safely to restrain the expansion at full working pressure. If the pore pressure is measured relative to atmospheric pressure then the transducer shall be calibrated by externally pressurising the instrument within a cylinder strong enough safely to restrain the applied pressure.

(d) Type 4. Membrane stiffness:

The instrument shall be clamped in a vertical position. A new membrane shall be inflated up to the maximum movement of the displacement transducers and deflated to the deflated instrument diameter at least three times before calibration.

The membrane shall be inflated in free air by applying pressure in increments until the expansion commences. There shall be sufficient increments of pressure to accurately define the initial portion of the expansion. Upon expansion a cavity strain rate shall be selected to give sufficient data to accurately define the expansion curve. The expansion shall continue until the maximum movement of one of the displacement transducers is achieved. The membrane shall then be deflated by reducing the diameter of the membrane in the same decrements as the increments used for inflation. The output from all the transducers shall be recorded at 10 second intervals.

The data for each transducer shall be converted to engineering units by applying the calibration coefficients determined in Type 1 and 2 and presented as a graph of measured total pressure against corresponding cavity strain or displacement for each displacement transducer. The membrane stiffness calibration coefficients shall be expressed as the pressures required to lift the membrane away from the body of the instrument and to move the membrane away from the body of the instrument to the maximum movement of the displacement transducers. The coefficients shall be expressed to at least two significant figures.

(e) Type 5. Membrane compression:

The instrument shall be placed in a cylinder of known elastic properties strong enough safely to restrain the expansion at full working pressure. A close fitting cylinder with end restraints shall be used for self-boring pressuremeters. A cylinder with a ratio of internal diameter of the cylinder to deflated instrument diameter of no greater than 1.1 shall be used with high pressure dilatometers.

The instrument shall be pressurised up to its working pressure capacity. The pressure in the instrument shall be reduced to 10% of the working capacity of the instrument and then increased up to the working capacity in equal increments. The maximum increment or decrement shall be no greater than 5% of the working capacity. The pressure in the instrument shall then be reduced to zero. The pressure at the end of each increment or decrement shall be held constant until the readings from the transducer remain sensibly constant, reading being recorded at 10 second intervals throughout.

The data for each transducer shall be converted to engineering units by applying the calibration coefficients determined in Types 1, 2 and 4. The data shall be corrected for the expansion of the cylinder and presented as a graph of total pressure corrected for membrane stiffness against average cavity strain. The membrane compression calibration coefficient shall be expressed as the average movement of the displacement transducers with pressure to at least two significant figures.

A3.2.6 The transducers shall be calibrated prior to the commencement and following the completion of the testing on site. A copy of the calibrations shall be presented to the Engineer.

A3.2.7 Membrane stiffness shall be carried out prior to the commencement of testing on site and after the completion of every exploratory hole. A new membrane shall be calibrated before use and after it is first removed from the exploratory hole. Calibrations stated in Types 1 to 3 shall not be required on change of a membrane.

A3.2.8 The displacement and pressure transducers shall be recalibrated on site following any repair of the transducers and associated instrument hardware.

A3.2.9 The Engineer shall be able to inspect the instrument calibration register, or shall be provided with copies where required in Schedule 1.13.

A3.2.10 The frequency of membrane compression calibration to be carried out shall be as stated in Schedule 1.13.

A3.3 Operator

A3.3.1 The operator of the equipment shall have at least three months' experience of the pressuremeter to be used under the full time supervision of a technician with a minimum of two years' experience in the use of the pressuremeters to be used. The operator shall be responsible to a Supervising Engineer who has a minimum of five years' experience in geotechnical engineering and is fully conversant with the operation of pressuremeters and the interpretation of the data obtained.

A3.4 Installation

A3.4.1 The self-boring pressuremeter shall be self-bored continuously from the ground surface or from the base of a pre-drilled hole. It shall be self-bored on at least 1 m from a previous test position or at least 1 m beyond the base of a pre-drilled hole. If the Engineer is satisfied that it is impracticable under the prevailing ground conditions to self-bore a length greater than 0.8 m but not greater than 1 m, or length as stated in Schedule 1.13, an expansion test may be carried out.

A3.4.2 Drilling or boring to advance the hole to a test location shall be carried out using equipment, techniques and a flushing medium selected to ensure minimum disturbance to the ground. Provision shall be made during construction of the exploratory hole for supporting the sides of the exploratory hole by a temporary casing, in which case it shall not extend beyond the base of the hole.

A3.4.3 During self-boring of the pressuremeter the setting, type and rotational speed of the cutter, type and characteristics of self-boring fluid, the self-boring fluid pressure, rate of advance and ram pressure shall all be adjusted to ensure minimum disturbance without causing undue risk of damage to the equipment.

A3.4.4 Where required in Schedule 1.13 the orientation of the instrument shall be recorded prior to commencement of self-boring and before it is removed from the test pocket.

A3.4.5 The output from the pore pressure transducers shall be recorded at the frequency stated in Schedule 1.13.

A3.4.6 In free draining soils, an expansion test shall be commenced as soon as practicably possible following the completion of self-boring. In all remaining soils and rocks there shall be a minimum of 30 minutes and a maximum of one hour between completion of self-boring and the commencement of the expansion test.

A3.5 Testing Procedure

A3.5.1 The following testing procedure shall be used for self-boring pressuremeter tests.

(a) Strain controlled tests shall be carried out at a constant rate of stress increase during the early stage of the test until expansion commences and then at a constant rate of strain of 1% per minute, with one unload-reload loop included in the loading sequence at approximately 1% total cavity strain. There shall be a sufficient number of readings taken to define accurately the

pressure at which expansion starts. Additional unload-reload loops and any time required to maintain constant pressure or constant strain before commencement of any unloading shall be as stated in Schedule 1.13.

(b) The pressuremeter shall be pressurised until either the maximum pressure capacity is reached, or any one of the displacement transducers has reached its full working range or there is undue risk or damage to the equipment.

(c) The pressuremeter shall be unloaded, both during the unload-reload cycle and the final unloading at the same rates as the loading stage.

(d) The reduction in stress during any unload-reload loop shall be limited to ensure that it remains within the elastic range of the ground under test.

(e) The output from the transducers shall be recorded at a minimum frequency of 10 seconds interval throughout the test.

A3.6 On Site Data Processing and Analysis

A3.6.1 The data for each transducer shall be converted to engineering units by applying the calibration coefficients determined in Types 1 to 3; the applied pressure shall be corrected for membrane stiffness (Type 4) and if necessary, the calculated cavity strains shall be corrected for membrane compression (Type 5) and thinning (change in thickness of the membrane due to expansion).

A3.6.2 The stiffness from the unload-reload cycle shall be determined using the analyses developed by Palmer (1972) and Windle and Wroth (1977).

A3.6.3 The strength shall be determined for clays using the analyses developed by Gibson and Anderson (1961) and for sands by Hughes, Windle and Wroth (1977).

A3.6.4 The horizontal stress shall be determined using the lift off procedure developed by Wroth (1982).

A3.7 Pressuremeter Testing Details

A3.7.1 Prior to commencing the pressuremeter testing on site the following details shall be submitted to the Engineer:

(a) Full details of the pressuremeter and testing equipment.

(b) Details of the proposed drilling equipment and flushing medium to be used for pre-drilling holes.

(c) Description of the methods of carrying out all the self-boring operations for forming a test pocket.

(d) Details of the experience of the proposed operator and Supervising Engineer.

(e) Typical test data sheets and forms for presenting test results.

A3.8 Preliminary results for each test

A3.8.1 The following preliminary information for each test shall be submitted to the Engineer within one working day of the completion of that test. All information shall be presented on A4 paper with all graphical plots presented at a scale which sensibly fills the entire A4 page size:

(a) Contract name and number, exploratory hole number, depth of the top and bottom of the test pocket, depth of the displacement measurement axes.

(b) Names of drilling and testing personnel.

(c) Details of equipment used.

(d) Details of boring, drilling and self-boring, including date and time of start and finish of all drilling, description and estimate of any drilling fluid returns and depth and size of casing used, if any.

(e) Tabulated output for the transducers, time of start and finish of test and rates of stress and/or strain.

(f) The calibration coefficients used to convert the test data to engineering units.

(g) Tabulated calibration data.

(h) A plot of total pressure against cavity strain in % for each displacement transducer.

(i) A plot of total pressure against displacement in mm for each displacement transducer.

(j) A plot of total pressure against cavity strain in % for initial stage of the test, i.e. up to about 1% cavity strain, for each displacement transducer.

(k) A plot of total pressure against cavity strain in % for the unload-reload cycle for each plot given in (h) above.

(l) Either a plot of total pressure against natural logarithmic value of volumetric strain, (clays and rocks), for each plot given in (h) above or a plot of natural logarithmic value of effective pressure against natural logarithmic value of current cavity strain, (sands) for each plot given in paragraph (h) above.

(m) An assessment of the parameters as outlined in paragraphs A.3.6.1 to A.3.6.4 above.

A3.9 Calibration Review

A3.9.1 Following the submission of the preliminary test results detailed in clause A.3.8.1 the calibrations as determined in clause A.3.2.5 of 'Equipment and Procedure' shall be reviewed by the Supervising Engineer. The data for each transducer shall be recalibrated, if required, by applying all the appropriate calibration coefficients determined following this review. The Supervising Engineer shall reassess the calibrated data to give the parameters outlined in clauses A.3.6.1 to A.3.6.4 above.

Information to be Submitted:

All information specified in clause A.3.8.1 of 'Equipment and Procedure' corrected as required following the review described in clause A.3.9.1 of 'Equipment and Procedure'.

APPENDIX 4

CONTAMINATION TESTING METHODS

Solids analysis

A4.1 Metals

A4.1.1 Arsenic, selenium. The equipment and procedure shall be as described in Reference C3. The information to be submitted shall include the concentration of the element in units of mg/kg dry: As, or mg/kg: Se respectively.

A4.1.2 Cadmium, chromium, copper, lead, nickel, zinc. The equipment and procedure shall be as described in Reference C1. The information to be submitted shall include the concentration of metal in units of mg/kg dry: metal.

A4.1.3 Mercury. The equipment and procedure shall be as described in Method D, reference C2. The information to be submitted shall include the concentration of mercury in units mg/kg dry: Hg.

A4.2 Non-metal inorganic determinands

A4.2.1 Asbestos. The equipment and procedure shall be appropriate for polarised light optical microscopy with dispersion staining and typing. The information to be submitted shall be the presence or otherwise of asbestos and the type of asbestos (if any).

A4.2.2 Cyanides. The equipment and procedure shall be as described in Methods 4500-CN^-B, E, Reference C4. If specified in Schedule 1.17, the following additional analyses shall be carried out:

(a) Ferro- and ferri-cyanide. The equipment and procedure shall be as described in method 4500-CN^-E, Reference C4.

(b) Free cyanide. The equipment and procedure shall be as described in method 4500-CN^-E, Reference C4.

(c) Thiocyanate. The equipment and procedure shall be as described in method 4500-CN^-E, Reference C4.

The information to be submitted for all cyanide analyses shall include the concentration of cyanide (total, ferro-, ferri-, free or thiocyanate) in units of mg/kg dry: CN.

A4.2.3 Sulphide. The equipment and procedure shall be as described in Method A, Reference C6. The information to be submitted shall include the concentration of sulphide in units of mg/kg dry: S.

A4.2.4 Boron (water soluble). The equipment and procedure shall be as described in Method 8, Reference C7. The information to be submitted shall include the concentration of water soluble boron in units of mg/kg dry: B.

A4.3 Organic determinands

A4.3.1 Phenols. The equipment and procedure shall be as described in Method A, Reference C5. If specified in Schedule 1.17, the concentration of monohydric phenols shall be determined, with the equipment and procedure as described in Reference C5. The information to be submitted for both phenol analyses shall include the concentration of phenols (total or monohydric) in units of mg/kg dry: C_6H_5OH.

A4.3.2 Polynuclear aromatic hydrocarbons (PAH). The equipment and procedure shall be as described in Method 6440B, reference C4. The information to be submitted shall include PAH in units of mg/kg dry: PAH.

A4.3.3 Mineral oils. The equipment and procedure shall be as described in Reference C13. The information to be submitted shall include mineral oils in units of mg/kg dry.

Water analysis

A4.4 General properties

A4.4.1 pH. The equipment, procedure and information to be submitted shall be as described in BS 1377: Part 3: Clause 9.

A4.4.2 Biochemical oxygen demand. The equipment and procedure shall be as described in Reference C11. The information to be submitted shall include the results in units mg/l O_2.

A4.4.3 Chemical oxygen demand. The equipment and procedure shall be as described in Reference C10. The information to be submitted shall include the results in units mg/l O_2.

A4.5 Metals

A4.5.1 Arsenic, selenium. The equipment and procedure shall be as described in Reference C3. The information to be submitted shall include the concentration of the element in units of µg/l.

A4.5.2 Cadmium, chromium, copper, lead, nickel, zinc. The equipment and procedure shall be as described in Method 3120B, Reference C4. The information to be submitted shall include the concentration of metal in units of µg/l.

A4.5.3 Mercury. The equipment and procedure shall be as described in Method 3112B, Reference C4. The information to be submitted shall include the concentration of mercury in units of µg/l: Hg.

A4.6 Non-metal inorganic determinands

A4.6.1 Ammoniacal nitrogen. The equipment and procedure shall be as described in Reference C8. The information to be submitted shall include the results in units mg/l: N.

A4.6.2 Cyanide. The equipment and procedure shall be as described in Methods 4500-CN^-B, E, Reference C4. If specified in Schedule 1.17, the following additional analyses shall be carried out:

(a) Ferro- and ferri-cyanide. The equipment and procedure shall be as described in method 4500-CN^-E, Reference C4.

(b) Free cyanide. The equipment and procedure shall be as described in method 4500-CN^-E, Reference C4.

(c) Thiocyanate. The equipment and procedure shall be as described in method 4500-CN^-E, Reference C4.

The information to be submitted for all cyanide analyses shall include the concentration of cyanide (total, ferro-, ferri-, free or thiocyanate) in units of mg/l: CN.

A4.6.3 Sulphate. The equipment, procedure and information to be submitted shall be as described in Clause 11.3.1.8.

A4.6.4 Sulphide. The equipment and procedure shall be as described in Method A, Reference C6. The information to be submitted shall include the concentration of sulphide in units of mg/l: S.

A4.7 Organic determinands

A4.7.1 Phenols. The equipment and procedure shall be as described in Method A, Reference C5. If specified in Schedule 1.17, the concentration of monohydric phenols shall be determined with the equipment and procedure as described in Reference C5. The information to be submitted for both phenol analyses shall include the concentration of phenols (total or monohydric) in units of µg/l: C_6H_5OH.

A4.7.2 Polynuclear aromatic hydrocarbons (PAH). The equipment and procedure shall be as described in Method 6440B, reference C4. The information to be submitted shall include PAH in units of µg/l: PAH.

Gas analysis

A4.8 Gases

A4.8.1 Methane, carbon dioxide, oxygen, nitrogen, hydrogen, hydrogen sulphide. The equipment and procedure shall be as described in Method A, Reference C12. The information to be submitted shall include the concentration of gas as a percentage of total volume.

References

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C2 Mercury in waters, effluents and sediments. Additional methods for the examination of waters and associated materials. The Stationery Office Ltd, 1985.

C3 Selenium and arsenic in sludges, soils and related materials, 1985. A note on the use of hydride generator. Methods for the examination of waters and associated materials. The Stationery Office Ltd, 1987.

C4 Standard Methods for the Examination of Water and Waste Water, 18th Edition, 1992. American Public Health Association, American Water Works Association, Water Pollution Control Federation.

C5 Phenols in waters and effluents by gas-liquid chromatography, 4-aminoantipyrene or 3 methyl-2-benzothiolinone Hydrazone. Methods for the examination of waters and associated materials. The Stationery Office Ltd, 1981.

C6 Sulphide in waters and effluents, tentative methods. Methods for the examination of waters and associated materials. The Stationery Office Ltd, 1983.

C7 The analysis of agricultural materials. A manual of analytical methods. Reference book 427. MAFF, The Stationery Office Ltd, 1986.

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C9 Oxidised nitrogen in waters. Methods for the examination of waters and associated materials. The Stationery Office Ltd, 1981.

C10 Chemical oxygen demand (dichromate value) of polluted and waste water (Second editions). Methods for the examination of waters and associated materials. The Stationery Office Ltd, 1986.

C11 Biochemical oxygen demand. Methods for the examination of water and associated materials. The Stationery Office Ltd, 1981.

C12 The analysis of sludge digester gas. Methods for the examination of waters and associated materials. The Stationery Office Ltd, 1979.

C13 The determination of Hydrocarbon Oils in waters by Solvent Extraction, Infra Red Absorption and Gravimetry Method A. Methods for the examination of waters and associated materials. The Stationery Office Ltd, 1983.

APPENDIX 5

LIST OF TESTS FOR UKAS ACCREDITATION

Table A5.1 Tests applicable to laboratories

Materials/Products Tests	Types of Test/Properties Measured Range of Measurement	Standard Specification Equipment/Techniques Used
ROCKS	Natural Water Content	Rock Characterisation Testing and Monitoring. Editor: E T Brown Part 2, ISRM Suggested Methods: 1981
	Dry Density/Porosity	Rock Characterisation Testing and Monitoring. Editor: E T Brown Part 2, ISRM Suggested Methods: 1981
	Slake Durability Index	Rock Characterisation Testing and Monitoring. Editor: E T Brown Part 2, ISRM Suggested Methods: 1981
	Point Load Test	As described in ISRM - Commission on Testing Methods (1985)
	Soundness by Magnesium Sulphate	BS 812: Part 121: 1989
SOILS	CBR value (Laboratory)	BS 1377: Part 4: 1990 Clause 7
	1-D Consolidation properties	BS 1377: Part 5: 1990 Clause 3
	Unconfined compressive strength - by Load frame method - by Autographic method	BS 1377: Part 7: 1990 Clause 7.2 Clause 7.3
	Undrained shear strength in triaxial compression without pore pressure measurement	BS 1377: Part 7: 1990 Clause 8
	Undrained shear strength in triaxial compression with multistage loading and without measurement of pore pressure	BS 1377: Part 7: 1990 Clause 9

Materials/Products Tests	Types of Test/Properties Measured Range of Measurement	Standard Specification Equipment/Techniques Used
SOILS (cont'd)	Permeability using a hydraulic consolidation cell	BS 1377: Part 6: 1990 Clause 4
	Permeability by the constant head method	BS 1377: Part 5: 1990 Clause 5
	Shear strength by direct shear (small shearbox)	BS 1377: Part 7: 1990 Clause 4
	Shear strength by the laboratory vane method	BS 1377: Part 7: 1990 Clause 3
	Frost susceptibility	BS 1377: Part 5: 1990 Clause 7 and BS 812: Part 124: 1989
	Chalk crushing value	BS 1377: Part 4: 1990 Clause 6
	Saturation moisture content of chalk	BS 1377: Part 2: 1990 Clause 3.3
	Moisture Content - by oven drying method	BS 1377: Part 2: 1990 Clause 3.2
	Moisture Condition Value	BS 1377: Part 4: 1990 Clause 5 SH7/83 (Scotland only)
	Liquid Limit - by cone penetrometer method	BS 1377: Part 2: 1990 Clause 4.3
	Plastic Limit	BS 1377: Part 2: 1990 Clause 5.3
	Plasticity Index and Liquidity Index	BS 1377: Part 2: 1990 Clause 5.4
	Particle size distribution - by Wet sieving method - by Dry sieving method	BS 1377: Part 2: 1990 Clause 9.2 Clause 9.3
	Organic Matter	BS 1377: Part 3: 1990 Clause 3
	Total sulphate and water soluble sulphate content of soil and groundwater	BS 1377: Part 3: 1990 Clause 5

Materials/Products Tests	Types of Test/Properties Measured Range of Measurement	Standard Specification Equipment/Techniques Used
SOILS (cont'd)	pH value	BS 1377: Part 3: 1990 Clause 9
	Chloride content	BS 1377: Part 3: 1990 Clause 7
	Dry density/moisture content relationship	BS 1377: Part 4: 1990 Clause 3
	Density measurement (Bulk and Dry density)	BS 1377: Part 2: 1990 Clause 7

Table A5.2 Tests applicable to field tests

Materials/Products Tests	Types of Test/Properties Measured Range of Measurement	Standard Specification Equipment/Techniques Used
SOILS	In situ CBR value	BS 1377: Part 9: 1990 Clause 4.3
	In situ density tests	BS 1377: Part 9: 1990
	- Sand replacement method (by using a small pouring cylinder)	Clause 2.1
	- Sand replacement method (by using a large pouring cylinder)	Clause 2.2
	- Water replacement method (Coarse grained soil)	Clause 2.3
	- Core cutter method (cohesive soil)	Clause 2.4
	- Nuclear method	Clause 2.5
	In situ vane shear strength of weak intact cohesive soil	BS 1377: Part 9: 1990 Clause 4.4
	Static Cone Penetration test (CPT)	BS 1377: Part 9: 1990 Clause 3.1

APPENDIX 6

TEST BY PROFICIENCY TESTED LABORATORIES

A6.1 General

A6.1.1 The tests listed in Table A6.1 are to be undertaken in laboratories which are participating in an inter-laboratory proficiency testing scheme and meet the performance score criteria specified in clause A6.2, unless the tests are undertaken to the methods specified in Appendix 4 by laboratories currently accredited for those tests by UKAS or equivalent EU bodies.

A6.1.2 Additional tests may also be required to be undertaken by laboratories participating in a proficiency testing scheme if specified in Schedule 1.17.

A6.2 Performance score

Laboratories undertaking analyses for the determinands listed in Table A6.1, and any additional determinands specified in Schedule 1.17, shall demonstrate acceptable performance scores for each of those determinands. For the CONTEST proficiency testing scheme, the Z score of the laboratory shall be taken as the performance score, and an acceptable performance shall correspond to a Z score of between +3 and -3. For alternative proficiency testing schemes an equivalent measure of performance shall be agreed with the Engineer and an equivalent performance demonstrated. The laboratory shall have obtained the required performance scores consistently over a period of 12 months prior to undertaking the tests for this contract.

Table A6.1: Tests applicable to laboratories

SOLIDS ANALYSIS
INORGANIC DETERMINANDS **Metals** Arsenic Cadmium Copper Lead Mercury Nickel Zinc **Non-Metals** Asbestos Total Cyanides Ferro/Ferricyanide Free Cyanide Thiocyanate Sulphide
ORGANIC DETERMINANDS **Composite Organic Constituents** Mineral Oils Phenols (Total) Phenols (Monohydric) Total Polyaromatic Hydrocarbons

WATER ANALYSIS

PHYSICAL PROPERTIES

Biochemical Oxygen Demand
(5 day ATU)
Chemical Oxygen Demand
pH

INORGANIC DETERMINANDS

Metals
Arsenic
Cadmium
Copper
Lead
Mercury
Nickel
Zinc

Non-Metals
Ammoniacal Nitrogen
Chloride
Total Cyanide
Ferro/Ferricyanide
Thiocyanate
Free Cyanide
Sulphide

ORGANIC DETERMINANDS

Composite Organic Constituents
Phenols (Total)
Phenols (Monohydric)
Total Polyaromatic Hydrocarbons

APPENDIX 7

REFERENCES AND BIBLIOGRAPHY

UK Standards (published by British Standards Institution)

Note: Latest editions of British Standards shall be used unless indicated in Schedule 1.8.

BS 812 Testing aggregates (Part 3: 1975, Part 4: 1976)
BS 812 (Parts 110,111)
BS 812 (Parts 112, 121)
BS 812 (Part 113)
BS 812 (Part 124: 1989)

BS 1047:1983 Specification for blast furnace slag aggregate for use in construction

BS 1377: 1990 Methods of test for soils for civil engineering purposes (Part1)
BS 1377:1990 (Part 2)
BS 1377:1990 (Part 3)
BS 1377:1990 (Part 4)
BS 1377:1990 (Parts 5-8)
BS 1377:1990 (Part 9)

BS 1610: Materials testing machines and force verification equipment (Part 1: 1985, Part 2: 1985)
BS 1610(Part 3: 1990)

BS 1881 Methods for analysis of hardened concrete (Part 124: 1988)

BS 1924 Stabilized materials for civil engineering purposes (Part 2:1990)

BS 3506: 1969 Specifications for unplasticised PVC pipe for industrial purposes (amended September 1973)

BS 3969:1990 Recommendations for turf for general purposes

BS 4019 Rotary core drilling equipment (Part 3: 1992)

BS 5589: 1989 Code of practice for preservation of timber

BS 5930: 1981 Code of practice for site investigations

BS 6437:1984 Polyethylene pipes (type 50) in metric diameters for general purposes

BS 7022: 1989 Geophysical logging of boreholes for hydrogeological purposes

BS 7430: 1991 Earthing

BS EN 471:1994 Specification for high visibility warning clothing

BS EN ISO 9001 Quality systems

Other British Standard publications

DD 175: 1988 Code of practice for the identification of potentially contaminated land and its investigation (Draft for Development).

Transport Research Laboratory publications

TRRL Laboratory Report LR 515: Determination of residual shear strength of clay by a modified shear box method (1972)

TRRL Supplementary Report SR 829: Specification for the TRRL frost heave test.

Stationery Office Ltd Publications

The Chemicals(Hazard Information and Packaging for Supply) Regulations 1994. Stationery Office Ltd, London, 1994.

Dissolved Oxygen in Natural and Waste Waters Methods for examination of water and associated materials. Stationery Office Ltd, 1979

General principles of sampling waters and accuracy of results. Methods for examination of waters and associated materials. Stationery Office Ltd, 1996.

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The Measurement of Electrical Conductivity and the Laboratory Determination of the pH value of Natural Treated and Waste Waters Methods for examination of water and associated materials. Stationery Office Ltd, 1978.

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SH7/83: Specification for Road and Bridge Works:soil suitability for Earthworking - use of the Moisture Condition Apparatus (DMRB 4.1)

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Crowhurst D. and Manchester S.J. The measurement of methane and other gases from the ground. CIRIA Report 131, CIRIA, 1993.

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Head K.H. Manual of soil laboratory testing. Pentech Press, Volume 1, 2nd edition, 1992; Volume 2, 1982; Volume 3, 1986.

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IRSM Commission on Testing Methods. Suggested method for determining Point Load Strength (revised version). Int J Rock Mech. Min. Sci. and Geomech. Abst., 22, 51-60 (1985).

Standard Methods of the Examination of Water and Waste-Water" 18th Edition APHA, AWWA, WPCF, 1992.

Bibliography

ASTM Special Technical Publications No. 402: 1966 (see Clark and also Neff below).

Bishop A.W. and Henkel D.J. The measurement of soil properties in the triaxial test. (Second edition), Edward Arnold 1962.

Clark G.B Deformation moduli of rocks. ASTM SP No. 402: 1966.

Deere D.U. et al. Design of surface and near-surface construction in rock. Proc. 8th US symp. on rock mechanics. AIME, New York, 1967.

Design Manual for Roads and Bridges. Volume 4: Geotechnics and Drainage (DMRB 4) Stationery Office Ltd.

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Gibson R.E and Anderson W.F. In situ measurement of soil properties with the pressuremeter. Civ Engng. Public Works. Rev May 1961.

Geological Society Engineering Group Working Party Report on Engineering Geophysics. Quarterly Journal of Engineering Geology, 21, pp. 207-271, 1988.

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Lea F.M., The chemistry of cement and concrete. Arnold; 3rd Edition 1970.

Neff T.L. Equipment for measuring pore pressure in rock specimens under triaxial load. ASTM SP No. 402 1966.

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Schedule 1: Information

1.1 - The scope and object of the Contract.
1.2 - A description of the route or development.
1.3 - A list of Drawings referred to in the tender.
1.4 - A general description of the Site Operations including Ancillary works.
1.5 - The geological formations likely to be encountered.
1.6 - The list of affected landowners, tenants and occupiers together with appropriate landplans.
1.7 - Form of Monthly Statement if required (Conditions of Contract clause 60).
1.8 - Particular general requirements (Section 3).
1.9 - Particular borehole requirements (Section 4).
1.10 - Particular rotary drilling requirements (Section 5).
1.11 - Particular pit and trench requirements (Section 6).
1.12 - Particular sampling requirements (Section 7).
1.13 - Particular in situ testing requirements (Section 8).
1.14 - Particular instrumentation and monitoring requirements (Section 9).
1.15 - Particular laboratory testing requirements (Section 11).
1.16 - Particular reporting requirements (Sections 10 and 12).
1.17 - Particular requirements relating to potentially contaminated land.

Schedule 2: List of exploratory holes

Exploratory Hole No.	Probable depth (m)	Profile Cut/Fill (m)	National Grid Coordinates		Remarks
			E	N	

Schedule 3: Engineer's facilities

3.1 - Accommodation
3.2 - Furnishings
3.3 - Services
3.4 - Equipment
3.5 - Vehicles

Schedule 4: Amended Specification clauses

Schedule 5: Additional Specification clauses