Planning, procurement and quality management

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The Geological Society

Water Services Association

SITE INVESTIGATION IN CONSTRUCTION

2 Planning, procurement and quality management

Site Investigation Steering Group

TI Thomas Telford, London

Publications in the **Site investigation in construction series:**

7. Without site investigation ground is a hazard

2. Planning, procurement and quality management

3. Specification for ground investigation

4. Guidelines for the safe investigation by drilling of landfills and contaminated land

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Contents

Executive summary

This report is written for the Client's Principal Technical Adviser on a construction project, since this professional is responsible for both directing the project and investigating its effects on the neighbourhood.

The Principal Technical Adviser is urged to understand the value of an adequate and timely investigation of the site and the underlying ground, in order to judge whether or not the Client's proposed investment is exposed to unacceptable risk and represents value for money.

Ground is the construction element about which least is known, and which behaves differently according to how it is used. Appropriately qualified and experienced technical advisers are necessary to make an adequate assessment of the hazards in the ground and how best to exploit the ground for the benefit of the project. The risks arising from hazards in the ground may severely limit the scope of the project and its financial success.

Where appropriate, the Client and/or the Principal Technical Adviser should obtain the services of a Geotechnical Adviser at the earliest stages of a project, in order to ensure the effective use of geotechnical skills during its planning, design and construction. The Geotechnical Adviser should be charged with determining the geotechnical requirements of the project, integrating these with the structural design, and advising on or procuring the necessary geotechnical services.

Once briefed, the Geotechnical Adviser should provide a detailed statement of work scope, methodology, deliverables, programme and budget cost estimates for all the geotechnical work required for the project. The Client should use this as a basis for the contractual agreement with the Principal Technical Adviser and the Geotechnical Adviser, and measure performance against this statement. The Client should ensure that the dialogue between these professionals continues throughout the project, because as construction proceeds more is revealed about the ground and planned changes may be necessary to contain costs.

Remuneration of Geotechnical Advisers is best based upon time-scale rates and expenses, measured against an agreed programme and budget estimate. If procurement procedures within an organisation prevent this arrangement, the Client or the Principal Technical Adviser should ensure that they do provide an appropriate level of working flexibility.

The implementation of any geotechnical ground investigation for the proposed site of building or construction may be carried out under a variety of contractual arrangements. However the work is procured, the Principal Technical Adviser/Geotechnical Adviser should ensure that

(a) an adequate desk study and geotechnical site inspection is carried out
(b) the ground investigation is properly planned, designed and directed
(c) appropriate standards of work are specified
(d) the work is properly supervised, to ensure that the technical standards are met
(e) the work is competently reported.

Ground investigation field and testing work may be carried out by the Geotechnical Adviser, as an individual or company, or may be carried out separately by a Geotechnical Contractor. Detailed contractual arrangements should preferably be selected from one of two recommended systems (see Section 3.1), to suit the resources of the Client and the Geotechnical Adviser.

Clients and construction professionals are urged to employ only those organisations and individuals who meet nationally recognised professional and technical standards, and who have experience of the type of work to be carried out.

The Client should be satisfied that the Geotechnical Adviser can meet the quality management needs of the project. When the Geotechnical Adviser is part of a company, that company should, preferably, have a certificated quality management system.

The Geotechnical Contractor should preferably operate a satisfactory quality management system; in the UK drillers should be accredited by the British Drilling Association and the tests required for the ground investigation should be conducted in a laboratory with equipment and procedures accredited by NAMAS.

1 Site investigation and its objectives

Site investigation aims to determine the nature and behaviour of all aspects of a site and its environs that could significantly influence or be influenced by a project.

Site investigation involves acquiring all types of information (hydrological, meteorological, geological, geotechnical and environmental), whereas the process of ground investigation aims only to investigate ground and groundwater conditions in and around the site of a proposed development.

The work involved in ground investigation is different from that of other aspects of the development of a site. The essence of ground investigation is the discovery of facts; ground investigation thus has more in common with research than with other construction processes.

The objectives of site investigation can be summarised as the provision of data for the following purposes.

Site selection

An appraisal of site suitability will take into account not only feasibility and cost, but also risk to life and property, and environmental impact. The construction of major projects depends on the identification and availability of a suitable site. For lesser projects economic factors are likely to be of primary concern.

Foundation and earthwork design

To design permanent structures for a proposed development, information is needed on *inter alia* the strength, compressibility and groundwater conditions of the underlying ground. These parameters must be determined before the design of the project can be finalised.

Temporary works design

The construction process may create temporary conditions, requiring a knowledge of site parameters which may be different from those used in the design of the permanent works. The builder or contractor will require this information about the ground to select the method of construction and to ensure the safety of the works during construction.

Identification of environmental effects

The proposed construction could affect the environment in many ways. For example, construction activities may cause movements, even damage, in adjacent buildings, lead to changes in the groundwater regime, and in some circumstances release harmful substances into the environment. During the planning stage, the investigation provides information to identify and assess these effects.

Safety assessments

The public needs to be reassured that construction remains safe. To meet this need, additional investigations may be required, perhaps when the original design life of the construction has been exceeded, after accidents occur (for example fire or impact by vehicles), or if signs of damage are observed and the cause is not understood.

Design of remedial works

If construction is seen to have failed, or is about to fail, understanding the cause or mechanism of failure and designing the remedial works usually involves the use of site investigation data.

2 Planning, design and reporting of information

General **2.1** The Client's Principal Technical Adviser is the most important decision-maker in regard to the quality of site investigation.

The following sections have been written to identify for the Principal Technical Adviser the main decisions to be made, when they are required and who should make them. The crucial importance of this professional's understanding of the vital ingredients of a good site investigation is emphasised, as are the responsibilities that this person should assume.

Knowledge of site investigation **2.2** The Principal Technical Adviser has to reach a full and clear understanding of the hazards and associated risks that the ground and groundwater pose to the development, and how the development could adversely alter the ground and site surroundings.

A full understanding of ground matters can only be provided by information from a site investigation uniquely planned and designed for the site and project. The site investigation should be supervised and interpreted by a Geotechnical Adviser (see Appendix I) unless the Principal Technical Adviser is suitably qualified and has extensive experience of the particular conditions of the locality of the site. The ground investigation should only be awarded to a competent Geotechnical Contractor. The Geotechnical Contractor is the organisation which undertakes the physical work of the site investigation designed by the Principal Technical Adviser or the Geotechnical Adviser. For many small and simple projects, the Geotechnical Adviser and the Geotechnical Contractor may be in the same organisation.

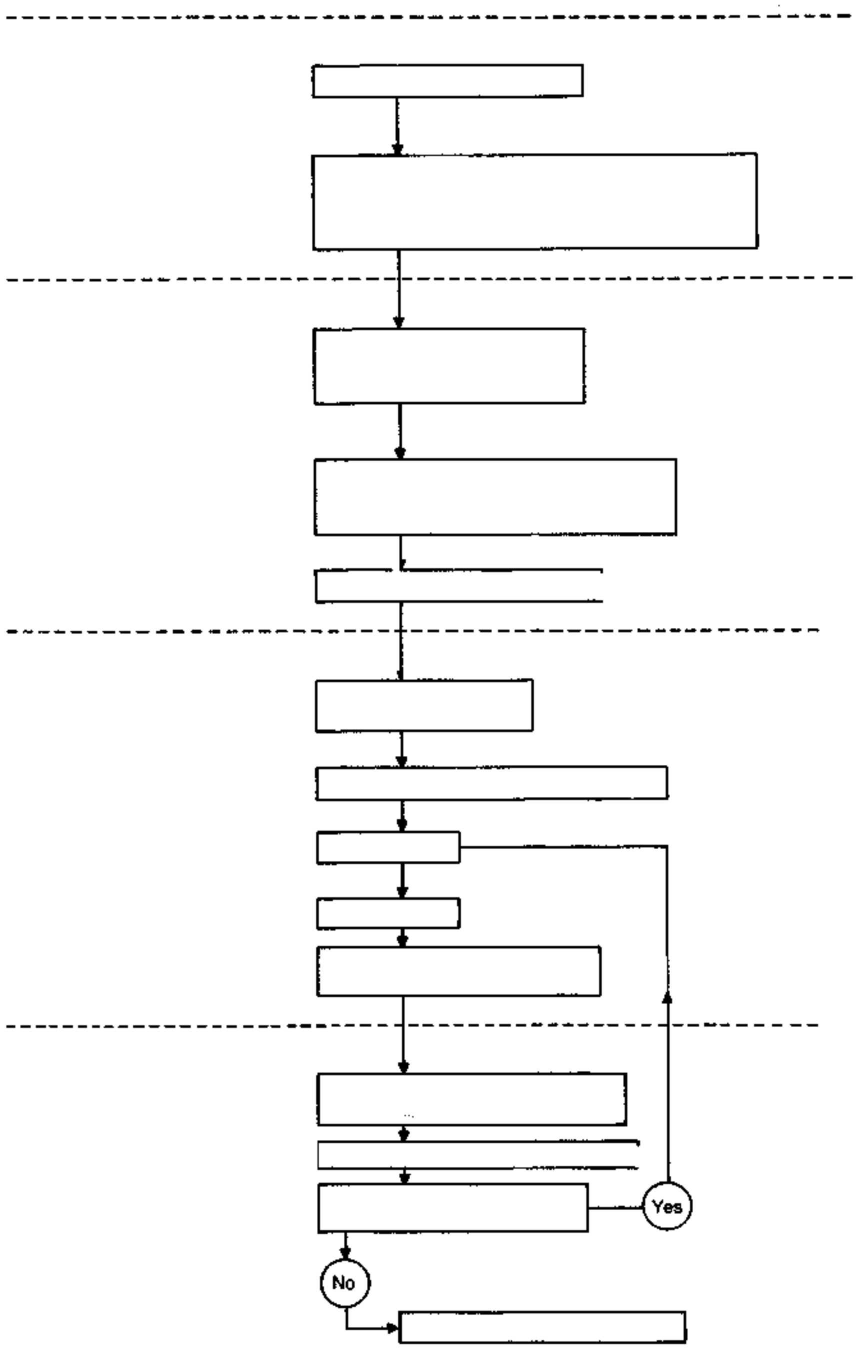
A ground investigation should be an interactive, flexible process of discovery of the ground; it requires contributions from several parties including the Principal Technical Adviser, the Geotechnical Adviser and the Geotechnical Contractor.

The use of professional people experienced in geotechnics is strongly recommended, and Appendix I provides definitions and training routes for a range of geotechnical personnel. Failure to use appropriate professionals may adversely affect insurance cover.

Decision-making process of site investigation **2.3** This process is represented by the flow chart of Figure 1 which indicates the stages of an investigation, the actions required, and those who have responsibility for carrying out the actions.

The Principal Technical Adviser, in reviewing the project commission and design brief, should ensure that all relevant information on the site is available, and where appropriate, should appoint a Geotechnical Adviser from his own organisation or advise the Client to obtain an independent Geotechnical Adviser.

In selecting the Geotechnical Adviser, the Principal Technical Adviser should bear in mind the nature of the project and the different but complementary skills that persons with particular expertise in either geotechnical engineering or engineering geology can offer. The geological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undertake the task. The conditions of engagement for either an individual or a firm should state explicitly what arrangements will come into effect should the named person become unable to continue with the task. If appropriate, suitable candidates for the position of Geotechnical Adviser should be interviewed before a final selection is made.

Following the appointment, the Principal Technical Adviser should meet the Geotechnical Adviser in order to

(a) ensure that due account has been taken of the ground conditions, for example prior to land purchase and planning a development
(b) agree basic requirements and technical and financial objectives
(c) define the role of each party
(d) agree a basic programme
(e) identify any constraints and site safety aspects, including ground contamination
(f) define lines of communication between the Principal Technical Adviser and the Geotechnical Adviser
(g) consider the need for the site investigation to be controlled by a suitable quality management system (see Section 4).

2.4 Principal elements of site investigation

The Principal Technical Adviser should normally expect to see a site investigation proceed in logical stages with planning for flexibility. It should demonstrably contain the following elements.

Initial appraisal

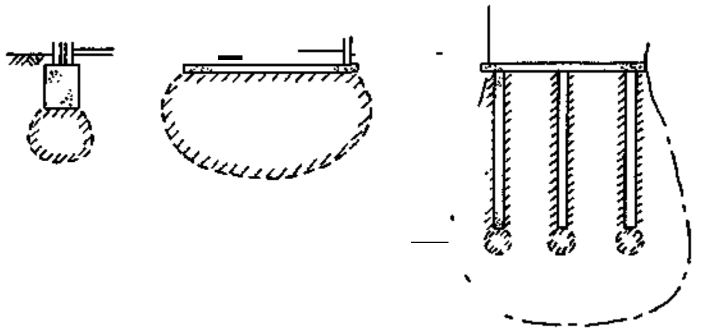
This is vital for developing a preliminary understanding of the geology of the site and the likely ground behaviour. The appraisal should normally comprise the examination of existing information, via a desk study and a walk-over survey. This will determine what is already known about the site and the ground and how the latter should be investigated. Before embarking on ground work, much valuable information may readily be gleaned from existing sources, such as geological and Ordnance Survey maps, aerial photographs and archival material. When examined by experienced personnel, such documents can yield much about site conditions, and following the walk-over survey, a geomorphological plan of the site should be prepared. A desk study cannot be regarded as complete without the walk-over survey.

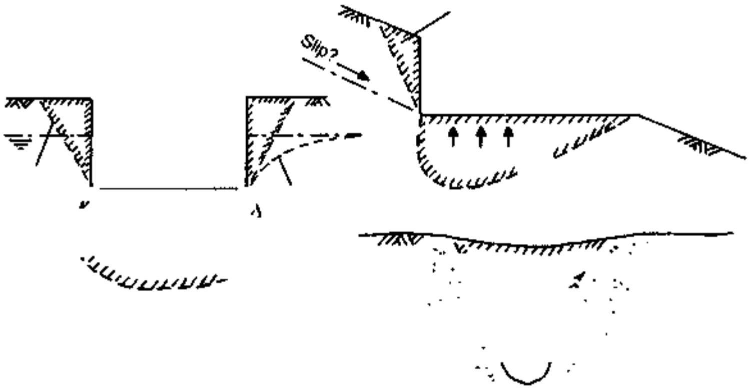
Desk studies and walk-over surveys often represent the most cost-effective element in the entire site investigation process. A desk study may reveal facts that cannot be discovered in any other way.

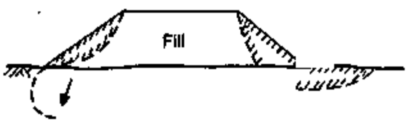
Interaction of the ground and proposed project

Of particular importance is consideration of how (and to what extent) the proposed project will affect the ground and vice versa. It is useful to think in terms of the 'zone' of ground that is being influenced as this may determine the layout and depth of exploration of the ground investigation.

The following examples illustrate different 'zones of influence' associated with various geotechnical activities and features; also listed are some of the technical problems that might require consideration during and subsequent to the initial appraisal.




Slip?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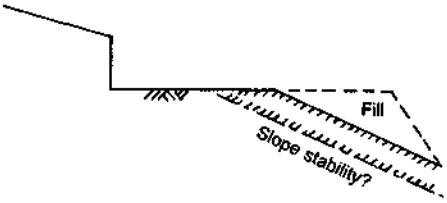
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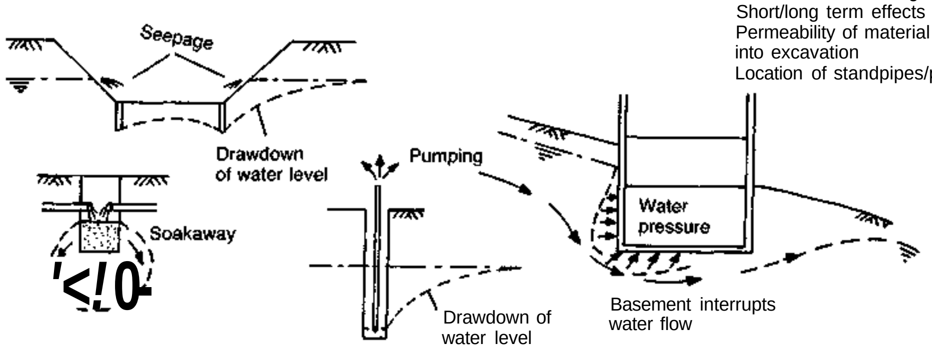
Slope stability?

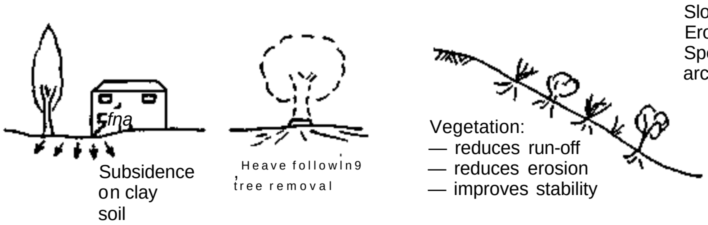
Drainage/groundwater effects

Type of drainage — soakaways, fin drains, slope drainage
Need for short term groundwater control
Short/long term effects on groundwater levels
Permeability of material to be drained and/or rate of inflow into excavation
Location of standpipes/piezometers



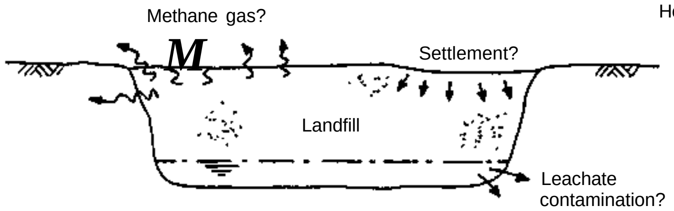
Vegetation: removal and planting

Effects of removal
Effects of planting
Slopes — depth/stability of topsoil
Erosion if topsoil omitted, e.g. chalk slopes
Special features/requirements — liaise with landscape architect/horticulturalist



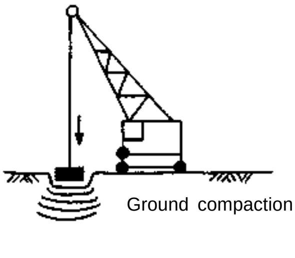
Environmental factors, e.g. landfills, contaminated land

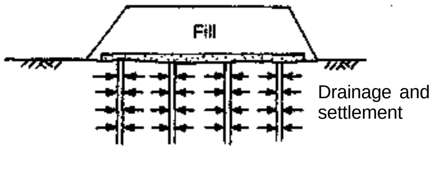
Nature and condition of existing material
Need to install monitoring equipment
Possible treatments prior to construction
Special factors e.g. Isolation of vibration
Planning permission constraints
'Designated areas' — Sites of Special Scientific Interest, areas of outstanding natural beauty, protected flora/fauna
Health and safety matters on contaminated sites



Ground improvement

Parameter to be improved, e.g. strength, compaction, construction speed
Methods available and information required to assess their suitability
Dewatering — effects on groundwater levels
Consult specialist contractors





Each project will be unique and will, therefore, require a ground investigation to be designed specifically for it.

A systematic examination of the interaction between the project and the ground does not necessarily lead to a more expensive ground investigation; rather the monies are employed in a more cost-effective way.

Design of a ground investigation

The objective of a ground investigation is to ensure economical design and construction by reducing to an acceptable level the uncertainties and risks that the ground poses to the project.

The initial appraisal will identify what is already known and will enable a preliminary understanding of the ground and its behaviour; this provides a basis for assessing the nature, location, extent and duration of subsequent field work, and laboratory tests on samples`obtained during the field work. It is the geotechnical model against which every piece of acquired data can be checked. As the field programme progresses so the model will either be confirmed or amended.

The scope and size of the ground investigation will depend both on what is known about the site and on the nature of the project. The ground investigation may, therefore, vary from a few trial pits dug by an excavator in one day for a small housing estate, to a major undertaking lasting many months for a large earth dam.

The design of the ground investigation can only commence once the following information has been obtained and Client or Principal Technical Adviser approval given

(a) a clearly defined purpose for the investigation
(b) an assessment of what information is required and when
(c) the areas and depths of ground to be investigated
(d) the time required for the investigation
(e) an estimate of the cost.

The case histories outlined in the companion publication *Without site investigation ground is a hazard* (1993a) illustrate that the Client will eventually pay for deficiencies in the ground investigation through conservative or inappropriate design assumptions, additional costs encountered on site, or the costs incurred through delays in completion or when the project does not meet the specification. For building structures, some assessment of appropriate levels of expenditure on ground investigations may be gained from the following considerations

(a) the costs of demolition, rebuilding and compensation arising from unexpected failure
(b) the costs of repairs and loss of function in the event of damage arising from cracking, displacement, corrosion and pollution.

Ground investigation works

The ground investigation can include many different activities such as:

trial pits, with descriptions of the materials exposed
boreholes, with sampling for later laboratory testing
tests in the boreholes, using simple or sophisticated instruments
probing from the ground surface
loading tests, at the surface or in excavations.

Ground contamination investigations are often required, especially on derelict sites; appropriate expertise is essential, and there are important health and safety considerations (Association of Geotechnical Specialists (AGS), 1992; Site Investigation Steering Group (SISG), 1993 a).

Arrangements for carrying out an investigation

Contractual relationships should be entered into when ground investigations are to be undertaken.

It is essential that the ground investigation is directed by the professional adviser who designed the investigation, because

(a) the scope of work may need to change in the light of discoveries
(b) the specification for the scheduled work must be rigorously followed.

Arrangements are also required for supervision of the work.

Key decisions of the Principal Technical Adviser

2.5 Before advising the Client to authorise expenditure on a site investigation, the Principal Technical Adviser should

(a) understand the reasons for and objectives of the investigation
(b) ensure that site access will be available when required
(c) confirm any site restrictions
(d) release any records and information that concern contamination and hazardous materials at the site
(e) confirm that the purpose of the investigation has not changed
(f) understand the reasons for the likely cost of the investigation
(g) accept that the methodology of the investigation, and hence its cost, may have to change as work progresses
(h) agree contractual arrangements for the employment of a suitable Geotechnical Contractor to undertake the ground investigation (see Section 3)
(i) be aware that a well-designed ground investigation may be completely ruined or frustrated in its aims by the appointment of an unsuitable Contractor.

The Principal Technical Adviser should warn the Client that supplementary investigations and, for very large or complex projects, field trials may be necessary for a cost-effective project.

The Principal Technical Adviser may choose to delegate these decisions to a Geotechnical Adviser.

Site investigation reports

2.6 The Principal Technical Adviser must receive reports on the results and interpretation of the site investigation. These reports are crucially important because

(a) many parties need to use them to reach an understanding of the ground and of the site
(b) they provide a vehicle for communication between parties involved in the project
(c) they constitute a primary reference for the contract for a project.

All the site investigation information obtained should be formally reported.

There are usually three stages of reporting, as shown below.

Preliminary report

Following the initial site appraisal the objectives of the preliminary report are

(a) to define briefly the scope of the project
(b) to summarise the results of the desk study and walk-over survey

(c) to develop the preliminary understanding of the ground and groundwater conditions (the geotechnical model)
(d) to make recommendations for the scope of the ground investigation work and other further studies.

Factual report

Following the ground investigation work, the factual report should describe concisely and accurately

(a) the site
(b) the ground investigation work carried out
(c) the results obtained from the fieldwork and the laboratory testing.

There is a variety of ways in which this can be done, and it is important for the Principal Technical Adviser to agree in advance with the Geotechnical Adviser (and, if necessary, the Client) the style and format of the presentations.

Interpretative report

Following the ground investigation work the interpretative report should

(a) draw together and review all the information obtained for the site
(b) confirm or modify the preliminary understanding of the ground
(c) describe the relationship of the ground with the project
(d) provide parameters suitable for design purposes
(e) identify the geotechnical issues and assess the likely problems
(f) establish any need for further investigation
(g) provide a range of design solutions, with guidance on which might be best in terms of cost, timing, ease of construction, future maintenance, etc.

The Principal Technical Adviser's requirements of the interpretative report may vary considerably from one job to another depending on the nature of the project and the project team. It is essential to agree in advance how far to proceed with the interpretation and design recommendations.

For small projects, the results of the three stages of reporting may be combined into one document.

The continuing process of ground investigation **2.7**

Since ground varies over small distances and an investigation examines only a limited volume, adequate discovery of the detailed features of the ground that will influence the project can often only be made during the construction process.

In some cases, monitoring of the performance of component elements of the project, for example the load-carrying capability of piles, will indicate the need for further ground investigation, leading to amendments to the project design.

The process may continue through to a post-construction monitoring phase.

The Principal Technical Adviser should, where appropriate, advise the Client to expect some investigations to extend beyond the processes outlined in this report.

The Geotechnical Adviser should be retained throughout the process.

3 Procurement of site investigation

General **3.1** This section provides guidance on the methods of obtaining professional advice and site investigation services, their procurement being critical to the quality and effectiveness of the site investigation process.

The process of site investigation requires the procurement of both specialist advice and services. In the absence of a suitably qualified and experienced Principal Technical Adviser, a Geotechnical Adviser should be appointed to provide specialist advice on the interaction of the project with the ground and to recommend any investigatory work which may be necessary. When ground investigation is required, this may be carried out either by the Geotechnical Adviser's company, or by a specialist Geotechnical Contractor. The key action in the entire process of site investigation is the appointment of a competent professional, whether working through a company or alone, to advise during the conceptual design stage of a project on geotechnical aspects.

Two systems of procurement are recommended for site investigation services (Uff and Clayton, 1986).

System 1: Use of a Geotechnical Adviser, with the separate employment of a Geotechnical Contractor for field work, laboratory testing and reporting as required.

System 2: Use of a single contract for geotechnical expertise, together with fieldwork, laboratory testing and reporting.

System 1 is widely used for civil engineering site investigations, particularly for large-scale, technically complex projects. It requires the Client to employ a design professional who has within the design team high-level geotechnical skill or alternatively, to employ a Geotechnical Adviser. The work of making exploratory holes and testing ground samples is carried out by a Geotechnical Contractor to the detailed specifications prepared by the Geotechnical Adviser (typically in a civil or structural engineering consultancy). System 1 is a traditional system, and success depends upon the Engineer under the contract (the Principal Technical Adviser) being technically strong and competent in geotechnics.

In System 2 the Client enters into a single 'package deal' geotechnical contract which embraces design of the site investigation, its direction, and any physical work required. This system is often used for building, and for smaller or overseas civil engineering projects. The success of this system depends upon the skill and experience of the geotechnical staff within the specialist geotechnical engineering organisation.

Procurement of a Geotechnicai Adviser **3.2** Site investigation work should be guided by a professional experienced in geotechnics. It has been noted (Section 2) that it is necessary to take geotechnical advice at a very early stage in the development of a construction project, in order to optimise the overall design. The key step of the identification and appointment of a Geotechnical Adviser is considered in the following paragraphs.

Identification

To identify suitable organisations or individuals, the British Geotechnical Society's Geotechnical Directory (British Geotechnical Society (BGS), 1992) may be consulted. This lists some 125 firms providing geotechnical consultancy services and gives details of over 700 geotechnical practitioners operating in the UK. Other organisations employing individuals of similar qualification and experience are also suitable, but for these the Client or the Principal Technical Adviser would have to obtain the necessary detailed information concerning the geotechnical skill and experience of personnel. Further guidance may be obtained from the *Geologist's directory* (Geological Society, 1993), and from trade sector organisations such as the Association of Geotechnical Specialists and the British Drilling Association.

For civil engineering works, a Geotechnical Adviser should have followed one of the routes illustrated in Appendix I and be able to demonstrate experience of the type of project proposed. It is unlikely that a single person will be able to provide the necessary breadth of experience required for a large civil engineering job, although small companies may be perfectly satisfactory for limited or highly-specialised projects. When a company is employed, the Client should check and be satisfied that it operates a quality management system satisfactory for the tasks envisaged. Preferably the company should have in place a quality management system certificated for compliance with national or international standards or by a government-accredited agency (see Section 4.3).

The prospective Geotechnical Adviser and team members should provide detailed personal CVs and a statement of the firm's size and business base, time in existence, commercial affiliations, financial standing and professional indemnity insurance cover. Before making an appointment, it is recommended that the potential advisers are interviewed.

Responsibilities

Clients, although they may not know exactly what professional services they will require, should define the key requirements of the project. It is therefore part of the Geotechnical Adviser's responsibility to define the scope of all geotechnical work on the project. At the earliest opportunity, the Geotechnical Adviser should be asked to provide a detailed appraisal, scope, methodology, list of deliverables, programme and itemised budget. This appraisal should include the staged design of a site investigation that will be suitable for the project. The scope of works should then form the basis for an agreement, against which the Geotechnical Adviser's performance can be measured.

Appointment and remuneration

For some construction projects it may be possible to agree a fixed fee in exchange for a well-defined scope of works, for example when System 2 is used. However, site investigation is by nature an exploration and therefore, a measure of uncertainty at the outset is implicit. Since the activities related to the site investigation often represent the major element of the Geotechnical Adviser's contribution to the project, it may be sensible to recognise this in the method of remuneration adopted. For large civil engineering projects the most equitable basis for remuneration is on time-scale charges and expenses, as described, for example, in the Association of Consulting Engineers' Conditions of Engagement (1981). However payments are calculated, they should still be based on a pre-agreed programme and budget-cost schedule.

3.3 Procurement of a Geotechnical Contractor

Successful ground investigation requires a systematic approach to the procurement of a specialist contractor, based on a number of factors in addition to price. These include the selection of a suitable company and the establishment of a relevant contractual basis.

Suitability

The identification of suitable Geotechnical Contractors should be the responsibiity of the Geotechnical Adviser. Preselection of tenderers is recommended on the following basis.

(a) The contractor's scale of operation, both technically and geographically, should be suitable for the size of the investigation that is envisaged.
(b) The contractor should be capable of providing the required level of resources, in terms of staff, plant and equipment.
(c) The contractor's staff should have previous experience of similar work.
(d) Key senior staff should be suitably qualified.
(e) The contractor should have a good reputation.
(f) Contractors prepared to furnish valid 'Certificates of Accreditation' for the drillers (e.g. issued by the British Drilling Association in the UK) should be preferred.
(g) Contractors should operate a suitable quality management system (see Section 4), and their laboratories should preferably be accredited by an appropriate body (e.g. NAM AS in the UK).

Methods of selection and procurement

For most ground investigations a select tender list of no more than three contractors of similar standing is appropriate. Occasionally it may be expedient or desirable to negotiate directly with a single contractor; this course of action should be agreed by the Client and/or the Principal Technical Adviser and the Geotechnical Adviser.

Contractual basis

As already indicated, the use of one of two systems is recommended.

In System 1, the Client separately employs two groups of geotechnical professionals, the Geotechnical Adviser, and the Geotechnical Contractor. Ground investigation work for major projects is generally let under either the ICE Conditions of Contract (Institution of Civil Engineers (ICE), 1991) or the ICE Conditions of Contract for Ground Investigation (ICE, 1983). A detailed Specification and Bill of Quantities must be prepared along the lines of the companion publication (SISG, 1993b).

System 2 is attractive for relatively straightforward building construction, because it provides single-point responsibility. The Client employs only a single geotechnical specialist who is responsible for all aspects of geotechnical work, including that which would otherwise be carried out separately by a Geotechnical Adviser. Small investigations are frequently procured on the basis of an informal letter contract which defines the purpose of the work, and does not define the methods to be used. Suitable contract documents for use with System 2 contracts are available (Uff and Clayton, 1986). Such contracts should be agreed on the basis that the Contractor will conduct site and laboratory work, in accordance with a recognised specification for ground investigation, such as the companion publication (SISG, 1993b).

Basis of remuneration

Under System 1 the Geotechnical Contractor is asked to give a price for each item of work (e.g. taking a soil sample), forgiven estimates of the quantities of each item of work. The amount of work actually done during the investigation is measured, and this determines payment. During tendering the contractor completes a Bill of Quantities, giving a price for each item. A suitable Bill of Quantities is appended to the *Specification for ground investigation* (SISG, 1993b).

Occasionally lump sum or multiple lump sums are required; the justification for this approach is usually weak. On overseas contracts it may be necessary to provide a mechanism for an initial down payment to assist mobilisation.

There is always a balance between cost and risk sharing; this is particularly so in major offshore investigations where daily rates for major items of plant may be more appropriate, together with clear identification of performance requirements and acceptance criteria. Additionally, in many larger investigations it is appropriate to have a selection of rates for various items of plant, labour and staff, so that extra minor works can be undertaken on a day work basis.

Under System 2 the payment process is greatly simplified, and contract administration is reduced to a minimum. Payments are made at the end of 'Work stages' defined by the Client or the Principal Technical Adviser.

4 Quality management of site investigation

Quality - the client's role 4.1

The correct professional team

Unlike manufactured building materials, ground has no constant properties and is unique at each site. Furthermore, its behaviour depends very much on what is done to it, so construction activity is continuously interactive with the ground. Many sites are relatively insensitive to construction, but skill and knowledge are necessary to know if this is the case for the site in question.

It pays to engage a professional adviser with the requisite knowledge.

The only tangible end product of a site investigation is a report. Its value depends on how others use it, as well as on its own qualities. The contained advice and data may or may not be sound, depending not only on the skill and experience of the report writer, but also on all those people who acquired and contributed information.

Good professionals, and good team management are needed to produce a good report.

An investigation report which confirms the preliminary thoughts about the nature of the ground provides confidence, as well as more detailed information. If it presents a different picture, it may save its cost many times over. In either case, the report's value is in assurance against the unexpected. However the quality of a report is much more than this.

BS 4778 (British Standards Institution (BSI), 1987a) defines quality as 'the totality of features or characteristics of a product or service that bear on its ability to satisfy stated or implied needs'. The reference to satisfaction of implied needs in this definition leads to expectation that the Client may rely on correct interpretation of the project by the employed professionals. In developing the project, their knowledge should guide them to foresee potential needs and to satisfy them.

A good service relies on the knowledge, skill, experience, foresight, confidence, motivation and integrity of individual people who provide it.

On all but the smallest projects they will work as a team, both within their own organisation, and when in contact with people from other organisations, to produce the data and informed advice, comprising the report.

The Client has a right to expect relevant professional service and good management from all those engaged.

The first step to good-quality site investigation is that the Client should select the right people to dedicate their professional skills and experience to the benefit of the project.

Selection of the professional team

It is not easy to select experts in an unfamiliar field. The Client and Principal Technical Adviser as individuals must have the mutual rapport, confidence and understanding necessary for any successful business relationship. Selection and appraisal of people is necessarily subjective, but a structured approach helps. It is fully consistent with a quality management system for any project and can reinforce opinions by quantitative 'scoring'.

Quality begins with the Client.

It helps if the Client

(a) appoints one senior person, the Principal Technical Adviser with authority and responsibility for the project
(b) has a clear concept of the project and writes it down, identifying the critical areas of risk as far as practicable
(c) identifies from risk areas the type of professional help required
(d) prepares a specific structured appraisal and 'scoring' system for selection of the Principal Technical Adviser to the project
(e) takes time and trouble to discuss the project with prospective professionals and assesses their reputation and references, relevant skills and resources; since ground investigation is invariably a critical element of the project, the Client should seek reassurance that a professional with adequate experience in geotechnics is dedicated to the project.
(f) does not select solely on the basis of cost.

The cost of good advice concerning investigation and concepts is insignificant relative to the eventual cost of misjudgements.

Essential provisions for the brief

Having selected the Principal Technical Adviser (team or person) the Client should agree a written policy brief. This should include guidance on quality policy for the project.

The professional will then exercise skills to draft an appropriate project plan for approval of the Client. Geotechnical requirements will necessarily be an important part of this plan.

There is no simple relationship between project value and complexity of the ground or the work to be done to the ground. A simple structure can be built on difficult ground or a complex structure on good ground. Accordingly ground investigations need to be developed iteratively (see Section 2). This may require extra time and provision for variability, with extended funding to allow appropriate solutions to be developed. Arbitrary limitations on the cost of investigation may preclude effective work or, conversely, encourage unnecessary work.

As a ground investigation develops, additional specialised skills may be needed, e.g. to deal with contaminated ground. It is important that the Principal Technical Adviser identifies new requirements and that the Client should not resist the introduction of extra but necessary expertise.

As the project progresses more people will become involved to contribute specialist skills. It is rewarding for the Client to ensure that there is clear accountability and clear lines of communication for everyone participating.

Quality starts on correct lines if the Client

(a) issues a clear, unambiguous written brief on policy for the project including quality policy and any specific requirement or limitations; this should be agreed with the lead professional firm, who will become responsible for its execution
(b) is satisfied that arrangements are in place, and continuously effective, for accurate and timely communications between participating people or groups offering diverse skills.

A quality management system applied to the project would address these issues.

Quality-the professional's role 4.2

Satisfying the Client's expectations

A Client starts a project with undeveloped concepts. These intangibles translate into specific objectives in iterative steps as the project plans evolve. Circumstantial and economic constraints progressively limit action and steer the concept from the desirable to the practical.

It is the job of the technical professionals (architects, civil engineers, structural engineers and geotechnical specialists) to translate initial ideas into reliable forecasts of ground behaviour within these constraints. To do this they need relevant current knowledge and organisation.

The Client expects them to be self-sufficient in these respects; if they are not, they are expected to know what help is needed and where it can be found.

Professional integrity as well as ability is important to the Client.

The Client's confidence should be earned and justified. Unless it comes from long experience, the Client must rely on reputation and references, as well as evidence of resources and a systematic approach to quality management.

The Client should be wary of assurances in lieu of evidence.

Quality management systems 4.3

Need for a formal system

The principles of quality management apply to all tasks but the more complex the job, the greater the need for a planned approach. Whatever the task, a structured system is likely to prevent oversights and be more efficient. The benefits are thus as much for the user as for the Client.

Documenting the procedure for a task allows its appraisal, criticism and refinement.

When there are several organisations and many people involved, a comprehensive system is needed. Large groups of people cannot be managed without a documented structure defining their activities. Thus every organisation, however large or small, benefits from formal structured management. The aim is always to take relevant and timely action in order to achieve the right results first and every time. A management system is a blueprint for action; it is as necessary as a blueprint for a structure.

The principles of a good quality management system are contained in British Standard 5750 (BSI, 1987b) and parallel international documentation (International Standards Organisation (ISO), 1990). These embrace philosophies primarily of self-discipline for individual people comprising an organisation. They include systems for continually checking actions and updating plans to accommodate change (see Appendix II).

Since each organisation is unique, a specific management system must be prepared and applied by each one. The means of establishing an appropriate system are detailed elsewhere (Oliver, 1990; National House-Building Council, 1991; AGS, 1991).

A successful system will not stultify thought nor constrain beneficial initiatives. Addressing key factors to improve efficiency is the system's purpose, not the detailing of unnecessary minutiae.

The best systems are derived within an organisation for its own use, but a quality consultant (AGS, 1991) can sometimes suggest improvements and can certainly test an existing system for compliance with BS 5750.

Third party certification

When selecting organisations, a Client may wish to see evidence of effective management. This is costly and time-consuming, for both the Client and those being considered. Many firms prefer to have their management systems certificated for compliance with national or international standards or by a government-accredited agency (see Figure 2).

The Client may then be assured that an appropriate management system is in place.

Validation of technical skills

Technical skills should be backed by certificates from universities, professional institutions or trade organisations, which can be checked if necessary. Such certification is desirable for all levels of skills from professionals to site or laboratory technicians in order to encourage consistency and uniformity of practice. Evidence of training ensures at least a basic standard of exposure to engineering and safety disciplines and required professional conduct.

Motivation of people

A formal system is of little value without proper motivation of individual people responsible for actions. Although knowledge and skill, and timely

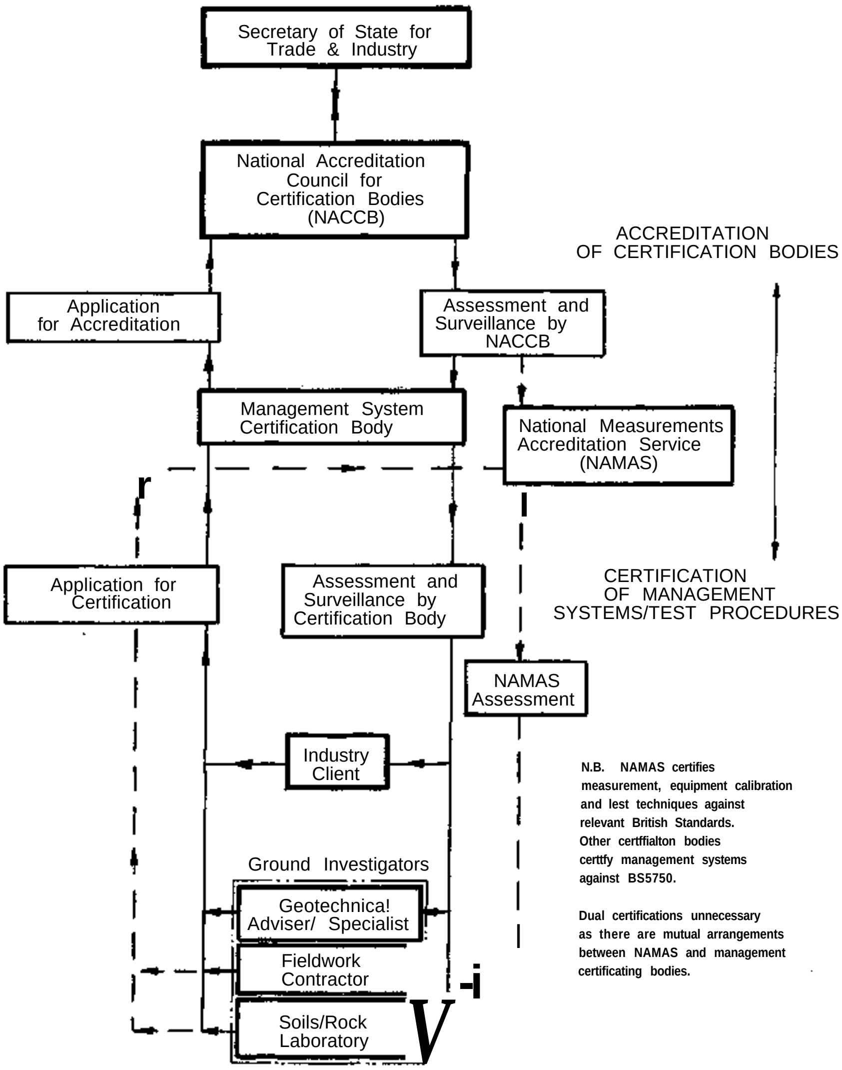


Fig. 2. Accreditation of certification bodies and third party certification

applications of these, are required for a service of quality, so is enthusiasm and a desire to produce good work. This is largely a matter of the culture of an organisation, i.e. its philosophy with regard to execution of its business tasks, which is primarily engendered by its Chief Executive.

Project quality plans

Each job is unique and requires a specific plan. The Client may have a master plan for the project of which the geotechnical investigation is a part. Communications between work groups as illustrated in Figure 3 are of special importance in the overall plan.

Where several organisations contribute to a site investigation, each organisation needs its own plan since it has its own perspective of the job.

The project quality plan functions within an organisation's overall management system and details the specific requirements and arrangements proposed for the management of the job in hand.

People working singly may require no more than a check-list, sequence and timings of tasks needed to accomplish their contribution. Teams of people

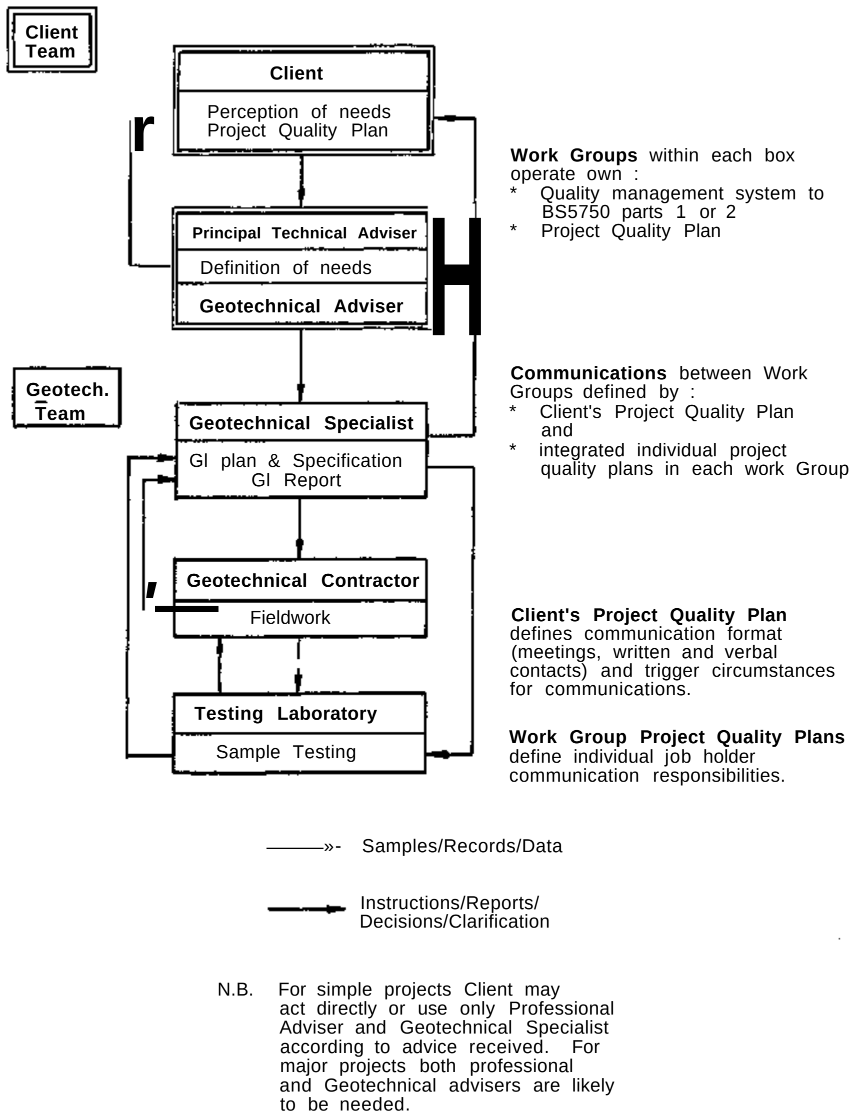


Fig. 3. Communication between work groups for site investigation

will require statements of authority and detailed programmes as well as delineation of individual tasks and method statements, sources of information, communication contacts with others, specifications, etc., leaving nothing significant to chance. Routine elements may be covered simply by references to standard documents from a library or data bank maintained for the purpose, e.g. test procedures, sampling procedures, but the job organisation will require a unique plan.

The nature of site investigation is such that the plan for the work has to be adaptable to findings. The initial plan can only define the authorities and general responsibilities of personnel involved, not specific tasks; these are defined in the project plan as it evolves against information acquired. The plan is continually appraised and revised as required, until the end of the job.

4.4 Sources of unsatisfactory services

In site investigation the greatest scope for misjudgements leading to unsatisfactory service is in the conceptual and planning phases.

The burden lies most heavily upon the Principal Technical Adviser. Often the fault is of omission (lack of proper professional awareness) despite an otherwise adequate plan. Subsequent and, perhaps, inevitable difficulties for the project usually originate from failure to appreciate potential problems and to bring to bear relevant and appropriate resources, geotechnical experience and skills.

Decisions made at this stage reflect through the whole project, since ground works precede almost every other phase of construction. This further emphasises the importance of obtaining the correct professional skills at the outset.

The activities of drilling contractors charged with field activities, including sampling and in situ testing, are more precisely prescribed by British Standard Codes of Practice such as BS 5930 and its international equivalents. Thus they depend most on alert management and organisation. A quality management system is potentially a potent benefit for this activity.

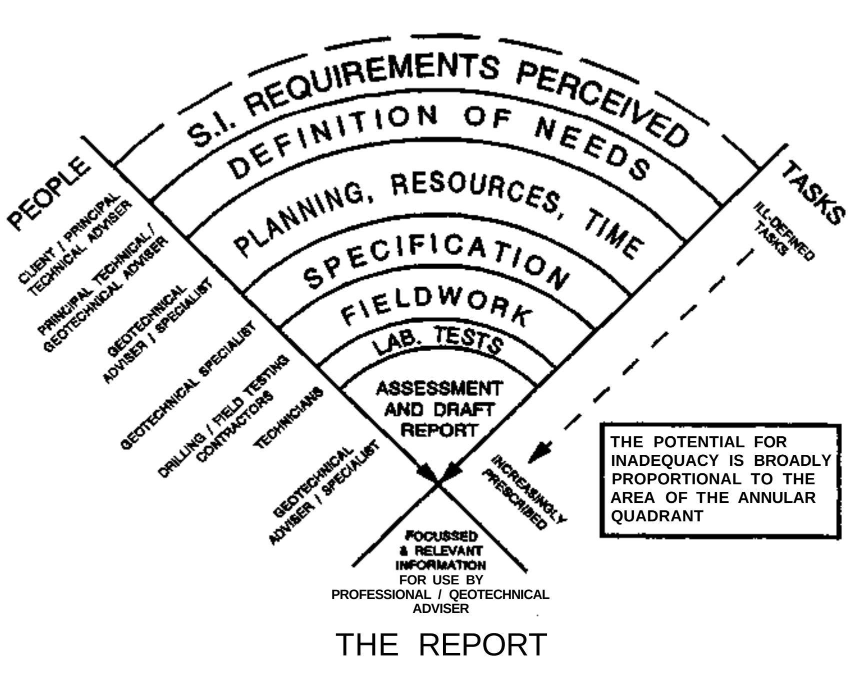


Fig. 4. Influence on quality of site investigation and dominance of early stages

Laboratory tests are even more closely constrained by specified routines in standards such as BS 1377 (BSI, 1990). There is little scope for variation. Moreover accredited laboratories are subject to close surveillance of technique by, for example, NAMAS.

Figure 4 illustrates this concept of increasingly prescribed tasks in the process of site investigation corresponding to lesser scope for error. The practitioners most commonly identified with each phase are also listed.

Design should begin with consideration of ground and economic restraints since they often dictate the form of the structure. Although economic considerations are always to the fore, the influence of the ground is often left too late in the conceptual phases of the design process.

4.5 Summary: the keys to quality site investigation

The Client should take pains to select professional technical help with relevant knowledge and experience.

Quality is unlikely to be delivered otherwise.

The Client should write a brief, defining policy for the project, to be agreed with the professional.

The Client should be satisfied that communications are effective between persons contributing to the project.

It is the job of the Principal Technical Adviser to translate the Client's concepts into reliable forecasts of ground behaviour.

This is the foundation of quality of a site investigation.

A formal documented management system complying with the principles of BS 5750 encourages every organisation or individual to perform most efficiently.

Company culture is embodied in the quality delivered: a paper system is not enough.

People must have skills and enthusiasm to apply them.

Each participating organisation should prepare its own quality plan for each project, defining responsibilities, resources, contacts and constraints so that it may exercise self-discipline and control.

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Appendix I: Definitions of geotechnical personnel

Geotechnical Specialist

A Chartered Engineer or a Chartered Geologist with a postgraduate qualification in geotechnical engineering or engineering geology, equivalent at least to an MSc and with three years of post-Charter practice in geotechnics;

or a Chartered Engineer or Chartered Geologist with five years of post-Charter practice in geotechnics.

The Geotechnical Specialist will generally be a Geotechnical Engineer or an Engineering Geologist. The graduate with general experience requires five years of post-Charter practice in geotechnics to compensate for a lack of formal education and training in geotechnics.

A non-graduate with 15 years of practice in geotechnics is encouraged to become chartered by a mature candidate route.

Geotechnical Adviser

A Chartered Engineer or a Chartered Geologist with five years of practice as a Geotechnical Specialist.

This individual, who may be a named person in an organisation, advises the Client or his Professional Technical Adviser of the geotechnical requirements of the project, and upon instruction arranges the procurement and interpretation of the necessary information and its validation during construction.

Geotechnical Engineer

A Chartered Engineer with at least one year of postgraduate experience in geotechnics and a postgraduate qualification in geotechnical engineering or engineering geology, equivalent at least to an MSc;

or a Chartered Engineer with at least three years of postgraduate experience in geotechnics.

Engineering Geologist

A Chartered Geologist with at least one year of postgraduate experience in geotechnics and a postgraduate qualification in geotechnical engineering or engineering geology, equivalent at least to an MSc;

or a Chartered Geologist with at least three years of postgraduate experience in geotechnics.

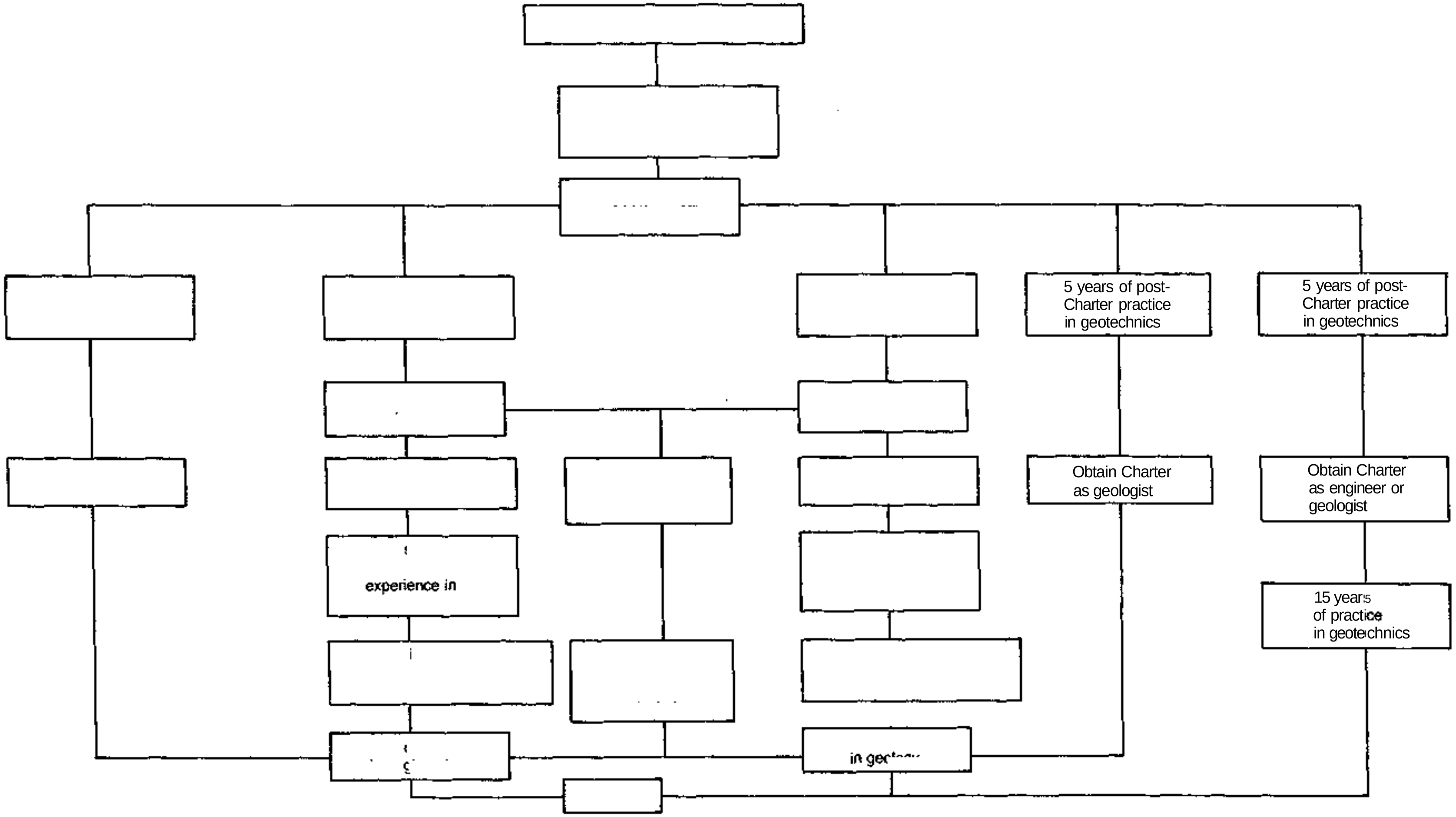
The definitions of Geotechnical Engineer and Engineering Geologist recognise the different but complementary roles they can impart through their knowledge, and the skills that the Geotechnical Adviser requires for successful ground engineering.

Geotechnician

An individual with specific training and experience in the use of specialist equipment and procedures for sampling, testing and monitoring.

Such a person should be supervised by a Geotechnical Specialist, Geotechnical Engineer or an Engineering Geologist. Further refinements could include limits of expertise, e.g. field or laboratory testing and years of experience.

The names of professional geotechnical personnel and organisations can be found in references contained in the companion publication (Site Investigation Steering Group, 1993a).



hydrogeology, rock mechanics, soil mechanics and

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Appendix II: Quality management systems

Elements which must be addressed to satisfy UK, ISO and EN Standards

Management responsibility and reviews - policy statement, organisation and job definitions; resources; regular review and updating; setting standards.

Quality system - documented by procedures; timely arrangements for independent internal audits and corrective action; records of improvement.

Contract review - of individual projects; quality plans and regular reviews; programmes, resources, controls and measurements, project standards; records.

Design action - input and output data, verification, control of changes.

Document control - approvals, issues, changes.

Purchasing - assessment of subcontractors, verification of purchased items, product identification, traceability.

Process control - work instructions, standards and quality controls.

Inspection of supplied equipment and materials before use; testing and calibration of equipment.

Control of non-conforming products - identification and correction of goods and equipment supplied, and to be delivered.

Handling, storage, packaging and transport; documentation and means of protection to prevent damage or deterioration.

Records - for accountability, traceability; statistical analysis for trends and acceptability of work.

Training - identification of needs, scope, standards and certificates.

Note: Reference to the relevant Quality System standard is recommended for amplifying detail.

Appendix III: Membership of Site Investigation Steering Group and working panels

Site Investigation Steering Group

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Mr G.P. Dean, BSc, CEng, MICE, Oscar Faber Consulting Engineers
Dr M.H. de Freitas, PhD, CGeol, FGS, Imperial College of Science, Technology and Medicine
Mr R.M.C. Driscoll, BSc, MSc, CEng, FICE, Building Research Establishment
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Mr R.W. Skinner, Foundation and Exploration Services Ltd.
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Working Panel 4: Planning of Site Investigation	Mr R.M.C. Driscoll, BSc, MSc, CEng, FICE, Building Research Establishment (Chairman) Mr G.P.Dean, BSc, CEng, MICE, Oscar Faber Consulting Engineers Dr M.H. de Freitas, PhD, CGeol, FGS, Imperial College of Science, Technology and Medicine Mr G.W. Herrick, Department of Transport Mr J.L. Hislam, BSc, MPhil,CEng, FICE, MASCE, Terresearch Ltd. Mr S. Quarrell, BSc, MSc, CEng, MICE, Soil Consultants Ltd. Dr M. Stroud, MA(Cantab), PhD, CEng, MICE, Arup Geotechnics
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British Drilling Association Working Panel: Safe Drilling of Landfills and Contaminated Land	Mr R.W. Skinner, Foundation and Exploration Services Mr J.A. Scarrow, MSc, BSc, Soil Mechanics Ltd. Professor G.S. Littlejohn, BSc, PhD, FEng, FICE,FIStructE, FGS, University of Bradford in conjunction with C.L. Associates, Environmental Specialists