ABSTRACT

This guideline has been prepared to assist in the planning, conducting and reporting of geotechnical investigation of new roads. The objectives for these guidelines are to describe the processes or stages of work to be followed for a road alignment investigation. The guideline also indicates standard of skill, workmanship and reporting to be applied in the investigation process.

This guideline document should be used as a guide and not approached or referred to as a limiting or standard geotechnical investigation/design specification.
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<td>REFERENCES</td>
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1. INTRODUCTION

This guideline document has been prepared to assist in the planning, conducting and reporting of geotechnical investigation of new roads. The objectives for these guidelines are to describe the processes or stages of work to be followed for a road alignment investigation. The guideline also indicates standard of skill, workmanship and reporting to be applied in the investigation process. Management of the investigation will involve the application of QA/QC procedures validated by independent external audit conforming to ISO 9000/9001.

2. OBJECTIVES

The objectives for these guidelines are to:

- describe processes or stages of work to be followed for a site investigation.
- indicate standards of skill, workmanship and reporting, which are to be applied.

The scope of the geotechnical investigation shall be strictly limited to the requirements of the project design and specification and shall not, except where necessary to meet project aims and objectives, address construction issues.

3. STAGES OF INVESTIGATION

3.1 Field Reconnaissance Survey

For most site investigations access and environmental constraints have major influences on cost. It is therefore necessary for a field reconnaissance survey to be conducted as the first stage of a geotechnical investigation. This may be undertaken by Main Roads Western Australia (MRWA) or by a Consultant specifically engaged for this survey. Information on the following should be obtained:

- Legal and physical aspects of access to site, for example, access for drilling rigs.
- Availability of any services or supplies of water, electricity, earthworks plant.
- Buried or overhead services.
- Photographs of surface conditions.
- Traffic control requirements.
- The possible effects of alternative investigation techniques on the environment (for example, ground disturbance, water discharge, noise etc).
- On-ground survey details.
- Tide, river level or other natural constraints.
Notes on any exposed geology, for example the presence of boulders, bedrock exposure, swamps etc.

The field reconnaissance survey must be diligently prepared and conducted to allow for reliable cost estimates to be prepared. Experienced and suitably qualified personnel should perform the survey. Further stages of the investigation should be held until the field reconnaissance survey has been completed.

### 3.2 Desk Top Study

Every site investigation should commence with a desk study directed towards collecting, collating and reviewing the following:

- Design drawings from any previous structure at the site.
- Previous site investigation reports, borehole logs, penetrometer results and construction experience e.g. piling records.
- Geological maps, survey data and records.
- Hydrological data.
- Aerial photographs.
- Regional seismicity data.
- Survey records, local knowledge and resources

Where possible, collection and collation of the above information should be undertaken during the field reconnaissance survey stage. However, further work to fully explore the extent of information available may be required.

### 3.3 Site Investigation

A comprehensive geotechnical investigation of the project site should be carried out in order to characterise the materials and conditions which will be encountered during the construction and operation of the project, their nature, variability, extent and any special requirements to be observed. The investigation should include an evaluation of the geology and hydrogeology of the site. The detail of the investigation should be commensurate with the potential risks, hazards and complexity of the project.

The investigation should include geological surface mapping, sampling of soils throughout the project site with appropriate logging of all excavations and boreholes, logging of existing cut slopes and excavations, field and laboratory testing including field monitoring, measurement of groundwater levels, moisture regimes, soil strengths and compressibility, analysis and interpretation of the results and preparation of a geotechnical report.
Where changes of soil type are encountered, the investigations should determine the boundaries and depths in sufficient detail to enable the extent of appropriate design units and treatments to be determined. Minimum standards (frequency of testing) to be adopted in geotechnical investigation and design work are listed below:

3.3.1 Embankment Foundation

The embankment foundation investigation should as a minimum consider the following issues:

- the range of materials in the embankment foundations and where appropriate the pavement subgrade (including subgrade strength)
- settlement potential
- stability
- hydrogeology, moisture regime and drainage requirements
- special construction requirements

Sufficient samples should be taken of the embankment foundations and pavement subgrades for testing purposes. Each pavement subgrade design unit shall be sampled and tested in accordance with Engineering Road Note No. 9 “Procedure for Thickness Design of Flexible Pavements” (June 1988).

Embankment foundation investigations should comply with the minimum standards requirements as given below:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum test pit/borehole spacing</td>
<td>500m</td>
</tr>
<tr>
<td>Minimum test pit/borehole depth</td>
<td>1.5m below subgrade level, or 0.5m below table drain or subsoil drain level, or 0.5m below culvert invert level, whichever is the greater or refusal</td>
</tr>
</tbody>
</table>
3.3.2 Cuttings in Soil

The cutting investigation should as a minimum consider the following issues:

- the range of materials in the cuttings and in the pavement subgrade
- slope stability
- subgrade strength
- suitability of cut materials for basecourse, sub-base and embankment fill
- excavation conditions
- hydrogeology, moisture regime and drainage requirements
- the extent of any problems which may be encountered during and after construction.

Except where refusal does not permit, each pavement subgrade design unit should be sampled and tested in accordance with Engineering Road Note No. 9 “Procedure for Thickness Design of Flexible Pavements” (June 1988).

Soil cutting investigations should comply with the minimum standards requirements as given below:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum test pit/borehole spacing</td>
<td>100m</td>
</tr>
<tr>
<td>Minimum test pit/borehole depth</td>
<td>1.5m below subgrade level, or</td>
</tr>
<tr>
<td></td>
<td>0.5m below table drain or subsoil drain level, or</td>
</tr>
<tr>
<td></td>
<td>0.5m below culvert invert level, whichever is the</td>
</tr>
<tr>
<td></td>
<td>greater or refusal</td>
</tr>
</tbody>
</table>

3.3.3 Cuttings in “Rock Excavation Materials”

For road construction specification purposes and for the purposes of this Guideline, MRWA defines “rock excavation materials” as

“all materials to be excavated to achieve the road design cross section including table drains which cannot be ripped and excavated with a tracked dozer in good condition with matching hydraulic single shank ripper of combined mass not less than 52 tonnes (this refers to a Caterpillar D10R or its equivalent) at a rate in excess of 90 cubic metres (solid) per hour. Isolated boulders greater than 0.8 cubic metres in volume may be included in this definition”
Where significant volumes of materials are encountered in cuttings which potentially fall within the definition of “rock excavation materials” then additional investigations should be conducted by one of the following two techniques:

(a) excavate trenches in the in-situ materials using a dozer complying with the above requirements supplemented with the drilling of boreholes (eg solid auger drilling), to determine extent of “rock excavation materials”.

(b) carry out a seismic refraction survey to determine the seismic velocity profile within the cutting materials and supplement with sufficient test pits or cored boreholes to identify rock type, strength and joint spacing. The seismic refraction survey should be undertaken by a suitably qualified and experienced geophysicist.

Dozer trenches should be logged in accordance with Section 3.5 Field Logging and Sampling Standards. Where dozer trenches are excavated, the log shall include time required to excavate trench, trench dimensions, descriptions of the in situ and excavated materials and good quality colour photographs of the finished trench and excavated material.

Rock cutting investigations should comply with the minimum standards requirements as given below:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Minimum Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum dozer trench spacing</td>
<td>200m</td>
</tr>
<tr>
<td>Maximum solid auger spacing</td>
<td>20m</td>
</tr>
<tr>
<td>Minimum depth of investigation</td>
<td>1.5m below subgrade level, or 0.5m below table drain or subsoil drain level, or 0.5m below culvert invert level, whichever is the greater or refusal</td>
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</tbody>
</table>

The solid auger penetration rates should be recorded in terms of the downward resistance experienced by the flight auger. Disturbed samples, based on cuttings accumulated around the top of the solid auger boreholes, should be logged and the information should be presented in Borehole Summary Sheets.
3.3.4 Soft/Wet Areas

Where soft/wet soils are found, particularly in the vicinity of low embankments, or in shallow cuttings, additional investigation, sampling and testing should be carried out to determine the in situ CBR of the proposed subgrade.

The location and characteristics of any soft/wet areas or springs should be recorded and reported. The treatment required to enable the construction and operation of the road across or through these areas should also be recommended.

Investigations of soft/wet areas should comply with the minimum standards requirements as given below:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum test pit/borehole spacing</td>
<td>50m</td>
</tr>
<tr>
<td>Minimum test pit/borehole depth</td>
<td>1.5m below subgrade level, or 0.5m below table drain or subsoil drain level, or 0.5m below culvert invert level, whichever is the greater or refusal</td>
</tr>
</tbody>
</table>

3.3.5 Embankment Materials

The suitability of materials encountered within the cuttings should be assessed for embankment or pavement construction. It should be considered and recommendations made as to the use of selected fill materials within one metre of pavement subgrade level and the placement of inferior quality materials in the lower parts of the fills.

3.4 Sampling and Testing

This stage of the geotechnical investigation is involved with exploration of sub-surface conditions and retrieval of test data for generating geotechnical parameters and geotechnical profiles.

Defining the scope of the investigation (eg. number of test locations, type of test and depth) is not covered explicitly by these guidelines.

The number, location and depth of tests is to consider:

- expected sub-surface conditions
likely extent of zones in ground influenced by embankment loading

need to achieve a reliable geotechnical model for analysis

requirement to minimise Contractor and MRWA risk of changes during the construction programme due to variations in the subsurface conditions from that reported during the investigation stage.

Allowance should be made for the anticipated level of variability in ground conditions and possible changes to the design. An experienced and suitably qualified personnel should make these decisions and discussion on the number, location and depth of the selected tests must be a part of the geotechnical report. This discussion must enable the reader of the report to understand what factors were used to assess these variables and provide a clear understanding of the deliverables.

While the above points should be covered by a well planned investigation there may be situations where during the investigation stage it is considered by MRWA or the geotechnical consultant that additional investigation will be required to generate a more reliable model and minimise risk. This work shall be undertaken at a schedule of rates agreed upon prior to the commencement of the investigation.

All in situ testing, for example Electric Friction-Cone Penetration (EFCP), testing should be carried out in accordance with the relevant standard and supervised accordingly.

Groundwater must be investigated to determine:

- the level of the permanent water table at the time of the investigation
- occurrence of a perched water table condition and its level
- estimated rates of inflow to excavations
- effects of de-watering on water table levels and on adjacent structures
- the presence of sub-artesian conditions
- potential aggressiveness of the soil and groundwater, for example SO$_4$, Cl, pH and Total Dissolved Solids (TDS) to buried concrete and steel.

For most cases it will be necessary to install standpipes in selected boreholes to enable sampling and observations of water to be made.
3.5 Field Logging and Sampling Standards

Logging of soils shall be carried out in general accordance with Appendix A, Section A2 of AS 1726 - 1993 “Geotechnical Site Investigations” except as varied below. Logging of rock shall be carried out in general accordance with Appendix A, Section A3 of AS 1726 - 1993 “Geotechnical Site Investigations”.

Where boulders occur in a soil, the log shall include the maximum size of boulder (eg. boulders to 800mm).

A log report shall be prepared and submitted for each excavation or borehole. The location of all test excavations and boreholes shall be accurately defined so that their position can be related to the alignment. This may require the pick up of all sites by surveyors. For excavation logs, the log shall include a factual record of the ease with which the various materials encountered were excavated.

All field logging and sampling shall be undertaken by a suitably trained and experienced geotechnical engineer, engineering geologist or soil technician. Sampling shall be conducted or supervised by the person logging the excavations and boreholes. All soil sampling shall be carried out in accordance with MRWA Test Method WA 100.1 “Sampling Procedures for Soil and Granular Pavement Materials”.

The log shall clearly distinguish between data obtained by visual observation and data obtained by field measurement. Laboratory test data shall not be included on the log.

Where appropriate the information provided must be supplemented with good quality colour photographs of the test trenches and the excavated material.

The location of all test excavations, boreholes and electric friction cone penetrometer test sites shall be surveyed to at least ±1.0m in plan position (AMG) and ±0.1m in level (AHD) so that their position can be related to the alignment.

3.6 Laboratory Testing

All testing shall be performed in accordance with the MRWA “Materials Testing Manual”. Where no MRWA Test Method exists, Australian Standards should be utilised. If no Australian Standard is appropriate other standards may be utilised with
the approval of the Project Manager. Laboratory testing shall only be carried out in NATA accredited laboratories for the particular tests in question. All test results shall be presented as NATA endorsed reports. The scope of laboratory testing should as a minimum include the following:

- Consistency or classification of each of the different characteristic layers identified during the field program is established, for example Atterberg limits or Particle Size Distribution
- Engineering parameters of different materials are established, for example consolidation testing on cohesive compressible soils or Unconfined Compressive Strength testing on rock
- Sufficient test results / data for estimation of “characteristic” design value are generated

4. GEOTECHNICAL DESIGN

Geotechnical design work should be carried out to accepted professional standards, commensurate with the potential hazards both to the Principal and the public, by suitably qualified and experienced geotechnical professionals.

The geotechnical report should clearly detail all design parameters and assumptions and where appropriate, the analysis approach adopted.

Design work which extends beyond the scope of work agreed at the time of tender, subject to the authorisation of the Project Manager, shall be undertaken as a variation.

The slope stability design should as a minimum include

- safe cut and fill slope angles
- consideration of drainage measures
- consideration of the scour potential of the cut or fill face and control treatments
- slope stabilisation measures
- potential for toe scour
- rock fall protection measures
- recommendation and design of field monitoring systems if necessary

All foundations shall be designed to meet satisfactory performance levels for bearing capacity and settlement. The need for field monitoring systems should be considered.
Where embankments are found to have potential for significant settlement, due to the presence of compressible foundation layers, a settlement analysis should be performed. Significant settlement shall be defined as a settlement likely to adversely impact the performance of the project including construction, operation and maintenance. The analysis should include an assessment of the impact of settlement on the road pavement.

Where appropriate, consideration should be given to foundation improvement options such as preloading, surcharging, dynamic compaction and vibrofloatation etc.

The requirements for drainage control measures, to protect the integrity of cut slope batters and pavement structures, should be assessed as part of the geotechnical investigation.

5. GEOTECHNICAL REPORTS

The report should provide sufficient information to allow tenderers to prepare bids and to manage the Principals risk of any subsequent contractual claims. The alignment, together with the location and results of all investigation, sampling and testing should be detailed in the Geotechnical Report. The report should identify the extent, nature and variability of all soil types and shall draw particular attention to the following matters:

- The scope of the investigation including a statement that only design issues were considered.

- A summary of all existing factual and interpretive geotechnical information pertaining to the site.

The information contained in a geotechnical report would normally be used for design, tendering and construction purposes. The report should be prepared in two parts.

Part 1 – (“Information for Tenderers Report”) details of all field and laboratory test data to be represented

Part 2 – (“Interpretative Report”) the geotechnical evaluation, interpretation, conclusions and recommendations

Each part should be complete in itself with Part 2 containing all the information presented in Part 1, Site Investigations Report. Both parts should contain keys to all symbols, terms and abbreviations used, together with a clear statement of any limitations which apply. A special preface sheet must be included with all information distributed to Tenderers or Contractors.
The Information for Tenderers Document shall contain all factual and interpretive data relevant to the construction of the works. Professional opinion shall generally be excluded. Where professional opinion is considered essential to minimising the Principals risk, it shall be clearly and appropriately qualified as opinion only.

Part 1 – Presentation of Information for Tenderers

The presentation of factual geotechnical information will include, but not be limited to, the following:

- Purpose and scope of the geotechnical investigation, including a discussion on the extent and scope of the investigation.

- Brief description of the project for which the geotechnical report is being compiled giving information about the location of the project.

- Dates between which field and laboratory work were performed.

- Detailed description of methods used for the field and the laboratory work with reference to accepted standards followed, and with discussion on rationale used to determine type, spacing, frequency and locations of all tests.

- Types of field equipment used.

- Presentation of field observations which were made by the supervising field personnel during the execution of the sub-surface explorations.

- The principal geological and topographical features of the area, with an appraisal of the terrain and hydrogeological conditions.

- A description of the investigation methodology, standards and scope of testing including an account of any site constraints encountered.

- A summary of each proposed cutting showing a minimum of:
  
  (i) the types of materials including their extent and variability, all test results including subgrade CBR values, the location and extent of any soft/wet areas.

  (ii) the presence and extent of any core stones, weathered rock and “rock excavation materials”.

  (iii) the factual excavation characteristics of the various materials. Where significant rock exists but is not “rock excavation materials”, a discussion of the results of the dozer excavations.
(iv) suitability of any cut materials for embankment or pavement construction, and if appropriate the treatments required to meet the specification for basecourse and sub-base.

- Data on fluctuations of ground water table with time in the boreholes during the performance of the fieldwork and in piezometers after completion of the fieldwork.

- Compilation of individual boring logs, penetrometer results etc. for each of the test locations with descriptions of sub-surface formations based on field descriptions and on the results of laboratory testing. In addition the location and level of each of the test locations should be accurately defined and may require survey control.

- Colour photographs of rock core.

- Grouping and presentation of field and laboratory test results in appendices and as summary tables.

Part 2 – Presentation of Evaluations, Conclusions and Recommendations

(a) Evaluation of geotechnical information

The evaluation of geotechnical information will include, but not be limited to, the following:

- Review of the field and laboratory work. Any particularly adverse test results should be considered carefully in order to determine whether they are misleading or represent a real phenomenon that must be accounted for in the design.

- Tabulation and graphical presentation of the results of the field and laboratory work in relation to the requirements of the projects.

- Determination of the depth to the ground water table and its seasonal fluctuations.

- Sub-surface profile(s) in graphic form (geotechnical profile or model), showing the disposition of the various sub-surface formations. Detailed description of all sub-surface formations in relation to their physical properties and their compressibility and strength characteristics. Comments on irregularities such as pockets, cavities etc.

- Collating and presentation of the geotechnical data for each sub-surface formation. This presentation should be in a form, which would enable selection of characteristic values for design.

- A summary of each proposed embankment foundation showing the types of materials, their boundaries, a summary of penetrometer readings and any remedial or construction requirements; where soft underlying layers are found, the boundaries and depth of these layers, test results of samples taken, predicted settlements and recommended remedial measures.
• Sites of low quality or unsuitable subgrade material and proposed treatments for these materials during construction.

• Comments on the gradeline, especially where the pavement may be affected by the ingress of water.

• The identification of subgrade design units, their boundaries, a summary of the test results and CBR values and comments on the presence of subsurface water or moisture.

• Other relevant aspects such as selection of materials for upper layers of embankments, slope stabilisation requirements, the need for subsoil drainage, presence of expansive clays, precautions if constructing in wet weather etc.

• Where design work has been undertaken, details of all design parameters and assumptions and where appropriate, the analysis approach adopted.

• Submission of proposal(s) for further field and laboratory work, if deemed necessary, with comments justifying the need for this extra work.

(b) Conclusions and Recommendations

The conclusions and recommendations of a geotechnical report will include, but not be limited to the following:

• Recommendations on the safe maintenance free angle at which the cut and fill batter slopes should be constructed in the various materials including details of any drainage or other requirements.

• Selection of suitable geotechnical design parameters.

• Settlement and stability computations.

• Recommendations concerning problems that may be encountered during excavations, placement of earth materials, construction of pavement etc.

A draft geotechnical report should be submitted to the Project Manager for review and comment. The review will be limited to considerations of general approach and compliance with the Brief and should not be considered an independent design check. Following the amendments made to the report as a result of the review, three bound copies and one loose-leaf copy of the final report should be provided.
## REFERENCES

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Road Note No. 9</td>
<td>Procedure for Thickness Design of Flexible Pavements, June 1988.</td>
</tr>
<tr>
<td>Standards Australia</td>
<td>Geotechnical Site Investigation, Australian Standards AS1726-1993.</td>
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**CLASSIFICATION** : 

**SUBJECT AREA** : Geotechnical Engineering

**KEYWORDS** : Guidelines, Geotechnical investigation