SUSTAINABLE SOIL MANAGEMENT - THE MANAGEMENT OF SOIL GROWING MEDIA DURING THE PLANNING AND DESIGN OF ROAD PROJECTS IN QUEENSLAND, AUSTRALIA

A.L. Jakobs[A] *and D.E. Baker*[B]
[A] Queensland Department of Main Roads, Australia
[B] Environmental Soil Solutions, Australia

Abstract
More emphasis is being placed on the efficient and sustainable use of soil resources in all areas of the construction and landscape industries. At Main Roads (MR) in particular, there is a growing awareness that the stuff typically referred to in the road building industry as 'unsuitable material', is a complex material that if misused, may cause more problems than anticipated.

In response to industry and environmental concerns MR has developed suites of soil tests that characterise and indicate the suitability of site soil for different uses. The suites are based on the Australian standard (AS)4419-2003 'Soils for landscaping and garden use'. This standard does not specifically cover insitu soils and it is typically these soils that MR prioritises for use over imported soils. It was therefore necessary to develop testing parameters relevant to insitu soils found throughout Queensland and a management tool to guide the best use of soil in road projects.

MR has developed a supplementary specification that includes the suite of soil tests and a Planting Media Management Plan (PMMP) as part of the contract documentation for a major road-building project in southeast Queensland. The specification and management plan were successfully trialed under the harsh conditions of the degraded Port of Brisbane Motorway site with its highly variable soil types and associated acidic and saline conditions. It has been further tested on two other major projects and developed from the learnings. The specification is under review for inclusion into the department's standard specification, and guidelines are being finalised to assist in its understanding and application.

Introduction
MR strives to achieve best practice in all departmental activities. Ecological sustainable development (ESD) and best practice environmental management (BPEM) are key components of the departmental wide best practice approach. Focusing on soil and its use as a growing media, MR prioritises the use of in-situ soils over imported soils in road construction and maintenance works, as it supports ESD (when properly managed). However, the best intentions are marred as vegetation and roadways fail because of unanticipated soil behaviour and / or lack of investigation of project in-situ soil characteristics. In response to this MR has developed suites of soil tests that characterise and indicate the suitability of in-situ soil for use as a planting media and for the construction of drainage devices. These suites are based on the AS4419-2003 with modifications to complement the characteristics of naturally occurring soils in Queensland.

Requirements and recommendations for the management of site soil have also been developed. The preparation of a PMMP has been an initiative of the supplementary specification to ensure that not only is the soil tested for compliance but also the soil, as a resource, is managed in the best possible manner. The specification was trialed and evaluated on three road projects including the Port of Brisbane Motorway, Stewart Road Interchange, Pacific Motorway and the Toowoomba Bypass Project. These projects cover various geographical areas, climates, landscapes, soil types, and site conditions testing the suitability and flexibility of the testing parameters and management plan.

The specific Main Roads definitions are presented (Table 1) to assist the reader in understanding the meaning and intended use of the key works in this paper.

Materials and Methods
Testing parameters
The MR supplementary specification MRS11.16 Landscape and Revegetation Works uses AS4419-2003 as the basis for testing planting media but with the following modifications and additions:

With reference to Table 1 – Scheme of Soils Testing, 'Low Density soil' and 'organic soil' types have been excluded and 'Natural soil or soil blend' types are included with the following modifications:

- organic content to range from 3 to 10% as opposed to a maximum of 15%;
- addition of acceptable pH ranges for naturally occurring acid and alkaline soils;
- deletion of the nitrogen draw down test (NDI) which is only required for soils with an organic content > 10%;
- deletion of toxicity testing – it is considered that the physical difference between the control sample and the project soil sample is too variable to conclude presence of toxic substances in the later;
- substitute of test for dispersibility with the Emerson dispersion test;
- increase in the acceptable maximum size of particles relevant to the intended use of planting media;
- deletion of clause 5.15 of AS4419-2003 but retention of note reference to Appendix J that contains a test method which may be used to assess the presence of propagules; and
- deletion of Appendix A – Guidelines on the taking of soil samples and inclusion of Clause 9.5.2 Sampling Method in the MRS11.16 Supplementary Specification.

Australian Laboratory Handbook of Soil and Water methods – 1995 (ALHS);

- exchangeable calcium and magnesium;
- calcium and magnesium ratio;
- exchangeable sodium, potassium and aluminium percentage; and
- effective cation exchange capacity.

AS1289.3.8.1-1997 Methods of testing soils for engineering purposes; and

- Emerson dispersion test.

AS1141.0-1999

- Optimum moisture content.

Table 1. Definitions of soil terminology specific to Main Roads MRS11.16 Supplementary Specification

Keywords/Term	Definition
growing media	MR recognises the term growing media and planting media to be one in the same. MR has historically used the later term in the department's standard specification. Growing media was used in the title of this paper as it is commonly used in soil related documents.
planting media	Ameliorated stripped site soil (topsoil or subsoil) or imported soil that complies with MRS11.16 Supplementary Specification, Clause 9.0 - Table 5 Properties of Site and Imported Planting Media.
reclaimable / non-reclaimable soils	A reclaimable soil = potential planting media (that is, a soil that will satisfy the planting media requirements after amelioration). A non-reclaimable soil is a soil that cannot feasibly be ameliorated.
soil – topsoil, subsoil	Soil refers to the solum that is, the upper part of the soil profile above parent rock. Topsoil refers to O and A_1 horizons. Subsoil refers to A_2 to B_2 horizons, the earthen surface of road fill embankments (Class A material – MRS11.04 General Earthworks) and areas stripped of topsoil beyond embankments.
suitable / unsuitable soil	These words are general terminology. A suitable soil (topsoil or subsoil) is a soil that satisfies the planting media definition with or without amelioration. An unsuitable soil does not satisfy the definition.
unsuitable material	This is civil engineering terminology referring to all earthen or rock materials not suitable for use as a foundation for earthworks or structure, and/or for use as general fill/backfill material.

The sub-suite of analyses (Table 3) was developed for use in preliminary risk assessment investigations. Sub-suite testing includes pH, electrical conductivity (EC) and soil cations K, Ca, Mg, Al and Na. From this data, the relationships between soil pH, soil exchangeable sodium percentage (ESP), calcium to magnesium ratio (Ca:Mg) and effective cation exchange capacity (ECEC) can be used as primary tools to assess the suitability of insitu soil as a planting media and its stability, that is, a soils ability to resist erosion and tunneling. Limiting the complexity of

tests during preliminary investigation reduces costs and sample processing time without compromising the assessment of a soil's suitability.

Table 2. Properties of site and imported planting media – Full-suite

Soil Test Parameter	Refer	Soil Test Parameter Requirements
AS4419-2003 – Soils for landscaping and garden use		
Bulk density	5.2	> 0.7kg/L
Organic matter (relevant to the organic carbon concentration)	5.3	3 to 10%
Wettability	5.4	> 5 mm/min.
pH (H_2O, 1:5) - general range a) Naturally occurring acid soils b) Naturally occurring alkaline soils	5.5	> 5.5 and < 7.5 > 4.5 and < 6.0 > 7.0 and < 8.5
Electrical conductivity - EC	5.6	< 1.2 dS/m
Extractable phosphorous content a) Very P sensitive plants b) Moderately P sensitive plants	5.8	< 5 mg/kg < 20 mg/kg
Permeability	5.12	2 - 100 cm/hr
Texture	5.13	Refer to Table AS4419, Table I1 Soil texture Classification
Large particles – planting media to: a) Turfed or grass seeded areas to be mown or slashed b) Batters to be mulched or hydraulic seeded and hydraulically mulched c) Broad acre areas to be direct seeded with native species	5.14	100% by weight to pass a 20mm sieve 100% by weight to pass a 50mm sieve 100% by weight to pass a 75mm sieve
AS1289.3.8.1-1997 – Methods of testing soils for engineering purposes		
Dispersion - Emerson class number	3.8.1	Class 2 or greater
ALHS (Australian Laboratory Handbook of Soil and Water Methods) - 1992		
Exchangeable calcium (Ca) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	≥ 2 meq/100g ≥ 5 meq/100g
Exchangeable magnesium (Mg) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	> 0.6meq/100g > 1.0meq/100g
Calcium magnesium ratio Exchangeable form for a) & b) soil textures	15B3	2 - 10
Exchangeable sodium percentage (ESP) (Na base saturation % = % Na of total cations) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	< 6 < 15
Exchangeable potassium (K) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	> 0.2meq/100g > 0.4meq/100g
Exchangeable aluminium percentage (Al base saturation % = % Al of total cations) a) Sands and loamy sands b) Sandy loams to clay loams	15G1	10 - 25 25 - 40
Effective cation exchange capacity (ECEC) (ECEC = sum of exchangeable cations) a) Sands and loamy sands b) Sandy loams to clay loams	15J1	> 5meq/100g > 10meq/100g

Table 3. Properties of site and imported planting media – Sub-suite

Soil Test Parameter	Refer	Soil Test Parameter Requirements
AS4419-2003 – Soils for landscaping and garden use		
pH (H_2O, 1:5) - general range c) Naturally occurring acid soils d) Naturally occurring alkaline soils	5.5	> 5.5 and < 7.5 > 4.5 and < 6.0 > 7.0 and < 8.5
Electrical conductivity – EC	5.6	< 1.2 dS/m
ALHS (Australian Laboratory Handbook of Soil and Water Methods) - 1992		
Exchangeable calcium (Ca) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	 ≥ 2 meq/100g ≥ 5 meq/100g
Exchangeable magnesium (Mg) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	 > 0.6meq/100g > 1.0meq/100g
Calcium magnesium ratio Exchangeable form for a) & b) soil textures	15B3	 2 - 10
Exchangeable sodium percentage (ESP) (Na base saturation % = % Na of total cations) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	 < 6 < 15
Exchangeable potassium (K) a) Sands and loamy sands b) Sandy loams to clay loams	15B3	 > 0.2meq/100g > 0.4meq/100g
Exchangeable aluminium percentage (Al base saturation % = % Al of total cations) a) Sands and loamy sands b) Sandy loams to clay loams	15G1	 10 - 25 25 - 40
Effective cation exchange capacity (ECEC) (ECEC = sum of exchangeable cations) a) Sands and loamy sands b) Sandy loams to clay loams	15J1	 > 5meq/100g > 10meq/100g

The final suite of analyses in the specification (Table 4) has been developed to characterise and indicate the suitability of soil for the construction of drainage devices as well as being able to support plant growth. The suite includes dispersion-testing, soil - sand, silt and clay content, Atterberg limits, optimum moisture content (OMC) and ESP. The shrink-swell potential of the material was chosen to provide a semi-permeable soil to form the devices as opposed to a non-permeable material typically required for dam linings. This resulted in providing a soil that will promote the establishment of water loving plants (to filter water impurities and create habitat), an approach that is now common practice and often a requirement of development.

Table 4. Properties of site and imported planting media for construction of drainage devices

Soil Test Parameter	Refer	Soil Test Parameter Requirements
Dispersion - Emerson class number	AS1289. 3.8.1	Class 2 or greater
Soil clay %	AS1289. 3.6.2	> 25%
Soil silt and clay %	AS1289. 3.6.2	< 45%
Atterberg limits: Liquid limit % Plastic index %	AS1289. 3.8.1	 > 45 > 25
Optimum moisture content (OMC)	AS1141.0-1999	± 2%
Exchangeable sodium % of total cations (ESP)	15B3	< 15

Planting media management
A PMMP has been developed to guide the planner, designer, constructor and maintenance staff to best use site soil resources in road projects. It is intended to be a dynamic document initiated during the planning phase and known as a PMMP Planning (P), developed further through the design phase and included as part of the tender documentation for use by the constructor to develop the PMMP Construction (C).

The following items are the key components of the PMMP:
Planning
- assessment of soil and geology types for suitability of topsoil and subsoil for use as planting media;
- calculation of volumes of suitable, reclaimable and non-reclaimable in-situ soils and imported soils (if needed);
- assessment of the feasibility (practicality, costs) to ameliorate site soil and / or import planting media;
- identify and cost any mitigation practices that will be required to manage any undesirable soil characteristic relevant to erosion and revegetation.

Design
- carrying out a planting media specific soil sampling scheme (as opposed to relying on geotechnical samples and soil maps) to confirm the extent and characteristics of various soils;
- confirmation of the suitability of imported planting media (if needed);
- confirmation of the limitations of the material to be used in outer embankments or exposed in cuttings and design revegetation approaches accordingly;
- identify and design other mitigation practices needed to manage undesirable soil characteristics; and
- rework quantities and cost estimates.

Construction
- Identify any issues and mitigation requirements related to soil in the EMP(C), Fire Ant Management Plan(C) and Acid Sulfate Soil Management Plan(C);
- identify the suitability of the in-situ soil and any potentially unsuitable characteristics (reference to the PMMP(P) may be all that is needed);
- describe the approach in managing reclaimable or non-reclaimable in-situ soils;
- include the rationale where a decision has been made to import planting media; and
- describe intended soil sampling methods and stockpiling management where approaches may differ from the specification.

Trials
The PMMP, including the testing parameters have been trialed on a range of projects (Table 5).

Table 5. Project case studies

Key Trial Components	Results and Discussion
Port of Brisbane Motorway, Murarrie to Hemmant – design and construction phases	
Saline soils.	Salt tolerant plant species specified for saline conditions.
Acid sulfate soils.	Extensive liming treatment controlled acidity.
Swale and detention basin construction in variable soils.	Liming treatment of acid sulfate and heavy clay soils; level of permeability of swales and basins controlled.
Embankment material with potentially low pH values.	Lime applied to planting holes in fill embankments resulting in successful plant establishment; confirmation of the advantage of including the sub-suite with the geotechnical testing requirements for embankment material (refer to Conclusion).
Variable fertility and hydrophobic soils.	Fertilising programs and applications of wetting agent addressed these issues.
Toowoomba Bypass, Warrego to Gore Highways – detailed planning phase	
Testing of soil with sub-suite parameters.	Testing of geotechnical bore samples to confirm soil types and suitability enabled 'ground truthing' of soil map

	information and quantifying and costing of soil resources; unreclaimable soils identified and alternate uses proposed and costed.
Development of soil suitability information	Soil Suitability Plans were developed combining geological and soil survey mapping with soil suitability classifications based on the sub-suite analysis results.
Stewart Road Interchange, Tugun, Pacific Motorway – design phase	
Saline and acid sulfate soils.	These soils were avoided as per SPP 2/02 (ASS State Planning Policy).
Swale and detention basin construction in sandy soils with clay capping.	Design was modified and retained flexibility to accommodate the combination of clay and sandy soil requirements.
Identification of soil suitability through site observation and field-testing to determine requirements of soil sampling/testing program.	Pre-design testing considered not critical due to interpretation of data gathered from site inspection. Data sufficient to enabled design to be developed relevant to soil limitations; information used to develop a Soil Suitability Plan that formed part of the contract documentation.

Conclusions

The specification, with its soil test suites and planting media management plan, was successfully applied to a number of road projects in the planning, design and construction phases. AS4419-2003 was used as the foundation to build soil testing and management tools specific to Queensland's road landscapes. Planting media guidelines are currently being finalising to support the understanding and application of the specification. Topsoils, subsoils, and soil characteristics for drainage devices have been covered to ensure the sustainable use of planting media in road projects.

Learnings from each project have been incorporated into the specification but we still don't know all the answers. For example, to date, the suitability of soil used as planting media has been addressed. However, the suitability of soil for road embankments only requires the testing of the plasticity index. Plants grow into this embankment material. It is therefore necessary to include planting media soil characteristics that support plant life and that are non-dispersive within the current geotechnical requirements. This and other similar issues requiring interdisciplinary sharing of information and co-ordination throughout the life of a project will be addressed by a recent initiative by MR. The department has embarked on a project to capture all learnings from environmental, geotechnical and road pavement disciplines within MR and produce an integrated guideline titled – 'Soil Considerations in Road Building' to promote best practices in the management of site soils. This documentation will bridge scientific and learned knowledge, standards, and soil uses across the department. It will serve as a guide during the development of existing and new documents. It will ensure consistency in data, testing and application methods across the department and guide staff to better understand soil characteristics and apply consistent, proven mitigation methods.

References

Rayment, G.E. and Higginson, F. R., eds. (1992). Australian Laboratory Handbook of Soil and Water Chemical Methods. Inkata Press, Melbourne.

Emerson, W.W. (1977). A classification of soil aggregates based on their coherence in water. *Australian Journal of Soil Research* 5, 47-57.

Australian Standard (AS)4419-2003, Soils for landscaping and garden use.

Australian Standard (AS)1289. 3.8.1-1997, Methods of testing soil for engineering purposes, Method 3.8.1-Soil classification tests-Dispersion-Determination of Emerson class number of a soil.

Australian Standard (AS)1141.0-1999, Methods for sampling and testing aggregates.