APPENDIX G:

Geotechnical Engineering

Tauranga City Council
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1.0: Reporting Guidelines
### Table 3: Description of geomorphological zones and assessment guidelines

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| **Active feature**                                              | 1. Initial assessment to be carried out by Category 1 Geologist/geomorphologist  
2. Examination, on foot, of the surface of the site and the surrounding ground, with the assistance of existing topographical maps  
3. Examination of available aerial photographs of the area (include selection from early to present time)  
4. Assessment of available geological data (IGNS and other maps, publications, university theses and any other published or unpublished data)  
5. Review of relevant files and other historical records  
6. Check with local residents and other sources for evidence of past instability, particularly during periods of heavy rainfall  
7. Prepare preliminary report including geomorphological map of site, detailed cross sections showing site stratigraphy, preliminary conclusions on site characteristics and recommendations for additional investigation, mapping and monitoring. Report to include specific reference to all aerial photographs and other sources of information used for the study.  
8. Geomorphological assessment to provide conclusion on characteristics of any landslide present and the history of movement (historical or current)  
9. If landslide with recent movement affects the site, further topographical surveys, ground investigations and stability analyses will be required to demonstrate that the site can be made adequately safe by remedial works  
10. Undertake investigations to determine the nature and distribution of the soils that may be prone to slip and develop engineering geology site model  
11. Measure groundwater pressures in the soils strata and evaluate the transient pressures that may develop under extreme rainfall conditions  
12. Produce engineering geological report with details of mass movement features and other ground failure hazards  
13. Carry out geotechnical evaluation, using Category 1 Engineer and including further sampling, laboratory testing, assessment of ground properties, groundwater monitoring, etc. If strength assessment has been made by reference to test data from other sites, provide detailed rationale for the use of such data  
14. Undertake slope stability evaluation using approved methods  
15. Make recommendations for use of site and provide design for remedial measures if appropriate. |
| **Probable or possible feature with no evidence of recent or current activity** | 1. Assessment to be carried out by Category 1 Specialist Advisor (Geologist/geomorphologist or Geotechnical Engineer)  
2. Examination, on foot, of the surface of the site and the surrounding ground, with the assistance of existing topographical maps  
3. Examination of available aerial photographs of the area (include selection from early to present time)  
4. Assessment of available geological data (IGNS and other maps, publications, university theses and any other published or unpublished data)  
5. Review of Council files and other historical records  
6. Check with local residents and other sources for evidence of past instability, particularly during periods of heavy rainfall  
7. If absence of recent or current landslide activity is confirmed, prepare report confirming this with appropriate documentation (map and representative sections)  
8. If ground hazard identified, follow Steps 7 to 15 of Zone 1 procedures |
| **Interpreted slope movement feature with either or both of the following:** | 1. Clearly defined headscarp  
2. Hummocky debris  

**No evidence of recent or current activity** Building within 2H:1V slope line or within 4H:1V runout distance. Some sites may require detailed engineering geological and geotechnical assessment. |
| **No evidence of landslides**                                  | 1. Site to be inspected by competent Category 2 person (Registered Engineer or Geologist with equivalent experience)  
2. Provide written confirmation of inspection and judgement that there is no landslide hazard at the site |
| **No requirement for engineering geology or geotechnical engineering expertise** | 1. Site to be inspected by competent Category 3 person |
2.0 General description of land form within Tauranga City

2.1 The land form and geology within Tauranga District have some features which demand particular attention.

(a) Minimum Building Platform Levels
Significant areas of Tauranga District are at risk of flooding through sea level rise, tidal surges within the harbour, storm-wave runup on the ocean coastline and the flooding of streams sewer drains, ponding areas and overland flow paths in extreme climatic conditions. Council has some “broadbrush” information on many possibly flood prone areas. More detailed investigations by appropriately qualified people may be required to be submitted in support of Resource and Building consents. Building platforms should be constructed with adequate freeboard above flood levels.

Council has adopted a minimum floor level policy. This level is available from Council on request from Council.

However due to the dynamic nature of the environment and the ongoing investigative work these levels may be reviewed at anytime.

For the purposes of this Section, a “building platform” is defined as the area of ground within a line 1.0m outside the perimeter of the building proper.

(b) Low Lying Land:
There are many areas of low-lying land (often adjacent to the harbour) which comprise soft or very soft foundation conditions. These conditions are characterised by normally consolidated fine grained alluvial sediments (silts and clays) which have been deposited in marine or estuarine environments. In many cases these low lying areas have been subject to random and non-engineered fillings. The underlying materials are prone to settlement caused by consolidation under even minor loadings. These areas require particular care and appropriate geotechnical investigation and advice prior to development concepts being prepared. Whilst most of the Mount Maunganui/Papamoa area has a sand formation underlying pockets of peat and “black sand” may occur which exhibit poor foundation support qualities. These shall be removed from building platform and roading subgrades.
2.2 **Tauranga Soils: (Coarse Overview)**

The foundation conditions of the low-lying areas in the District have been described above. The near surface geology of the higher ground within the City comprises a series of weathered fine grained rhyolitic ashes known locally as the Older Ashes and defined in published geology as the Matua Sub-group. The Older Ashes consist of the undifferentiated tephras and sediments that can include some moderately to highly sensitive soils which require special consideration in design. The older ashes are overlain by the Hamilton Ash a stiff to hard fine grained soil. At the top of the Hamilton Ash is a sequence known as the “chocolate” and marks the boundary between the Old and Younger Ash sequences.

Overlying the Older Ashes is a series of coarse friable silts, sands and pumice lapilli (ashes) which tend to mantle the topography formed within the Older Ashes and are known as the Younger Ashes.

On some sloping ground, particularly the present and relic slips adjacent to the harbour, the ashes often have marginal stability and there are numerous examples of past and recent instability. Deep seated failures are generally confined to the steep banks which are or have in their history been subjected to active toe erosion. Development is usually set back from the top of such steep banks, with the set back distance being determined by appropriate geotechnical investigations and analysis carried out by a person who is Pre-qualified with Council as Specialist Geotechnical Advisor, Category 1 Chartered Professional Engineer or Engineering Geologist.

2.3 **Relic Slips**

Over 2500 relic slips have been identified within the City through several studies. The latest study undertaken in 2001 by Richards and Bell (TL485) forms the backbone of how to address the issues potentially associated with these geomorphic features and outlines in detail their age and possible characteristics.
From this report comes the performance criteria used by the City to manage these features at the time of building or resource consent. These criteria are reporting guidelines, and the 2H:1V and 4H:1V zones used to provide an indication of the order of risk possibly associated with steep land and/or relic slips.

A copy is available electronically from Council to provide greater knowledge of these issues.

2.4 The majority of other failures on modest to steeply sloping ground are shallow failures (involving the top 1m to 3m of soil), but are nonetheless of serious consequence to any building development. Such failures are usually initiated by extreme climatic conditions. Any sloping ground greater than 15° gradient should be subject to appropriate review investigations to determine whether the ground is adequately stable for residential development.
3.0 Phases of a Site Investigation

3.1 A rationale approach to site investigations for urban land subdivision is given in the NZS 4404 Land Development and Subdivision Engineering.

(a) **Preliminary Exploration**

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

(b) **Field Investigation**

A preliminary exploration will in most land development projects, be followed by a specific and detailed field investigation, with in situ and laboratory tests as appropriate. This investigation will yield the basis of the detailed geotechnical appreciation of the site, and will provide guidelines for the development of the site, including limitations on that development. Frequently, detailed design is likely to be progressing concurrently with reporting and must be accommodated.

(c) **Construction Observation**

Observation during construction is essential to verify the appreciation obtained from (a) and (b). It is not unusual for the appreciation to be modified as site development proceeds, resulting in further investigation and changes in design and/or construction concepts.
(d) Performance Observation

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

4.0 Site Investigation Logic

4.1 General

The objectives of a site investigation are to:-

- Assess the suitability of a site for its proposed use.
- Foresee construction difficulties.
- Collect enough information for satisfactory design.

A site investigation should address the following factors:
- Ownership
- Geology ) Nature and
- Groundwater ) extent of soils
- Subsoil conditions, ) and rocks etc.
- Foundation conditions )
- Stability and settlement potential
- Services
- Access

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

- Geological maps and reports.
- Data from adjacent sites – i.e. previous investigations.
- Aerial photographs.
- Performance of related and/or adjacent developments.

The logic of site investigations for land subdivision and development projects is summarised in Drawing G3, Section 3.
4.2 Development Evaluation Report

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

(i) **Scope**

A brief description of the scope and context of the report.

(ii) **Geology**

Investigate, examine and report on the general geology of the area and its influences on foundation conditions.

(iii) **Soils**

Investigate and report on the soil characteristics of the site with regard to foundation and construction condition.

(iv) **Foundation Requirements**

Consider the types of building likely and their load requirements, and evaluate the foundation design parameters for building development. Consider the type of road and evaluate the foundation at subgrade level.

(v) **Effluent Disposal**

In areas where sewage treatment is by means of septic tanks, the report should also comment on the suitability of the site to accept septic tank effluent disposal and its influence on land stability.
(vi) **Slope Stability**

Where slope in excess of 15° are present, carry out a slope stability appraisal to determine whether the development will provide stable and accessible building sites that can be satisfactorily built on.

(vii) **Non-Engineered Fills**

Identify the existence of previous filling activities on the site, and comment on the quality and suitability of such fills for development purposes.

(viii) **Earthworks Development and Control**

Discuss earthworks aspects of the site and provide a specification for earthworks control, dust and silt management plans and the installation of services.

(ix) **Conclusions and Recommendations**

Set out the findings of the investigation and provide recommendations for:-

- Restriction on use of the land if all or part of the land is unsuitable for some uses.
- Suggested changes to a subdivisional layout to achieve better use of the site, and/or minimise construction difficulties.
- Control during construction.
- Further investigation where required.
- Regulation and control, or future action necessary to maintain suitability.

A check list for reporting is given in Drawing G4.
5.0 Slope Stability

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

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

5.3 An experienced person can recognise previous landslip areas by stereoscopic examination of pairs of aerial photographs. This is a fast and economical means for assessing the general slope stability characteristics of a large area.

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

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

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

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

Coastal erosion or flowing water from rainfall is constantly changing the shape of the earth's surface. Water action frequently creates slopes that are over steep and subject to landslip, (i.e. are marginally stable).

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

It follows then that many slopes are potentially unstable in their natural state, and must therefore be considered unsuitable for residential development.

In the situation where the concept of land development is to minimise earthworks and to leave the land in its largely undisturbed natural state, many problems arise and are experienced between the practitioner and local authorities in determining acceptable slope stability criteria, levels of risk and reporting.
5.5 Preliminary reconnaissance using site inspection, air photo interpretation and available geological and geotechnical records provides an initially low cost sound basis for the conceptual planning of a land development project. This preliminary appraisal should identify:

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

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

5.8 An acceptable concept for the investigation and assessment of the suitability of land developments in which natural slopes are intended to be left undisturbed provides for the delineation of a Building Line Restriction which represents the closest proximity to a slope for any building development.

5.9 The determination of building line restrictions should be derived from an assessment of potential risk under varying site conditions.

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

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

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

- the geometric accuracy (e.g. of the slope or retaining wall being designed);
- the soils strength (which is likely to vary from point to point even in the same soil “layer”);
- the method of analysis adopted (which is usually two dimensional and have simplifications that may not accurately reflect the actual situation);
- the validity of assumptions made (e.g. depth to groundwater level, depth to rock or hard layer, etc.).

For these reasons, it is customary to adopt a factor of safety value of 1.5 for subdivisions or housing development. This factor of safety does not in every case assure safety from instability or slope movement.
6.0 **Earthworks**

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

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

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

6.3 In summary, the proper appreciation of the earthworks concepts for land development will identify:

- The suitability of the site for the concept, including the appraisal of aerial photo for larger sites and records of previous filling.
- Particular engineering measures that will need to be incorporated in the engineering design.
- The influence of the earthworks concepts on slope stability and mitigating design measures.
- Special measures that might be required for settlement considerations, depending on fill depths, etc. (ie. settlement monitoring, delays on building construction, etc.).
- Control measures for earthworks. Dust and sediment control to Regional Council standards and guidelines.

In almost all circumstances, it will probably prove to be prudent for the developer/engineer to at least obtain an initial appraisal by a geotechnical engineer to provide input to the conceptual design.

In many circumstances (eg. where the size of the development is sufficiently small), a visual appraisal will suffice. In most circumstances, however, some form of investigation will be required.
7.0 Earthworks Quality Assurance and Control

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

- Adequate strength.
- Limited volume change.

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

7.3 A considerable amount of judgement is involved in the determination of quality control criteria.

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

- Visual inspection.
- Quantitative testing.

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

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

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

- on completion of clearing and removal of unsuitable soils;
- on completion of compaction of each fill layer until completion of the whole fill;
- all with clearly dated and surveyed test points.

Corrective measures need to be specified and carried out where the target quality is not met.

The final fill control certificate provides a record of work done and tests carried out (quality control record).

Visual inspections should be made:

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

Quantitative testing should be related to the control criteria determined by the soils engineer and should have a higher frequency (say about 500 to 1000m³ intervals) at the initial stages of earthworks to sort the operations out, with a lesser frequency as the fill progresses, the compaction criteria are being achieved, and visual appraisal indicates the overall operations are satisfactory.
8.0 Settlement

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

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

8.3 Settlement will also occur within earth fills due to the self weight of the fill.

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

9.1 Bearing Capacity. The strength of the ground resisting general shear failure (and resulting gross deformation) under the building foundations is a local phenomenon distinct from settlement.

It should be noted, however, that despite careful construction there may still be localised soft areas in the upper layers of fill within the zone of influence of the building. If localised soft areas are present, then tests should be made to determine the required treatment of the fill material, of or the foundations. These tests should extend to a depth below the footings as judged appropriate by the Soils Engineer and may include shear strength tests, field load tests or dynamic penetrometer tests or other recognised soil strength tests.

It should be noted that the dynamic penetrometer tests should be accompanied by identification of the soils present by boreholes.

The adequacy of subgrade compaction and proposed pavement depth for road works may need to be confirmed by tests on the finished subgrade.

9.2 Shrinkage and Expansion. Because some clay soils are likely to undergo shrinkage and swelling when subjected to seasonal or other changes in water content, special examination of swelling and shrinkage characteristics should be made in the case of highly plastic soils.

Where applicable, the need for a foundation depth or design sufficient to minimise these effects, particularly for continuous brittle walls, should be made in the case of highly plastic soils.