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THE DESIGN OF PERMANENT SLOPES FOR RESIDENTIAL BUILDING DEVELOPMENT

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ABSTRACT

The NZ Building Code requires a minimum Factor of Safety (FOS) of 1.5 for permanent slopes in building developments. No further qualification is made on how to calculate this FOS or indeed if there are other more important requirements. NZ Territorial Land Authorities vary in their interpretation of the applications of the Code. For example, many require the conservative approach of a FOS ≥ 1.5 under full saturation of slopes regardless of soil conditions, geometry and geohydrology. However, this FOS requirement is not mandatory and alternative solutions may be accepted by Territorial Land Authorities. The Building Act allows for consents to be issued under section 36(2) for land stability. There are also parts of the Earthquake Commission Act which need to be taken into account. Much time has been wasted discussing consent applications on an ad hoc basis. What is needed is a consistent approach to stability assessments as agreed by Territorial Land Authorities and the geotechnical community.

This paper draws on the results of a questionnaire to Councils and geotechnical consultants throughout New Zealand proposed to promote a consensus of interested groups. The Hong Kong system is also considered as a basis in which the quality of technical data, economic risk and risk to life will be considered. Reference is also made to the Australian position on stability assessments and their risk approach. The results of this review will be used to promote revisions to the NZ Building Code and the required factors for the stability of permanent slopes.

EQC RESEARCH FOUNDATION

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1.0 INTRODUCTION

The NZ Building Code was formulated to cover the requirements for buildings in NZ and is generally considered to be the means of applying the Resource Management Act 1991 and the Building Act 1991 legislation. While there are associated codes and standards for the likes of timber, steel and concrete design and construction, the range of codes available for earth structures, formations and slopes are relatively few. Given the complexities of slope stability, the clauses which deal with the design of slopes are very short indeed. A set of guidelines for the use of designers and reviewers is seen as the best way of establishing an industry "benchmark" rather than a set of prescriptive standards. These guidelines could then be referred to in the NZ Building Code in much the same way as the "Guidelines for the Description of Soils and Rock in Engineering Use" published by the NZ Geomechanics Society.*

Much of the published work on slope stability in NZ over the past few decades has outlined the problems and made some resolutions but a wide variance of professional opinions has left the place of a national set of guidelines vacant. There is an increasing trend for Territorial Land Authorities (TLA's) to write their own geotechnical standards. The Building Act sought to avoid the proliferation of varying standards in NZ.

With ' legislation such as the Consumer Guarantees Act allowing unlimited liability for domestic projects (as opposed to commercial projects), and recent increases in insurance premiums for consultancies with a history of geotechnical based P.I. claims, the need for an industry benchmark is more pressing for practising geotechnical specialists and approving authorities. Courts of law in NZ rely on expert witness to advise them on "normally accepted geotechnical practice".

This paper outlines the current issues and proposed changes for preparation of stability assessments and presents a draft guidelines checklist for the use of geotechnical practitioners and reviewers. The need for further work on a comprehensive set of guidelines is outlined.

2.0 OBJECTIVES AND RELEVANCE OF RESEARCH

The principal objectives of the research project are to:

(a) outline the issues to be resolved in stability assessments, in particular:
- current legislation
- site risk/hazard assessment
- site geology, topography and groundwater
- factor of safety and determination of soil strength parameters
- application to earthquake loadings/risk
- role of peer reviewers

* *The NZ Geomechanics Society changed its name to the NZ Geotechnical Society in February 1996.*

(b) review existing slope stability guidelines developed for Hong Kong and Australia
(c) liaise with the Australian Geomechanics Society who are also currently reviewing their stability assessment guidelines
(d) liaise with selected NZ territorial authorities, geotechnical engineers and engineering geologists
(e) prepare a draft set of guidelines which would also be submitted to the NZ Geotechnical Society for publishing in their national newsletter.

3.0 THE ISSUES

3.1 General

There are many issues to be resolved with regard to the consistency of stability assessments in NZ. Much work has been done in recent decades to address slope stability issues in residential/land development and these include:

- "Stability of Slopes in Natural Ground" (1974)
- "Slope Stability in Urban Development" (1977)
- "Stability of House Sites & Foundations" (1980)
- "Geomechanics in Urban Planning" (1981)
- "Assessment of Slope Stability at Building Sites", BRANZ (1987)
- "Geotechnical Issues in Land Development" (1996)
- "Draft Geotechnical Guidelines for Residential Land Development" (1996).

The earlier work tended to identify the technical and planning problems and broadly outline appropriate solutions. While some excellent work was done, particularly the detailed guidelines included in the BRANZ (1987) document, only a few codes were produced for earthworks and urban subdivisional development (ref NZS4404 & NZS4431), and these largely avoided the difficult task of producing detailed requirements for stability assessments in NZ. Recent legislation broadly outlines the requirements for stability assessments for subdivisional development (RMA 1991) and building development on lots (Building Act 1991 and the NZ Building Code). Again, few specific detailed requirements are given in this legislation. More recent work including the papers presented at the 1996 Symposium on Geotechnical Issues in Land Development outlined the deficiencies in the current practice (ref D.K. Taylor, Bell et al and others *(Ref 6)*. It was also recommended that a code or a set of national guidelines should be compiled to set minimum professional standards for geotechnical stability assessments. This would help to achieve greater consistency in the preparation, review and approval of these assessments throughout NZ.

The fundamental issues are these:

- When is an assessment necessary?
- Who is the appropriate person to carry out the assessment?
- What should the assessment address?
- Who should review and approve the assessment?

While some Territorial Authorities in NZ have their own guidelines for stability assessments, these appear to vary widely both in documented form and in their interpretation.

The principal focus of this research project is on the above third question and to compile a set of draft guidelines to produce a consistent set of requirements for the content of stability assessments. Further work will be required to resolve all the fundamental issues but this is beyond the scope of this research project. However, it is hoped that the results of this project will be used in the preparation of a more holistic set of guidelines and this matter is currently being reviewed by the NZ Geotechnical Society.

The main issues to be addressed by this research project on the design of permanent slopes are outlined as follows.

3.2 Current Legislation

A brief summary of the relevant legislation, namely the Resource Management Act 1991 and the Building Act 1991 and associated NZ Building Code 1993 is presented below. More thorough discussion of this legislation is presented by J. Milne 1996. The general process of hazard identification and the stability assessment of land is outlined in Figure 1. In the event of a natural disaster (including landslip) the Earthquake Commission may cover investigation & remediation of residential properties. An outline of the extent of cover and the issues involved is presented in the following sections.

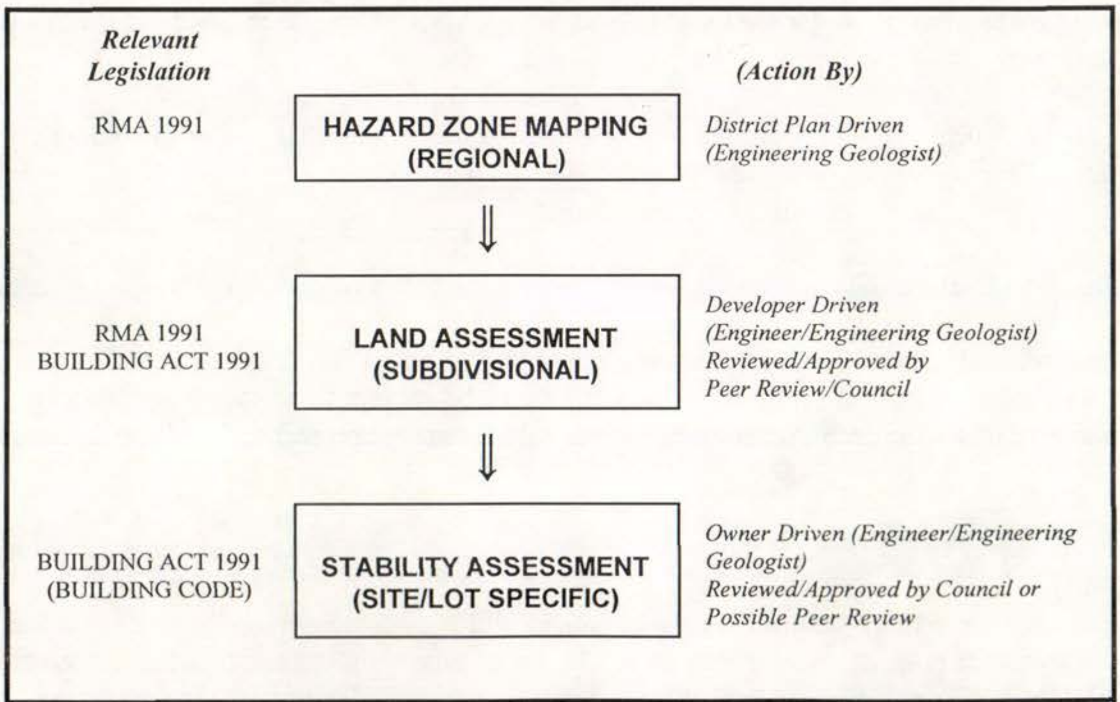

FIGURE 1: PROCESS OF LAND STABILITY ASSESSMENT

(a) The Resource Management Act (RMA) 1991

As outlined by D.K. Taylor at the 1996 NZ Geotechnical Society Symposium on Geotechnical Issues in Land Development keynote address:

> "... the Act requires Regional Territorial Councils to consider natural hazards including ... landslip ... where uses such as:
> - erection and modification of buildings
> - excavation or other disturbance of the land
> - deposition of any substance on the land
> - primary production
>
> will or may adversely affect human life, property or other aspects of the environment.

All of this applies whether the land is subdivided or not, but it is only when it is subdivided that technical standards are provided (namely NZS4404 and NZS4431).

In Part X Clause 220, conditions of subdivision may include:

- provision be made to the *satisfaction* of the territorial authority for ... protection against ... slippage ... arising or likely to arise;
- filling and compaction of the land and earthworks be carried out to the satisfaction of the Territorial Authority."

Many authors and practitioners (ref. 4,6) refer to the use of GIS (Geographical Information Systems) and the older Urban Land Use Surveys - *NWASCA publication 105 (1987)* - to record various types of hazards including landslips on a regional and local authority scale.

Isaac & Turnbull (1997) outline an exciting prospect of nationally coordinated and produced geological layered maps using QMAP and GIS. Their intention is to make this map information widely available to the public via the internet.

(b) The Building Act 1991*

Section 36(1) of the Act states that the Territorial Authority (TA) "*shall refuse* to grant a building consent ... if the land is subject to or is <u>likely</u> to be subject to ... slippage ... *unless the TA is satisfied* that adequate provision has been or will be made to protect the land ... or restore damage ...".

Section 36(2) of the Act provides an alternative for issuing of a building consent to a landowner where the Territorial Authority transfers the *civil liability* to the landowner under certain circumstances (e.g. the building development will not accelerate ... slippage ... on land that is subject to or is likely to be a subject to ... slippage). We understand that the degree of transfer of liability from a landowner or developer to a geotechnical consultant is largely dependent on the terms of engagement of the Consultant. Section 36(2) does not cover transfer of liability for

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* *(An extract of Section 36 of the Building Act 1991 courtesy of NZ Geomechanics News Dec. 1994, is appended to this paper.)*

manslaughter or criminal negligence in the event of loss of life and/or damage to property as a result of a landslip.

No guidance is given with regard to the four fundamental issues outlined earlier in 3.1. Also, it is noted that there is no legal requirement in the legislation to adhere to factors of safety. This is stipulated in the non-mandatory part of the NZ Building Code (B1/VM4).

District Plans may also require a minimum land area (typically 150 - 200 m^2) be made available to form an adequate building platform. The application of the NZ Building Code would then require a minimum factor of safety of 1.5 unless specific engineering design and construction is carried out to improve a substandard platform (or part thereof), or else no development could proceed under section 36(1) of the Building Act.

(c) The NZ Building Code 1993*

The NZ Building Code *non-mandatory* Verification Method B1/VM4* simply requires all permanent slopes be designed for a minimum factor of safety of 1.5. No further qualification regarding geological and soil conditions, slope geometry and the influence of surface and subsurface groundwater is made. This is however essential for a suitable analysis and calculation of a factor of safety. In addition, no comment is made on the proximity of non-complying slopes to residential dwellings or land boundaries (eg the threat of an 'unstable' slope near adjacent flat land). However, slightly more elaboration is provided on what must be addressed in a site investigation prior to construction or earthworks on a building site.

Hence, it is considered necessary that upgrading of the sections relating to geotechnical site investigations and slope stability be carried out.

(d) The Earthquake Commission Act 1993

Landslip Issues

The Earthquake Commission Act 1993 provides for cover for damage to residential property caused by a natural disaster. This includes:

- Natural landslip damage to buildings or parts of buildings which contain dwellings (homes or holiday homes) or provides accommodation for the elderly to the lesser of; insured value, $100,000 per dwelling (subject to an excess amount).

- Land loss within 8 m of the residential building to a maximum of minimum area of land allowable under district plan, or 4,000 m^2.

* *(Relevant extracts from the NZ Building Code, courtesy of New Zealand Geomechanics News dec. 1994, are appended to this paper.)*

- Land loss and damage to structures on the main access way including bridges, retaining systems and culverts within 60 m of the residential building (and land immediately supporting such access way).

- Damage to services to the residential building within 60 m of the building.

- Landslip damage to retaining walls within 60 m providing support for the areas above.

Exclusions include:

- non-residential buildings - the part of these buildings which are residential (if any) will be covered

- mobile property such as caravans, mobile homes or vehicles

- dams and walls that are not an integral part of the residential building or its access way

- pavements

- reservoirs, pools and tanks other than tanks for supply to a residential building

- crops, vegetation, tennis courts and artificial surfacing, jetties, natural wharfs or landings (although the land loss will be covered).

Landslip excludes subsidence, soil expansion soil shrinkage, soil compaction and internal or surface erosion from the definition of landslip but provides for natural disaster damage by a storm or flood to land only.

The Earthquake Commission may also limit insurance or decline a claim where previous claims have been settled, particularly if suitable mitigating measures are not completed and/or further or repetitive loss or damage is likely to recur. The Commission will only cancel cover if the total loss has been paid.

After completion of work to accepted standards, reinstatement of full insurance cover may be sought.

3.3 Site Risk/Hazard Assessment

The use of hazard zoning by regional and district councils appears to vary throughout NZ. Some councils have gone to great lengths to record and map landslip hazards (along with earthquake and flooding etc) while others have virtually nothing in map form. The more sophisticated maps describe different degrees of hazard based on steepness of slope, behaviour of (characteristically weak) materials, likely earthquake intensity and/or economic risk and may be cross referenced to PIM's (Project Information Memoranda) and LIM's (Land Information Memoranda). Simpler maps identify only if a stability hazard is possible or likely.

The RMA requires Territorial Land Authorities (TLA's) to maintain a hazard register, not necessarily in map form. Maps are, however, the most comprehensive and accessible way of recording past problems and likely future conflicts with development of land as well as showing those areas not currently known about. The perceived problems with maps include:

- liability - what happens if an area is incorrectly mapped as suitable when it is later found to be unsuitable?
- economics/politics - the cost to developer (either real or perceived loss in value) because of the broad brush regional zoning effects on specific lots or small parcels of land near zone boundaries where it is unclear whether specific lots are geotechnically unsuitable.
- cost - the expense of engaging staff or specialists to review or map areas previously not known about.

In some ways, councils are damned if they do map and damned if they don't.

When a site specific stability assessment is prepared, reference should be made to the "District Hazard Map". An outline of the process of geotechnical investigation, design and construction observation process is presented in Figure 2. The use of possible supplementary investigation and feedback of information into the hazard register or (GIS) hazard map is highlighted.

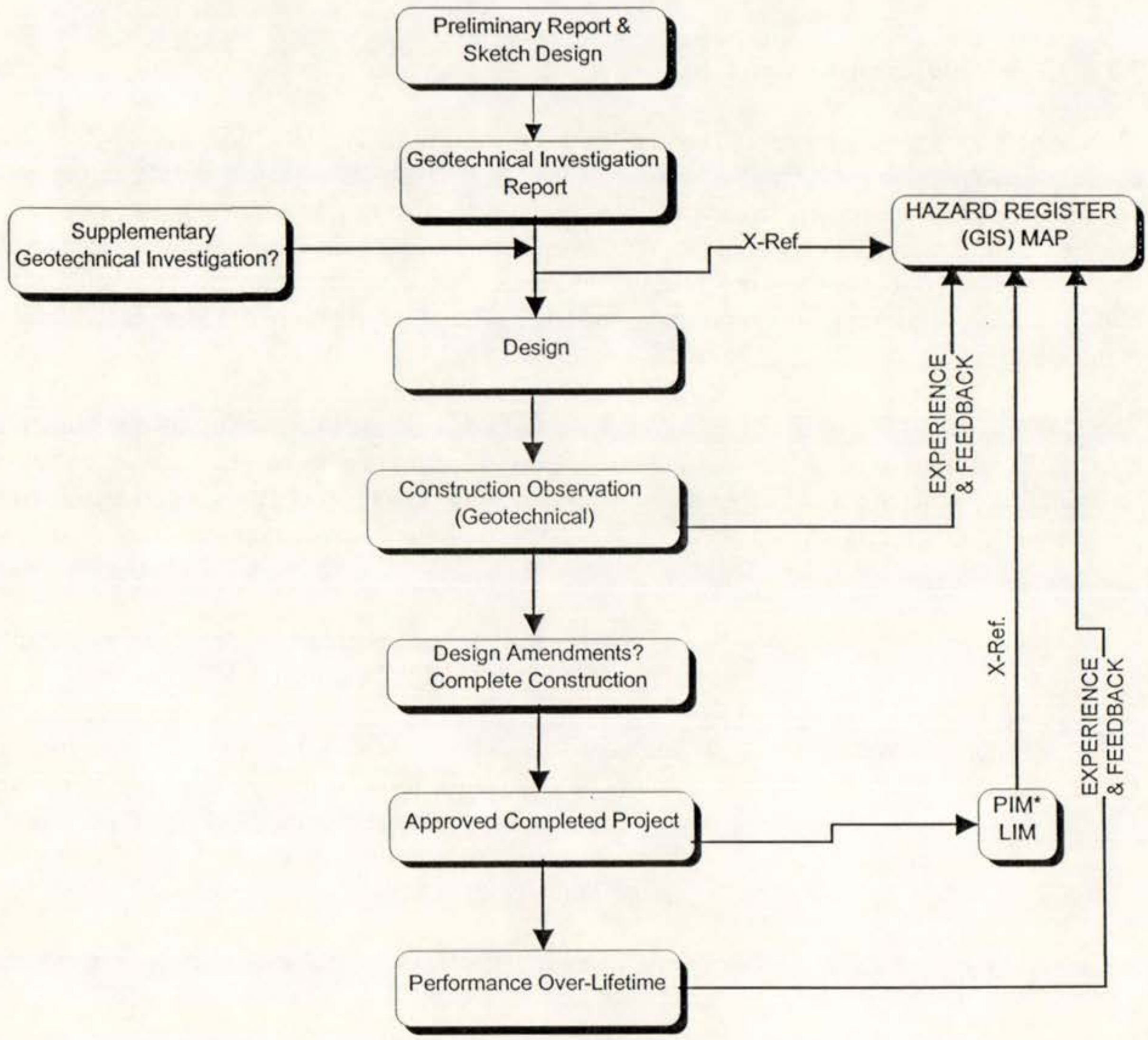

Figure 2: Geotechnical Investigation/Design Observation Process

** Users of PIM's & LIM's need to be cautious when relying on this information. Records may not be complete or accurate with respect to historical site development, fill placement and stability issues for information prior to the RMA (1991). Records after this date are required to be maintained by TLA's as part of their responsibilities under the RMA.*

3.4 Site Geology, Topography and Groundwater - Investigations

The Building Code (B1/VM4)* outlines the topics which the site/lot specific assessment should address including landform, geology, previous earthworks, site history, flooding, groundwater changes, etc. (clause 2.1), but concludes that ... "ground conditions should be investigated to the extent necessary ... (to) provide sufficient data for the design of the *building*" (clause 2.2).

While it is up to the geotechnical specialist to determine the methods of investigation to be used on a site, some guidance should be given to outline the options, particularly for non-specialists who may be reviewing the assessments or for the "civil engineer who dabbles in the geotechnical field."

There are a number of NZ references which adequately deal with this issue and it is recommended that these be referred to in this case-ref. BRANZ (1987), Slope Stability in the Urban Environment (1997).

3.5 Factor of Safety, Soil Strength Parameters & Groundwater

The generally accepted minimum factor of safety for slope stability for residential development in NZ has long been 1.5, although lower values are also regularly used for extreme conditions. It is not surprising that "FOS $\geq$1.5" appears in the NZ Building Code. What is needed, however, is some explanation or qualification of what design conditions should apply and what level of risk can be adopted (e.g. worst case groundwater conditions or soil strength parameters or a certain return period rainstorm or "average" soil strength conditions. Indeed some would ask if a numerical analysis is valid at all. Large parts of NZ are geologically young and many steep slopes in NZ are close to equilibrium or failure as a result of their formation, and consequently have factors of safety close to 1.0. However, as the NZ Building Code stipulates a minimum factor of safety of 1.5, many councils or TLA's feel as though they must comply for "safe" legal reasons. On the other hand, at least one council has stated in their engineering standards that:

> "In most cases, it is unnecessary or impracticable to measure quantitatively the factor of safety against shear failure"...

Clearly, there is a wide variance of opinion.

The numerical analyses of slopes, particularly existing natural slopes, is very dependent on the selection of soil strength parameters and assumed groundwater levels. The measurement of such soil and water parameters is often very expensive, dependent on time and even weather. Often assumptions have to be made and there is the possibility of input data being manipulated to obtain the "appropriate" result for compliance purposes.

The use of numerical analyses alone without an engineering geological assessment is considered

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* *(Relevant extracts from the NZ Building Code BI/VM4, courtesy of New Zealand Geomechanics News Dec. 1994, are appended to this paper.)*

to be incomplete. These quantitative and qualitative methods of stability assessment are best seen as complementary rather than mutually exclusive. The use of numerical analyses is often best applied to measure the sensitivity of a slope model to variations in groundwater profile/conditions assumed soil parameters, changes in slope profile (e.g. cuts, fill, retaining walls) and the effectiveness of remedial works.

3.6 Earthquake Loadings/Risk

Again the NZ Building Code does not specifically mention the need for earthquake assessment and the level of loading for slope stability. The NZ Loadings Code (NZS 4203) does, however, identify earthquake zones and levels of loading in the absence of site specific seismic assessments. This code identifies loadings for buildings for 450 year return periods while it is normal practice to design earth structures for 150 year return periods.

A strict reading of the NZ Building Code (clause 3.2 "Slope Stability")* requires permanent slopes be designed for a factor of safety (FOS) of 1.5. TLA's vary widely in their interpretations of earthquake requirements from a minimum FOS of 1.5 to "generally not required".

3.7 Role of Peer Reviewers

The use of peer review by TLA's also varies widely from never to "all geotechnical investigations". Often the response of TLA's is that peer review is used in high risk or complex situations.

The degree of complexity perceived and the need for engaging a geotechnical specialist review is often dependent on the expertise of the TLA reviewer. We understand that the most frequent insurance claims are for situations where civil engineers "dabble" in the geotechnical field on what are often seen as simple stability jobs.

Even when a geotechnical specialist is engaged for peer review, the brief and extent of liability is often ill-defined. This is not surprising as there is generally little guide as to these requirements. In August 1995 the NZ Geomechanics Society Auckland Branch held a forum on 'The Role of Peer Review'. This forum identified a general lack of information on guidelines for peer review with very little presented in international literature. Some guidance on the role of a peer reviewer is given in the article in NZ Geomechanics News.

An outline of the qualifications, experience and the role of the peer reviewer (either within a TLA or an engaged geotechnical specialist) is not included in the current NZ Building Code. However, the Building Act implies by the words "the territorial authority shall, if it is satisfied ... grant the building consent ..." that an adequate level of geotechnical competence is required on the part of the TLA.

* *(Relevant extracts from the NZ Building Code B1/VM4, courtesy of New Zealand Geomechanics News Dec. 1994, are appended to this paper.)*

4.0 NZ GEOTECHNICAL SOCIETY QUESTIONNAIRE - REVIEW

In July 1994, the NZ Geomechanics Society ran a questionnaire on the current practice of assessing stability in NZ and the application of the current legislation (The Building Act) and the NZ Building Code. Many engineers working for Territorial Land Authorities (TLA's) responded including those from:

- Whangarei District Council
- Rodney District Council
- North Shore City Council
- Auckland City Council
- Waitakere City Council
- Manukau City Council
- Thames Coromandel District Council
- Tauranga District Council
- Western BOP District Council
- Matamata Piako District Council
- South Waikato District Council
- Taupo District Council
- Ruapehu District Council
- Stratford District Council
- Wanganui District Council
- Hutt City Council
- Porirua City Council
- Marlborough District Council
- Nelson City Council
- Westland District Council
- Selwyn District Council
- Queenstown Lakes District Council
- Clutha District Council

Comments were also obtained from most of the geotechnical practices in NZ including geotechnical engineers and engineering geologists. Some civil engineers responded as well.

The questions posed in this nationwide survey are grouped as follows:

- From whom are stability assessments acceptable?
- What is the place of qualitative and quantitative assessments (i.e. engineering geological assessments or numerical analyses)?
- What are the requirements for factor of safety soil strength and groundwater parameters and when should they be tested for a site?
- What are the suitable earthquake requirements?
- What role does peer review play?
- How is Section 36(2) of the Building Act applied?

A breakdown of responses according to the categories of the respondents (i.e. TLA engineers, engineering geologists and geotechnical engineers) was published in the December 1994 issue of *NZ Geomechanics News*. A copy of the extract from this technical newsletter is appended to this research paper.

A summary of the responses is as follows:

a) From whom are stability assessments acceptable?

The responses varied for TLA engineers but typically the experience of the assessor was compared with the complexity and degree of risk of the particular site, with a tendency towards preferring geotechnical specialists. Some councils required a report from a Registered Engineer.

The responses from geotechnical practitioners indicated that assessments from geotechnical professionals only (engineers or geologists) should be accepted.

b) Is an engineering geological (i.e. non-quantitative) assessment acceptable?

TLA engineers generally considered that non-quantitative assessment was sometimes acceptable and the suitability of this type of assessment is generally dependent on the degree of risk of instability, i.e. if low risk then it's suitable.

Geotechnical engineers' responses varied but generally considered where there was previous instability or changes to the subject slope, a numerical analysis was required. This was, however, supplementary to an engineering geological assessment.

Engineering Geologists almost all responded with a yes to this question but noted that numerical analyses could sometimes be used in conjunction with a qualitative approach. The engineering geological assessment was considered to be the appropriate approach for landslip hazard mapping.

c) What are the requirements for factor of safety, soil strength and groundwater parameters?

The TLA engineers typically considered that the application of *average* soil strength parameters in conjunction with *average* groundwater profiles was appropriate for a FOS $\geq$ 1.5 for slope stability.

This was also generally the case with geotechnical engineers or engineering geologists. It is interesting that those firms who employed both geotechnical engineers and engineering geologists generally indicated average to worse case conditions for soil strength and groundwater for a FOS$\geq$1.5.

There was again wide variation in answers to this question and many respondents supplied qualifying comments, the most frequent being that a lower FOS could be adopted for temporary slopes (typically 1.3) and for extreme conditions or failure of drainage remedial works (typically 1.0 to 1.2). Other respondents commented that the design FOS could be lowered for conditions of lower economic/property risk or where risk to human life was negligible. Also for areas prone to large scale landslides or mass movement a FOS of 1.5 may be difficult to achieve.

There was general agreement by all parties that strength testing of soils was not mandatory for small sites and that results of testing on similar soils from other sites could be used. Strength testing of soils for large sites and developments, or difficult sites was generally considered necessary.

d) What are suitable earthquake requirements? (e.g. factor of safety and return period)

There was great variation here for TLA engineers with their required FOS's for seismic slope stability ranging from "seismic analyses not required" to generally 1.5 (with one respondent indicating a FOS between 2.0 and 4.0). The return period suggested was typically 150 years and 450 years.

For geotechnical practitioners, there was a general consensus that the seismic stability FOS should be between 1.0 and 1.3 (and typically 1.2) with a return period of 150 years. Some qualified their responses with a FOS $\geq$ 1.0 for the maximum credible earthquake and that the consequences of slope failure should be taken into account.

e) What role does peer review play?

Again a wide variation for TLA engineers but there were essentially three camps:

i) peer reviews are not required
ii) peer reviews are done for all assessments
iii) the use of peer reviews is dependent on the level of risk and the degree of complexity for each site

There was general agreement between geotechnical professionals on three points:

i) in-house review was required before submission of an assessment to a TLA
ii) peer review was necessary on large scale projects
iii) peer review was preferable for difficult small scale sites

Two other significant points made were:

- if a peer review was carried out then, it should be done by a suitably qualified professional and not the *most available* "qualified" professional within a TLA

- a peer review should be restricted to a check of procedures, content and method and NOT regarded as a second opinion in disguise.

f) How should section 36(2) of the Building Act be applied?

TLA engineers generally treated this section with caution and restrained responses. This suggests an awareness of greater risk for 36(2) approvals. (Some responses indicated that legal advice was sought for these types of consents.) As a result it was difficult to determine whether there was technical uniformity of application of section 36(2). Section 36(2) of the Act was, however, rarely used and was generally applied to specific sites of known instability where the proposed development would not exacerbate the current situation. Some respondents indicated that the council chooses not to partake in the development risk for 36(2) consents and this must be taken by the developer. Accordingly, the land title must be "tagged".

The geotechnical practitioners also indicated that caution was necessary in becoming involved with 36(2) consent applications, although there were differing opinions as to who carried what risk. Those stating previous involvement with section 36(2) consents indicated different TLA's are applying 36(2) differently. There is apparent agreement that the developer/owner carries the risk, that the TLA or EQC accepts no risk and that limited risk is accepted by the geotechnical professional and this needs to be defined in the consultants terms of engagement.

D K Taylor, a senior member of the NZ geotechnical profession responded as follows:

> "(Section 36(2) is an extraordinary return to the "Caveat Emptor" philosophy which may lead to some interesting court decisions in the future. The TLA should apply it (36(2)), <u>not</u> the consulting engineer."

5.0 EXPERIENCE IN AUSTRALIA & HONG KONG

5.1 The Australian Experience

The authors have had some limited experience of slope stability assessment in NSW, Australia. An article on the "Geotechnical Risks Associated with Hillside Development"* was presented in Australian Geomechanics News in 1985.

This is a concise (7 page) summary of stability issues in the Sydney Basin. While being specific to this area in terms of geological conditions and modes of slope failure, it grades typical site conditions in terms of risk : very low, low, medium, high and very high and outlines how a geotechnical assessor can arrive at a risk classification. It indicates the typical implications for development and illustrates examples of good and poor engineering practice for various types of common developments. This document was used by geotechnical practitioners and local Councils in the Sydney Basin. We understand that this document was to be updated but to our knowledge has not yet been republished.

Since then, the 'Threadbo Incident' on 30 July 1997 (in which 18 people were killed by a landslip) has initiated a major review of the guidelines by a combined task force committee. This task force comprises senior geotechnical professionals from the Institution of Engineers Australia and the Australian Geomechanics Society. They are undertaking a 'Review of Landslides and Hillside Construction Standards'.

This taskforce has agreed to terms of reference in November 1997 and has set themselves a programme (March 1998) as follows:

1st draft of guidelines	24/12/98
2nd draft of guidelines	31/8/99
3rd draft of guidelines	24/12/99

* *A copy of this article is appended to this paper*

4th draft of guidelines	31/5/2000
Print final guidelines	30/9/2000

The NZ Geotechnical Society is liaising with the task force with a view to providing assistance to each other.

5.2 The Hong Kong Approach

The approach to stability assessments in Hong Kong is outlined in the "Geotechnical Manual for Slopes" (1994). The Hong Kong approach is reviewed because of the previous involvement of some NZ engineers (ex Ministry of Works) in the Geotechnical Engineering Office (formerly the G.C.O.) in Hong Kong. It is referred to by some geotechnical practitioners in NZ because of its summary outline on recommended FOS's and associated levels of risk. It is noted that the FOS's are related to a ten-year return period rainfall. There has been significant research on correlation of rainfall to landslides in Hong Kong and this appears to be reviewed and published annually. This intensive level of work has not been carried out in NZ. It is noted that "Risks to Life" and "Economic Risk" are graded in terms of negligible, low and high. Typical examples of determination of these risk levels are summarised on Table 5.2* and 5.3*. Recommended FOS are outlined for new slopes (Table 5.1) and existing slopes and remedial works to slopes (Table 5.4).

The *recommended* FOS's indicated are 1.2 for low risk and 1.4 for high risk for new slopes with a FOS > 1.1 for predicted worse case groundwater conditions.

For existing slopes and remedial works to slopes the *minimum* FOS's are 1.1 for low risk (to life) and 1.2 for high risk. However, there are rigorous requirements noted for the use of these FOS's.

Some guidance on when the services of an "experienced geotechnical engineer or engineering geologist are necessary" is given in Table 2.1 for formed or natural slopes and the three risk categories.

It is noted that the slope angles mentioned are typical of the weathered (granite or volcanic) rock profiles in Hong Kong and caution is recommended in applying these directly to NZ situations without consideration of site specific conditions.

There are also requirements in Hong Kong for regular "maintenance inspections" with recommended inspection intervals between six months to 5 years, dependent on risk category and the experience of the inspector.

* *Refer to appended extracts from the Hong Kong Geotechnical Manual for Slopes (Table 5.1 to 5.4, 2.1).*

6.0 PROPOSED GUIDE FOR NZ

6.1 General

There are a wide range of issues to be addressed and resolved by a set of national guidelines. The fundamental questions asked in section 3.1 of this paper all need to be covered. The principal focus of this paper is 'what should the stability assessment address?' Further work is therefore required to prepare a complete set of guidelines. It is proposed here to address the particular issues outlined and present a draft checklist for stability assessments which can be used by both those preparing and reviewing assessments.

It is appreciated that geological and geotechnical conditions will vary around NZ and that local addendums will be required (e.g. for low strength materials such as 'Onerahi Chaos and apparently high strength soils such as the Port Hills loess). Previous work is referenced, to capitalise on well compiled technical references, although some minor updating of these documents is required.

6.2 Working within the Current Legislation

While there are deficiencies in the NZ Building Code clauses relating to slope stability, it is proposed that minor amendments be made to the text of B1/VM4 which should include a reference to a set of national guidelines for slope stability assessment . This will avoid the augmentation of an already bulky code. The preparation of these guidelines is currently being undertaken by the NZ Geotechnical Society sub-committee for the preparation of stability assessment guidelines. This paper will be used to form part of these new guidelines.

This approach will avoid prescriptive standards which are likely to prove unworkable for the complexities of slope stability and should minimise the need for amendments to the Building Code and associated legislation.

6.3 Application of the Earthquake Commission Act (1993)

With regard to the Earthquake Commission Act 1993 and natural disasters or impending worsening of a natural landslip, the following comments are made. Many comments will be of particular relevance to Council (TLA) staff:

<u>Landslip Issues</u>

- property which complies with the land cover provisions and has been subject to consent approval and construction approved as complying with laws and bylaws is likely to be covered.

- unsatisfactory construction including construction on uncertified fill undertaken by previous owners which could not be reasonably known by the current owner may be covered. Such work carried out by current owner is unlikely to be covered.

- the above do not preclude EQC seeking to recover from TLA's and previous owners if work has not been completed in accordance with accepted practices or work is undertaken on properties of known high risk.

- damage to property where the owners agent(s) (builder, engineer, developer) or Council may be reasonably expected to identify a potential hazard may result in EQC seeking recovery.

- where a property is in imminent danger from a natural disaster that has occurred, EQC may opt to undertake repairs prior to the loss occurring

- property owners are responsible for mitigating against further damage following initial damage.

- Once a claim has been reported, the property owner must be helpful and allow EQC or its agents to investigate the claim

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- claims must be reported within 30 days of damage being apparent.

- surface erosion is unlikely to be covered but destabilisation due to undercutting may be covered.

- slope debris removal costs will only be covered for material within the zone of landslip cover or if it is causing a major risk of further landslip to insured property.

- if uninsured parties or other parties in the vicinity are contributing to a potential hazard, e.g. soak holes injecting surface stormwater into the groundwater system, EQC has no authority to mitigate these risks. Councils may need to be approached to effect mitigation under their powers provided by the Building Act.

- EQC do not cover betterment for retaining walls and land claims unless the property is in imminent danger. Upgrading to current standards of buildings is covered.

- dwellings constructed under Clause 36(2) of the Building Code may have claims declined if the damage is caused by nature of the property rather than a specific event.

<u>Stormwater Issues</u>

The Act excludes erosion from the definition of natural slip but provides cover for natural disaster damage by a storm or flood to land only. Damage to residential buildings, from storm and flood, is covered by insurance companies.

Coastal & Riverbank Issues

Current interpretation of the Act by the Commission is that undercutting of cliffs and riverbanks which induces landslip damage to properties is generally covered. There are increasing concerns by EQC advisors that properties which are inherently at high risk from this type of damage should require consents authorities to consider the potential for a landslip claim, e.g. if cliff top regression of up to 5 m is expected to occur within the design life of the dwelling, then a landslip claim may be expected to be made if the dwelling is located within 8 + 5 m of the edge. Currently, consents authorities (TLA's) permit structures within this zone, exposing EQC to a high probability of claim.

Neighbours are responsible for the stability of adjoining properties where a cut is made in natural ground. There have been several instances when Council have obtained easements or legal ownership on coastal zones or riverbanks where ongoing erosion has resulted in councils taking responsibility for the cost of protection works to mitigate against further erosion. This is not an Earthquake Commission Act issue but may have a future impact on potential recovery of costs by EQC.

EQC has the option to take action (under Clause 11 of the 3rd Schedule of the Act) particularly if it believes that the chance of recovering loss from the third party is good.

6.4 Hazard Assessment

The "District Hazard Maps" are invaluable geotechnical tools and give TLA's a way of complying with the hazard register requirements and enforcement of the Resource Management Act. It is likely that a well prepared map will minimise TLA's exposure to legal action rather than increase their liability. Such maps are best prepared by experienced engineering geologists and geotechnical engineers to identify areas subject to or prone to landslip as well as a wide range of other hazards. Reference to these "District Hazard Maps" by geotechnical professionals is essential for the preparation and review of stability assessments, particularly for subdivisions. This will require TLA's to compile a series of maps and make them available at reasonable cost to the public.

It is important that such maps are separated from (but cross referenced to) the District Plans. Because of the uncertainties of hazard zoning and the constant input of new information from new geotechnical assessments, these maps should be updated continuously as more information arises.

Many authors have presented their views on the need, preparation and effects of hazards zone mapping and the application of Geographical Information (GIS) systems in New Zealand. Further information on the preparation and use of hazard mapping can be found in Session 4 of the Proceeding of the 1996 NZGS Symposium on Geotechnical Issues in Land Development. The reader is referred to these documents for a more complete outline than can be included in this paper.

Reference to these hazard maps is essential for the preparation and review of stability assessments. To this end wider publication and distribution of the current hazard zone maps should be carried out. The Geotechnical Society, EQC or some independent non-profit making national body, could facilitate this by producing and maintaining lists of hazard maps and key maps to identify those regions in NZ which are covered. This relatively simple task could be funded by the Ministry for Local Government and used as a means to enforce the RMA hazard identification requirements.

Further, there is a need for a simple national guide to be prepared to standardise mapping legends, risk categories and allow for co-ordinated overlapping of grids and hazard zones at boundaries between TLA districts. This is one of the main recommendations made by this project and we consider work should be done as soon as possible. Again this co-ordinating function should be funded by the NZ Government and organised by the NZ Geotechnical Society or some other non-profit making national body.

6.5 Geotechnical Site Investigations

The Building Code (B1/VM4) outlines the topics which the site/lot specific assessment should address including landform, geology, previous earthworks, site history, flooding, groundwater changes, etc. (clause 2.1), but concludes that ... "ground conditions should be investigated to the extent necessary.

The extent of investigation is a function of the complexity of the site, the perceived risk of instability, the hazard to property, assets and human life, and the scale of the development proposed. While it may be too expensive to carry out triaxial testing for the 'normal' house site investigation, for example, some relatively inexpensive index tests could be carried out to allow correlation with other fundamental soil properties. On the other hand, for a subdivisional development both types of testing may be desirable. This is not only because of the scale involved (and the larger financial backing) but also to provide soil strength and property data for possible site specific investigations on the subdivision.

The geotechnical professional should be responsible for determining the extent of the investigation necessary. It may be appropriate that a staged investigation be carried out to more effectively target potential problem areas. Some guidance of the level of investigation with relation to risk classification is suggested in Table 1.

More detailed guidelines are well presented in the BRANZ (1987) document "Assessment of Slope Stability at Building Sites". Minor updating of this document is required but the technical content is generally still valid.

In addition, a "Checklist for Stability Assessments" has been compiled for the use of geotechnical practitioners and council reviewers alike. This checklist is appended to this paper.

It is noted that Australia has recently issued a standard for site investigations. The preparation of a similar standard for NZ conditions could be undertaken to encourage uniformity and minimisation of poor investigations. This would need to be looked into by the NZ Geotechnical

Society in association with Standards NZ. It may be possible to provide an addendum to the Australian standard in order to make it a joint ANZ standard as there is a trend for this approach to standards.

6.6 Risk Assessment and Required Factors of Safety

As outlined earlier in this paper not all stability assessments need to include a numerical factor of safety. Such assessments are very dependent on the expertise of the assessor. In order to go some way to standardising assessment, it is recommended that a risk classification procedure be developed for NZ which also addresses the consequences of failure. This should be based on the recommendations of the BRANZ (1987) document (section 4.2) and could be presented in a similar way to the Australian Geomechanics News article (1985), or the Hong Kong Manual 1994, i.e. sites (or parts thereof) could be classified on a scale of "very low risk" to "very high risk". A suggestion for risk categories is presented in Table 1.

The higher levels of risk could require (numerical) slope analyses to be carried out as part of the assessment. The risk classification could be reduced if suitably designed remedial works were constructed.

This risk classification system could be addressed by the NZ Geotechnical Society in developing the national stability assessment guidelines. Further comment from the geotechnical community would be required to establish a suitable risk classification system which can accommodate local geotechnical characteristics.

The risk classification could be used by councils for supplementary purposes such as standardising hazard mapping classifications and ease of use for GIS. Other follow-ons could be relating risk classification to:

- minimum requirements for site investigation
- geotechnical design requirements for development remedial works
- degree of construction supervision
- extent of post-construction site monitoring/maintenance

It would also allow prospective purchasers of hillside properties to assess the level of risk associated with a particular site and the need for on-going routine maintenance of any slope remedial works (e.g. surface and/or subsurface drains).

6.7 Soil Strength Parameters Groundwater Assumptions and FOS

It is essential that an engineering geological assessment is carried out for the whole of the site, and extended area affecting the stability of any development. A decision can then be made on the need for a numerical analyses. Selection of critical sections for such analyses can be made and a suitable geotechnical model formulated for analyses. This model should be referenced to drawings showing surface and subsurface site data. Unless this assessment of geology, soil properties and groundwater is carried out, the performance of the numerical analyses is pointless and the results are likely to be misleading.

Table 1: RISK CLASSIFICATION FOR SITES SUBJECT TO INSTABILITY

(This table has been produced to provide a simplified classification which can be readily understood by a lay person and to provide a uniform code of terms for geotechnical professionals)

RISK OF INSTABILITY	EVIDENCE/ TYPE OF INSTABILITY	CONSEQUENCES OF INSTABILITY	IMPLICATIONS FOR DEVELOPMENT	EXTENT OF INVESTIGATION REQUIRED
VERY HIGH	Evidence of active or past instability - landslip or rockface failure; extensive instability may occur within site or beyond site boundaries.	High risk of loss of life. Catastrophic or extensive significant damage or economic loss.	Unsuitable for development unless major geotechnical work can satisfactorily improve the stability. Risk after development may be higher than normally accepted (includes Building Act Section 36(2)).	Extensive geotechnical investigation required.
HIGH	Evidence of active creep, potentially progressive/regressive/minor slips or minor rockface instability; significant instability may occur during and after extreme climatic conditions and may exceed beyond site boundaries	Low risk of loss of life. Significant damage or economic loss	Development restrictions and/or geotechnical works required. Risk after development may be higher than normally accepted (may include Section 36(2)).	Engineering geological assessment drilling investigation required.
MEDIUM	Evidence of possible soil creep or a steep soil covered slope; significant instability can be expected if the development does not have due regard for the site conditions.	Virtually nil risk of loss of life. Moderate damage and economic loss	Development restrictions may be required. Engineering practices suitable to hillside construction necessary. Risk after development generally no higher than normally accepted.	Visual assessment. Hand and possible drill investigation methods.
LOW	No evidence of instability observed; instability not expected unless major site changes occur.	Minor damage, limited to site unless major development occurs.	Good engineering practices suitable for hillside construction required. Risk after development normally acceptable.	Visual assessment. Possible hand investigation method.
VERY LOW	Typically shallow soil cover with flat to gently sloping topography.	Virtually nil.	Good engineering practices should be followed.	Visual assessment.

Until recently a factor of safety of 1.5 was typically being required by many TLA's, for all sites under conditions of full saturation of the slope. In practice full saturation may be unlikely to occur on some sites and/or under design conditions. It is accepted that, if no detailed investigations have been undertaken, the requirement for a factor of safety (FOS) exceeding 1.5 for full saturation is generally reasonable.* However, a less conservative approach can be adopted where full saturation is only likely to occur under extreme conditions and a good understanding of ground conditions is available due to the:

- detailed engineering geological mapping and subsurface investigations
- groundwater conditions being defined by monitoring of water levels or geohydrological assessment
- slope geometry being defined
- defined drainage conditions including permeability of strata being well known
- extent of recharge and catchment area being limited
- back analysis of existing failures being carried out to determine soil properties or groundwater conditions.
- soil properties being known within reasonable confidence limits. These should be compared to typical parameters for local materials based on published information and previous laboratory testing. If site specific tests indicate lower strengths then the lower bound soil properties should be used.
- precedence of low incidence of instability in the area.

This would recognise the added value of the improved appreciation of conditions affecting stability and encourage more detailed study of the critical factors involved.

A minimum factor of safety of 1.5 is recommended for the conditions which may be expected to occur during the design life of the structure - 100 years for dwellings and 50 years for retaining structures beyond 8 m from the dwelling, while a reduced minimum factor of 1.2 is applicable for extreme conditions. These extreme conditions include:

- failure of stabilisation measures and drainage systems (provided the latter includes access for maintenance)

- full saturation where investigations indicate that there is a high confidence level this condition will not occur during the design lifetime of the structure. i.e. A check on full saturation may still be applicable to ensure that failure should not occur under this extreme condition.

We consider that factors such as limited catchments, natural drainage conditions such as permeable strata and slope geometry may preclude full saturation under design conditions. In these cases a reduced groundwater level can be determined for the design case from extrapolation

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* *It is acknowledged that some subdivisions have been developed on large blocks of land with a stability FOS <1.5. Assessments of these subdivisions should be subject to geotechnical peer review. Approval of such developments should be subject to intensive investigation, geotechnical and seismic modelling, and ongoing monitoring. Consents should be issued under section 36(2) of the Building Act.*

of monitored seasonal levels, seepage analyses or observation of geological evidence such as weathering, staining, etc.

The designer is responsible for providing convincing evidence that a reduced groundwater condition can be used for the design condition (i.e. FOS $\geq$ 1.5), and in such cases a check on the extreme cases of full saturation, or failure of any installed slope drainage measures, is also required to confirm that the FOS > 1.2. This approach has been promoted to and accepted by a number of certifying bodies including most of the Auckland region (TLA) certifiers.

We consider that the application of this FOS approach would effectively recognise the benefits detailed evaluation of stability and ultimately lead to an improved level of safety in the application of geotechnical principles.

Variation from these factor of safety guidelines is possible but should be based on an assessment of the level of economic risk and risk to life. Such variations should be subject to specific geotechnical peer review and approval.

6.8 Earthquake Provisions

The design loadings for a numerical analysis of a slope affecting residences should be consistent with the zoning requirements of the NZ Loadings Code NZS 4203 and a 150 year return period. It is noted that section 4.11 of this code allows for a 0.25 structural performance factor for soil loads on structures rather than the 0.67 factor for building loads. A 50 year return period should be applied for retaining structures located further than 8 m away from a dwelling.

For numerical analyses of the seismic slope stability, a FOS $\geq$ 1.2 should be adopted for the above return periods. Potential slope failures which do not extend to within 8 m of a dwelling or cross a property boundary do not need to be analysed for seismic slope stability.

6.9 Development Approaches

<u>Building Line Restrictions</u>

While there has been much discussion on assessment, analysis and remediation of slope instability, alternative approaches are available and are used. These apply in particular to properties near the crest or toe of a slope where a setback distance or building line restriction is imposed. For the case where a site is located on flat land near an unstable slope, failure of that slope could seriously affect the subject site. The approach using a building line restriction (beyond which a slope is considered stable) is often used for lots near cliffs or crests of slopes. For a site near the toe of a slope, a similar approach can be adopted using a buffer zone next to a structure or property to accommodate any failure debris.

The comments made previously (in 6.3 - Coastal & Riverbank Issues) regarding cliff top regression also apply here, ie where TLA's permit structures within 8 m of the building line restriction or buffer zone, thus exposing the EQC to a high probability of an insurance claim.

Large Scale Instability

This issue relates to instability which covers more than one property. For new developments, the potential for large scale instability should be addressed at District Plan (by hazard maps) or at the subdivision of land stage by a geotechnical assessment. Site specific development within such instability may need to be carried out under section 36(2) of the Building Act.

For existing developed sites within large scale instability, the problem is very complex and often difficult to obtain neighbours' consent and finance to remediate. In some cases where remediation is necessary to make properties re-habitable or consents are required to restore non-habitable areas of land, the process is slow and often involves legal disputes. Where resolution is not feasible, the sites are essentially written off for habitable development.

Soil creep

Soil creep is generally considered to be a natural and continuing downslope movement of shallow soils exceeding about a 1(V) in 4(H) grade. Creep which extends to below about 0.5 m below the ground surface may often be difficult to distinguish from a shallow landslip , as it is effectively a progressive landslide. Structural foundations should extend below the creep zone and be designed to resist the lateral loads applied by the creeping soil.

6.10 Peer Review Requirements

The results of the December 1994 NZ Geomechanics News survey indicate a wide variation in when TLA engineers might expect to require a peer review by a geotechnical specialist (see 4 (e) of this paper).

There was some common ground by all surveyed that peer review was dependant on the scale of development, the level of risk and the complexity of each site. The first item is generally apparent and the latter two can be addressed in the assessment and related to the "risk classification" (see 6.6 of this paper).

We suggest the use of peer review by TLA's (or indeed by developers prior to submission of the assessment to the TLA) as shown in Table 2.

Table 2: Peer Review Requirements: When is a Peer Review Required?

Scale of Project	Risk Classification*	Requirement for Review by Geotechnical Specialist
Small Scale (Lot Specific)	**Very Low to Low Risk**	Review by non-specialist / TLA engineer
	Medium Risk	Peer review preferred
	High to Very High Risk	Peer review required
Medium Scale (Small Subdivision, 2 to 20 lots)	**Very Low to Low Risk**	Review by non-specialist / TLA engineer
	Medium to Very High Risk	Peer review required
Large Scale (Subdivision, > 20 lots)	**Very Low to Low Risk**	Peer review optional
	Medium to Very High Risk	Peer review required

*Note: Risk Classification to be determined by the geotechnical professional preparing the assessment and to be in accordance with NZ Geotechnical Society Guidelines. (Refer Table 1 of this report)

The requirements of a peer reviewer are outlined in the article "The Role of Peer Review" in the December 1995 issue of NZ Geomechanics News. Issues such as:

- different categories or review
- defining the scope of the review
- contractual arrangements and liability
- what sort of person should do the review
- interaction between the assessor of a site and the reviewer
- legal considerations and legislation.

Any reviewer (peer or otherwise) should have a checklist of items to be addressed by the Stability Assessment, if only for his or her own professional use. A suggested checklist is appended to this paper.

7.0 CONCLUSIONS

- The nationwide survey carried out in 1994 by the NZ Geomechanics Society * indicates there is a wide variation in opinions on stability issues amongst Territorial Land Authorities and to a lesser extent amongst Geotechnical practitioners. It is generally agreed amongst the profession that there is a need for a set of guidelines on assessment of slope stability for NZ.

* *The NZ Geomechanics Society changed its name to the NZ Geotechnical Society in February 1996.*

- The current NZ Building Code (B1/VM4) does not adequately address issues of slope stability and geotechnical investigation. It is proposed that minor modifications to this document be made including a reference to a new set of guidelines on assessment of slope stability.

- This paper outlines the issues to be covered by the new set of guidelines namely risk/hazard assessment, extent to investigations, FOS and parameter requirements for numerical slope stability analyses and the role of peer review.

- Reviews have been carried out on the nationwide questionnaire survey and documents covering slope stability for Hong Kong and NSW, Australia. The risk classification approach outlined in these latte documents needs further development for NZ conditions. These aspects are currently under review by the NZ Geotechnical Society.

- There is ongoing liaison with the Australian Task Force on Landslides and Hillside Construction as they develop guidelines after the Threadbo Landslip Incident.

- District hazard registers are required of each Territorial Land Authority by the RMA. However, this approach has produced a fragmented coverage of NZ. Standardization and coordination of "District Hazard Maps" is required to produce a nationwide register. It is suggested that the NZ Geotechnical Society/EQC be funded by the Ministry of Local Government to undertake the relatively small task of coordinating these maps by means of standard map legends and national key maps. It may be preferable to utilise the QMAP and GIS approach outlined by Isaac & Turnbull (1997) to allow open access to a national hazard mapping system. Access can be via the Internet.

- There is a wide variation of opinions on the place of engineering geological assessment and the parameters to be used in numerical slope stability analyses.

- A review of opinions amongst the geotechnical profession of requirements for earthquake design loadings has been undertaken and again variation found amongst those who apply and approve seismic slope design for residential development. More guidance is needed in the NZ Building Code.

- There is an inconsistent approach across NZ to the use of peer review for approving stability assessments.

- There is a variance of opinion on the responsibilities of TLA's, consultants and owners/developers when applying the consents under Section 36(2) of the Building Act. However, there is apparent agreement that the developer/owner carries the risk, that the TLA accepts no risk and that limited risk is accepted by the geotechnical professional, and this needs to be defined in the consultant's terms of engagement.

- EQC may decline a claim if the title is noted under Section 36(2) of the Building Act. This is generally when the damage is caused due to the nature of the site rather than through a specific event, for example a storm or an earthquake, in these cases the claim would normally be accepted.

It is hoped that this paper will go a long way to providing a consensus on what should be addressed in a slope stability assessment and provoke constructive criticism where gaps may be perceived by the wide range of views held by the geotechnical community.

8.0 RECOMMENDATIONS

- The results of this research and the draft guidelines included be used as input to the preparation of the national guidelines for stability assessments. This work is to be undertaken by the NZ Geotechnical Society.

- The NZ Building Code (B1/VM4) be modified slightly including a reference to the new above national guidelines.

- References (2, 3, 5 & 7) be updated to include technical advancements, changes in legislation and to incorporate hazard maps and geotechnical requirements for specific local areas where conditions vary widely from the norm, e.g. Onerahi Chaos, Port Hills loess, etc.

- An engineering geological assessment should be made as the first step in a site stability assessment.

- The use of a risk/consequences classification system (namely very low, low, medium, high and very high) be adopted for NZ, firstly for hazard mapping and secondly as one of the conclusions reached in a stability assessment. A suggested format is presented in Table 1 but further work is required to prepare a system for NZ, and this should be covered by the NZ Geotechnical Society national guidelines.

- The risk classification applied to each site be used as one of the means of determining
  i) the minimum requirement or extent of geotechnical site investigations
  ii) the need for numerical slope stability analyses for a site
  iii) the requirements for geotechnical design
  iv) the level of construction supervision
  v) the extent of post-construction site monitoring and slope maintenance.

- The risk classification could be assessed by prospective property purchasers of hillside properties to assess the level of risk associated with a particular site.

- Factors of safety (against instability) be adopted for defined soil strength, groundwater and earthquake conditions (refer sections 6.7 and 6.8 of this paper). This requires a minimum FOS of 1.5 for design conditions and a lesser minimum FOS of 1.2 under extreme conditions.

- The use of geotechnical peer review by TLA's (or developers) be carried out as suggested in Table 2: Peer Review Requirements.

- When applying Section 36(2) of the Building Act, the responsibilities and liabilities need to be clearly defined between landowner and consultant and these should be written into the consultant's terms of engagement.
- The draft "Checklist for Stability Assessments" be adopted for normal practice by TLA engineers/approvers and geotechnical practioners throughout NZ.

- These guidelines be published in NZ Geomechanics News June 1998 and constructive comment be sought from the geotechnical community and Territorial Land Authorities throughout NZ.

9.0 APPLICABILITY

This research report has been prepared solely for the benefit of EQC as our client with respect to the particular brief given to us and data or opinions contained in it may not be used in other contexts or for any other purpose without our prior review and agreement.

10.0 ACKNOWLEDGEMENT

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22. Earthquake Commission Act (1993) - An Act to make provision with reference to the insurance of residential property against damage caused by certain natural disasters.

APPENDIX

Checklist for Stability Assessments

Extract: The Building Act 1991 - Section 36 (courtesy of NZ Geomechanics News, Dec 1994)

Extract: The NZ Building Code 1993 - Verification Method B1/VM4 (courtesy of NZ Geomechanics News, Dec 1994)

NZ Geomechanics News No. 48 (Dec.1994), "Stability Assessments for Land Development - Responses to Questionnaire"

Geotechnical Risk Associated with Hillside Development - Australian Geomechanics News Article, No. 10 (Dec 1985).

Extract: "Geotechnical Manual for Slopes" - Geotechnical Engineering Office, Civil Engineering Dept, Hong Kong Government (1994)

Table 2.1*- Guidance on Site Investigation
Table 5.1*- Recommended FOS for New Slopes
Table 5.2*- Typical Examples of Slope Failures (Risk to Life)
Table 5.3*- Typical Examples of Slope Failures (Economic Risk)
Table 5.4*- Recommended FOS for Existing Slopes

CHECKLIST FOR STABILITY ASSESSMENTS

FACTUAL INFORMATION

1. **INTRODUCTION**
   - ☐ Report prepared for who?
   - ☐ Site Location
   - ☐ Outline of proposed development[b]
   - ☐ Comment on need for earthquake assessment
2. **TOPOGRAPHY**
   - ☐ Outline current landform (slope shape, height gradient, irregularities, erosion, soil creep/terracettes)
   - ☐ Outline surface drainage patterns[b]
   - ☐ Review aerial photos
   - ☐ Comment on any previous earthworks
   - ☐ Comment on any existing instability[c]
   - ☐ Additional site features (e.g. vegetation/trees structures[b] retaining walls, roads/driveways, services)
3. **SITE HISTORY**
   - ☐ Outline current/previous landuse
   - ☐ Comment on previous siteworks[b]
   - ☐ Reference "District Hazard Map"/GIS
   - ☐ Comment on previous instability[c]
   - ☐ Performance of existing structures
   - ☐ Review aerial photos
   - ☐ Comment on previous contamination[c]
4. **GEOLOGY**
   - ☐ Describe geological setting
   - ☐ Refer to relevant maps
   - ☐ Geological influences on stability (e.g. bedding, weak materials, faults)
   - ☐ Describe seismic setting
5. **INVESTIGATIONS**
   - ▸ FIELD
     - ☐ Inspection by geotechnical specialist
     - ☐ Descriptions of soils/rock in borelogs (Ref.1)
     - ☐ Outcrop/cutting descriptions[c]
     - ☐ Record Extent of any cracking[c]
     - ☐ Other field tests (e.g. CPT, etc.)
     - ☐ Monitoring of ground movements[c]
     - ☐ Groundwater measurements and observations (seepage, subsurface erosion)[c]
   - ▸ LABORATORY
     - ☐ Outline tests undertaken
     - ☐ Summarise results
     - ☐ Previous testing in local area
6. **SUBSURFACE CONDITIONS**
   - ☐ Geological interpretation[c]
   - ☐ Summarise subsoil conditions, e.g. extent of fill[c] topsoil, nature and distribution of soils/rock
   - ☐ Describe soil strengths/density, likely behaviour - refer to tests and logs
   - ☐ Highlight weak/sensitive/loose soils or rock defects
   - ☐ Describe groundwater conditions, subsurface drainage, expected seasonal fluctuations

APPENDICES
- ☐ Borelogs, Testpit Logs, Logs of Exposures (Ref.1)
- ☐ Laboratory Results
- ☐ Specifications for Remedial Works/Fills
- ☐ Site Photos

INTERPRETATION/DISCUSSION

7. **SLOPE STABILITY (Ref. 2,3,4)**
   - ▸ ENGINEERING GEOLOGICAL ASSESSMENT:
     - ☐ Discuss site features
     - ☐ Discuss geological setting/influences[e]
     - ☐ Influence of rainfall/groundwater
     - ☐ Reasons for landform (local, regional)
     - ☐ Likely slope failure mechanisms
     - ☐ Potential for Instability
     - ☐ Effects of the development on slopes[f]
     - ☐ Consequence of instability
     - ☐ Empirical assessment (qualitative)
     - ☐ Risk rating applied[g]
     - ☐ State whether stability analyses are required
   - ▸ GEOTECHNICAL ENGINEERING ANALYSES
     - ☐ Geotechnical slope model correct?
     - ☐ Analytical method stated
     - ☐ Determination of critical section of slope
     - ☐ Assessment of strength parameters
     - ☐ Assessment of groundwater profile/rainfall
     - ☐ Back analysis of any existing failures
     - ☐ External loads due to the development
     - ☐ State need for seismic analysis
     - ☐ Normal FOS requirements:
       - Static (Design gwt) FOS $\geq$ 1.5
       - Static (Extreme gwt) FOS $\geq$ 1.2
       - Seismic (150 year EQ) FOS $\geq$ 1.2
     - ☐ Sensitive analyses for parameters required?
     - ☐ Results and comments
8. **GEOTECHNICAL EFFECTS OF DEVELOPMENT**
   - ☐ Slope stability risk increased or reduced?
   - ☐ Is the development feasible?
   - ☐ Need to drain slopes (surface/subsurface)?
   - ☐ Need to remove/upgrade fill?
   - ☐ Subsurface drainage beneath fills?
   - ☐ Need to retain slopes/secure rock faces?
   - ☐ Foundation conditions/requirements
   - ☐ Effect of stormwater/effluent disposal
   - ☐ Effect of service lines rupture (e.g. SW, sewer)
   - ☐ Effect of river/coastal erosion
   - ☐ Seismic effects on development and slope
   - ☐ Maintenance requirements for life of the development
9. **CONCLUSIONS AND RECOMMENDATIONS**
10. **STATEMENT BY GEOTECHNICAL ASSESSOR AS TO THEIR ABILITY & QUALIFICATIONS TO PREPARE THIS GEOTECHNICAL ASSESSMENT**

DRAWINGS/FIGURES
- ☐ Site Plan[d]: ☐ Borehole/Testpit Locations
  ☐ Outline of Proposed Development
- ☐ Site Engineering Geological Maps[d]
- ☐ Site Contours Maps[d] } Cuts and fills
- ☐ Cross Sections } indicated
- ☐ Geotechnical Model
- ☐ Stability Analyses Results

REFERENCES
1. Guidelines for the Description of Soils & Rock, NZ Geomechanics Society (1985)
2. Assessment of Slope Stability at Building Sites, BRANZ Study SR4, (1987)
3. Slope Stability in Urban Development, DSIR Series 122 (1981)
4. Stability of House Sites & Foundations, Earthquake & War Damages Commission, NZ Geomechanics Society (1980)
5. Land Assessment for Development Suitability, Burns & Farquhar, NZ Geotechnical Symposium (1996)

NOTES
(a) This checklist is intended as a guide for typical stability investigation & assessments for residential developments. There may be additional requirements for specifically difficult sites, large scale developments and regional hazards
(b) Indicate on site plan
(c) Indicate on site engineering geological map
(d) These plans/maps are best combined if possible
(e) Ref.3 provides a valuable outline of stability problems peculiar to selected areas of NZ
(f) Refer BRANZ document Fig 3 (ref.2 above), Stability House Sites and Foundations (ref. 4 above)
(g) See 6.6 -"Risk Rating", Design of Permanent Slopes for Residential Development, Crawford & Millar for EQC (1998)

Limitations and Restrictions on Building Consents

36. Building on land subject to erosion, etc.-

(1) Except as provided for in subsection (2) of this section, *a territorial authority shall refuse to grant a building consent* involving construction of a building or major alterations to a building *if*-

(a) *The land on which the building work is to take place is subject* to, or is likely to be subject to, *erosion*, avulsion, alluvion, falling debris, *subsidence, inundation, or slippage;* or

(b) *The building work itself is likely to accelerate, worsen, or result* in erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage of that land or any other property

unless the territorial authority is satisfied that adequate provision has been or will be made to -

(c) *Protect the land or building work or that other property* concerned from erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage; or

(d) Restore any damage to the land or that other property concerned as a result of the building work.

(2) *Where a building consent is applied for and the territorial authority considers that* -

(a) *The building work itself will not accelerate,* worsen, or result in erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage of that land or any other property; but

(b) *The land on which the building work is to take place is subject* to, or is likely to be subject to, erosion, avulsion, alluvion, falling debris, *subsidence*, inundation, or *slippage*; and

(c) The building work which is to take place is in all other respects such that the requirements of section 34 of this Act have been met-

the *territorial authority shall, if it is satisfied that the applicant is the owner in terms of this section, grant the building consent, and shall include as a condition of that consent* that the territorial authority shall, forthwith upon the issue of that consent, notify the *District Land Registrar* of the land registration district in which the land to which the consent relates is situated; and the District Land Registrar *shall make an entry on the certificate of title* to the land that a building consent has been issued in respect of a building on land that is described in subsection (1)(a) of this section.

(3) Where the territorial authority determines that the entry referred to in subsection (2) of this section is no longer required it shall send notice of the determination to the District Land Registrar who shall amend his or her records accordingly.

(4) *Where -*

(a) Any building consent has been issued under *subsection (2)* of this section; and

(b) The territorial authority *has notified the District Land Registrar in* accordance with subsection *(2)* of this section that it has issued the consent; and

(c) The territorial authority has *not notified* the District Land Registrar under *subsection (3)* of this section that it has determined that the entry made on the certificate of title of the land is no longer required; and

(d) *The building* to which the building consent relates later *suffers damage* arising directly or indirectly from erosion, subsidence, avulsion, alluvion, falling debris, inundation, or slippage or from inundation arising from such erosion, subsidence, avulsion, alluvion, falling debris, or slippage -

the *territorial authority* and every member, employee, or agent of the territorial authority *shall not be under any civil liability* to any person having an interest in that building on the grounds that it issued a building consent for the building in the knowledge that the building for which the consent was issued or the land on which the building was situated was, or was likely to be, subject to damage arising, directly or indirectly, from erosion, subsidence, avulsion, alluvion, falling debris, inundation, or slippage or from inundation arising from such erosion, subsidence, avulsion, alluvion, falling debris, or slippage.

(5) Where an application made by or on behalf of the Crown is such that, if the applicant were not the Crown, subsections (2) and (4) of this section would otherwise apply, the territorial authority, in approving any such application, shall notify the appropriate Minister and the Chief Surveyor for the land district in which the land is situated, and include with that notification a copy of the project information memorandum issued in respect of the building consent; and such notification shall be deemed to meet the requirements of this section.

(6) Where an application made by or on behalf of the owners of Maori land is such that, if the application were not in respect of Maori land, subsection (2) of this section would otherwise apply, the territorial authority, in approving any such application, shall notify the Registrar of the Maori Land Court, and include with that notification of a copy of the projecf information memorandum issued in respect of the building consent; and such notification shall be deemed to meet the requirements of this section.

(7) Where any notification is given pursuant to subsection (5) or subsection (6) of this section, the Chief Surveyor or the Registrar of the Maori Land Court, as the case may be, shall enter in his or her records the particulars of the notification together with a copy of the project information memorandum included with that notification.

(8) For the purposes of subsection (2) of this section, the term "owner" means the person having ownership of the fee simple of the land on which the building work is or has taken place.

VERIFICATION METHOD B1/VM4 FOUNDATIONS

2.0 SITE INVESTIGATION

2.0.1 The characteristics of the ground shall be assessed before the start of *construction* or any earthworks on a *building* site.

2.1 Preliminary investigation

2.1.1 The preliminary site assessment must address:

a) General land form, geology and any conditions likely to facilitate landslip, soil creep, shrinkage and expansion, or subsidence.

b) Available records of previous constructions, excavations, fillings, *drains* and concealed works, on and adjacent to the site.

c) History and behaviour of neighbouring *buildings*, and details of their foundation types, depths and loadings.

d) Potential for flooding (see also NZBC E1), and seasonal changes of soil characteristics.

e) Seasonal, tidal or other natural ground water changes.

f) Presence of corrosive soil and ground water, and effluents (see also F1/VM1).

2.2 Detailed investigation

2.2.1 The ground conditions at the *building* site shall be investigated to the extent necessary by test bores and excavations, inspection, laboratory and field testing of soil and rock samples, or by seeking the advice of a person with appropriate expertise and experience. The investigations shall provide sufficient data for the design of the *building*.

2.2.2 The description of the foundation material shall be recorded.

Comment:

A suitable method for describing soil and rock is contained in "Guide-lines for the field description of soils and rocks in engineering use" published by the New Zealand Geomechanics Society.

2.2.3 The site investigation record shall include a site plan showing the locations of the test bores and excavations.

3.2 Slope stability

3.2.1 Slope stability shall be analysed using unfactored loads. Slopes include unsupported earth faces, banks and vertical ground profiles.

Comment:

Work is underway on developing limit state designs for slope stability but is yet to be finalised.

Amd 2
Aug '94

3.2.2 Permanent slopes shall have a *factor of safety* against instability of no less than 1.5.

3.2.3 The *factor of safety* for temporary slopes shall be evaluated for each specific case, having regard to confidence in the soil and rock data and the consequence of failure.

STABILITY QUESTIONNAIRE INTRODUCTION

"Slope stability assessment as part of land development consents is well established in our country. However the geotechnical community is aware of difficulties between consultants and Territorial Authorities in agreeing on a consistent approach to stability assessments. The problems are exacerbated by the specification in the Building Code Approved Document of a Factor of Safety of 1.5 for land stability, without any explanation or qualification. This is not a mandatory requirement and alternative solutions may be accepted by Territorial Authorities. Building consents are also issued under Section 36(2) of the Building Act. However, each Authority seems to have its own interpretation of both the application of the factor of safety and the application of Section 36(2) to land stability, and much time has been wasted debating the issues on an ad hoc basis."

The above paragraph summarises some of the difficulties with slope stability in land development. Geomechanics News has initiated a discussion of the subject by sending a letter and questionnaire to every Territorial Local Authority in NZ, the main geotechnical and engineering geological consultants, and other geotechnical persons. It was decided to solicit the views of Territorial Authorities, companies and practices involved in stability assessments, rather than solicit the views of individual members of the Society. Some companies and individuals may have been missed out unintentionally. If you are one and wish to make your views known then please do so by setting them out in a letter to the editor which will be published in the next issue.

The letter and questionnaire are published below together with a summary of the responses. Responses were received from 20 of the 73 Territorial Authorities, and 29 of the Consultants and others. The aim of this first step in the discussion is to publish the approaches to stability used by different groups and to encourage further contributions and debate of the issues in future issues of Geomechanics News. The Society will use the discussion to draw together a common approach to slope stability assessments for Territorial Authorities and Consultants to use. The next Symposium in February 1996 on "Geotechnical Issues in Land Development" may provide a suitable forum to finalise matters.

The responses to the questionnaire are summarised and comments published where respondents gave permission. Most respondents gave permission to publish comments and also their names. Some included letters and additional information which are published.

Responses are published as received and may not necessarily represent the views of all of a particular organisation or company. It is expected that views may be modified upon publication of a wide variety of opinions. The questionnaire was not intended to be comprehensive but rather to open up the subject of stability assessments. Therefore some responses may have been constrained by the particular questions posed.

COVERING LETTER AND QUESTIONNAIRE

Dear Sir

SLOPE STABILITY IN LAND DEVELOPMENT

Slope stability assessment as part of land development consents is well established in our country. However the geotechnical community is aware of difficulties between consultants and Territorial Authorities in agreeing on a consistent approach to stability assessments. The problems are exacerbated by the specification in the Building Code Approved Document of a Factor of Safety of 1.5 for land stability, without any explanation or qualification. This is not a mandatory requirement and alternative solutions may be accepted by Territorial Authorities. Building consents are also issued under Section 36(2) of the Building Act. However, each Authority seems to have its own interpretation of both the application of the factor of safety and the application of Section 36(2) to land stability, and much time has been wasted debating the issues on an ad hoc basis.

The Geomechanics Society, which embodies the geotechnical community in NZ, is initiating a discussion of the subject through its newsletter (Geomechanics News). You are invited to fill out the attached questionnaire and return it to the editor of Geomechanics News. Territorial Authorities are invited also to send a copy of their policy for slope stability assessments or a letter outlining their policy. Consultants and others are invited also to send a letter outlining their approach to slope stability assessments particularly as they apply to land development.

It is intended to summarise the results of the questionnaire and publish any comments made (with your permission). A copy of the newsletter will be sent to you if you do not already receive one.

This letter is being sent to every Territorial Authority in NZ, the main geotechnical and engineering geological consultants, and other geotechnical persons. The society will use the results of this questionnaire to draw together a common approach to slope stability assessments for Territorial Authorities and consultants to use. **Please return your questionnaire to the editor by 11 November.**

Please phone me on 0-9-379 1200 if you need clarification of any aspects.

Yours faithfully,

GEOFFREY FARQUHAR
EDITOR GEOMECHANICS NEWS

SLOPE STABILITY ASSESSMENTS FOR LAND DEVELOPMENT QUESTIONNAIRE

1. From whom are assessments acceptable?

   □ Registered Engineer (civil engineer) □ Registered Engineer (geotechnical specialist)
   □ Engineering Geologist □ Firm of Engineering Geologists
   □ Firm of Consulting Engineers (no geotechnical specialist in firm)
   □ Firm of Consulting Engineers (geotechnical specialist in firm)

   Do you have any comments? .....

2. Is an engineering geological assessment of stability (i.e. a non analytical approach based on study of the previous performance of the slope) acceptable?

   □ Yes □ No □ Sometimes (please give circumstances) .....

3. Is a numerical slope stability analysis that produces a factor of safety always necessary?

   □ Yes □ No (please give circumstances) .....

4. A minimum factor of safety of 1.5 is acceptable for the following conditions :

   Groundwater profile : □ High □ Average □ Low
   Soil strength : □ Upper bound □ Average □ Lower bound

   Please give any comments ......

5. Is strength testing of soils required to establish strength parameters for each specific site?

☐ No ☐ Yes ☐ Sometimes (please specify) .....

Can parameters established by testing of similar soils from other sites be used?

☐ No ☐ Yes (please specify) .....

6. What factor of safety is required for earthquake loading?

....

7. What earthquake return period is required?

....

8. Is a factor of safety less than 1.5 acceptable for extreme conditions (excluding earthquake)?

☐ No ☐ Yes (please specify the extreme conditions and factors of safety) .....

9. If drainage works are used to stabilise land, should their failure to operate be considered?

☐ No ☐ Yes (please give circumstances) .....

10. What role does peer review of assessments play? .....

11. How is Section 36(2) of the Building Act applied? .....

12. Please make any other comments .....

13. Name of Territorial Authority, company or person whose views are represented in this questionnaire .....

14. Can the comments you have made to the various questions be published in Geomechanics News?

☐ Yes ☐ No

If yes, can your name be given alongside them?

☐ Yes ☐ No

If no, can your comments be identified as "Territorial Authority" or "Other"?

☐ Yes ☐ No

15. If you are attaching a letter setting out either a TA policy or your approach to stability assessments, can this be published as is, i.e. photocopied?

☐ Yes ☐ No ☐ Not applicable

If no, can the text of the letter be published and identified as from a "Territorial Authority" or "Other"?

☐ Yes ☐ No

QUESTION (1): From whom are assessments acceptable?

Summary of Results	Territorial Authority	Other		
		Geotechnical Engineers	Engineering Geologists	Firm of Engineers & Geologists
Registered Engineer (civil)	12	3	3	0
Registered Engineer (geotechnical specialist)	18	18	6	5
Engineering Geologist	12	12	6	5
Firm of Engineering Geologists	10	11	6	4
Firm of Consulting Engineers:				
Without geotechnical specialist	9	4	1	0
With geotechnical specialist	14	14	6	4
TOTAL NO. of Questionnaire Replies	**21**	**18**	**6**	**5**

Comments:

	Would accept assessments from ...	Comments	Identification
Territorial Authorities	geotechnical specialists, engineering geologists or firms with these staff	**On difficult sites, Council usually seeks its own assessment from a third party (Geotechnical Specialist)**	Territorial Authority
	all options presented in questionnaire	**Nelson City Council has been a leader in NZ for requiring stability certificates with new subdivisions. We require a certificate from an experienced geotechnical engineer, however, on larger lots or more stable land, certificates can with prior approval be provided by registered civil engineers.**	Nelson City Council
	all options presented in questionnaire	**Acceptance of any of the above would depend on the degree of difficulty, risk and assessed need for competency**	Territorial Authority
	registered (civil) engineer and Firm of Consulting Engineers with no geotechnical specialist in firm	**There are no local "geotechnical" engineers and generally a letter from a Registered Engineer is accepted by WDC regulatory people.**	Wanganui District Council

	Would accept assessments from ...	Comments	Identification
	registered engineer (geotechnical specialist)	see attached letter	Waitakere City Council, senior subdivision engineer (personnel view)
	all options presented in questionnaire	Council's Code of Practice requires a Registered Engineer experienced in soils engineering or such other person as the Council may specifically approve upon the recommendation of Council's Engineer.	Territorial Authority
	all options presented in questionnaire	It would depend on the nature, magnitude, and risk associated with the work. If it were a large job with considerable financial risk, a firm of consulting engineers with geotechnical specialists in the firm would be required.	Bruce Dobson, Chief Engineer, Ruapehu District Council
	geotechnical specialist only	We prefer reports from forms specialised in geotechnical engineering	Territorial Authority
Geotechnical Engineers	geotechnical specialists (a firm or alone) or engineering geologist)	The question is case specific, and probably more important to be person specific. Individuals need to work within their sphere of expertise.	C.J. Newton
	geotechnical assessments from geotechnical specialists or engineering geologists whether in a firm or sole practitioners)	Slope stability assessments are a specialty science and should only be carried out by specialists in this field	Mark Mitchell
	Registered Engineer (geotechnical specialist) whether in a firm or sole practitioner	Engineering geologist (or firm) if it is the first level of assessment only (geological/ geomorphological assessment) that is required (see my response to question 2). (However, even then there may be engineering issues that need to be evaluated with the judgement as to satisfactory performance, in which case we need an engineer in the picture somewhere).	Prof. M.J. Pender
	geotechnical specialist engineers whether in a firm or sole practitioners	Often subjective judgements required and reliability of assessment is dependent on the experience of the person undertaking the assessment, and in case of a larger firm, the senior reviewer of the assessment	A.W. Smith, Jackson Clapperton & Partners

	Would accept assessments from ...	Comments	Identification
	registered engineer (geotechnical specialist) or engineering geologist	**Only accepted by NCC (Nelson City Council) subject to prior approval of credentials**	Paul Russell, Royds Consulting Nelson
	geotechnical specialists and possibly engineering geologists, whether in a firm or sole practitioners	**Whether the engineer is registered or not is irrelevant; the important thing is being properly qualified and experienced in the geotechnical field. Some engineering geologists would be acceptable, but others would not**	Laurie Wesley
	geotechnical specialists whether sole practitioners or in a firm	**The assessor must be an individual with appropriate specialist experience**	D.K. Taylor
	all options presented in questionnaire	**As with all engineering judgement the degree of specialisation needs to reflect the degree of risk/difficulty and engineering registration puts limits on how registered engineers approach their work.**	Peter Geddes, Hawthorn Geddes - Civil and Structural
	geotechnical specialists or engineering geologists, whether in a firm or sole practitioners	**We are concerned at the number of slope stability assessments carried out by unqualified people**	Soil & Rock Consultants
	geotechnical specialists or engineering geologists whether in a firm or sole practitioners	**Provided assessment is carried out/approved/ reviewed by the geotechnical specialist**	Brian Patterson
	geotechnical specialists or engineering geologists whether in a firm or sole practitioners	**Slope stability is a specialist science and as such should be dealt with by a specialist**	Babbage Consultants Ltd - N.S. Luxford
	geotechnical specialists or engineering geologists whether in a firm or sole practitioners	**Engineering geologist would be acceptable if registered under a recognised system similar to engineer's registration or member of recognised institution. Should utilise specialist unless straightforward site**	Fraser Thomas Ltd

	Would accept assessments from ...	Comments	Identification
Engineering Geologists	all options presented in questionnaire except a firm of consulting engineers without geotechnical specialist	Assessments should be from people with appropriate expertise	R.D. Beetham
	all options presented in the questionnaire	I have ticked all boxes simply because it is unprofessional for anyone to operate outside their field of expertise. Under some circumstances, any one of the above could carry out a suitable assessment, however that is defined	Dr D.H. Bell
	all options presented in the questionnaire except a firm of consulting engineers without a geotechnical specialist	Not necessarily any of the above unless done by suitably qualified and experienced professionals	Independent Self Employed Consultant
	geotechnical specialists or engineering geologists whether in a firm or sole practitioners	Firm of engineers with an engineering geologist or geotechnical engineer should be acceptable so long as report is reviewed/ written by the geotechnical engineer or engineering geologist with required expertise	Other
Firm employing both geotechnical engineers and engineering geologists	geotechnical specialists or engineering geologists whether from a firm or sole practitioner	Assessments are of a specialist nature and it is not appropriate for a generalist practitioner (unless there is specific local experience)	D.N. Jennings, Works Consultancy Services (Hamilton)
	geotechnical specialists or engineering geologists whether in a firm or sole practitioners	Slope stability assessments require specialist skills and therefore should only be undertaken by appropriately qualified and experienced people	Worley Consultants Ltd
	geotechnical specialists or engineering geologists whether in a firm or sole practitioners	A multi-disciplinary approach is preferable.	Tonkin & Taylor Ltd (Auckland, Wellington, Christchurch & Dunedin)

QUESTION (2) **Is an engineering geological assessment of stability (i.e. a non-analytical approach based on study of the previous performance of the slope) acceptable? (If "No", give circumstances).**

Summary of Results	**Territorial Authority**	**OTHER**		
		Geotechnical Engineers	**Engineering Geologists**	**Firm of Engineers & Geologists**
YES	4	6	5	1
NO	4	0	0	1
Sometimes	12	13	4	3
TOTAL NO. of Replies	**20**	**18**	**6**	**4**

Comments:

	Answer (Yes/No/ Sometimes)	Comments	Identification
Territorial Authorities	Sometimes	**In areas of the city known not to experience difficulties over the last 20 or so years.**	Territorial Authority
	Sometimes	**The normal situation would be a non-analytical approach as only two or three firms provide the certificates and they have done the ground work for the Nelson soils and know how they perform in the conditions.**	Nelson City Council
	Sometimes	**Particularly where there is a low degree of risk**	Territorial Authority
	No	**(see attachment - letter)**	Personal View - Waitakere City Council Senior Subdivision Engineer
	Sometimes	**In addition to the factors outlined in question 1, the degree of certainty that we have with regard to the problems in a particular locality would influence the judgement.**	Bruce Dobson, Chief Engineer, Ruapehu District Council

	Answer (Yes/No/ Sometimes)	Comments	Identification
	Sometimes	**This entirely depends on the type of the slope i.e. slope angle, slope height, soil strength information. Example:** **1. A slope of 14° or less in weathered Waitematas or volcanic residuals may only need an engineering geological assessment i.e. boreholes to confirm soil strength parameters.** **2. A flat site in developed region may not even need a geotechnical assessment provided that there are no other evidence of unsuitable soil such as uncontrolled fill or peat.**	Territorial Authority
Geotechnical Engineers	Sometimes	**In many situations, clear cut decisions can be made on unstable or stable land, however, it is the boreline case that need specialist involvement**	C.J. Newton
	Sometimes	**Particularly to provide <u>general</u> guidelines for land zoning**	Mark Mitchell
	Sometimes	**1. Uniform geology** **2. history of performance on similar nearby areas** **3. availability of nearby areas for inspection**	Bruce Horide
	Sometimes	**Where formation is variable and characteristic cannot be easily modelled (i.e. not deep uniform formation) with easily measurable characteristics)**	Other
	Sometimes	**I like to think of a hierarchy of three levels: geomorphological (geological?) assessment, stability assessment, and stability analysis. This has a progression of increasing depth (an expense) of investigation. For straightforward applications (in an area where there is no history of ground instability) a geomorphological assessment will be adequate.**	Prof. M.J. Pender
	Sometimes	**Dependent on ground slope, nature of assessment and proposed development non-analytical approach may be suitable for a preliminary appraisal, but any major development should be assessed by testing and analysis**	A.W. Smith, Jackson Clapperton & Partners
	Sometimes	**Usually providing the proposed development is not worsening the situation or field evidence from adjacent sites can be applied**	Paul Russell, Royds Consulting Nelson
	Yes	**But not based entirely on the previous performance of the particular slope. Performance of other slopes in the same material would come into the assessment**	Laurie Wesley

	Answer (Yes/No/ Sometimes)	Comments	Identification
	Sometimes	As a means of zoning land with various degrees of risk and to indicate the extent of subsequent investigations, assessment or analysis appropriate to specific sites/areas.	D.K. Taylor
	Yes	Where instability is manifested, then a more rigorous approach would be needed.	Peter Geddes, Hawthorn Geddes Civil & Structural
	Sometimes	A qualitative assessment of slope stability is an essential part of the overall assessment that should be carried out in all cases. We consider the qualitative assessment to be of major, if not greater, importance than the quantitative (or analytical) assessment.	Soil & Rock Consultants
	Sometimes	Normally a study of previous performance of the slope is only part of the engineering geological assessment. If the slopes are not going to be modified or natural drainage interfered with, a simple study of slope movement history is adequate provided the nature and general performance of materials are acceptable.	Brian Patterson
	Sometimes	Only rarely for reasons given in (comments to) Question 3	R. Melville-Smith, Foundation Engineering Ltd
	Yes	Where stresses on slope are undergoing negligible future changes	N.S. Luxford, Babbage Consultants Ltd
	Sometimes	(a) When the slope is obviously unstable; or (b) When slope is shallow and obviously stable, based on study of past performance; (c) When done in conjunction with a numerical analysis	Fraser Thomas Ltd

	Answer (Yes/No/ Sometimes)	Comments	Identification
Engineering Geologists	Yes/Sometimes	Sometimes it is the most realistic method for assessing stability - particularly if there is little subsurface investigations data.	R.D. Beetham
	Yes/Most Times	Design by precedent is entirely acceptable in all cases where it can be demonstrated that there is no existing slope instability, and where all codes etc., are complied with in relation to long-term site stability. Where active ground movement is occurring some form of analytical approach is probably required, but again I would caution against total reliance on the numbers obtained. Without an accurate site model and correct input parameters a quantitative analysis can be misleading	Dr D.H. Bell
	Sometimes	Analogy can be drawn (similar geological foundations and loading conditions). NB: engineering geological assessments do not have to be non-analytical at definition	Independent Self Employed Consultant
	Yes/Sometimes	Should be used in conjunction with analytical methods to provide a better assessment of a site and enable incorporation of observations/ measurements in any back analysis of a slope	Other
Firms employing both geotechnical engineers and engineering geologists	No	Little confidence can be given to an engineering geology approach if the mechanisms of failure are not understood and similar little confidence can be given to an analytical analyses without a realistic geological model. The quantum of each is site selective, i.e.: (i) If the slope is in weathered soil/rock with a stability condition that is structurally controlled there is little point in obtaining a safety factor from a series of soil test strength parameters and software that assumes an uncontrolled failure surface. The analytical analyses must be limited to the topography and the soil/rock structure conditions and a "worst case" model of these conditions "back-analysed" to obtain an appreciation of the likely range of strength properties. The analysis may be a relatively simple manual type. These values can then be used for the development evaluation where the topography is to be altered.	Glyn R.W. East, Works Consultancy Services Ltd, (Auckland)

	Answer (Yes/No/ Sometimes)	Comments	Identification
		(ii) Likewise if the slope is in relatively homogeneous and monotonous clay type soils or a fill/embankment over weak soils there is little the geology can aid to the evaluation apart from identifying a non-structurally controlled soil. In this case, an analytical analysis must be carried out on strength tested soils. **My experience is such that the former is the more typical in the land development situation.**	
	Sometimes	• **where there is clear evidence of geological conditions and long term stability; and** • **where there are no proposed changes in the environmental conditions (e.g. run-off, soakage, loading of slopes)**	D.N. Jennings, Works Consultancy Services Ltd (Hamilton)
	Sometimes	**Where careful assessment of slope angle, outcrops and borehole information by an experienced person suggests stability is unlikely to be critical**	Engineering Geology Ltd
	Yes	• **generally, the "past performance" approach should be the prime assessment procedure. Obviously this requires an appropriately skilled assessor.** • **numerical analysis may be warranted if appropriate data is available and/or engineering works are contemplated to decrease unacceptable risks. The analyses can help assessment of the degree of improvement**	Worley Consultants Ltd
	Sometimes	**Only in situations where there is <u>no</u> precedent of instability and risk to structures and life is low. In all other situations, subsurface investigation is required to establish the soil strength profile and groundwater regime, so that it can be compared with situations where instability has occurred.** **The Engineering Geologist approach is likely to be at least as useful/necessary as pure analysis, and an analytical approach alone is not acceptable. The engineering geologist approach should be the first stage of any assessment, i.e. should precede a numerical analysis - however, only as a stand-alone report where no instability is identified.**	Tonkin & Taylor Ltd (Auckland, Wellington, Christchurch & Dunedin)

QUESTION (3): Is a numerical slope stability analysis that produces a factor of safety always necessary?

Summary of Results	Territorial Authority	OTHER		
		Geotechnical Engineers	Engineering Geologists	Firm of Engineers & Geologists
YES	5	3	1	1
NO	14	15	6	4
TOTAL NO. of Replies	19	18	7	5

Comments:

	Answer (Yes/No)	Comments	Identification
Territorial Authorities	No	As per comments to question 2	Territorial Authority
	No	Usually only require such an analysis when structures are involved or it involves more steep or difficult hillsides	Nelson City Council
	No	Depends on the history, topography and geology of the site	Territorial Authority
	No	Where it can be demonstrated that a particular treatment, including a stable slope, has proved successful in identical circumstances	Territorial Authority
	No	District Council takes the view that the specialist would carry out the necessary level of investigation appropriate to the site	Territorial Authority
	No	Generally not required and never given if ever requested	Wanganui District Council
	No	Surface slope - slight Depth of weathered material - not deep G.W.L. - deep and not able to rise to surface Borehole Investigation - shows high shear strengths - strength rising with depth	Waitakere City Council, Senior Subdivision Engineer - Personal view

	Answer (Yes/No)	Comments	Identification
	No	The factors outlined in (responses to questions) 1 and 2 would be taken into account.	Bruce Dobson, Chief Engineer, Ruapehu District Council
	No	For slopes such as that mentioned in (response to) question 2.	Territorial Authority
Geotechnical Engineers	Yes	The numerical answer is the combination of all the inputs and it will show up any oversights that may have occurred	C.J. Newton
	No	When soil strengths are relatively high, experience will indicate that adequate factors of safety occur	Mark Mitchell
	No	Underlying rock with erodible surface layers causing slab failures cannot be easily assumed	Other
	No	"Calculated" factors of safety are quite misleading without appropriate investigation. The numbers are worthless (they can even create a misleading air of "scientific" rigour) if a proper and thorough investigation has not been done. Generally the appropriate investigation is too expensive. Thus a stability assessment is about as far as one could expect to go.	Prof. M.J. Pender
	No	It is sufficient to comply with the performance provisions of clause B1-Structure, i.e. clauses B1.3.1, 3.2 and 3.3	Paul Russell, Royds Consulting Nelson
	No	I believe the production of a safety factor by numerical analysis would contribute about 5% to the data pool on which a slope stability assessment would, or should, be based	Laurie Wesley
	No	Not necessary if an engineering geologist's, or experienced geotechnical engineer's, assessment of the area is that the risk of instability is low	D.K. Taylor
	No	(Not necessary when) knowledge of local conditions previously experienced	Other
	No	See (comments to question 2)	Peter Geddes, Hawthorn Geddes Civil & Structural

	Answer (Yes/No)	Comments	Identification
	No	Slope stability analysis only provides useful and reliable results if the geology and soil profiles, groundwater levels and pressures, and soil strength parameters are all reasonably well known. In many circumstances, the investigation required to determine this information is uneconomic, and unnecessary, unless stability is seen as critical from other aspects of the site assessment.	Other
	No	The qualitative assessment considered in conjunction with the development considerations may often be sufficient, e.g.: • site development (retaining walls/basements/etc) provide the necessary stabilisation • thin veneer of weathered residual soil on hard less weathered base • well drained side slope of spur or ridge, etc.	Soil & Rock Consultants
	No	Generally an investigation leading to determination of a factor of safety is not required unless there is a serious concern about the stability, and the nature and size of the development warrants it	Brian Patterson
	No	Nearly always, but sometimes the slope geometry and/or the shape of the failure plane makes computer analyses unrealistic. I like to run analyses to test sensitivities to groundwater levels and to changes in soil properties	R. Melville-Smith, Foundation Engineering Ltd
	No	Many situations dealing with natural soils where ground strengths vary considerably are best assessed using regional experience, careful/detailed site inspection and review of existing data such as air photos and geological maps	N.S. Luxford, Babbage Consultants Ltd
	No	(a) When the slope is obviously unstable (b) When slope is shallow and obviously stable, based on study of past performance	Fraser Thomas Ltd
Engineering Geologists	No	Some slopes are too complex for numerical analysis to be meaningful	Riddolls & Grocott Ltd
	No	Some analyses are quite inappropriate because of lack of data, etc.	R.D. Beetham

	Answer (Yes/No)	Comments	Identification
	No	As noted above there is no requirement for quantitative analysis in situations where existing stability is maintained, and the associated costs of obtaining "correct" site data cannot be justified. Even where existing slope stability is identified it will not always be necessary to analyse slope stability quantitatively as s36(2) allows for approval provided that stability is not worsened by the development. In my view, qualitative (i.e. not quantitative) assessment is justified in the great majority of cases.	Dr D.H. Bell
	No	As (per comment to Question 2). Also probabilistic based analysis may be preferable	Independent self employed consultant
	Yes	Useful in providing a benchmark, however, every specialist will do it slightly differently. Should still only be used as an indication rather than as it is currently assumed to be an exact answer	Other
Firm employing both geotechnical engineers and engineering geologists	Yes	Some type of numerical analyses is always necessary for an appreciation of the stability conditions and any methods to improve the situation. If the topography is to be altered, there is no way a terrain evaluation without some analytical input can satisfy any stability criteria (on the assumption that the slope in question is to be steepened or loaded). As mentioned (in my response to question 2), this analysis may be confined to "back-analysis" or may be a relatively simple manual type	Glyn R.W. East, Works Consultancy Services (Auckland)
	No	Where the slope is obviously stable (based on known geology, nature of development, and previous experience/analysis in similar situations) - c.f. (answers to question 2).	D.N. Jennings, Works Consultancy Services Ltd (Hamilton)
	No	Only required in cases where an experienced judgement suggests that stability could be critical or to check remedial works necessary to improve an existing instability situation.	Engineering Geology Ltd
	No	See comments for (question 2). In addition, the analytical approach, particularly sensitivity analyses, can be useful to assess relative risk	Worley Consultants Ltd

	Answer (Yes/No)	Comments	Identification
	No	**(Refer comments for Q.2). Where there is a significant risk to life or structures and/or there is a precedent of instability (i.e. landslips in similar materials or similar slopes) and/or where the slope is to be modified, i.e. cuts, fills, retaining structures, surcharge, raising of groundwater levels. Very often it is not possible to determine parameters and geological model sufficiently accurately to warrant numerical analyses in which case analysis can show improvement by proposed works.**	Tonkin & Taylor Ltd (Auckland, Wellington, Christchurch and Dunedin)

QUESTION (4): A minimum factor of safety of 1.5 is acceptable for the following conditions:

Summary of Results	Territorial Authority	OTHER		
		Geotechnical Engineers	Engineering Geologists	Firm of Engineers & Geologists
Groundwater Profile:				
High	2	4	1	3
Average	8	6½	0	2
Low	0	2½	1	0
Soil Strength:				
Upper Bound	1	½	½	0
Average	10	9½	½	2
Lower Bound	0	2	0	3
TOTAL NO. of Replies	**18*1**	**18*2**	**6*3**	**5*4**

* Notes:

1. 8No. Territorial Authority respondents commented that for these conditions they rely on independent specialist advice

2. 2No. respondent stated these conditions are site specific
   2No. respondents replied "don't know" or "didn't understand the question"
   3No. respondents stated a sensitivity analysis is required

3. 3No. respondents stated these conditions are site specific
   1No. respondent stated a sensitivity analysis is required
   1No. respondent stated disagreement with options presented

4. 2No. respondents stated these conditions are site specific

Comments:

	Answer		Comments	Identification
	GWT	Soil Strength		
Territorial Authorities	-	-	**This is a site specific issue, general answer not appropriate**	Territorial Authority
	Average	Average	**We have no guidelines on this issue at present and the answer given is intuitive**	Territorial Authority
	-	-	**Act on recommendations of consulting engineer**	Territorial Authority
	-	-	**Refer (comments to question) 3 and (question) 12**	Territorial Authority

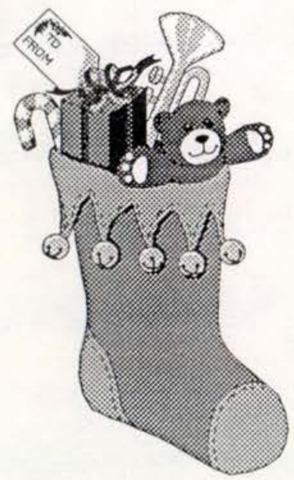
	Answer		Comments	Identification
	GWT	Soil Strength		
	-	-	Refer (comments to question) 3	Wanganui District Council
	-	-	Shear vane tests and boreholes done at time of subdivisions. Registered covenants placed against title if necessary.	Territorial Authority
	Average	Average	Probably of more importance would be the extent to which we could be satisfied with the consistency of the groundwater profile and soil strengths. If there was a high degree of (precision) and low financial risk a factor of safety of 1.5 would probably be acceptable	Bruce Dobson, Chief Engineer, Ruapehu District Council
	-	-	See attachment (personnel view in letter from WCC Senior Subdivision Engineer)	Waitakere City Council Senior Subdivision Engineer - personal view
	High	Average	The slope stability analysis is carried out for realistic maximum ground water level and agreeable realistic values of c′ and ϕ'. The realistic values of c′ and ϕ' should be either established from laboratory tests or estimated from in-situ tests such as shear vane reading in a test bore. The groundwater level should be considered saturated unless hydrological evidence is produced to justify a lower level.	Territorial Authority
Geotechnical Engineers	Low	Average	Need to ensure groundwater remains low and the failure mass is relatively small. Large ancient landslides are unlikely to obtain factors of safety of 1.5	C.J. Newton
	Average	Average	If you are working with lower bound soil strengths, you may be able to accept a FS of 1.3, particularly if the soil strata is well established with test borings, etc.	Mark Mitchell
	-	-	Depends on the application and the site conditions. The consequences of failure, the uncertainty in the groundwater conditions, how much local knowledge is available about the soil, the variability of the soil deposit (e.g. volcanic worse than sedimentary).	Prof. M.J. Pender

	Answer		Comments	Identification
	GWT	Soil Strength		
	Average	Average	Geotechnical assessment and design should be moving towards (say) "10 percentile" strengths and load factors as used in structural design and NZS 4203!	Bruce Horide
	-	-	Load factors define ultimate state ϕ factors materials (NZS 4203 1992)	Other
	Average	Average	Use limit state. For groundwater factor depends on "permanency" of profile. Temporary conditions could use FS 1.3	Paul Russell, Royds Consulting Nelson
	-	-	Whether it is acceptable depends on how detailed the site investigation has been, and how carefully the samples for $c'\phi'$ measurements have been selected etc.	Laurie Wesley
	High	Average	Reliance on analysis may lead to equally misleading results as reliance on engineering assessment. Both approaches need to be made as appropriate	Peter Geddes, Hawthorn Geddes (Civil & Structural)
	Average	Average	Factors of safety can only be realistically used if a sensitivity analysis is made for variations in parameters so that a judgement can be made as to whether average values are unduly conservative, or optimistic	Other Engineers
	High	Average	High GWT - reasonably regular seasonal event. Strength parameters - not easily defined re Upper, average, lower for different soil deposits. Computer analyses allow sensitivity of slope stability to variations in strength (particularly c') to be investigated	Soil & Rock Consultants
	Average	Average	The requirement to determine a minimum factor of safety for every site assessment is unnecessary and unrealistic. I suggest that there will be only a few sites that require sufficient investigations and lab tests etc., to obtain a realistic and meaningful factor of safety determination	Brian Patterson
	Average	Average	See (comments to question) 12	N.S. Luxford, Babbage Consultants Ltd

	Answer		Comments	Identification
	GWT	Soil Strength		
Engineering Geologists	Low	Upper bound/Av	Very conservative requirement for many hill areas	Mark Yetton, Geotech. Consulting
	-	-	This question pre-supposes that a minimum factor of safety is a pre-requisite. The use of a minimum safety factor (regardless of the conditions) leads to the possibility for manipulation of the input data to comply with standards	Riddolls & Grocott Ltd
	-	-	A factor of safety of 1.5 would be very conservative in some conditions. A factor of safety has to be tailored for the particular problem and knowledge of conditions	R.D. Beetham
	-	-	I don't agree with any (of the groundwater or soil strength options presented). I consider that a factor of safety of 1.5 is too conservative under almost all conditions, and it therefore becomes highly debatable as to whether or not the analysis should be carried out under worst case conditions. My approach would be to consider a factor greater than 1.0 for the worst case conditions likely within the design life of the structure, but only of course in situations where a quantitative analysis is deemed necessary.	Dr D.H. Bell
	-	-	Extremely sensitive sites or structures, or where failure modes/mechanisms/input parameters are uncertain and have not been properly accommodated in the analysis	Independent Self Employed Consultant
	High	-	1. Groundwater: each site needs to be treated separately and potential for development of a high groundwater table addressed, e.g.: ridge crest or slope toe site. This blanket requirement for saturated conditions assessment is not always realistic. However, by not doing so (it) makes it more difficult for Councils to review a report. 2. Where strengths are very high, it best to do some back analyses to assess realistic soils parameters for the assessment. Where strengths are low, it is similarly as important. Basically, each site requires specific assessment to address constraints.	Other

	Answer		Comments	Identification
	GWT	Soil Strength		
Firm employing both geotechnical engineers and engineering geologists	High	Lower Bound	Reasonable cf 4402 gw for 100 yr return period. However, for extreme parameters FS=1.2 would be acceptable. The factor of safety adopted needs to reflect: • the level of knowledge (e.g. estimate v measured gw and strength parameters) • hazard and risk (cf proposed development) A more rational approach would reflect the Hong Kong Geotechnical Manual for slopes approach (see attached extract) i.e. a graduated factor of safety for input parameters and hazard.	D.N. Jennings, Works Consultancy Services Ltd (Hamilton)
	Average	Average	"Normal acceptable practice" suggests that low probability events can have a lower factor of safety reflecting either transient, long return period, or lower bound conditions	Worley Consultants Ltd
	High	Lower Bound	With proviso that: (a) the SF > 1 with the appropriate pseudo horizontal seismic force for the site; and (b) the SF >1 with maximum possible groundwater profile What is the safety factor of a slope? Apart from man-made structures or perhaps embankment over weak soil any first order prediction analyses of a factor of safety must be viewed with suspicion within the normal bounds of field and laboratory testing and the precision of the geological model. It would be more appropriate that there was a qualified graduated scale for: (a) Level of knowledge; and (b) The hazard risk of failure. In some cases, this may require a SF >1.5.	Glyn R.W. East, Works Consultancy Services Ltd (Auckland)

	Answer		Comments	Identification
	GWT	Soil Strength		
	High	Lower Bound	**A FOS of 1.5 should be applied under soil/rock and groundwater conditions which can reasonably be expected to occur in the lifetime of the development, (100-150 years), i.e. does not necessarily mean maximum credible groundwater condition or groundwater at the ground surface.** **The factor of safety should depend on degree of confidence in the model and the design parameters.** **If investigation or monitoring of groundwater levels is carried out to prove very wet winter conditions, then these should be adopted along with FOS=1.5.** **Consequences of failure should also be addressed where determining FOS, i.e. if low consequence of failure then FOS > 1.3 could be used, e.g. rural property and potential failure not over property boundaries. For urban works FOS > 1.5 suitable for design conditions and FOS > 1.2 for potential failure of drainage systems and extreme events of full saturation (if this is not the design condition) and earthquake.**	Tonkin & Taylor, (Auckland, Wellington, Christchurch & Dunedin)



QUESTION (5):

Is strength testing of soils required to establish strength parameters for each specific site? (If "Sometimes", please specify)

Summary of Results	Territorial Authority	OTHER		
		Geotechnical Engineers	Engineering Geologists	Firm of Engineers & Geologists
YES	4	3	0	0
NO	7	3	1	0
Sometimes	9	11	4	5
TOTAL NO. of Replies	**20*1**	**18**	**5**	**5**

Notes: *1 2No. respondents seek specialist advice

Can parameters established by testing of similar soils from other sites be used?
(If "Yes", please specify)

Summary of Results	Territorial Authority	OTHER		
		Geotechnical Engineers	Engineering Geologists	Firm of Engineers & Geologists
YES	14	17	4	5
NO	5	0	0	0
TOTAL NO. of Replies	**20*1**	**18**	**4**	**5**

Notes: *1 1No. respondent considers this question is not applicable

Comments:

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	2nd Part Yes/No		
Territorial Authorities	No	Yes	(2nd Part): Provided they are of a similar nature	Territorial Authority
	Sometimes	Yes	(1st Part): Depends on the location of the site and how it is intended to be developed (2nd Part): Where soil type is similar then parameters previously established are used	Nelson City Council
	Sometimes	Yes	(1st Part): Test results from similar soils could be used	Territorial Authority
	Sometimes	Yes	(1st Part): (act on recommendation of consulting engineer) (2nd Part): depending on proximity	Territorial Authority
	Yes	Yes	(1st Part): (specialist would carry out the necessary level of investigation appropriate to the site) (2nd Part): Adjacent sites only	Territorial Authority
	Sometimes	Yes	(1st Part): Where only one site is possible on a lot and it has a less than certain stability. Notable exceptions are 5 ha blocks that have many possible building sites and at least one is suitable for NZS 3604 (2nd Part): These are part of the experienced Geotechnical Engineer's store of knowledge	Personal View - Waitakere City Council Senior Subdivision Engineer
	Sometimes	Yes	(1st Part): It would depend on the factors covered in responses to questions 3 and 4. (2nd Part): Depending on the degree of predictability and financial risk	Bruce Dobson, Chief Engineer, Ruapehu District Council
	Sometimes	Yes	(1st Part): Test bores and a minimum of shear vane readings will be required. (2nd Part): Sites which are assessed as complying with NZS 3604 need no further geotechnical investigation.	Territorial Authority

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	2nd Part Yes/No		
Geotechnical Engineers	No	Yes	(1st Part): Average soil strength tests can be used with a degree of confidence provided (the soils) are identified correctly. (2nd Part): Provided a number of test results are used and engineering judgement is used	C.J. Newton
	Yes	Yes	(1st Part): But may only be field tests (2nd Part): So as to provide guidelines. But always need to carry out some testing	Mark Mitchell
	Sometimes	Yes	(1st Part): If reasonably able to be measured with modern methods and reliably (2nd Part): If engineering geological assessment suggests that this is reasonable	Bruce Horide
	-	-	Refer to response to question 3. More often the question is can the job (client) afford to do what is required to support a proper investigation. Data from other sites permissible if local knowledge suggests that this is a valid approach. The validity of this should be confirmed by classification testing.	Prof. M.J. Pender
	No/Sometimes	Yes	(1st Part): If unfamiliar materials are encountered, otherwise conservative values can be used for smaller projects (2nd Part): ref above	Other
	Yes	Yes	(2nd Part): Adoption of typical but conservative soil parameters c', ϕ' and bulk density from similar soils after an assessment by a Geotechnical Specialist of the character of the site soils	A.W. Smith, Jackson Clapperton & Partners

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	2nd Part Yes/No		
	No	Yes	**(1st Part): Net economically viable for domestic sites. We would adopt conservative values based on experience. Lab testing would apply where costs ensured construction savings or safety demanded testing (2nd Part): As an intermediate option between zero and full testing this approach is viable providing a geological or simple lab test correlation (e.g. Atterberg limits) can be found**	Paul Russell, Royds Consulting Nelson
	Sometimes	Yes	**(1st Part): When no knowledge of a particular soil's properties is held, when the significance of slope failure is high in terms of the hazard to life and property. (2nd Part): For uniform soil types for which extensive knowledge of strength parameters is held, preferably, but not essentially, when classification parameters are available to allow correlation.**	Fraser Thomas Ltd
	Sometimes	Yes	**(1st Part): Normally I would not consider slip circle or other methods of analytical analysis to be of much importance for assessing house site or subdivision stability. However, on questionable sites, especially sites where past movement has clearly occurred, some test data on c', ϕ' values may be of assistance (2nd Part): Sometimes, if it is clear that soil conditions at the other site are essentially identical to those at the site under consideration**	Laurie Wesley

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	2nd Part Yes/No		
	Sometimes	Yes	(1st Part): See below. Index tests (limits, moisture content) are necessary to confirm correlation with other sites. (2nd Part): Provided those test results, including index tests to correlate soil types, are presented with the report, or identified by specific reference to the "TA's" files where the results are available to the TA relay.	D.K. Taylor
	Sometimes	Yes	(1st Part): Depends on soil type and uniformity of soils (2nd Part): • if origin of soils known to be the same • if previous testing has verified this	Other
	Yes	Yes	(1st Part): Unless there are circumstances which make it obviously unnecessary i.e. back analysis of an adjacent slip. (2nd Part): Depending on how critical the results are to the final outcome.	Peter Geddes, Hawthorn Geddes (Civil & Structural)
	Sometimes	Yes	(1st Part): This depends on local geology and previous testing in (the) region, e.g. Port Hills loess in Christchurch has been extensively tested and shows little variation over a wide area. (2nd Part): as above	Other
	Sometimes	Yes	(1st Part): Valid for large scale projects - strength testing expensive - conservation in design can have major cost implications (2nd Part): Requires good statistical data base - implies co-operation between Consultants & TA's	Soil & Rock Consultants

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	2nd Part Yes/No		
	Sometimes	Yes	**(1st part): Strength testing may be required if the stability of the site is a serious concern because of the performance of the natural slope or the intended major slope modification, nature of development e.g. water retaining structures. (2nd Part): Need to be confident about the similarity and should only use parameters to determine sensitivity of site stability**	Brian Patterson
	Sometimes	Yes	**(1st Part): If site conditions are unusual or Engineer lacks experience, tests should be done. We have a Telarc laboratory and have built up an extensive library of test results. We often rely on these, especially low budget jobs. (2nd Part): If Engineer is sure conditions <u>are</u> similar**	R. Melville-Smith, Foundation Engineering Ltd
	No	Yes	**(1st part): Experience is often much better than testing for actual soils. Back analysis too and parametric analyses can give a much better understanding of how a slope may perform under a range of conditions than rigid adherence to test results. (2nd Part): Where conditions can be correlated with index properties and the geological setting is consistent.**	N.S. Luxford, Babbage Consultants Ltd
Engineering Geologists	Sometimes	-	**(1st Part): For loess, ϕ is relatively constant, but the huge wild card is cohesion ranging from 1-2 kPa to > 100 kPa. Most is apparent cohesion from soil suction**	Mark Yetton
	Sometimes	Yes	**(1st Part): 1 - When the importance of the site warrants. 2 - When the geological and groundwater conditions dictate that testing of specific strata is warranted. (2nd Part): When the regional geology is well known and when a large body of representative strength data has been collected over time.**	Riddolls & Grocott Ltd

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	**2nd Part Yes/No**		
	No/Sometimes	Yes	**(1st Part): Back analysis can be used and is often better than testing if failure surface is well known, and present stability condition**	R.D. Beetham
	Yes/Sometimes	Yes/ Sometimes	**(1st Part): If quantitative analysis is being carried out then strength testing should be carried out unless exactly similar materials have already been tested. There are situations when generalised parameters (based on experience) can be used. (2nd Part): It is quite feasible to carry out back analysis of a failed slope using assumed parameters based on experience, but for forward analysis this is debatable.**	Dr D.H. Bell
	Sometimes	Yes	**(1st Part): Where the following are absent: not where geological analogy can be drawn and that experience/ database can be applied to the site or where back analyses can be used. Back analysis can be worth a 1,000 Test! (2nd Part): As above (analogy?)**	Independent Self Employed Consultant
	Sometimes	Yes	**(1st Part): Important for marginal sites however, in general observation/ measurement of existing slopes in the vicinity should provide the necessary parameters. (2nd Part): Soils are heterogeneous so all additional data to assist in an assessment is useful.**	Other
Firm employing both geotechnical engineers and engineering geologists	Sometimes	Yes	**In the majority of cases terrain evaluation and back analyses of a know geological unit provides suitable effective strength parameters for analyses but one would need to be careful about assigning an explicit safety factor.** **If an explicit non qualified safety factor is required (as in 4/) there seems no way out but to test each site.**	Glyn R.W. East, Works Consultancy Services Ltd (Auckland)

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	2nd Part Yes/No		
	Sometimes	Yes	(1st Part): Yes, if site does not satisfy the coarse sieve observation/precedent assessment. Yes, if there is no local information/experience. (2nd Part): Yes, provided the geology and stratigraphy are similar. Need to establish ground conditions/geology with confidence.	D.N. Jennings, Works Consultancy Services Ltd (Hamilton)
	Sometimes	Yes	(1st Part): For critical slopes, difficult sites or multi-layer soil profiles may need triaxial tests, otherwise undrained shear strengths are adequate as a guide. (2nd Part): For well known soils with "typical" properties. Budgets often do not allow for expensive triaxial tests.	Engineering Geology Ltd
	Sometimes	Yes	(1st Part): If sensitivity analyses indicate marginal stability for average conditions, then actual strengths are useful. This also applies to other elements of the model (groundwater, geology) (2nd Part): All testing represents a point sample and is therefore only representative of conditions. If material identification is adequate, then using "off-site" results can also be "representative".	Worley Consultants Ltd

	Answers		Comments	Identification
	1st Part Yes/No/ Sometimes	2nd Part Yes/No		
	Sometimes	Yes	**(1st Part): This is not practical or appropriate for the majority of small site investigations. Correlations should be established between conventional field testing (shear vane/Scala penetrometer) and effective strength parameters. If testing not done, then parameters must err on conservative side and factor of safety must be higher than if testing done. Back analysis of existing failures in similar conditions is very useful and the use of sensitivity analyses is encouraged. (2nd Part): Needs judgement and experience. Parameters can be derived by: • Back-analysis of existing slips in similar soils • Correlation of conventional parameters • However, important to establish shear strengths of materials critical to stability for identified failure mode**	Tonkin & Taylor Ltd, (Auckland, Wellington, Christchurch & Dunedin)

QUESTION (6): What factor of safety is required for earthquake loading?

QUESTION (7): What earthquake return period is required?

	Comments	Identification
Territorial Authorities	6. Variable 7. Elastic design	Territorial Authority (TA)
	6. Code Requirement 7. We are in a "B" rated area	TA
	6. 1.5 7. 150 years	Nelson City Council
	6. nil 7. not required	Wanganui District Council - T. Moran
	6. NA 7. NA	TA
	6. as per code 7. as per code	TA
	6. 1.2 7.	Waitakere City Council - Senior Subdivision Engineer - personal view)
	6. 1.2 7. 150 years	TA
	6. 1.2? 7. 450 years?	TA
	6. It would depend on all of the above factors including the sophistication of the analysis, 2.0 - 4.0 say 7. Would depend on above factors, 50-120 years	Bruce Dobson, Ruapehu District Council
Geotechnical Engineers	6. 1.1 7. 100 years	Babbage Consultants Ltd - N.S. Luxford
	6. 1.2 7. 150 years	Foundation Engineering Ltd
	6. 1.2-1.3 7. > 100 years	Soil & Rock Consultants
	6. 1.0-1.2 depending on location, importance, etc. 7. 450 year to be consistent with loadings code	Other
	6. - 7. Location dependent	Hawthorn Geddes Civil & Structural - P. Geddes

	Comments	Identification
	6. 1.1 7. ?	Fraser Thomas Ltd
	6. Building Code - 1.2 7. not specified	Royds Consulting Ltd - Paul Russell
	6. 1.2 dependent on adopted loading 7. relative to economic life of anticipated use	Jackson Clapperton & Partners - A. Smith
	6. Residual displacement may be a better criteria 7. Depends on site location and consequences of failure	Other
	6. 1.3 7. 150 years	Mark Mitchell
	6. 1.2 7. 150 years	Bruce Horide
Engineering Geologists	6.& 7. Depends on sensitivity of site/structure, etc.	Independent Self Employed Consultant
	6. Depends how well other parameters are known 7. Varies depending on site etc.	R.D. Beetham
	6. - 7. 100 years = design life of structure	Brian Patterson
	6. > F5 = 1.0 7. 50 years	Riddolls & Grocott Ltd
	6. > 1.1 7. 50 year	Geotech Consulting Ltd - M. Yetton
	6. 1.3? 7. 100-150 years	Dr D.H. Bell
Firms employing both geotechnical engineers & engineering geologists	6. recommend 1.3 for 7. 150 year return period	Engineering Geology Ltd
	6. 1.2 7. nominally 150 years	Worley Consultants Ltd

	Comments	Identification
	6. Depends on the sensitivity of the structure to damage, consequences of failure and also the soil type • for MCE (max. credible earthquake), FOS $\geq$ 1.0 • for DBE (design basis earthquake), FOS $>$ 1.2 7. What earthquake return period is required: • for DBE (design basis earthquake) return period FOS $\geq$ 150 years • again the return period adopted is dependent on type of structure and the consequences of failure	Tonkin & Taylor Ltd, (Auckland, Wellington, Christchurch, Dunedin)
	6. $>$ 1.0, Displacement approach (Newmark sliding block) not acceptable for a building 7. 450 year (cf NZS 4203)	D.N. Jennings, Works Consultancy Services Ltd, Hamilton
	6. SF (earthquake) $>$ 1 7. Return period = 150- years (qualified by the hazard condition)	Glyn R.W. East, Works Consultancy Services (Auckland)

QUESTION (8) Is a factor of safety less than 1.5 acceptable for extreme conditions (excluding earthquake)? (If "Yes", please specify the extreme conditions and factor of safety)

Summary of Results	Territorial Authority	Other Geotechnical Engineers	Engineering Geologists	Firms of Engineers & Geologists
No	11	1	0	0
Yes	5	13	6	6
TOTAL NO. of Replies	16	14	6	6

	Answer (Yes/No/ Sometimes)	Comments	Identification
Territorial Authorities	No	But depends on definition of 'extreme' i.e. generally NOT acceptable but prepared to listen to argument re 'extreme' case	TA
	No (generally)	Or at least I can't think of the circumstances, although we would be fairly relaxed if the application was to build a "chook house"	Bruce Dobson, Ruapehu District Council
Geotechnical Engineers	Yes	A factor of safety of 1.5 is set to allow for variations from anticipated conditions. Using worst credible soil strength parameters and ground water conditions a Factor of Safety = 1.0 - 1.2 may be acceptable depending on the perceived likelihood of occurrence/exceedance and the consequences of failure.	Babbage Consultants Ltd - N.S. Luxford
	Yes	Fully saturated ground conditions case when such conditions are extremely likely to occur or can only occur for short periods of time. Here I use 1.2 (or would if Council agreed)	Foundation Engineering Ltd - R. Melville-Smith
	Yes	(i) Temporary works 1.3-1.4 (ii) Rural blocks - slopes away from development 1.3 (iii) In certain cases, fully saturated slope 1.3-1.4 (iv) Lower bound shear strength & high GWT combination 1.3-1.4 (v) Where qualitative assessment largely positive e.g. mature bush on slope	Soil & Rock Consultants
	Yes	Assuming lower bound conditions for water table, soil strengths, etc., say 1.3	Other

	Answer (Yes/No/ Sometimes)	Comments	Identification
	Yes	**I think the assessment of a slope should be that it has "adequate stability to be acceptable as a house site", which implies it has a minimal (but not zero) risk of failure in any reasonably foreseeable circumstances. Trying to go beyond such an assessment is futile; it will produce numbers not much related to reality.**	Laurie Wesley
	Yes	**Not tested in this area Live load, vehicle loads**	Royds Consulting Ltd - Paul Russell
	Yes	**Possibly 1.3 to 1.4 for 100 year return period event, but dependent on confidence in adopted soil parameters**	Jackson Clapperton & Partners - A. Smith
	Yes	**Under a 1:150 year return period earthquake a f.,o.s. of 1.3 would seem adequate**	C. Newton
	Yes	**1.20 low significance - e.g. rural road 1.30 moderate significance 1.40 high significance - e.g. hospital acceptable for extreme conditions say 1 in 10 year return period storm**	Fraser Thomas Ltd
	Yes	**When have good reason to conclude that a good understanding of the situation is available. Control of the soil present - a compacted embankment rather than a natural slope. Consequences of failure - an embankment for a minor road not as serious as a building foundation. When it is possible to work from the back analysis of an existing failure. When very good groundwater monitoring data is available. (The cost of groundwater monitoring could be set against the gains from using a lower factor of safety.)**	Prof. M.J. Pender
	Yes	**1.3 OK if soil parameters were established, e.g. man made dam Also OK if average strength parameters used rather than minimum values**	Mark Mitchell
	Yes	**1. Earthquake - NZS4203 - design : 1.1 2. g.w.l. - upper bound and soil strength lower bound together: 1.1**	Bruce Horide

	Answer (Yes/No/ Sometimes)	Comments	Identification
Engineering Geologists	Yes	**Provided earthquake and other eventualities have been ... for in the analysis**	Independent Self Employed Consultant
	Yes	**FS < 1.5 was used in <u>all</u> the Cromwell Gorge slide stabilisation works. Often ~ 5% increase in stability was all that could realistically be achieved**	R.D. Beetham
	Yes	**Short duration high intensity rainfall events**	Riddolls & Grocott Ltd
		In Auckland we do not normally design for earthquake loadings	Other
	Yes	**Because most established hill areas in Christchurch with no significant slope problems when back analysed have FS < 1.5 for prolonged rainfall**	Geotech Consult. Ltd - M. Yetton
	Yes	**I would suggest that FS = 1.5 is far too high for most situations, especially given the numbers of properties located on landslides in New Zealand. Where structures such as retaining walls form part of the site design. I would agree that 1.5 is realistic with earthquake loading**	Dr D.H. Bell
Both geotechnical engineers & engineering geologists	Yes	**Unrealistically high groundwater FOS = 1.3 adequate when remediating existing landslide**	Engineering Geology Ltd
	Yes	**- Extreme groundwater levels - Long term downcutting/erosion of slope toe by stream action**	Worley Consultants Ltd
	Yes	**Extreme conditions are defined as the most unfavourable soil/rock and groundwater conditions which can be reasonably expected to occur in the lifetime of the structure. The factor of safety should be related to the probability of groundwater conditions. Where sufficient investigation/monitoring shows that a groundwater level at surface condition is very unlikely, then could accept FOS < 1.5 (but > 1.2 for extreme conditions). This also applies to failure of drainage systems, particularly horizontal drains which are prone to blockage during the lifetime of a structure.**	Tonkin & Taylor Ltd, (Auckland, Wellington, Christchurch, Dunedin)

<table>
<tr><th></th><th>Answer (Yes/No/ Sometimes)</th><th>Comments</th><th>Identification</th></tr>
<tr><td></td><td></td><td>Also where an existing failure occurs and requires remedial work, back analysis provides greater confidence and therefore a FOS > 1.3 could be acceptable under some circumstances e.g. large mass landslide. Effects of creep need to be considered for such cases and transient piped water tables causing shallow instability. Also dependent on consequences of failure.</td><td></td></tr>
<tr><td></td><td>Yes</td><td>cf the Hong Kong approach
<table>
<tr><th>Geology</th><th>Soil Strength</th><th>Ground-water</th><th>Dev. Definition/ Slope</th><th>FS</th></tr>
<tr><td>Known
Known</td><td>Lower bound
Lower bound</td><td>Average
High (> 100 yr)</td><td>Known
Known</td><td>1.5
1.2</td></tr>
</table></td><td>D.N. Jennings, Works Consultancy Services Ltd, Hamilton</td></tr>
<tr><td></td><td>Yes</td><td>Under conditions that the safety factor of a cut/natural slope can be satisfactorily controlled to 1.5 with drainage. Or in the case of an embankment with weak foundation soils that will increase to 1.5 with time.

As mentioned in 4/ a graduated scale for (a) Level of knowledge; and (b) The hazard risk of failure, may be more appropriate</td><td>Glyn R.W. East, Works Consultancy Services (Auckland)</td></tr>
</table>

(see Page 149 for more information)

QUESTION (9) **If drainage works are used to stabilise land, should their failure to operate be considered? (If "Yes", please give circumstances).**

Summary of Results	Territorial Authority	Other Geotechnical Engineers	Engineering Geologists	Firm of Engineers & Geologists
No	0	2	1	0
Yes	15	14	6	5
TOTAL NO. of Replies	15	16	7	5

	Answer (Yes/No/ Sometimes)	Comment	Identification
Territorial Authorities	Yes	Old age, failure to maintain, progressive blockage with fines	TA
	Yes	It is important that any mitigation measures continue to work and are regularly maintained	TA
	Yes	Land should still be stable to 1.2	Waitakere City Council, Senior Subdivision Engineer - personal view
	Yes	Access for clearing, cleaning etc. to be considered at outset. Access for inspection/repair to be considered	TA
	Yes	Our experience is that subsoil drains can become inoperative within 2 or 3 years. Once again would depend on all the above factors and the extent to which the drains were designed to remain operative	Bruce Dobson Ruapehu District Council
	Yes	Under the failure of bored drains, a factor of safety of 1.2 should still be maintained provided that the factor of safety of 1.5 is achieved with the installation of drains.	TA
Geotechnical Engineers	Yes	The implications should always be assessed. A low factor of safety under failure but at least 1.0 should be considered.	Babbage Consultants Ltd - N.S. Luxford
	Yes	But only if a factor of safety of 1.2 can be tolerated under these conditions	Foundation Engineering Ltd - R. Melville-Smith

	Answer (Yes/No/ Sometimes)	Comment	Identification
	Yes	**Proper installation and maintenance of drains is necessary - does not happen though. If drainage required to raise FS from <u>less than</u> 1.3 to 1.5 failure of the drains is of greater concern**	Soil & Rock Consultants
	Yes	**Drainage works need to be designed to be fail safe in some way, or conservatively designed to ensure satisfactory performance in accordance with good engineering practice**	Other
	Yes	**Consider a compliance schedule (hydraulic structure) to ensure they remain operational through ABWF inspection. Refer to Whangarei District Council policy on dams**	Hawthorn Geddes Civil Structural - P Geddes
	Yes	**Of course. A major deficiency of many reports is a lack of direct long term measurement of piezometric pressures/water levels.**	D.K. Taylor
	Yes	**Bored horizontal drains are probably the least reliable on a long term basis, and hence their failure to operate should certainly be considered**	Laurie Wesley
	Yes	**A sensitivity study should be undertaken to assess reduction in F/S due to rise in g.w.l. following drainage failure, and this related to confidence in the maintenance procedures proposed to apply to the drainage system.**	Jackson Clapperton & Partners - A. Smith
	Yes	**This should be investigated and some degree of redundancy built into the works should be considered as part of the design**	C Newton
	Yes	**Otherwise what is the purpose of the drainage works? Perhaps one might say that having decided to install drainage works there is a maintenance responsibility on the owner**	Prof. M.J. Pender
	Yes	**Only to establish the extent of maintenance required**	Mark Mitchell
	Yes	**1. Long term 2. Risk of third party injury/damage 3. Variability/reliability of drain construction materials/ workmanship**	Bruce Horide
	Yes	**If consequences of failure are likely to be serious**	Fraser Thomas Ltd
Engineering Geologists	Yes	**Where their failure would affect ....**	Independent Self-employed Consultant
	Yes	**Drainage and other remedial works require regular checking and maintenance to ensure their proper function**	R. D. Beetham
	Yes	**If failure of drainage is critical to stability and consequences of slope failure is unacceptable**	Brian Patterson

	Answer (Yes/No/ Sometimes)	Comment	Identification
	Yes	If stability is dependent on drainage this eventuality must be addressed	Other
	Yes	All drains should be accessible for later cleaning by flushing or pig. If this is done they can be viewed as acting indefinitely	Geotech Consult Ltd - M Yetton
	Yes	Long-term maintenance of drainage measures must be carried out in all situations involving slope stability. This raises the question as to who assumes responsibility once consents are issued, and these matters should be addressed at that stage.	Dr D.H. Bell
Firms employing both geotechnical engineers & engineering geologists	Yes	But would allow a much lower safety factor than 1.5	Engineering Geology Ltd
	?	Drainage works that have been engineered and constructed according to acceptable standards should have the normal performance expectations of other engineered works (e.g. retaining walls). Rather than imposing a failure criterion, it would be better to ensure that any works are designed adequately and have been reviewed as part of the normal checking process.	Worley Consultants Ltd
	Yes	Monitoring systems such as piezometers or drain discharges should be included in drainage works in situations where failure of the drains could cause instability problems Where appropriate other components of the remedial works should be designed to allow for drain failure, i.e. foundations, retaining structures. In this situation, a reduced factor may be acceptable. Note potential for shallow failures and creep in Q.8 above	Tonkin & Taylor Ltd, (Auckland, Wellington, Christchurch, Dunedin)
	Yes	There are concerns about acceptability of subsurface drainage in a domestic environment related to reliability of maintenance	D.N. Jennings, Works Consultancy Services Ltd, (Hamilton)
	Yes	The maintenance of remedial or stability improvement drainage is not adequately addressed. A formalised approach to maintenance should be required for a building or subdivision consent that includes stability drainage.	Glyn R.W. East, Works Consultancy Services (Auckland)

QUESTION (10) What role does peer review of assessments play?

	Comment	Identification
Territorial Authorities	None	TA
	When the recommendations come up with requirements or approvals we do not consider are appropriate we ask for a peer review	Nelson City Council
	Building Consents are not generally reviewed by a Registered Engineer	Wanganui District Council - T Moran
	No formal review	TA
	1812 Overture	TA
	Peer review would be appropriate in high risk situations - i.e. where failure would likely cause loss of life or extensive physical damage	TA
	Auckland City Council carries out a peer review of all geotechnical investigation. If there is any disputes further independent review may be sought.	TA
	Important	TA
	None so far. Queries are redirected to the Soils Engineer for further consideration	Waitakere City Council Senior Subdivision Engineer - personal view
	Significant, especially when very specialised reports, calculations are received	TA
	Council does not employ Geotechnical staff and to date has not engaged consultants to review another Geotechnical specialist investigation/design	TA
	ALL: Peer review is important depending on the degree of complexity, cost, etc.	Bruce Dobson, Ruapehu District Council
Geotechnical Engineers	Internal peer review is used on a routine basis	Babbage Consultants Ltd - N.S. Luxford
	Helps ensure a more uniform (and higher) standard of stability reporting	Foundation Engineering Ltd, R Melville-Smith
	Maintains a standard of quality in an area where rigorous rules are difficult to establish. However, guidelines on the standards to be achieved is necessary to avoid confusion and argument.	Soil & Rock Consultants

	Comment	Identification
	For important, or difficult sites, peer review is appropriate	Other
	Important for difficult or high impact situations. Not required in all cases	Hawthorn Geddes, Civil Structural - P Geddes
	To ensure that basic principles are sound	Other
	Should be restricted to a check of procedures, content and method and NOT regarded as a second opinion in disguise.	D.K. Taylor
	Indemnity insurance spread i.e. risk spread	Other
	Most of our work is domestic; checking is carried out in-house under our QA plan	Royds Consulting Ltd - Paul Russell
	Provide quality assurance to ensure that all significant factors are taken into account in the assessment.	Fraser Thomas Ltd
	Appropriate to differences in opinion between assessor, and approving authority	Jackson Clapperton & Partners - A Smith
	All projects of this nature which has a degree of risk should be reviewed by another Geotechnical specialist	C Newton
	Valuable independent assessment	Prof. M.J. Pender
	Should only be required on major structure, or where the TA has some concerns with the design	Mark Mitchell
	Essential, but for bottom line recommendations only i.e. yes/no answers	Bruce Horide
Engineering Geologists	Leads to consistency but also possible BIAS	Independent Self-employed Consultant
	Essential for major works	R.D. Beetham
	Very important role of checking adequacy of the investigation and determination/judgement/ interpretation of data	Brian Patterson
	Can only be justified for very large projects/assessments	Riddolls & Grocott Ltd
	Maintains and improves standards by dissemination of ideas and methodology	Other
	Only required for large projects where the budget normally means reasonable testing and good data is available, plus the time for the inevitable discussions	Geotech Consult Ltd - M. Yetton

	Comment	Identification
	I would expect peer review in critical situations where there is concern for a particular site, or for the analysis that has been presented in support of a consent application. This poses real problems for smaller TAs who may not have sufficient expertise to recognise this concern. Peer review "between consultants" would rarely be required on residential slope stability issues.	Dr D.H. Bell
Firms employing both geotechnical engineers and engineering geologists	Useful for difficult or critical stability situations. Not generally required if experienced person has prepared report.	Engineering Geology Ltd
	Peer review should be mandatory for all geotechnical assessments involving public liability	Worley Consultants Ltd
	Peer review provides the client/local authority with assurance that an appropriate professional assessment has been undertaken (it usually involves identifying issues which may have been overlooked). It has a significant benefit in promoting professional standards	D.N. Jennings, Works Consultancy Services Ltd (Hamilton)
	• To ensure a satisfactory level of investigation/analysis/design is applied, appropriate to the slope stability hazards/risks and the implications to the development. • The review is then carried out by suitably qualified professionals and not the most available "qualified" professional within a TA. • A peer review may allow more reasonable and economic design. Particularly useful to endorse matters of judgement and to confirm acceptable levels of risks	Tonkin & Taylor Ltd, (Auckland, Wellington, Christchurch, Dunedin)
	A peer review provides a TA/Client without specialist geotechnical knowledge some assurance that all issues have been addressed. Perhaps whether a peer review is required is part of a qualified graduated hazard scale (4/ above). The peer review should not be a "nit-picking" exercise and ideally the project should be discussed with the reviewer throughout the investigation and assessment, i.e. the reviewer should be appointed at an early stage.	Glyn R.W. East, Works Consultancy Services (Auckland)

QUESTION (11) **How is Section 36(2) of the Building Act applied?**

	Comment	Identification
Territorial Authorities	Construction is registered against the title. The act says shall.	TA
	Consents refused for known problem sites	TA
	We require a certificate from a geotechnical specialist advising that 2(a) will apply before acting on Section 36(2) ourselves	Nelson City Council
	Generally only flooding is considered and then really only in respect to floor levels. Where a site has been considered a problem by say myself, the applicant can usually find a Registered Engineer to sign a letter etc. to say that the site is suitable for building on etc. This TA would rarely refuse to grant a building consent and under previous legislation in one case refused a building permit for similar reasons to S36, was challenged in court - lost, issued a permit, the site slipped causing damage, Council was successfully sued for damages!!	Wanganui District Council - T Moran
	This is handled by the Regulatory unit of council. We (Engineering Services) are seldom consulted at the Building Consent stage even if a lot has been "tagged".	TA
	According to law	TA
	In the knowledge of some potential failure but, as best as can be determined, that the proposed works will not exacerbate the situation. Only a few actions taken to date	TA
	Where building and site works such as driveways and services are suitably protected against land movement, but still there is a risk of land movement or subsidence. Council can approve a building consent under Section 36(2) of the Building Act and reference may be made to this clause when subdivision consent is given.	TA
	We have not had any cases since the Building Act has become law.	TA
	It is applied on: - known sites which have a past history of trouble - known areas which have a past history of trouble - doubtful proposals where developers are not prepared to take all reasonable steps to protect subsequent structures - situations where it is felt the development is unwise for a number of reasons. Therefore the developer may take the risk if they so choose but Council chooses not to partake in that risk. (Private Certifiers may overcome this last situation) All cases judged on an individual basis	TA
	Generally by applying judgements to each particular circumstance	Bruce Dobson, Ruapehu District Council

	Comment	Identification
Geotechnical Engineers	My interpretation is that Council cannot refuse to grant consent under Section 36(2) subject to its disclaimer. This is dangerous for the Geotechnical Engineer who carries the whole can. His disclaimer should be loud and clear in this case.	Foundation Engineering Ltd, - R Melville-Smith
	Have had little experience of the TA applying this Section of the Act	Soil & Rock Consultants
	If there is no hazard to life, and owner has been fully briefed of the risks, Sec. 36 is appropriate	Other
	Generally consistent within each TA but different TA's are applying it differently. Little change from 641(A) in the past	Hawthorn Geddes, Civil & Structural - P Geddes
	This is an extraordinary return to the "Caveat Emptor" philosophy which may lead to some interesting court decisions in future. The TA should apply it, <u>not</u> the consulting engineer	D.K. Taylor
	Has significant influence on resale value of existing properties if applied in recent times	Other
	NCC (Nelson City Council) have a hazard map. Any property with a notice recorded against it needs an opinion. If the Building Regulations (Clause B1) cannot be met, i.e. low probability, Section 36(2) of the Act must be resorted to. The TA accepts the opinion of the Geotech. Engineer with respect to the work not worsening, accelerating or resulting in any of the listed effects. The TA tags the title as required.	Royds Consulting Ltd - Paul Russell
	Appropriate to ancillary structures, physically separate from habitable buildings where the owner is fully aware of the condition and accepts the risk of probably uninsurable loss.	Jackson Clapperton & Partners - A Smith
Engineering Geologists	The council requires the consultant to address the risks of building on the site i.e.: • stability • flooding • inundation If subject to specific design they identify this on the title	Other
	With great caution in Christchurch. The CCC have not used it yet to my knowledge for hill property. They are concerned regards their liability for injury or death. I disagree with their interpretation of the Act and consider Section 36(2) a useful approach in a lot of cases	Geotech Consult Ltd - M Yetton
	I recommend s36(2) approvals in cases where I endorse house site construction on existing "dormant" landslides. This is based on the premise that the site is currently stable, and that drainage and other measures would not lessen the status quo. Implicit in s36(2) approvals is the acceptance of long-term risk by the property owner, who must be fully informed of these issues at the time. No quantitative analysis is carried out in such cases, as the costs would be prohibitive, and there is reliance of geological precedent.	Dr D.H. Bell

	Comment	Identification
Firms employing both geotechnical engineers and engineering geologists	Very unevenly applied amongst TA's - seems to absolve them of all risk. Many TA's overcautious and use 36(2) to cover their uncertainties.	Engineering Geology Ltd
	Cases assessed on their own merits and client would be advised of potential problems with site	Worley Consultants Ltd
	The geotechnical advisor should: (1) Advise the client very clearly on the slope stability hazards and risks affecting the sites and the likely implications to the development. (2) Where appropriate, design remedial works to improve the FOS to meet the Building Code Requirements (modified to take foreseeable conditions into account) (3) Recommend against purchase/development in situations which do not comply with the Building code (under Registered Engineers) (4) Advise client of consequences of construction under 36(2). No acceptance of risk by Council, EQC and limited (defined) liability accepted by Designer, i.e. at client's own risk. (5) Recommend structures which are relocatable.	Tonkin & Taylor Ltd, (Auckland, Wellington, Christchurch, Dunedin)
	No experience with this provision for slopes. This provision has been used for a site where there was potential for consolidation induced settlement	D.N. Jennings, Works Consultancy Services Ltd, Hamilton
	Section 36(2) is relatively clear providing the TA accepts the geotechnical stability assessment and the peer review. A client must accept the fact that geotechnical specialist cannot alter ground conditions to suit his requirements. It must be accepted that some hazard building sites such as some cliff tops and some North Auckland Onerahi Chaos sites must be "tagged". Some problems have been experienced in defining the "life of the development" in relationship to some natural progressive instability such as cliff top regression which should be qualified by TA's.	Glyn R.W. East, Works Consultancy Services (Auckland)

QUESTION (12) Please make any other comments

	Comment	Identification
Territorial Authorities	We will soon be requiring specific design of foundations plus geological reporting for all buildings on sloping sections	TA
	Normal procedure at subdivision approved stage is to impose a condition to the effect that "specific foundation design will be required at building consent time". Regulatory unit are advised of this requirement and expected to police it.	TA
	Because of a lack of projects which have required slope stability analysis, this Council has not developed a policy on the issue. It would welcome some guidance on the issues involved	TA
	We have not had any applications for land development on ground subject to slope stability problems. Our District is relatively "flat" and has not been a problem. However, I am interested in the outcome of this questionnaire so we can have a better "understanding" of the current and generally accepted practice.	TA
	Council tries to have a reasonable attitude towards all of geotechnical investigations.	TA
	Building Act Section 36(2) - presently a grey area. TA's are using 36(2) but I understand the DLR is not cooperating - Act doesn't spell out who pays for this part of the process. Until a case is tested in law we may be kidding ourselves thinking that all is in order. Applicants don't like 36(2) and yet it is reasonable from the TA viewpoint that they have an out when there is real doubt over certain sites. TA's under the Act accept considerable liability for work they don't do i.e. builder does the work but TA issues the CCC : TA can't be on site to observe everything yet once CCC issued becomes liable. Applicants must realise that some sites should be left alone - Abbotsford comes to mind - irrespective of their potential to make suitable home sites. Rarely does the TA gain the profit from the subdivision but it ends up carrying the mistakes and short cuts left by the developer.	TA
	This covers land development only. Comments do not apply to Building Consents	TA

	Comment	Identification
	This District mainly deals with smaller buildings i.e. houses and holiday homes. Larger buildings including all industrial developments are on essentially flat land.	TA
	Our level of engineering input into building permits has been low to date, but our experience of local conditions and experience is extensive mainly through roading construction. We have not had to give a "hell of a lot" of thought to Section 36(2)	Bruce Dobson, Ruapehu District Council
Geotechnical Engineers	A qualitative assessment should always be carried out as part of any overall slope stability assessment. The quantitative or analytical assessment forms only part of the overall assessment. However, the problem is that many Consultants and TAs become pre-occupied with the Factor of Safety of 1.5 which can result in certain cases of an unsound or conservative judgement being made	Soil & Rock Consultants
	While there is a general tendency towards specialisation and in many circumstances this is justified, the policy proposed needs to recognise the very wide range of circumstances and possible impacts of the sort of work which will be covered by it. The society (Geomechanics) does not want to be seen as attempting to "close the shop".	Hawthorn Geddes, Civil & Structural - P Geddes
	Some TA's want to avoid direct involvement of their staff in slope stability assessments and place "first-line" responsibility upon consultant's reports (usually engaged by "developers") perhaps with Peer Review. In that case the TA must show discretion as to the capability of the reporters - this can be more or less formal - <u>but</u> it is much more important that TA's promulgate Codes of Practice which set out fairly detailed requirements for the extent of investigations and the content of reports. This is essential in order to: (a) bring the reporters to a reasonable standard of capability (b) prevent reporters being pressurised by "developers" who do not want to face the real costs, but will pass off the responsibility to the reporters. Some SI reports, currently, are woefully deficient in fundamental aspects well observed by experienced practitioners.	D. K. Taylor

	Comment	Identification
	I do not think the blanket requirement of a SF of 1.5 is a sensible approach to this issue. The approach should be that a competent person or organisation undertake the stability assessment, and their report should be the basis on which a decision is made as to whether or not the site is acceptable. The geotechnical issue with regard to numerical stability analysis is not simply one of measuring c′ and Ø′, and the seepage situation, it is whether the overall geology of the site has been properly identified and whether its implications for stability are appreciated. Thinking of stability assessment as simply an exercise in obtaining c′ and Ø′ values is "unhealthy".	Laurie Wesley
	Nelson City Council have kept hazard maps since circa 1975. Their procedure is consistent and established. They have also required geotechnical consultants including geologists to have prior approval of credentials for some time. The system works logically. We very rarely use B1/VM4 for stability work apart from retaining walls. We usually use the provisions of the Building Regulations. We have regularly considered work under Sect 36(2). The NCC have insisted on a formal statement for all stability reports and this must include both the NCC and the client as the named parties covered; we can exclude use by all other parties without consultation.	Royds Consulting Ltd - Paul Russell
	Variability of soils, and difficulty of ensuring that worst case soils are identified and tested, and in this case of "back analysis", the accuracy of assessing pre movement profile means that most assessments reflect the judgement of the assessor. i.e. Geotechnical Engineering more an "ART" than a "SCIENCE" A further complication lies in the recording of an assessment where care should be taken to avoid jargon which could make a report unintelligible to a layman and product user	Jackson Clapperton & Partners - A Smith
	The "minimum FS of 1.5" needs to be replaced with: "The minimum FS shall be in the range of 1.3 to 1.8 and the value adopted shall be justified by the Designer with adequate documentation.	Mark Mitchell

	Comment	Identification
	In a non analytical approach to site stability assessment, a qualified/experienced engineering geologist is probably the best qualified person to carry this out. In an ideal world the engineering geologist in association with a geotechnical engineer should combined to carry out assessment of important sites	Brian Patterson
Engineering Geologist	Presumably this questionnaire has been prompted by: 1. The inability of IPENZ to accept suitably qualified and experienced professional professionals into its ranks as professional engineers. (I am an example - 1st Degree BSc Geol Hons Masters in Engineering Rock Mechanics with 25 years of experience in rock and slope engineering, specialising in slope stability) 2. The tendency of geologists not to get involved in analysis Both 1. and 2. are ludicrous in today's technical world	Independent Self-employed Consultant
	Slope instability needs to be assessed on a site by site basis. Blanket requirements for a FS of 1.5 are ridiculous.	R. D. Beetham
	The primary problem facing engineering geologists working in the area of slope stability assessment for subdivision or individual dwellings is the requirement of some councils for those reports to be signed by a registered engineer. It seems however to matter little if that engineer has limited experience dealing with stability of slopes. In my own case I work in with a geotechnical engineer for foundation design to address problems identified on difficult sites. It would be an advantage to both engineers and engineering geologists if IPENZ looked seriously at addressing this registration problem (?) instead of hoping it will go away. We will see an increasing number of engineering geologists working in this area in the future.	Other
	I think the FS > 1.5 is one of those "good" ideas made by somebody after reading a few textbooks. Any one who has actually done slope analysis knows how sensitive the outcome is to input data, and generally how restricted the data is. The big problems are pore water pressures and cohesion. Cohesion, either apparent or true, holds up so many slopes in nature that it cannot be ignored in analysis. Yet there are few reliable methods to assess this properly. Back analysis is the best way, and an experienced engineering geologist actually does a visual "back analysis" of the site in his assessment.	Geotech Consult Ltd - M Yetton

	Comment	Identification
	1. From more than 15 years of experience with urban planning and development in New Zealand, the greatest hazard to homes comes from debris flows generated in steel catchments. Large-scale instability, such as at Abbotsford, is rare, and the precedent (i.e. qualitative) approach outlined earlier is suitable as a first stage of assessment of slope stability. Note also that under the Building Act and RMA a number of hazards have to be addressed, and I remain satisfied that the engineering geology approach which I have developed and used is entirely suitable for this initial appraisal and at least subdivision consent approval. If every slope on which a house has to be located requires a FS - 1.5, then there is something radically wrong. 2. Quantitative analysis requires a realistic engineering geological site model, and sufficient funds must be made available for these investigations. Very few clients have the money required, and I quite simply do not believe that such investigations are warranted in the great majority of cases. As a matter of interest the pre-quarrying factor of safety at Abbotsford was 1.07, whilst Pukaki Dam has FS - 1.3 under 0.3g - nowhere near 1.5 in either case, and I am reminded also that Brewery Creek went from 0.96 to 1.03 with the spending of $100M. I am afraid that the BIA approach is flawed fatally. 3. I have recommended approval of dwellings on existing landslides in Havelock North, the Marlborough Sounds and in Queenstown. The reasons for these approvals are that the property owners are prepared to accept the risks involved, and that the development will not worsen the situation. In each of these cases s36(2) allows this fact to be identified, and future owners of the land protected. Whilst in principle I do not recommend close residential subdivision of landslide areas, I am also sufficiently well aware from precedent that in many cases people can live safely on landslides.	Dr D.H. Bell

	Comment	Identification
Firms employing both geotechnical engineers & engineering geologists	The factor of safety approach alone to ground stability assessment is inappropriate. It has evolved into a practice in lieu of Risk Assessment (i.e. it is a defacto risk assessment). It takes no account of the probabilities of events occurring that may 'trigger' instability. At best it provides a 'safety' margin against unknowns that are used in stability analyses.	Worley Consultants Ltd
	Section 36(2) should only be applied in special circumstances where the client is already financially committed to the development (i.e. the existing property or landowner) and where it is not practical to improve the stability to meet the Building Code requirements, e.g. a single property owner on a large landslide which extends beyond the owner's property. All practical steps should be taken to mitigate the hazard, and the conditions on the site should not be worsened as a consequence of the development. FOS should be determined on basis of risk, hazard and confidence of ground conditions e.g. refer to Hong Kong slope design manual. A manual like this could be developed for NZ conditions.	Tonkin & Taylor Ltd, (Auckland, Wellington, Christchurch, Dunedin)
	With regards to items 4 and 8 it is important that a realistic range of strength and groundwater parameters are considered. It is not acceptable to assume average conditions (and FS = 1.5). Where calculated stability is assessed it is important that all potential mechanisms of instability are considered and that they are realistic. Probably the most important issue is that of "what information is the assessment based on?" Too often assessments are based on insufficient data to adequately define the site and its characteristics. Consequently questions of assumptions and analysis are premature.	D.N. Jennings, Works Consultancy Services Ltd, (Hamilton)
	(a) Slope stability assessment must apply both the engineering geology terrain evaluation and an analytical assessment based on a realistic model from the geological conditions. Little confidence can be given to an engineering geology approach if the mechanisms of failure are not understood and similarly little confidence can be given to analytical analyses without a realistic geological model.	Glyn R.W. East Works Consultancy Services (Auckland)

	Comment	Identification
	(b) What is the safety factor of safety? Apart from man made structures or perhaps embankment over weak soil any first order prediction analyses of a factor of safety must be viewed with suspicion within the normal bounds of field and laboratory testing and the precision of the geological model. The arbitrary unqualified safety factor of 1.5 probably allows for the unknowns but it would be more appropriate if there was a qualified graduated scale for (a) Level of knowledge; and (b) The hazard risk of failure. In some cases, this may require a SF >1.5. Whether a peer review is required could be part of this scale. (c) TA's (and the insurance industry) should give some consideration to the terrain evaluation/"back analyses" approach to stability assessments as an alternative approach to that of a safety factor from some arbitrary analytical analysis. In some terrain, notably partially weathered volcanics and greywacke, this is the only meaningful approach. With this approach, the stability conditions of an existing slope, or nearby slope in the same geological unit and structure, is physically and analytically assessed to obtain realist soil properties that are then used on the proposed slope. The safety factor results of the new slope can only be quantitatively qualified in relation to the existing slope (as a percentage of the existing slope). With this approach, TA's would need to accept the judgement of the geotechnical specialist that the slopes the assessment was based on, are stable and the proposed slope has a similar or better qualified safety factor. The approach allows for assessments to improve the stability by drainage, etc. (d) Consideration should be given to the need, or otherwise, of a Limit State Design approach to stability of slopes. Is the concept of a Safety Factor value out of date? A Limit State Design could allow more flexibility especially in relation to the "back analyses" approach.	

Geotechnical Risk Associated with Hillside Development

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1. INTRODUCTION

Slope instability has been a problem in both house and sub-divisional development on hillsides in the Newcastle-Sydney-Wollongong region for some time. Instability in its geotechnical sense is dramatically observed as landslips, landslides and mudflows and these phenomena have been recorded in the region at least since the turn of the century. Slope instability has become particularly evident in the past 30 years with the more intense development of available land and the greater acceptance of, and even preference for, house sites on steeply sloping land. In the most severe problem areas land instability has led to the destruction of houses, whilst in other cases the development of large areas has been severely restricted.

Members of the Sydney Group of the Australian Geomechanics Society have been particularly aware of the problems and in 1985 a sub-committee was established to develop a risk classification for slope instability and to provide guidelines for hillside construction. The sub-committee subsequently prepared a classification and terminology system which can be uniformly used by geotechnical consultants and which can be readily understood by landowners as well as council engineers and surveyors, structural engineers and architects.

2. GEOLOGICAL ENVIRONMENT

The region particularly considered by the sub-committee was the area geologically defined as the Sydney Basin, the approximate extent of which is shown on Figure 1. Detailed discussion of the Sydney Basin is not attempted here, though a brief and simplified description follows to provide the geological setting.

As its name implies, the Sydney Basin consists of various sedimentary rock strata that have been deposited in an elongated trough during several geologic ages. The oldest outcropping and sub-cropping rocks occur along the margins and are principally the coal bearing strata of Permian age, though other older rocks occur in the southern limit of the Basin. The coal bearing strata, which include many rocks other than coal, are generally called the Illawarra Coal Measures though they are also known as the Newcastle Coal Measures along the northern margin of the basin. These beds are overlain by rocks of the Narrabeen Group, the Hawkesbury Sandstone and finally the Wianamatta Group which together underlie the majority of the Sydney Basin.

The Narrabeen Group rocks, which consist of interbedded siltstones, claystones and sandstones, form the spectacular cliff lines around Katoomba and crop out along much of the coast from Swansea to Wollongong. The Hawkesbury Sandstone underlies a large portion of the city of Sydney and its northern metropolitan area. The Wianamatta Group consists principally of shales and underlies the majority of the Sydney metropolitan area. Faults and igneous intrusions occur throughout the sequence.

The weathering and erosion of the rocks has created slopes covered with a mantle of residual soils, transported soils (commonly known as colluvium) and fragments of rocks. In a geological sense and time scale, these slopes are all inherently unstable. In terms of human development, however, the rate of downhill movement of the slope materials may or may not be appreciable. It is these soil and rock slopes and their risk of instability to which this paper is directed.

3. SLOPE INSTABILITY

A detailed discussion of the cause of slope instability in the Sydney Basin is beyond the scope of this paper though the major factors involved include: the geological setting of the slope; the strength and depth of the colluvium, bedrock and residual soils; the slope gradient and the topographic setting of the site; and the vegetation cover. Most important are the groundwater regime, its variation, and man-made changes such as cuts, fill and drainage.

Instability of slopes occurs throughout the entire Sydney Basin. Table 1, entitled "Slope Instability and Geological Setting", provides an appreciation of the extent and nature of slope instability in the Sydney Basin. It should be noted that instability will and does occur in areas other than those listed in the table, and also that only small portions of the listed areas are actively unstable. Other areas of the Sydney Basin will prove unstable (in the domestic and sub-divisional sense) as development expands.

The varying geological conditions which occur in the listed areas mean that the major causes of instability in one area may be quite different to another. Indeed, changes in subsurface and other conditions can be considerable even between neighbouring lots resulting in significantly different assessments of the risk of instability.

4. CLASSIFICATION OF RISK OF SLOPE INSTABILITY

It must be appreciated that a risk is associated with development on hillsides. By tailoring the development to the particular site constraints, the risk of instability may be reduced. The onus is upon the owner, potential owner or interested parties to decide whether the level of risk presented in the assessment is acceptable.

The risk of slope instability can be evaluated either by a visual assessment or by a geotechnical investigation involving drilling, sampling, laboratory testing and engineering analysis. This latter option is usually expensive and time consuming, particularly for single allotments. Furthermore, the influence of groundwater variations usually requires long-term monitoring before adequate information is available to assist the relevant analyses. Assessment and investigation techniques require an intimate knowledge of complex geotechnical principles and should only be conducted by a highly experienced and qualified geotechnical consultant (i.e. geotechnical engineer or engineering geologist) to obtain satisfactory results.

The method for assessment of risk of instability discussed herein is that of visual appraisal and collection of basic geological measurements. Such an assessment is predominantly deductive and incorporates judgement based on experience. In many cases, this visual assessment will be sufficient to enable development to proceed - particularly for single allotments. In some situations, however, detailed geotechnical investigations will be required to confirm the assessment and define development options.

Table 2, entitled "Classification of Risk of Slope Instability", is a brief description of the relevant considerations and procedures followed by a geotechnical consultant in completing an assessment. The same table also explains the meaning of the five adopted classes of risk which are self-explanatory and should be closely read to fully understand the recommended classification system.

5. GUIDELINES FOR HILLSIDE CONSTRUCTION

A summary of good and poor engineering practices related to hillside construction is given in Table 3. This table is not a totally exhaustive list of good and poor practices. Sound engineering practice and adherence to the relevant codes and ordinances still apply in all cases. Figure 2 illustrates some of the salient features of the table.

It must be understood that in all domestic and sub-divisional development it is assumed that the owner will properly maintain the site. Further, it must be accepted that some cracking and distortion of the structure may occur.

6. ACKNOWLEDGEMENT

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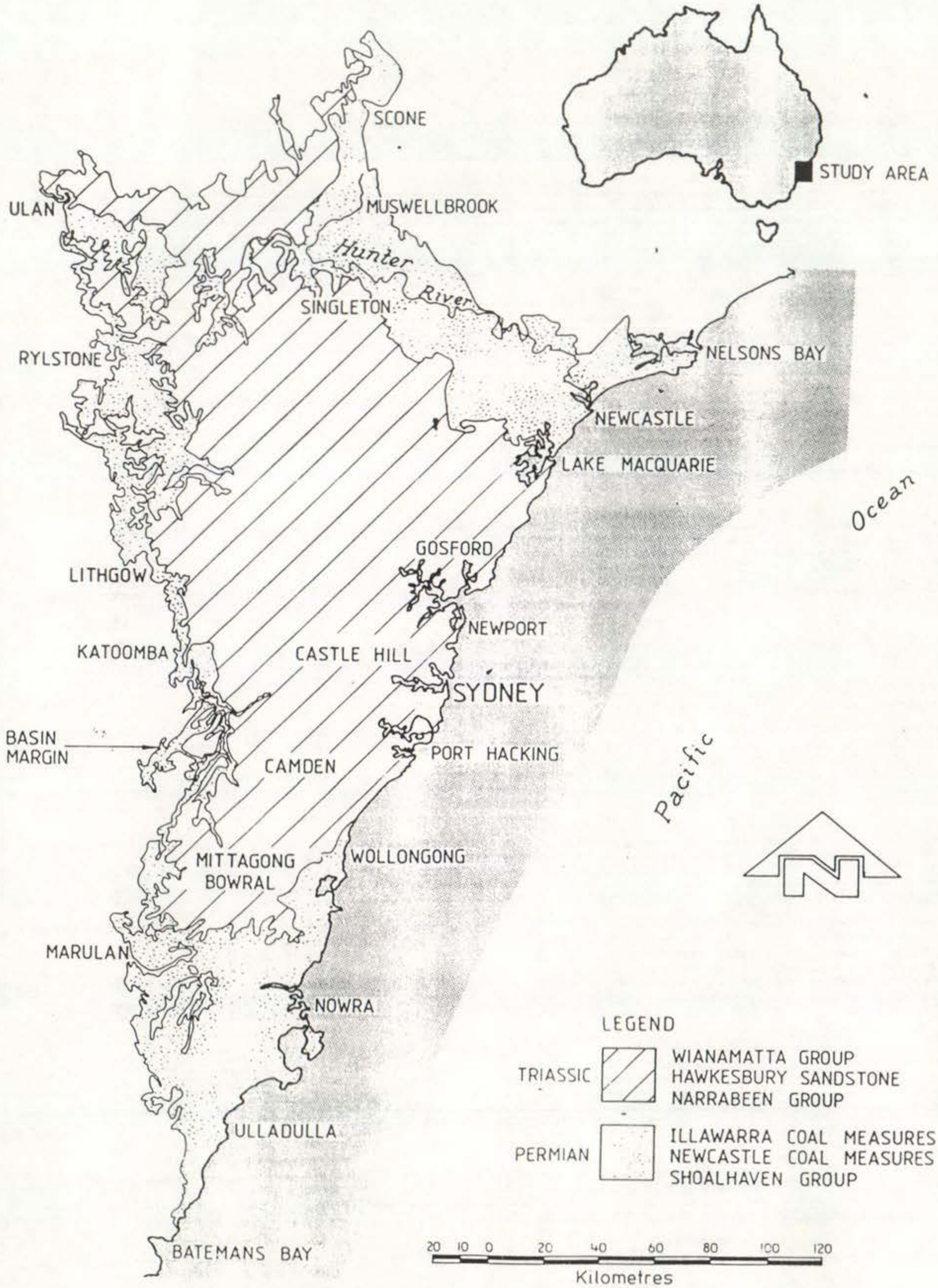


FIGURE 1 Extent of the Sydney Basin

This figure is an extract from GEOTECHNICAL RISKS ASSOCIATED WITH HILLSIDE DEVELOPMENT as presented in Australian Geomechanics News, Number 10, December, 1985, which discusses the matter more fully.

TABLE 1

SLOPE INSTABILITY AND GEOLOGICAL SETTING

GENERAL GEOLOGY	MAJOR INFLUENCES ON SLOPE INSTABILITY	EXAMPLES OF SLOPE INSTABILITY
ALL AREAS	Man-made changes - refer to Table 3.	
NEWCASTLE - LAKE MACQUARIE	FROM NEWCASTLE TO WALLSEND AND SOUTH TO CATHERINE HILL BAY AND ERARING	
Newcastle Coal Measures - interbedded sandstone, conglomerate, siltstone, claystone, coal and tuffs.	Instability predominantly in colluvium but also occurs in weathered bedrock. Colluvium up to 20 metres thick. Wide occurrence of low shear strength claystone. Coal seams often act as aquifers. Mining subsidence.	Large slow moving ancient slides (up to 400m x 200m plan, 20m deep), some with instability in the last 30 years, leading to total disturbance and mudflows. Seven houses slid towards Lake Macquarie in 1977-85. Fill, with coal seam aquifer, slid and demolished house in 1983. Road and railway affected by sliding during 1970-1985.
GOSFORD - CENTRAL COAST	FROM THE ENTRANCE TO OURIMBAH AND SOUTH TO BROKEN BAY	
Narrabeen Group - interbedded sandstone, conglomerate, shale, siltstone and claystone.	Instability in colluvium with thickness up to 4 metres. Groundwater seepage concentration over shale and claystone beds. Shale, siltstone, claystone and some sandstone weather to predominantly clay soils. Sandstone joints allow surface water into slope.	Generally localised sliding of colluvium on steeper (typically greater than 25°) slopes. Often initiated by construction of cuts and fills for roads or houses. Railway cutting failures in Gosford area.
	FROM WYEE TO WYONG	
Narrabeen Group - claystone and sandstone.	Claystone weathers to low shear strength clay soil. Colluvium up to 10 metres thick.	Major freeway cutting slide in claystone.
NEWPORT PENINSULA	FROM PALM BEACH TO CHURCH POINT AND SOUTH TO NARRABEEN	
Narrabeen Group capped by Hawkesbury Sandstone.	Instability in colluvium with thickness up to 7 metres, though typically 3 to 5 metres. Groundwater seepage concentration over shale and claystone beds. Shale, siltstone, claystone and some sandstones weather to predominantly clay soils. Sandstone joints allow surface water into slope.	Generally localised sliding of colluvium on steeper (typically greater than 25°) slopes. Often initiated by construction of cuts and fills for roads or houses. Three houses demolished by sliding in 1972. One house demolished in 1977 by sliding fill. Major road fill slip at Newport in 1974.
CASTLE HILL AREA	FROM PENNANT HILLS TO CASTLE HILL AND NORTH TO GLENHAVEN	
Wianamatta Group - interbedded shale, siltstone, laminite, and sandstone.	Instability in colluvium with thickness up to 6 to 8 metres. Shallow dips in downslope direction. Low shear strength bedding planes. Existence of aquifers in weathered bedrock.	Slow moving ancient slides with areas up to 300m x 200m, 6m deep. 13 areas known, some showing current activity. Damage to houses has occurred. Ground slopes often only 10-12°.
PORT HACKING - SUTHERLAND	FROM TAREN POINT TO EAST HILLS AND SOUTH TO GRAYS POINT	
Hawkesbury Sandstone underlain by Narrabeen Group.	Instability in thin colluvium cover on steep slopes. Undercutting of sandstone clifflines and floaters. Sandstone joints allow surface water into slope.	Generally localised sliding of colluvium on steeper (typically greater than 25°) slopes. Often initiated by construction of cuts and fills for roads of houses.
WOLLONGONG - SOUTH COAST	THE COASTAL STRIP FROM OTFORD TO UNANDERRA	
Illawarra Coal Measures - interbedded sandstone, siltstone, claystone, shale, coal and conglomerate. Overlain by Narrabeen Group and Hawkesbury Sandstone.	Instability of claystone. Coal seams often act as aquifers. Cliff line recession. Mining subsidence. Groundwater seepage concentration over shale and claystone beds. Sandstone joints allow surface water into slope.	Slow moving ancient slides of large areas (up to 1 km x 300m in plan, 20m deep), some with instability in the last 30 years leading to total disturbance and damage to housing. Long term problems with railway lines on Illawarra and Unanderra - Moss Vale lines. Large landslides in Bulli pass.
	FROM UNANDERRA TO GERRINGONG	
Gerringong Volcanics - latite, tuff, sandstone and basalt.	Instability of residual soils. Volcanics act as aquifers. Residual soils often sensitive to moisture changes.	Construction on flow slides at Gerroa.
CAMDEN - RAZORBACK RANGE	FROM CAMDEN TO PICTON AND WEST TO THE OAKS	
Wianamatta Group.	Claystone weathers to low shear strength clay soil at soil-bedrock boundary. Steep slopes and high groundwater inflows due to sandstone bedrock capping.	Very extensive colluvial instability and mudflows on slopes typically greater than 11°. Extensive sliding on Hume Highway in 1950's and 1960's.
MITTAGONG - BOWRAL	FROM MITTAGONG TO BOWRAL	
Wianamatta Group, Hawkesbury Sandstone, Narrabeen Group and volcanic intrusions.	Inclined strata. Groundwater seepage concentration over shale and claystone beds. Thick colluvium on flanks of intrusion. Sandstone aquifers in bedrock.	Numerous landslips on flanks of Mt. Gibraltar. Sliding in tertiary alluvials in Berrima area.

NOTES: 1. This table is intended only to give an appreciation of the extent and nature of slope instability in the Sydney Basin. The types of instability are diverse.
2. Only small portions of the above listed areas are subject to slope instability.
3. Instability does occur in other areas.

This table is an extract from GEOTECHNICAL RISKS ASSOCIATED WITH HILLSIDE DEVELOPMENT as presented in Australian Geomechanics News, Number 10, 1985 which discusses the matter more fully.

TABLE 2

CLASSIFICATION OF RISK OF SLOPE INSTABILITY

INTRODUCTION

In the Sydney Basin, which includes Wollongong to Newcastle and inland to Lithgow, there are many naturally occurring slopes which are the result of weathering and downslope transport of a mantle of soil and rock fragments. These may be unstable and will continue to move at varying rates, usually only appreciable over very long periods of time. However, on some sites the rate is fast enough to have a significant effect upon hillside development. Natural factors that effect the rate are:

* geology.
* nature and extent of the mantle of soil and rock fragments.
* groundwater.
* slope gradient and topography.
* vegetation.

Unstable rock slopes also occur.

ASSESSMENT PROCEDURE

The risk of slope instability should be assessed by an experienced geotechnical consultant. An assessment would normally include:

* study of geological and topographic maps supplemented by the consultant's experience in the area.
* consideration of information made available by the client about the site and its surrounding area (including previous instability, building distress and drainage problems) and development proposals.
* visual appraisal of the site and surrounding area including signs of instability, soil and rock exposures, seepage and vegetation.
* collection of basic geological measurements from the site to produce a geological sketch model.
* consideration of possible effects of high rainfall.

The assessment applies to the site at the time of the inspection.

Although the assessment is predominantly deductive and incorporates judgement based on experience, in many cases it will be sufficient to enable development to proceed. On very high, high and some medium risk sites geotechnical investigation will be required to confirm the assessment and define development options. The scope of any investigation depends upon the risk of instability and the proposed development and will involve subsurface investigations and possibly soil testing to improve the geotechnical consultant's understanding of the site.

DEVELOPMENT

Building techniques are available to enable development of many higher risk sites. Inappropriate development on the site and neighbouring properties can cause slope failure and serious damage. Inappropriate development includes:

* unsupported excavation or placement of fill.
* excessive clearing of vegetation.
* introduction of water to the slope.
* surface footings founded on the mantle of soil and rock fragments.

The owner's decision to develop the site involves an acceptance of a level of risk following development as assessed by the consultant. Even with suitable hillside construction techniques some minor cracking may occur.

Some sites may be unsuitable for economic development.

Other engineering constraints unrelated to slope instability may apply.

CLASSIFICATION

The following table has been produced to provide both a simplified classification which can be readily understood by a lay person and to provide a uniform language for geotechnical consultants.

RISK OF INSTABILITY	EXPLANATION	IMPLICATIONS FOR DEVELOPMENT
VERY HIGH	Evidence of active or past landslips or rockface failure; extensive instability may occur.	Unsuitable for development unless major geotechnical work can satisfactorily improve the stability. Extensive geotechnical investigation necessary. Risk after development may be higher than usually accepted.
HIGH	Evidence of active soil creep or minor slips or rockface instability; significant instability may occur during and after extreme climatic conditions.	Development restrictions and/or geotechnical works required. Geotechnical investigation necessary. Risk after development may be higher than usually accepted.
MEDIUM	Evidence of possible soil creep or a steep soil covered slope; significant instability can be expected if the development does not have due regard for the site conditions.	Development restrictions may be required. Engineering practices suitable to hillside construction necessary. Geotechnical investigation may be needed. Risk after development generally no higher than usually accepted.
LOW	No evidence of instability observed; instability not expected unless major site changes occur.	Good engineering practices suitable for hillside construction required. Risk after development normally acceptable.
VERY LOW	Typically shallow soil cover with flat to gently sloping topography.	Good engineering practices should be followed.

This table is an extract from GEOTECHNICAL RISKS ASSOCIATED WITH HILLSIDE DEVELOPMENT as presented in Australian Geomechanics News, Number 10, December, 1985, which discusses the matter more fully.

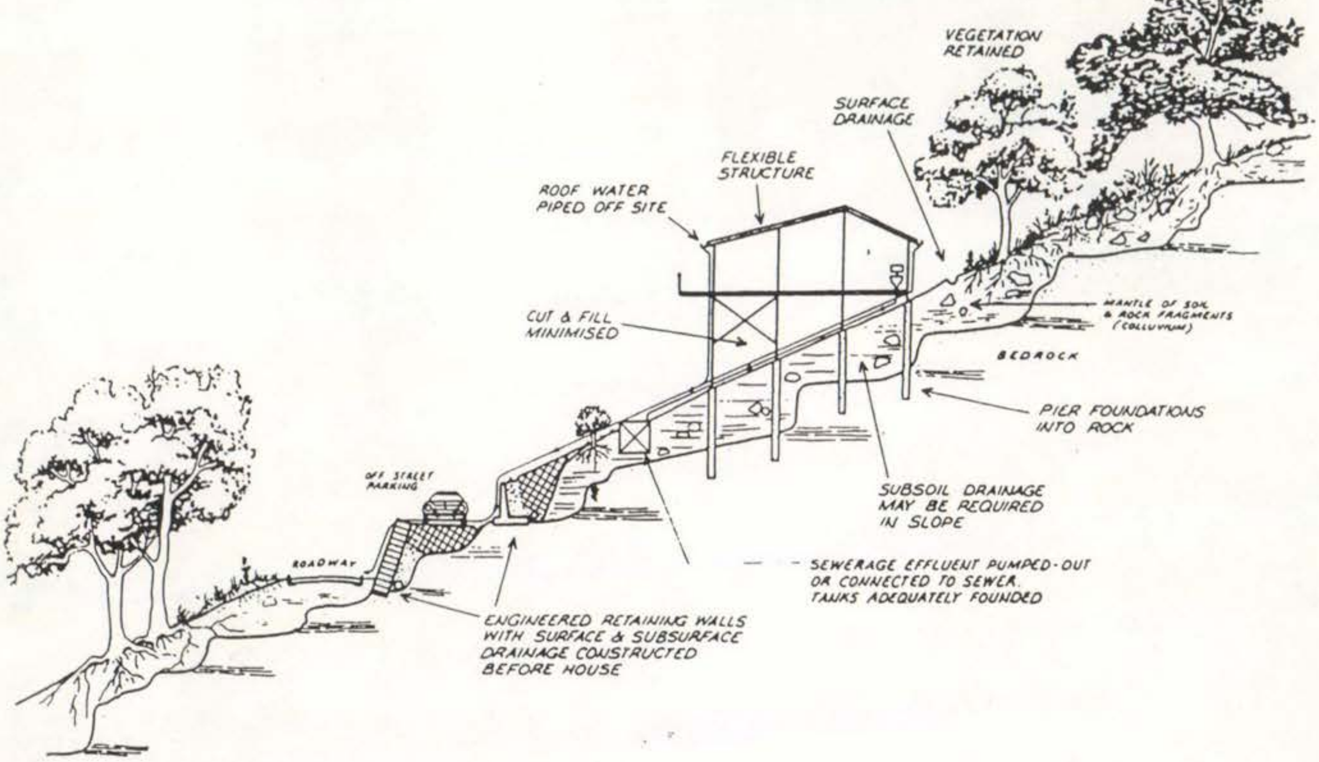
TABLE 3

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the Risk of Instability and Implications for Development in mind.	Plan development without regard for the Risk of Instability.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements.
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use and compact clean fill materials. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may become unstable. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOUNDATIONS	Support on or within rock where practicable. Use rows of piers or strip foundations oriented up and down slope. Design for lateral creep pressures. Backfill foundation excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide generous falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to disipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some low risk areas. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant.	
SITE VISITS	Site Visits by consultant may be appropriate during construction.	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident seek advice. If seepage observed, determine cause or seek advice on consequences.	

This table is an extract from GEOTECHNICAL RISKS ASSOCIATED WITH HILLSIDE DEVELOPMENT as presented in Australian Geomechanics News, Number 10, December, 1985, which discusses the matter more fully.

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE

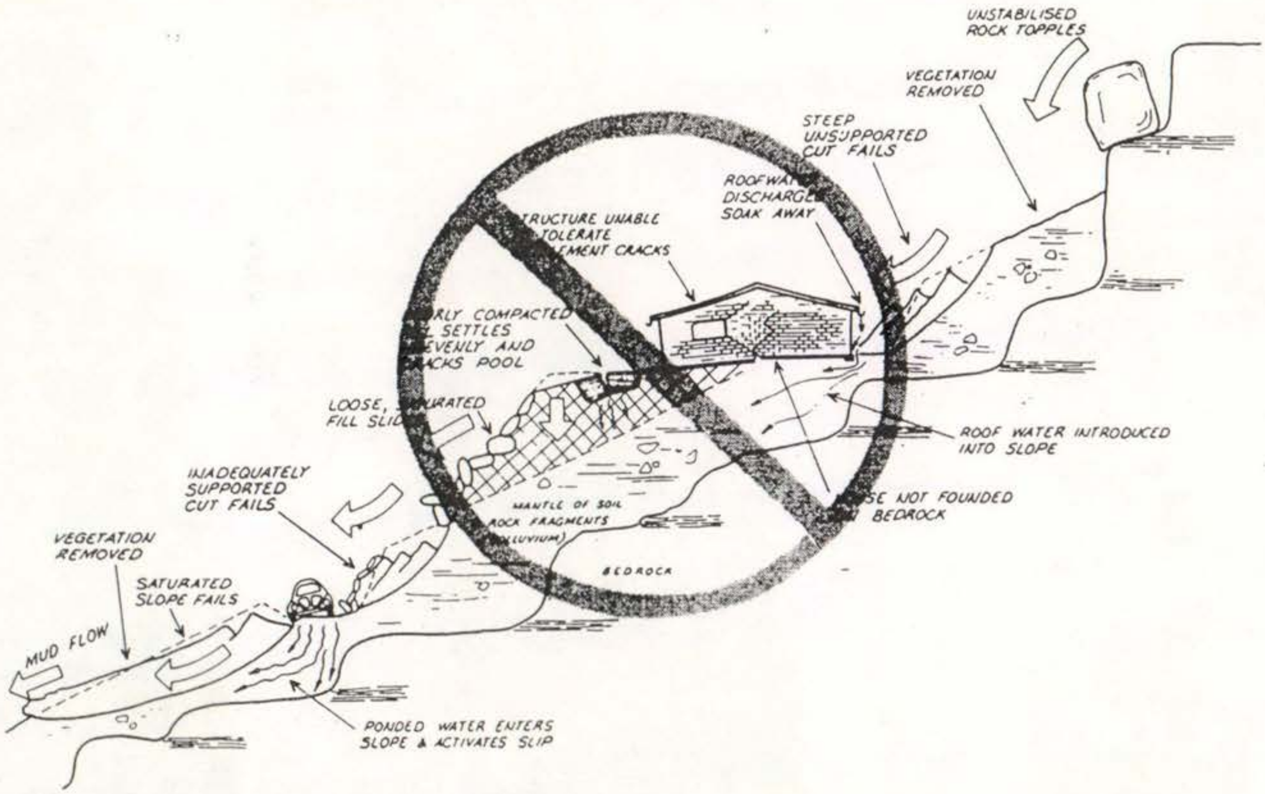


FIGURE 2 Illustrations of Good and Poor Hillside Practice

This figure is an extract from GEOTECHNICAL RISKS ASSOCIATED WITH HILLSIDE DEVELOPMENT as presented in Australian Geomechanics News, Number 10, December, 1985, which discusses the matter more fully.

Table 2.1 - Guidance on Site Investigation

Risk Category		Formed Slope Classification					Angle of Natural Hillside in the Vicinity of the Site		
Category	a. Loss of Life b. Economic Loss	Features	Soil		Rock	Retaining Wall	0° to 20°	20° to 40°	Greater than 40°
			Fill	Cut			Description of Site Investigation		
Negligible	a. None expected (no occupied premises). b. Minimal structural damage. Loss of access on minor roads.	 Angle	$\ngtr$ 7.5 m $\ngtr$ 50°	$\ngtr$ 5 m $\ngtr$ 30°	7.5 m -	3 m -	Assessment of surrounding geology and topography for indication of stability. Visual examination of soil and rock forming the site or to be used for the embankment. Specialist Advice - Requirement (A)	As for 0° to 20°. More detailed geology and topography survey. For the steeper slopes information on soil and rock joint strength parameters. Survey of hydrological features affecting the site. Specialist Advice - Requirement (B)	As for 20° to 40°. Area outside confines of site to be examined for instability of soil, rock and boulders above the site. Specialist Advice - Requirement (B)
Low	a. Few (only small occupies premises threatened). b. Appreciable structural damage. Loss of access on sole access roads.	Height Angle	$\ngtr$ 15 m $\ngtr$ 60°	$\ngtr$ 10 m $\ngtr$ 30°	7.5 m -	6 m -	Geology and topography survey of site and surrounding area. Soil and rock joint strength parameters for foundations and cut slopes. For embankments steeper than 1 on 3, recompacted strength parameters of fill. For cuts, information on groundwater level. Specialist Advice - Requirement (B)	As for 0° to 20°. Survey of hydrological features affecting the site. Specialist Advice - Requirement (B)	As for 20° to 40°. Extend outside limits of site to permit analyses of slopes above and below the site. Specialist Advice - Requirement (C)
High	a. More than a few. b. Excessive structural damage to residential and industrial structures. Loss of access on regional trunk routes.	Height Angle	> 15 m > 60°	> 10 m >30°	> 15 m -	6 m -	Detailed geology and topography survey of site and surrounding area. Soil and rock joint strength parameters for foundations and cut slopes. Recompacted strength parameters for fill. For cuts, information on groundwater level. Specialist Advice - Requirement (B)	As for 0° to 20°. Survey of hydrological features affecting the site. Extend investigation locally outside limits of the site to permit analyses of slopes above and below the site. Specialist Advice - Requirement (C)	As for 20° to 40°. Extend investigation more widely outside limits of site to permit analyses of stability of slopes above and below the site. Specialist Advice - Requirement (C)

Note : (1) This Table is intended to provide guidance only. Each situation must be assessed on its merits to decide whether or not the recommended investigation procedures are necessary or if peculiar conditions require even more detailed examination.

(2) Whilst the above gives an indication of the requirements for a site investigation under certain general conditions, Table 2.2 gives more precise information on how the above requirements can be met.

(3) For slopes on which there are unstable boulders, the services of an experienced geotechnical engineer or engineering geologist will always be necessary.

(4) Risk category should be assessed with reference to both present use and development potential of the area.

(5) Formed slope classification to be based upon either slope height or angle whichever gives the highest risk category.

(6) Requirements for specialist advice :
(A) Services of an experienced geotechnical engineer or engineering geologist not necessary.
(B) Services of an experienced geotechnical engineer or engineering geologist to depend on location relative to developed or developable land.
(C) Services of experienced geotechnical engineer or engineering geologist essential.

Table 5.1 - Recommended Factors of Safety for New Slopes for a Ten-year Return Period Rainfall

ECONOMIC RISK \ RISK TO LIFE		Recommended Factor of Safety against Loss of Life for a Ten-year Return Period Rainfall		
		Negligible	Low	High
Recommended Factor of Safety against Economic Loss for a Ten-year Return Period Rainfall	Negligible	>1.0	1.2	1.4
	Low	1.2	1.2	1.4
	High	1.4	1.4	1.4

Note : (1) In addition to a factor of safety of 1.4 for a ten-year return period rainfall, a slope in the high risk-to-life category should have a factor of safety of 1.1 for the predicted worst groundwater conditions.

(2) The factors of safety given in this Table are recommended values. Higher or lower factors of safety might be warranted in particular situations in respect of economic loss.

Table 5.2 - Typical Examples of Slope Failures in Each Risk-to-Life Category

Example	Risk to Life		
	Negligible	Low	High
(1) Failure affecting country parks and lightly used open-air recreation areas.	√		
(2) Failures affecting roads with low traffic density.	√		
(3) Failures affecting storage compounds (non-dangerous goods).	√		
(4) Failures affecting densely used open spaces and recreational facilities (e.g. sitting-out areas, playgrounds, car parks).		√	
(5) Failures affecting roads with high vehicular or pedestrian traffic density.		√	
(6) Failures affecting public waiting areas (e.g. railway platforms, bus stops, petrol stations).		√	
(7) Failures affecting occupied buildings (e.g. residential, educational, commercial, industrial).			√
(8) Failures affecting buildings storing dangerous goods.			√

Table 5.3 - Typical Examples of Slope Failures in Each Economic Risk Category

Example	Economic Risk		
	Negligible	Low	High
(1) Failures affecting country parks.	√		
(2) Failures affecting rural (B), feeder, district distributor and local distributor roads which are not sole accesses.	√		
(3) Failures affecting open-air car parks.	√		
(4) Failures affecting rural (A) or primary distributor roads which are not sole accesses.		√	
(5) Failures affecting essential services which could cause loss of that service for a temporary period (e.g. power, water and gas mains).		√	
(6) Failures affecting rural or urban trunk roads or roads of strategic importance.			√
(7) Failures affecting essential services, which could cause loss of that service for an extended period.			√
(8) Failures affecting buildings, which could cause excessive structural damage.			√
Note : These examples are for guidance only. The designer must decide for himself the degree of economic risk and must balance the potential economic risk in event of a failure against the increased construction costs required to achieve a higher factor of safety.			

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Geotechnical Control Office,
Engineering Development Department,
Hong Kong

Table 5.4 - Recommended Factors of Safety for the Analysis of Existing Slopes and for Remedial and Preventive Works to Slopes for a Ten-year Return Period Rainfall

	Recommended Factor of Safety Against Loss of Life for a Ten-year Return Period Rainfall		
Risk to Life	Negligible	Low	High
	> 1.0	1.1	1.2

Note : (1) These factors of safety are minimum values to be used only where rigorous geological and geotechnical studies have been carried out, where the slope has been standing for a considerable time, and where the loading conditions, the groundwater regime and the basic form of the modified slope remain substantially the same as those of the existing slope.

(2) Should the back-analysis approach be adopted for the design of remedial or preventive works, it may be assumed that the existing slope had a minimum factor of safety of 1.0 for the worst known loading and groundwater conditions.

(3) For a failed or distressed slope, the causes of the failure or distress must be specifically identified and taken into account in the design of the remedial works.