2. GEOTECHNICAL

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2. GEOTECHNICAL

2.A MINIMUM REQUIREMENTS

2.A.1 Every allotment shall contain a building site suitable for building types appropriate to the zoning of the land.

2.A.2 All resource consent for subdivision and multiple household units shall be accompanied by a geotechnical investigation report relevant to the site.

2.A.3 An allotment which has specific geotechnical requirements may be approved subject to restrictions which shall be registered on the title to the land by a consent notice, security documents if required by the Resource Management Act, and the Council Property Information Register as appropriate.

2.A.4 For every subdivision for which a resource consent has been granted, a geotechnical completion report shall be submitted in respect of every allotment/building site whether affected by work or not.

2.A.5 All geotechnical investigation and completion reports shall be prepared by a professional engineer who is experienced in the practice of geotechnical engineering and registered under the Engineer's Registration Act 1924 and who has professionally indemnity insurance cover.

2.B MEANS OF COMPLIANCE

2.B.1 Introduction

2.B.1.1 This document provides a means of compliance with the Manukau City Council Engineering Quality Standards, Section 2, GEOTECHNICAL.

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One of the problems which has affected the orderly assessment of the suitability of land for development and building foundations has been a lack of uniformity of understanding between practitioners in their approach to the issues, and Council officers in their interpretation of these approaches.

It is recognised and accepted that no two engineers will approach any one problem in exactly the same way, nor will they reach entirely the same conclusion, nor present their data and interpretations in exactly the same way.

2.B.1.2 The document is presented in a manner which outlines an acceptable methodology for achieving compliance with Council's standards. It is presented with matching commentary where considered appropriate. The commentary is provided so as to provide a means of clarification for practitioners, and for Council officers who are required to interpret Council's standard requirements, and the data submitted to Council in compliance with those standards.

Often the comparative lack of specialised knowledge or experience acts to hinder the rationalisation of these issues, usually at considerable cost to all parties involved, including the practitioner and the Council.

This Means of Compliance document provides a quality management means of overcoming these issues of communication and understanding within the framework of a generalised set of expectations.

2.B.1.3 This document has been developed on the basis of consensus between a working party of Council officers and practitioners.

2.B.2 Phases of a Site Investigation

2.B.2.1 A rationale approach to site investigations for urban land subdivision is given in NZS 4404:1981, New Zealand Standard Code of Practice for Urban Land Subdivision, and the IPENZ (Auckland Branch) Code of Practice for Urban Land Development (c.1979), from which NZS 4404 was developed.

2.B.2.2

Drawing G1 presents the relationship of site investigation to all forms of civil engineering works, and particularly to large scale land development. The principle is as follows:

i) **Preliminary Exploration**: A preliminary exploration is necessary to gain an initial appreciation of a site. In the case of land development, this is usually simply a visual appraisal. In some cases a visual appraisal is all that is necessary,

ii) **Field Investigation**: A preliminary exploration will in most land development projects, be followed by a specific and detailed field investigation, with in situ and laboratory tests as appropriate. This investigation will yield the basis of the detailed geotechnical appreciation of the site, and will provide guidelines for the development of the site, including limitations on that development. Often as not, detailed design is likely to be progressing concurrent with reporting and must be accommodated,

C2

In terms of a quality management approach to the satisfaction of engineering criteria it is necessary for a geotechnical engineer to consider his approach to an investigation with respect to:

(i) The end use of the site,

(ii) The liability consequences in the event of a wrong appreciation to:

- ***(a) The client and subsequent owners,***
- ***(b) The engineer,***
- ***(c) The Local Authority.***

The reality is that the backstop in terms of liability is:

- ***(a) The engineer's own professional indemnity insurance,***
- ***(b) The Local Authority's insurance.***

Neither the insurers, the client, nor the Local Authority will thank you for making a wrong appreciation.

A quality management approach then says that the process of site investigation is not complete until the construction aspects of the project are complete.

An incomplete or less than thorough approach to a site investigation is a waste of effort, inconclusive and fraught with risk.

iii) **Construction Observation:** Observation during construction is essential to verify the appreciation obtained from (i) and (ii). It is not unusual for the appreciation to be modified as site development proceeds, resulting in further investigation and changes in design and/or constructions concepts,

iv) **Performance Observation:** Performance observation may be necessary where the earthworks design predicts post construction performance, and which is critical to the ultimate land usage - for example, the monitoring of the settlement of deep fills and fills underlain by highly compressible organic soils.

The principles relating to geotechnical investigation for land development/ subdivision purposes are the same, irrespective of whether an intensive urban subdivision or a rural subdivision is being considered. What differs is the extent of the process that needs to be followed. Often the methodology can be abbreviated is site conditions are appropriate. The important element is the provision for hazard assessment and risk mitigation.

2.B.2.3 In summary, investigation in one form or another should be continued throughout construction, and may extend beyond the construction phase.

2.B.3 Site Investigation Logic

C3

All sites will not require the application of the Means of Compliance to the same degree. For example, a flat site with no obvious risks or identifiable hazards may simply require a short letter stating that the site has been inspected by a competent person and an appropriate judgement appreciation made. This assessment should be reported in letter form to ensure continuity of record of the Quality Assurance audit trail.

2.B.3.1 General

The objectives of a site investigation are to:

i) Assess the suitability of a site for its proposed use,
ii) Foresee construction difficulties,
iii) Collect enough information for satisfactory design.

A site investigation should address the following factors:

i) Ownership,
ii) Geology,
iii) Groundwater,
iv) Subsoil conditions, foundation conditions and stability,
v) Services,
vi) Access.

(Items ii) to iv): Nature and extent of soils and rocks etc)

A review of the existing information is essential, and may include:

1. Geological maps and reports,
2. Data from adjacent sites - ie. previous investigations,
3. Aerial photographs,
4. Performance of related and/or adjacent developments.

The logic of site investigations for land subdivision and development projects is summarised in Drawing G2.

2.B.3.2 Geotechnical Investigation Report

Geotechnical investigation reports should generally cover, but not necessarily be restricted to, the following:

i) **Purpose:** To investigate, examine and report on the general geology of the area and its influences on foundation conditions and comment on the likelihood of any problems with the stability of slopes in cut, natural or filled ground,
ii) **Soils:** Investigate and report on the soil characteristics of the site with regard to foundation and construction condition,
iii) **Foundation Requirements:** Consider the types of building likely and their load requirements, and evaluate the foundation for each allotment. Consider the type of road and evaluate the foundation at subgrade level,
iv) **Effluent Disposal:** In areas where sewage disposal is by means of septic tanks, the report should also comment on the suitability of the site to accept septic tank effluent disposal and its influence on land stability,
v) **Non-Engineered Fills:** Identify the existence of previous filling activities on the site, and comment on the quality and suitability of such fills for development purposes,
vi) **Slope Stability:** Where appropriate, carry out a slope stability appraisal to determine whether the development will provide stable and accessible building sites,

vii) **Earthworks Development and Control:** Discuss earthworks aspects of the site and provide a specification for earthworks control and the installation of services,

viii) **Conclusions and Recommendations:** Set out the findings of the investigation and provide recommendations for:

(a) Restriction on use of the land if all or part of the land is unsuitable for some uses,

(b) Suggested changes to a subdivisional layout to achieve better use of the site, and/or minimise construction difficulties,

(c) Control during construction,

(d) Further investigation where required,

(e) Regulation and control, or future action necessary to maintain suitability.

A check list for reporting is given in Drawing G3.

2.B.4 Slope Stability

2.B.4.1 A primary objective of land development engineering is to provide stable and accessible building sites. These considerations are important, particularly in the case of residential land development, which is proceeding more and more into areas of marginal stability, previously avoided in past years.

2.B.4.2 A principal factor of a site investigation is to identify indications of past instability and to determine and recommend mitigating measures to provide an acceptable level or risk against future slope failure.

2.B.4.3 An experienced person can recognise previous landslip areas be stereoscope examination of pairs of aerial photographs. This is a fast and economical means for assessing the general slope stability characteristics of a large area.

2.B.4.4 Visual signs of ground instability include cracked or hummocky surfaces, crescent shaped depressions, crooked fences, leaning trees or power poles, swamps or wet ground in elevated positions, and water seepage.

C4

Most landscapes are caused by an increase in the slope angle of the land surface and/or a decrease in the shear strength of the slope materials. A large number of interrelated factors do, however, apply.

Flowing water from rainfall is constantly changing the shape of the earth's surface. The water cuts out a channel and the side slopes of the resulting channel or valley are left oversteep and subject to landslip, (ie. are marginally stable).

These side slopes gradually become less steep as the topography matures, and erosion and landslipping become less frequent. Steeper parts of the valley system may, however, remain in a state of only marginal stability and some incident, such as excavation or exceptionally heavy rain, can cause further landslipping to occur.

It follows then that many slopes are potentially unstable in their natural state, and must therefore be considered unsuitable for residential development unless improved by properly designed engineering works.

The filling of gullies and flattening of hill slopes in subdivisional development converts the young and potentially unstable slopes found in many parts of New Zealand to a more mature and stable land form, thus

2.B.4.5 The evaluation of slope stability by the measurement of soil strengths and groundwater conditions, and the calculations of theoretical factors of safety, is a difficult task and which requires the exercise of a large measure of skill and judgement. The problem is exacerbated by the need to consider:

i) The range of parameters assumed to be applicable, given the present state of stability of a slope,
ii) Present and future groundwater levels,
iii) The consequences of and limitations on future site development.

2.B.4.6 Preliminary reconnaissance using site inspection, air photo interpretation and available geological and geotechnical records provides an initially low cost sound basis for the conceptual planning of a land development project. This preliminary appraisal should identify:

i) Areas where previous slope failures have been positively identified,
ii) Areas where it is suspected that slope failures may have occurred many years ago (ie. historic features),
iii) Areas of surface soil creep,
iv) Springs, swamps, or other areas of either poor drainage or high groundwater conditions.

2.B.4.7 Subsequent specific investigations should provide data on subsurface conditions and establish specific design criteria for such factors as maximum slopes, subsoil drainage, retention or establishment of vegetation, soakage to dispose of septic tank effluent, and the like.

2.B.4.8 An acceptable concept for the investigation and assessment of the suitability of land developments in which natural slopes are intended to be left undisturbed provides for the delineation of building limits as follows:

i) A **Building Line Restriction** which represents the closest proximity to a slope for any building development,
ii) A zone, defined as the **Specific Design Zone**, extending from the Building Line Restriction to the Building Line Limitation,

achieving in a short term what nature would otherwise achieve through landslips and erosion in many thousands of years.

In the situation where the concept of land development is to minimise earthworks and to leave the land in its largely undisturbed natural state, many problems arise and are experienced between the practitioner and local authorities in determining acceptable slope stability criteria, levels of risk and reporting.

Traditionally, if a theoretical factor of safety of 1.5 can be achieved by analysis, then the slope is deemed to be stable. The problem arises in determining the correct parameters to use and the influence of subsurface conditions on the form of analysis, and which is consequently dependent on the nature and level of investigation.

Cumulating experience suggests that the proper selection of a theoretical factor of safety for slope stability purposes is dependent upon a proper assessment of the level of risk.

Brand (1982) on analysis and design in residual soils, reports the established practice in Hong Kong (Geotechnical Control Office, 1979) in which the design factor of safety is related to the risk category. The risk category for a particular slope is assessed in terms of the likelihood of loss of life should the slope fail. Typical of high risk slopes are high cut slopes immediately adjacent to schools and occupied apartment blocks. An example of a low risk slope is one which threatens only a secondary road.

Typical values of acceptable factors of safety in residual soils are given in Table C1. The design "standard" of slope safety (ie. the probability of failure) is (logically) governed largely by the consequences of failure in terms of loss of life, damage to property, and disruption of communications and services.

TABLE C1: ACCEPTABLE SOLUTIONS OF SAFETY FOR SLOPE IN RESIDUAL SOILS (Based on Brand, 1982)

Risk Category	***Minimum Factor of Safety for Transient Condition (eg. 1:10 Year Storm)***
Low	***1.2***
Significant	***1.3***
High	***1.4***

within which building development requires specific design by a registered engineer either experienced in soil mechanics, or with the assistance of an engineer experienced in soil mechanics, and in particular, slope stability,

iii) A zone (the **Non Specific Design Zone**), delineated by the Building Line Limitation, extending beyond the Specific Design Zone in which building development can be carried out in accordance with the appropriate Codes of Practice (eg. NZS3604:1990, New Zealand Standard Code of Practice for Light Timber Frame Buildings not requiring specific design) without risk from slope instability.

It is noted that factors of safety adopted by engineers in geotechnical design have been developed to cover uncertainties in:

i) ***the geometric accuracy (eg. of the slope or retaining wall being designed),***
ii) ***the soils strength (which is likely to vary from point to point even in the same soil "layer"),***
iii) ***the method of analysis adopted (which is usually two dimensional and has simplifications that may not accurately reflect the actual situation),***
iv) ***the validity of assumptions made (eg. depth to groundwater level, depth to rock or hard layer, etc.).***

For these reasons, it is customary to adopt a factor of safety value of 1.5 for subdivisions or housing development. This factor of safety does not in every case assure safety from instability or slope movement. Based on references (1 to 3) noted below, the average risk of failure for different factors of safety adopted are:

Factor of Safety	***Risk of Failure Per Annum***
1.1	***1:10***
1.3	***1:50***
1.5	***1:200***
1.7	***1:1000***

References:

1. Meyerhof, G., Canadian Geotechniques, Vol. 7, No. 4 (11/70)
2. Wu, T.H., et al, ASCE, SM2 (3/70)
3. Semple, R.M., Ground Engineering (9/81)

2.B.4.9 The determination of the zones should be derived from an assessment of potential risk under varying site conditions. The start of the Non Specific Design zone, defined by the Building Line Limitation, would typically commence 3m to 5m (or possibly more) beyond the Building Line Restriction, and would assume a factor of safety against slope regression of 1.5 or greater. The respective zones are to be defined by a suitable diagram which can be used to establish relevant ground control points.

C5

In almost all circumstances, it will probably prove to be prudent for the developer/engineer to at least obtain an initial appraisal by a geotechnical engineer to provide input to the conceptual design.
In many circumstances (eg. where the size of the development is sufficiently small), a visual appraisal will suffice. In most circumstances, however, some form of investigation will be required.

2.B.5 Earthworks

2.B.5.1 Earthworks can be loosely defined as any alteration to the ground by means of excavation and/or backfilling.

2.B.5.2 The engineer/investigator should, when initially considering a land development project, address at least the following. to provide a preliminary assessment of potential difficulties or the need for specialist advice:

i) The present topography and any surface features such as hummocky ground, irregular land forms, rushes, and obvious geological features which might infer past or present instability,
ii) Any exposures of soil types, which might indicate potential difficulties of construction, ie. sands, clay, rock,
iii) Existing drainage conditions, and their relationship to the proposed development,
iv) The performance of similar engineering works (cut and fills) in adjacent areas.

2.B.5.3 In summary, the proper appreciation of the earthworks concepts for land development will identify:

i) The suitability of the site for the concept, including the appraisal of aerial photographs for larger sites and records of previous filling,
ii) Particular engineering measures that will need to be incorporated in the engineering design (eg. tomos),
iii) The influence of the earthworks concepts on slope stability and mitigating design measures,
iv) Special measures that might be required for settlement considerations, depending on fill depths, etc. (ie. settlement monitoring, delays on building construction, etc.),
v) Control measures for earthworks.

2.B.6 Earthworks Quality Assurance and Control

2.B.6.1 The quality control of earthworks is an essential phase of land development, and is aimed at providing a uniform construction in terms of engineering performance. Earthworks should be certified as to the way in which they have been carried out and their suitability for their end use. The form of quality control will evolve from the earthworks appreciation and will generally be developed about:

i) Adequate strength,
ii) Limited volume change.

2.B.6.2 The engineering performance of soils depends on their condition at the time of compaction and cannot be adequately reflected in a single parameter.

2.B.6.3 A considerable amount of judgement is involved in the determination of quality control criteria.

2.B.6.4 Quality control should be undertaken either by, or under the direct supervision of an experienced geotechnical engineer and should involve:

i) Visual inspection,
ii) Quantitive testing.

C6

It is recommended that a full quality assurance system be developed to ensure that the end product, ie. the completed house lot, is suitable for its end purpose.

In addition to following guidelines, set out in national publications (such as NZS4431:1989, New Zealand Standard Code of Practice for Earth fills for Residential Subdivisions), it is recommended that progressive testing be carried out to avoid rework and to avoid unsuspected poor quality fill.

The fill needs to have sufficient checks (quality assurance procedure) at progressive stages of the works, ie:

i) ***on completion of clearing and removal of unsuitable soils,***
ii) ***on completion of compaction of each fill layer until completion of the whole fill,***
iii) ***all with clearly dated and surveyed test points.***

Corrective measures need to be specified and carried out where the target quality is not met. The final fill control certificate provides a record of work done and tests carried out (quality control record).

Visual inspections should be made:

i) ***After stripping and prior to filling..***
ii) ***During installation of drains.***
iii) ***Sufficiently often to check that:***
   (a) ***Fill is not placed over soft of organic ground, unless provided for by design,***
   (b) ***Seepages and potential seepage areas are provided with drains,***
   (c) ***Unsuitable materials are not used as fill,***
   (d) ***Compaction operations are systematic and uniform,***
   (e) ***Conditions encountered are in keeping with those anticipated form the initial site investigation.***

Quantitive testing should be related to the control criteria determined by the soils geotechnical engineer and should have a higher frequency (say about 500 to 1000m^3 intervals) at the initial stages of earthworks test is to ensure that, with a lesser frequency as the fill progresses, the compaction criteria are being achieved, and the overall operations are satisfactory.

2.B.7 Settlement

2.B.7.1 Settlement of soils (consolidation) is a complicated natural phenomenon, which is influenced by a number of factors, including the nature and mineralogy of the soil, the soil particular arrangement, whether the soil is undisturbed or remoulded, its past stress history, the drainage conditions affecting the particular circumstances, etc.

2.B.7.2 For land development works, the pre-development soils investigations should identify areas of risk, such as organic soils, swampy areas, etc. and the likely performance of the foundation under earth fills.

2.B.7.3 Settlement will also occur within earth fills due to the self weight of the fill.

2.B.7.4 The consolidation settlement and elastic compression of fills are a function of time, albeit of long or short duration, thus in some cases it may be necessary to allow a period of time to elapse from the placement of fill the commencement of building construction.

C7

Because of the variables in the theoretical appreciation of the likely magnitudes of settlement, monitoring of the actual settlement performance of earth fills can often expedite the release of the development.

The absolute magnitude of settlement, except when it is large, is often of lesser concern for most forms of construction than the magnitude of differential settlement and thus angular distortion. It is often overlooked that conventional analytical processes generally imply settlements of the order of approximately 25mm.

It is also often overlooked that seasonal moisture variations, and the associated swelling and shrinking of the soil, will occur with the associated likelihood of seasonal swell/shrink movements of the order of at least 10mm. These natural effects may cause distortion of building frames, and may cause doors and windows to jam. In many instances, and as more difficult country is developed, earth filling of narrow gullies is occurring with considerable variations in fill thickness over short distances, and thus with the potential for differential settlement.

Consequently, the limits of earth filling and the variations in the depths of fills should be clearly identified on "as-built" drawings.

The expansive nature of many of the soils within the greater Manukau area needs to be recognised also, as generally provided for in NZS3604:1990, New Zealand Standard Code of Practice for Light Timber Frame Buildings not requiring specific design.

2.B.8 Subgrade Design

2.B.8.1 The general principles of earthworks investigation, construction and control as outlined in this Means of Compliance also apply to road subgrades.

2.B.8.2 For subgrades in fill materials, it is usual to attempt to achieve a higher strength fill within the upper 500mm to subgrade formation level.

2.B.8.3 Two principal methods of pavement design are currently used:
i) CBR method,
ii) Deflection method.

C8

The geotechnical report should address any specific design criteria perceived necessary for subgrade preparation (eg. stabilisation, recompaction, geotextile, drainage, etc.)

2.B.8.4 The CBR method is most commonly used and is based on laboratory or in situ tests and is independent upon approval of the subgrade for uniformity and standard of construction. Uniformity may be assessed by proof rolling or in situ tests such as the dynamic cone (Scala) penetrometer.

2.B.8.5 The deflection method is based on end of service empirical performance criteria and requires the in situ testing of the subgrade by Benkelman beam prior to placing the metal courses.

2.B.8.6 In general, cut ground may require more treatment for acceptance to road subgrade standards than a controlled earth fill. Undercutting and recompaction is often a prudent course to follow on cut ground.

2.B.9 Geotechnical Completion Report

2.B.9.1 A geotechnical completion report should cover, but not necessarily be restricted to, the following:

i) **Purpose:** To report on the development after completion of the works with a view to recording construction information and extending the site investigation report if appropriate, and expressing an opinion on the suitability of all lots within the subdivision for their intended use,
ii) **Scope:** The report should describe all activities from the preliminary site investigation, to the completion of the physical works, including earthworks compaction control testing.

2.B.9.2 The report should cover, and re-evaluate where necessary, the requirements of the Geotechnical Investigation Report, the requirements of NZS4431:1989, New Zealand Standard Code of Practice for Earth fills for Residential Subdivisions, where appropriate, and requirements are set out in the conditions of subdivision consent.

C9
Not all soils will require the application of the Means of Compliance to the same degree. For example, a site with no obvious risks or identifiable hazards, and which has not been subject to earthworks or other engineering works such as the installation of services, may simply require a short letter from a competent person reaffirming the suitability of the site for its intended purpose. This assessment should be reported in letter form to ensure continuity of record of the Quality Assurance audit trail.

2.B.9.3 The description should include sufficient test results, site inspection data, and other information to enable an independent assessment to be made as to the suitability of the development.

2.B.9.4 The emphasis of the report should be on stating what happened during construction, supported by detailed field notes, test results, and construction reports to provide an accurate detailed "as-built" record.

A suitable check list for reporting is given in Drawing G2.

2.B.10 Summary

2.B.10.1 A good guide to the various aspects that should be addressed as a Means of Compliance with the Manukau City Council Engineering Quality Standards, Section 1, Geotechnical Assessment, is provided in the IPENZ (Auckland Branch), Code of Practice for Urban Land Development Control and NZS4404:1981, New Zealand Standard Code of Practice for Urban Land Subdivision. These documents set out the areas in which the rational processes of engineering appraisal and design (site investigation) are necessary, and which require the involvement of a geotechnical (soils) engineer.

2.B.10.2 In summary, engineering appraisal and design are required:

i) Prior to detailed planning, which usually involves some form of subsurface investigation,

ii) During the review of and advice on design concepts,
iii) During construction to ensure the adequacy of the bulk filling and the execution of the earthworks design,
iv) After construction, to provide certification and/or define limitations of the works.

C10

Site investigations for land development projects require the exercise of considerable skill, experience, and judgement, depending on the nature and complexity of the project.

With most of such projects, the site investigation aspects of a project extend throughout the project and may require considerable flexibility during the development phase, particularly if complex and varying conditions not anticipated from the formal phases of investigation are encountered.

The processes that have been outlined provide the mans of achieving the objectives of sound foundation investigation for subdivisional and land development purposes, viz:

i) ***identifying any constraints on land use,***
ii) ***mitigating any risks,***
iii) ***reducing the potential liability of all parties involved in the processes***
ie. the owner
the engineer
the local authority

These processes define the state of the practice for subdivisional and land development investigation, which being based largely on a common sense pragmatic approach to hazard identification and risk mitigation, in conjunction with a good measure of practical down to earth experience, will ensure:

i) ***A low risk outcome for all parties involved,***
ii) ***A product which is readily understood be most local authority officers, and which, through a logical process, should address their concerns,***

iii) ***As a consequence of (b), a relatively easy progression through the approvals processes, which has a nett benefit to a client in terms of minimal delays,***

iv) ***For a well engineered subdivision or land development project, a product which is readily marketed, as a consequence of identified and mitigated risks ie. minimum uncertainties.***

The object and development of these processes has the underlying objective of communicating a technical appreciation of a site in a manner which addresses all the relevant issues, and in a manner which can be readily understood by all parties involved, including the lot purchaser/home owner.

The process may be subject to variation, depending on specific site circumstances. However, if followed rationally, the outcome should always be the same - a quality managed engineering product based on hazard identification and risk mitigation, and which can vary from a one page letter through to a sizeable report, depending on the specific site circumstances.

It should be noted that any aspects submitted to Council in compliance with the Geotechnical Assessment requirements of Council's Engineering Quality Standards are the copyright of the writer, and belong to the persons for whom the report was prepared.