LAND SUITABILITY ASSESSMENT TECHNIQUES

1.0 SCOPE

This guideline provides advice on the applicability and use of land suitability assessment techniques to determine pre-mining land suitability and post-mining land use potential.

This guideline is ADVISORY ONLY and is not intended to prescribe mandatory standards and practices. This guideline is intended to assist the development of project-specific environmental management practices.

2.0 OBJECTIVES

(1) To facilitate the achievement of acceptable post-mining disturbance land use suitability and/or capability through the use of appropriate land resource assessment techniques at the pre-mining stage.

(2) To ensure that adequate land resource data are collected to enable proper assessment of land suitability and/or capability.

3.0 RELATED GUIDELINES

- Growth Media Management
- Determination of Post-Mining Land Use

4.0 INTERPRETATION

For the purposes of this guideline, a distinction is drawn between land **capability** and land **suitability** assessments:

"Land capability" classifications (Reference 1) provide a ranking of the capacity of each part of a land resource to sustain broad land use classes (with lower number classes suited to more intense uses, and higher number classes suited only to low intensity rural use, conservation and the like). Land capability assessment is more appropriate to broad hectare areas where the land use choices are farming, grazing or non-agricultural.

"Land suitability" rankings are more refined and apply to the capacity of land resources to sustain particular forms of land use such as arable farming, irrigated agriculture, forestry (Reference 2). Such rankings can be applied to smaller land units and are thus more useful in determining post-mining land use options. For this reason, land suitability techniques have generally superseded land capability assessments and are recommended for use in the mining industry.

5.0 BACKGROUND

The Department of Minerals and Energy's *Environmental Management Policy for Mining in Queensland* includes the following objective:

> ***"Achievement of acceptable post-disturbance land use capability.***
>
> *Mining and rehabilitation should aim to create a landform with land use capability and/or suitability similar to that prior to disturbance, unless other beneficial land uses are pre-determined and agreed."*

In accordance with this Policy, mine rehabilitation should seek to return disturbed areas at least to the same status (ie. having a similar suitability and range of land use options) as existed prior to mining, or to a condition appropriate for the agreed specific land use or uses. This requires an understanding of:

(a) the existing status of the land resources likely to be affected by the proposed mining operations, and

(b) how the resources are likely to be affected by the proposed operations.

Such understanding can be obtained through compiling a Land Resource Inventory (LRI) from which data can then be analysed through a process of Land Resource Evaluation (LRE).

Preparing a LRI involves collecting basic land resource data using soil survey techniques. The procedures to be used in undertaking such studies are well documented and there is a considerable amount of existing data available for many parts of Queensland which can provide a useful starting point. Much of this information is held by the Queensland Department of Primary Industries (QDPI) and a listing of the available data was published by the Department of Housing, Local Government and Planning (1993) as an Appendix to Planning Guidelines - The Identification of Good Quality Agricultural Land (Reference 3).

These data can then be used to determine land suitability through LRE, which is a generic term covering land suitability classification systems. Such classifications can be used to identify the end land use potential of lease areas - described here as preferred land use. The concept of preferred land use is that use for which the land resource is potentially suited in the pre-mining environment and which is anticipated as applying in the post-mining environment.

Where a land unit has equal potential for two or more uses (eg. pastures and horticulture), the preferred land use option should be the one that is the most viable in the area ie. the one which represents the "highest and best" use of that land. Examples of the application of this approach would be:

- Land suited for rainfed farming, pastures and horticulture may have only pastures and rainfed farming as the preferred end land use if there is no established horticulture industry in the general region because the area is isolated from markets.

- Land suited for rainfed farming and pastures in a region of rainfed farming would be returned to rainfed farming status even if the pre-mining land use was pastures.

Relevant to LRE are the Queensland Government's *State Planning Policy on Good Quality Agricultural Land* (GQAL) and accompanying *Planning Guidelines* (References 3 and 4). This policy requires that future land use planning in the State should not alienate or diminish areas designated as GQAL unless there is an overriding community benefit.

Where possible rehabilitation after mining on GQAL should aim to return a proportion of GQAL. The relevant local government should be initially contacted to determine whether such areas have been identified in the local government's town planning scheme documentation. However, the fact that the local government may not have identified such land does not necessarily mean that it does not occur in the lease area. Where GQAL exists in the lease area, particular care should be taken to ensure the adequate rehabilitation of such land.

6.0 IMPLEMENTATION STRATEGIES

6.1 Compilation of Land Resources Inventory (LRI) - Pre Mining Studies

Effective land management of undisturbed areas and the rehabilitation of mined-over areas require a reasonable technical understanding of the soils on the site and their distribution. The procedures to be used in undertaking the investigations necessary to determine soil types and distribution are well documented and there is a considerable amount of existing data available for many parts of Queensland which can provide a useful starting point (References 5, 6 and 7).

The tasks involved in compiling the LRI as the first stage of land suitability assessment process should include the following:

(a) initial review of available land resource information,

(b) detailed review including unpublished QDPI and CSIRO data that is available,

(c) mapping of soils and terrain to suitable scale,

(d) nomination of representative reference sites and characterisation of these sites,

(e) soil classification in accordance with (one or more) suitable schemes, and

(f) reporting of findings as a land resource inventory.

6.1.1 Initial Review

An initial review of the available information covering the area. All of Queensland is covered at a scale of over 1:2,000,000 by the *Atlas of Australian Soils*. For most, if not all, mining areas this work is too broad to be of practical use. Large parts of Queensland are also covered by the Land Systems mapping of CSIRO at scales of 1:250,000 or 1:500,000 and by other mapping more recently undertaken by the QDPI. Again this work is mostly too broad to be useable. Some areas of Queensland are covered by 1:100,000 soils mapping with a few areas covered at larger scales. These surveys are useful for indicating the broad types of soils and landscapes that may occur in a lease area. Where mapping work is available every attempt should be made to use the existing nomenclature system in all new site mapping work. The responsible QDPI Land Resource Officers should be consulted to determine whether this is feasible as historically a variety of nomenclature systems have been used in Queensland.

A listing of QDPI and CSIRO maps for Queensland is available from QDPI regional offices. Reference 3 provides a listing of surveys which identify good quality agricultural land.

The review should not be restricted to published reports. Both the QDPI and the CSIRO have assembled data from over 2000 soils sampled and analysed across Queensland and are continuing to gather information. Enquires should be made to determine the availability of any data relevant to the lease area. Any available information should be obtained and incorporated into the LRI.

6.1.2 Site Mapping

Mapping of the soils and terrain should then proceed.

For most mines, the area of the lease can be divided into two separate areas:

- those parts of the lease which <u>will not</u> be disturbed by the mining activity

- those parts of the lease area which <u>will</u> be disturbed by mining - the forms of disturbance may include, excavation/pit areas, storage and building areas, stockpiles, borrow pits, areas to be undermined and potentially subject to subsidence, tailings dams, water supply dams etc. These areas are important as they are the sources of future growth media for rehabilitation and will have to be returned to an agreed post-mining land use suitability.

The areas of the lease area which will not be directly disturbed by mining should be mapped at a sufficient level to characterise the broad land resource conditions of the areas surrounding the mine site. Table 1 summarises the most appropriate scales of mapping. For smaller lease areas of a few tens of hectares, mapping areas that will not be disturbed may not be justified.

Within the proposed disturbance area mapping will be required and should be at scales which can be confidently related to the mining site conceptual design and layout maps - commonly 1:2,500 for smaller mines and 1:5,000 for larger mines.

Generally, the average site density should exceed one sample per square centimetre of the map. The procedures used to describe soils and define soil boundaries are widely documented (References 6 and 7). However, up to one quarter of all sites should be described in detail following the *Australian Soil and Land Survey* procedures. The remainder of the sites may be described in lesser detail but sufficient to define the boundaries between different soils.

For example, an area of 1000 ha mapped at a scale of 1:25,000 would give a mapped area of around 160 sq cm. If the area's soil distribution is relatively uniform, in the order of 160 sites would require description, and of these only about 40 would have to be described in detail. (A competent and experienced land resource specialist can describe up to 10 detailed sites or 50 lesser sites in one day). If the area is more complex and contains more soils distributed in a complex pattern, the site density may have to be increased accordingly.

Field survey techniques which rely on air photo interpretation should be used initially then refined using mapping of appropriate scale.

For areas with commercial forest value, forest inventory and mensuration data covering log yields and quality may be needed. In forestry lease areas, such data is often available from the Forest Services Business Group within the QDPI.

For conservation, aquatic and coastal areas, environmental resource data should also be obtained at this time, while for urban localities, social and more detailed land use data is also likely to be relevant and should be collected.

6.1.3 Soil Characterisation

This requires nomination of reference sites and detailed characterisation of their physical and chemical properties. This involves identifying sites which are representative of main soil units, accurately mapping their location using detailed topographic maps or Geographic Information System (GIS) technology, sampling of the soils at the site, and preparing and submitting the samples for analysis. Reference sites should be permanently marked in the field.

Reference sites serve two primary purposes. Firstly they serve as benchmarks or baseline sites against which successful rehabilitation can be measured by post rehabilitation sampling. Secondly, they are the only sites where chemical data is collected and as such are critical to the estimation of such factors as the amount of suitable growth media/'topsoil' availing to the miner to undertake rehabilitation. Examples of the presentation of such data are given in References 2, 5, 6 and 7.

Samples from every 10 cms of depth in the reference site should be collected during the pre mining stages. In most situations this will involve sampling to a depth of 1.5 to 2 m or to hard impenetrable or non-excavatable horizons.

The main exception to this is in sand dune and estuarine areas of marine origin where sampling to several metres may be required if peat, acid sulphate or coffee rock conditions could be expected. The initial review of the available information, together with a working knowledge of the stratigraphy from exploratory drilling, etc will often provide a useful guide to such materials. For exploratory drilling data to be of use in soil investigations, particular attention should be given to the logging of overburden materials. The only non-coastal exception to these sampling procedures is in situations where the overburden is known to be pyritic (as happens in parts of the coal provinces).

Chemical and physical analysis should be undertaken by a NATA approved soils laboratory using procedures identical to those used by the QDPI, or described in the physical and chemical methods handbook included in the reference list.

The minimum requirements for characterising soil unit chemical and physical properties is for Electrical Conductivity (EC), pH and Chloride (Cl) testing to be completed on every sample, and exchangeable cations, Cation Exchange Capacity (CEC), exchange acidity, particle size, and total Phosphorus, Potassium, Sulphur (PKS) determined for every major soil horizon. Surface soils should also have micronutrients, aluminium, free and total iron, sulphate available Nitrogen, Organic Carbon and replaceable Potassium determined. Where toxicity from heavy materials is a concern, testing for these should also be completed. The Growth Media Management Guideline contains information on the effect of various soil chemical and physical properties on plant growth.

6.1.4 Soil Classification

All soils can be classified in accordance with:

- Great Soil Groups
- Principal Profile Form (PPF)
- Australian Soils Classification
- Engineering classifications as required for soil layers.

The preparation of a report documenting the above findings, including a map of Land Resource Units based on the defined soil units, and an associated data base - should preferably be in a format compatible with any relevant existing public authority GIS.

6.2 Determination of Pre-Mining Land Suitability

6.2.1 Procedure

To determine the pre-mining land use suitability of the lease area:

(a) Class definitions and ratings tables should be formulated based on the LRI data and land use requirements.

(b) These ratings and definitions should be applied to the mapped units.

(c) The land suitability rating and preferred end land use for each mapped unit should be specified.

(d) A report should be prepared documenting the suitability assessment procedures used, the justification for the nominations of preferred end land uses and the implications of the findings for rehabilitation programmes and post mining land use.

6.2.2 Class Definitions

Class definitions for land use suitability are now generally standardised as a five rank system (Reference 2). An abbreviated summary of these classes as they might apply to mining lease areas is as follows for agricultural and conservation uses:

Class 1

Agricultural - Suitable Land with negligible limitations - Land which is well suited to a proposed use.

TABLE 1
DESIRABLE MAXIMUM MAPPING SCALE FOR LEASE AREAS THAT WILL NOT BE DISTURBED BY MINING PROJECTS

Pre-Mining Land Use	Total Lease Area (Hectares)			
	<5,000	5,000 - 25,000	25,000 - 50,000	>50,000
Intensive Irrigation	1:10,000	1:25,000	1:50,000	1:50,000
Rainfed Arable, High Value Native Forest, and Agro-forestry Areas	1:10,000	1:25,000	1:50,000	1:50,000
Intensive Livestock	1:10,000	1:25,000	1:50,000	1:50,000
Mixed Livestock and Farming	1:10,000	1:25,000	1:50,000	1:50,000
Extensive Livestock	1:50,000	1:50,000	1:100,000	1:250,000
Forestry	1:50,000	1:50,000	1:100,000	1:250,000
Conservation Areas	1:10,000	1:25,000	1:50,000	1:50,000
Aquatic/Estuarine	>1:10,000	1:25,000	1:50,000	1:50,000
Urban	>1:10,000	1:25,000	1:25,000	1:25,000

Note: The number of sites sampled for analysis is commonly less than 10% of those described. For example a lease area of 1000 ha mapped at 1:25,000 using 160 description sites may result in 5 soil units being identified.

Conservation - Areas well suited for conservation uses must posses significant conservation benefits in the pre mining environment and be capable of being returned to that use post mining.

Class 2

Agricultural -Suitable Land with minor limitations - Land which is suited to a proposed use but which may require minor changes in management to sustain the use.

Conservation - These areas are suited to conservation use in that a significant component of the pre mining conservation values can be restored post mining. There will however be some loss in conservation values where soil terrain or hydrological post-mining conditions may inhibit the full replication of the pre-mining values.

Class 3

Agricultural - Suitable Land with moderate limitations - Land which is moderately suited to a proposed use but which requires significant inputs to ensure sustainable use.

Conservation - These lands contain significant conservation values pre mining, however, restoration of all of these values may not be feasible. These areas could however, be restored to a form of conservation use which provides alternative conservation benefits.

Class 4

Agricultural - Marginally Suitable Land - Land which is marginally suited for a proposed use and would require major inputs to ensure sustainability. These inputs may not be justified by the benefits to be obtained in using the land for the particular purpose and is hence considered presently unsuited.

Conservation - These lands contain limited conservation value pre mining and/or are incapable of being effectively restored post mining to any alternative conservation use which provides similar benefits. The area could however be restored to provide a stable form of use which does not impact on surrounding conservation values.

Class 5

Agricultural - Unsuitable Land with extreme limitations - Land which is unsuited and cannot be sustainably used for a proposed use.

Conservation - These lands contain no significant conservation values.

Where a range of land use options is being considered, a class ranking should be applied to each type of use.

6.2.3 Ratings (or Factor/Criteria) Tables

(a) Agricultural Uses

Whereas Class definitions have been standardised for assessments throughout Queensland, the ratings tables on which the allocation of classes are based are more variable.

Ratings tables applicable to agricultural uses need to contain criteria for slope, the chemical properties of soil and physical soil characteristics. Such ratings tables have been developed by the QDPI for many parts of Queensland and should be used where available for the region in which the mine project is being proposed. Some examples of the application of Factor/Criteria Tables in land suitability assessment are given in Attachment 1 of this guideline while a generic system covering grazing and cropping land uses in the central Queensland area is given in Attachment 2. A broad indication of the range of agricultural potential across Queensland is also given in mapping by Weston et al (Reference 8).

(b) Non-Agricultural Uses

For non-agricultural uses, such as urban, or rural residential, no specific rating tables have as yet been formulated in Queensland. Systems have been developed and published in New South Wales (by the Soil Conservation Service - Conservation and Land Management Department), Victoria (Soil Conservation Service, Department of Conservation and Environment) and Western Australia (WA Department of Agriculture).

Existing systems can often be adapted to apply to non-agricultural uses as they rely on a similar data set to those for agricultural uses. When importing such systems, a check should first be made to determine whether the criteria are applicable to Queensland.

(c) Conservation Uses

For conservation uses only some relevant criteria could be derived from the LRI. Other baseline data relating to nature conservation would be needed. Such information may be available from the QDPI, the Department of Environment and Heritage, the CSIRO, Land Care or Catchment Management groups or other conservation organisations. A key consideration in ranking the mined area for conservation uses is whether the disturbed site is integral to the adjoining habitats and ecological values of the general area.

Some of the factors that could be relevant to a ratings table used to define conservation classes include:

- Rare and endangered status: a criterion covering the presence of any rare or endangered species or habitats. Sites which contain such species or are likely to be able to be rehabilitated in such a way as to preserve such species and their habitats would have a high suitability ranking under this criteria.
- Regional significance: a criterion covering how regionally significant a fauna or flora species, community or habitat. Sites which play a significant role in the regional pattern of flora and fauna or could be rehabilitated to enhance regional or local significance would rank highly. Examples would include sites which had been developed for cropping and grazing by land clearing which could be rehabilitated to provide a wildlife corridor, nesting/breeding grounds etc would rank high for conservation uses.
- Catchment conservation: a criterion covering the presence of any water catchment values (water quality, salinisation, etc.) This criteria would apply where the mined area occurred in a catchment where agricultural development or deforestation had led to increased land degradation and hence a decline in water quality via erosion or salinisation. In these circumstances sites which are located in the catchment in such a way as to be useful either as buffer zones, recharge / transpiration / discharge zones would rank highly for this suitability and thus may be more appropriately rehabilitated to these end land uses rather than the current agricultural use.
- Sustainability: a criterion covering whether an area can sustain conservation values given that area's size and location.

6.3 Determination of Post-mining Land Suitability

6.3.1 Procedure

To determine the post-mining land suitability of the lease area:

(a) overburden (or waste or spoil) characterisation survey at an appropriate scale, should be undertaken,

(b) a mass balance of the waste materials should be undertaken to establish the volumes of different waste types,

(c) a strategic rehabilitation landform design should be undertaken to establish feasible and practically achievable landform designs for the post-mining situation,

(d) the post-mining land use suitability should be nominated (in the EMOS) including criteria that (the achievement of which) would indicate successful rehabilitation to the nominated land suitability, and

(e) measurement of land suitability criteria on rehabilitated areas and reporting of achievement of the nominated land suitability in monitoring reports should be carried out.

6.3.2 Waste Characterisation

In post-mining landscapes sufficient sites and sample depths should be taken to characterise the chemical and physical properties of wastes to be excavated (or already excavated). Two guidelines on growth media management provides information on placement and criteria which would assist in determining land suitability. Attachment 2 is a useful land suitability scheme applicable to the mining industry. Reconnaissance testing may include pH, conductivity, PAWC while detailed testing (based on samples selected during the reconnaissance testing) may include nutrient, metals ESP and crust strength.

6.3.3 Mass Balance

A calculation of the volumes of the types of waste materials identified should be carried out. Materials that can best perform the task of topsoil substitute and materials that will need to be isolated from the surface should be identified and volumetric calculation performed.

6.3.4 Landform Design

A strategic landform design is required to estimate the volumes of waste materials that will need to be moved and the costings for such. The production of contour plans will aid this exercise. At this stage the potential final land suitability of the disturbed (or to be disturbed) areas should be under consideration.

6.3.5 Preferred Land Suitability

Taking into account the following:

(i) pre-mining land suitability and rating (criteria) tables,

(ii) physical and chemical characteristics of the substrata,

(iii) Contaminated Land Act requirements (waste management plans),

(iv) landform designs (strategic),

(v) land suitability rating (criteria) tables,

nominate post-mining land suitability and present in EMOS (or supporting document to EMOS) as comparison of pre-mining and post-mining land suitability. This will indicate (for assessment by stakeholders) any degradation or change in land suitability of the lease area brought on by the mining project.

Note: Steps (i) to (v) may need to be iterative ones in order to optimise the land suitability goals

6.3.6 Monitoring and Reporting

The land suitability criteria defined in association with the land suitability classes nominated in the EMOS will need to be monitored and reported upon. Rehabilitated areas that are shown to have achieved the criteria can then be considered for lease surrender. Criteria may include many of those outlined in Attachments 1 and 2. Monitoring would need to be to a suitable scale (see 5.1.3) appropriate to the variability of the waste materials on the lease.

6.4 Land Capability for Small Miners

Small mining operations can use the simpler land use capability classification (Reference 1) as the basis of determination of post mining land use and completion of the EMOS document for the project. The DME small miner environmental document packages use land capability to describe pre and post-mining land use. Table 2 lists land capability classes.

TABLE 2
LAND CAPABILITY CLASSIFICATION (REFERENCE 1)

CLASS	
Class I	Land suitable for all agricultural and pastoral uses
Class II	Land suitable for all agricultural uses with slight restrictions to cropping.
Class III	Land suitable for all agricultural uses with moderate restrictions to cropping.
Class IV	Land primarily used for pastoral uses but can be carefully cropped occasionally.
Class V	Land primarily used for pastoral uses but can be cropped if limitations were removed.
Class VI	Land not suitable for cultivation but well suited to pasture improvement.
Class VII	Land not suitable for cultivation and only careful pastoral use possible.
Class VIII	Land not suitable for agricultural or grazing uses

An assessment of land capability should be made based on limiting factors of soil depth, soil structure, soil nutrient fertility, soil salinity/sodicity, soil water availability, rockiness, extent of gullying, topographic relief and climate (Reference 1).

6.0 REFERENCES

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ATTACHMENT 1

EXAMPLES OF APPLICATION OF LAND SUITABILITY FACTOR/CRITERIA TABLES

Source: Shields, P.G. and Williams, B.M. (1991), *Land resources survey and evaluation of the Kilcummin area, Queensland,* Queensland Department of Primary Industries, Land Resources Bulletin QV91001.

Water erosion (e).

Rainfed cropping generally increases the potential for soil loss from rainfall and subsequent runoff compared to land with little effective disturbance. The accelerated soil loss is due to an increased volume of runoff, increased velocity of water flow and decreased protection of the soil surface when devoid of vegetation. The result is declining productivity, increasing difficulty to cultivate and, eventually, an inability to produce a crop in most years. Thus, only land that can sustain rainfed cropping in the long-term is considered suitable for that use.

Accelerated soil loss is a product of the climate, landform, soil properties, vegetative cover and management practices for any one area. The water erosion limitation was determined for each UMA using a combination of landform and soil attributes as criteria. The criteria were set for the climate at Kilcummin assuming that the current QDPI recommendations for vegetative cover and management practices are adopted. The potential for soil loss by water erosion will be greater if these recommendations are not followed. The landform and soil attributes used as criteria for determining the water erosion limitation are indicated in Table 1.1.

Water erosion was considered a negligible limitation (e_1) on all UMAs, regardless of the dominant soil, where slopes are mainly less than 0.5%. The remaining UMAs (with slopes of 0.5% and greater) have a limitation of some degree (e_2-e_5).

TABLE 1.1
CRITERIA USED FOR DETERMINING THE WATER EROSION LIMITATION FOR RAINFED CROPPING

Limitation Level	Landform Attributes	Soil Types
1	level plains (most slopes <0.5%)	all soils
2	level plains (most slopes 0.5 - 1%) or	clays without melonhole gilgai; red earths, reddish prairie, euchrozems, calcareous clay loams, light clays, non-calcic brown soils
	gently undulating plains and rises (slopes 1-3%)	clays with melonhole gilgai
3	gently undulating plains and rises (slopes 1-3%)	clays without melonhole gilgai; and as above, plus shallow loams
4	gently undulating rises to undulating low hills (most slopes 2-7%)	clay soils; as above
5	undulating rises to very steep hills and plateau remnants (most slopes >3%) or	clay surface variant; shallow sands and loams, shallow sandy non-sodic duplex soils and shallow reddish prairie soils
	level or gently undulating plains and rises. Miscellaneous soils (most slopes >0.5%)	duplex soils with sodic subsoils

TABLE 1.2
APPLICATION OF WETNESS/CRITERIA IN LAND SUITABILITY ASSESSMENT

Limitation	Effect	Assessment	Diagnostic land attribute	Land attribute code	Attribute ranges
WETNESS (w)	Soil wetness has two principal effects: • in sensitive species yield reduction or death can occur • access to the field can be hampered by prolonged periods of wetness	Movement of water through the soils and drainage from it are assessed by examining soil morphology, vegetation and landscape positions. These observations were complemented by the placement and monitoring of neutron moisture metre access tubes in key soils. These data were then modelled with the PERFECT cropping systems model and historic daily rainfall data to predict periods of soil saturation.	Soil permeability and drainage classes (McDonald et al. 1990).	35	Highly permeable, well drained
				34	Highly permeable, moderately well drained
				33	Highly permeable, imperfectly drained
				32	Highly permeable, poorly drained
				25	Moderately permeable, well drained
				24	Moderately permeable, moderately well drained
				23	Moderately permeable, imperfectly drained
				22	Moderately permeable, poorly drained
				21	Moderately permeable, very poorly drained
				13	Slowly permeable, imperfectly drained
				12	Slowly permeable, poorly drained
				11	Slowly permeable, very poorly drained

TABLE 1.3
LIMITATION OF WETNESS LEVELS FOR A RANGE OF CROPS

Limitation	Code	Attribute Ranges	Limitation Level of Land Use Activity							
			Peanuts	Sorghum	Maize	Soybeans	Mungbeans	Forage sorghum	Stylo pasture	Grass-legume pasture
Wetness (w)	35	Highly permeable, well drained	1	1	1	1	1	1	1	1
	34	Highly permeable, moderately well drained	2	1	1	1	1	1	1	1
	33	Highly permeable, imperfectly drained	3	3	3	3	3	3	2	2
	32	Highly permeable, imperfectly drained	4	4	4	4	4	4	3	3
	25	Moderately permeable, well drained	1	1	1	1	1	1	1	1
	24	Moderately permeable, moderately well drained	2	1	1	1	1	1	1	1
	23	Moderately permeable, imperfectly drained	4	3	3	3	3	3	1	1
	22	Moderately permeable, poorly drained	5	4	4	4	4	4	2	2
	21	Moderately permeable, very poorly drained	5	4	4	4	4	4	3	3
	13	Slowly permeable, imperfectly drained	4	3	3	3	3	3	2	2
	12	Slowly permeable, poorly drained	5	5	5	5	5	5	4	4
	11	Slowly permeable, very poorly drained	5	5	5	5	5	5	5	5

Source: Wilson, P.R. and Baker, D.E. (1990) *Soils and Agricultural Land Suitability of the Wet Tropical Coast of North Queensland: Ingham Area,* Queensland Department of Primary Industries, Land Resources Bulletin QV90001.

Rockiness (r)

Effect

Coarse (rock) fragments[1] and rock[2] in the plough zone interfere with the efficient use of, and can damage agricultural machinery. Surface rock in particular interferes with the harvesting machinery of sugar-cane, soybean, root crops and some vegetables.

Assessment

Based on the size, abundance and distribution of coarse fragments in the plough layer, together with machinery and farmer tolerance of increasing size and content of coarse fragments.

Diagnostic land attributes

Size and amount of coarse (rock) fragments (McDonald et al 1984) in the plough layer.

Subclass determination

Consultation, particularly related to farmer tolerances which are implicitly related to profitability and technological capability.

TABLE 1.4
APPLICATION OF ROCKINESS CRITERIA IN LAND SUITABILITY ASSESSMENT

Diagnostic land attribute level (Rockiness)		**Suitability subclass for various crops**				
Size	Amount (%)	Avocado, Citrus, Pawpaw, Mango, Lychee, Rambutan, Pastures	Banana, Pinus Pineapple	Sugar-cane, Maize, Rice, Sorghum, Tea, Sweet corn	Soybean, Veges Cucurbits	Peanut Sweet potato
20 to 60 mm	<2	1	1	1	2	3
(gravel)	2 to 10	1	1	2	3	4
Codes:	10 to 20	1	2	3	4	5
G1 to 5	20 to 50	2	3	4	5	5
	>50	3	4	5	5	5
60 to 200 mm	<2	1	1	2	3	4
(Cobble)	2 to 10	1	2	3	4	5
Codes:	10 to 20	2	3	4	5	5
C1 to 5	20 to 50	3	4	5	5	5
	>50	4	5	5	5	5
200 to 600 mm	<2	1	2	3	4	5
(Stone)	2 to 10	2	3	4	5	5
Codes:	10 to 20	3	4	5	5	5
S1 to 5	20 to 50	4	5	5	5	5
	>50	5	5	5	5	5
No coarse fragments Code: 0	1	1	1	1	1	1

[1] Coarse fragments are particles greater than 2 mm in diameter and not continuous with underlying bedrock.
[2] Rock is defined as being continuous with bedrock.

ATTACHMENT 2

LAND SUITABILITY CLASSIFICATION FOR CROPPING AND GRAZING IN THE SEMI-ARID SUB-TROPICS OF QUEENSLAND

The following ratings tables present criteria for determining land suitability for rainfed broadacre cropping and for beef cattle grazing in the semi-arid sub-tropics (see Note 1). These tables are based upon Queensland Department of Primary Industries guidelines for agricultural land evaluation (Land Resources Branch 1990). The criteria used in these tables are necessarily general to be applicable over a wide area. The Department of Primary Industries is developing land suitability classifications for several specific locations within the semi-arid sub-tropics (Shields and Williams 1991) as part of detailed land resource surveys and the Department's detailed land suitability criteria may be more appropriate for each of these locations.

TABLE 2.1
SUITABILITY FOR RAINFED BROADACRE CROPPING

Limitation	Land suitability class				
	1	2	3	4	5
Water availability (See Table 1.3)	PAWC >150 mm	PAWC 125-150 mm	PAWC 100-125 mm	PAWC 75-100 mm	PAWC <75 mm
Nutrient deficiency	Bicarbonate P >10 ppm	Bicarbonate P 5-10 ppm <u>and</u> Exchangeable K >0.3 meq. %	Bicarbonate P 5-10 ppm <u>and</u> Exchangeable K ≤0.3 meq. % <u>or</u> pH <5 60-90 cm below surface <u>or</u> pH >9 60-90 cm below surface	Bicarbonate P <10 ppm <u>and</u> Exchangeable K ≤0.3 meq. %, <u>and</u> Exchangeable Ca <3 meq.%, <u>or</u> pH <5 30-60 cm below surface, <u>or</u> pH >9 30-60 cm below surface	pH <5 within 30 cm of surface <u>or</u> pH >9 within 30 cm of surface
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), <u>or</u> Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm)	Cracking clays with coarse self-mulch (peds 10-20 mm) <u>or</u> Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds at the surface (≥20 mm)	
Soil workability	Friable cracking clays (indicated by very fine self-mulch), <u>or</u> Rigid soils with a loose, soft or firm surface when dry	Firm cracking clays (indicated by fine self-mulch) <u>or</u> Rigid soils with a hard setting surface when dry	Stiff cracking clays (indicated by coarse self-mulch with peds>10 mm, crusting or hard setting surface)		
Salinity	Rootzone EC <0.1 5mS/cm <u>or</u> Rootzone Cl <300 ppm	Rootzone EC 0.15 -0.3 mS/cm <u>or</u> Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm <u>or</u> Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm, <u>or</u> Rootzone Cl 900-1500 ppm	Rootzone EC >1.2 mS/cm <u>or</u> Rootzone Cl ≥1500 ppm
Rockiness	<10% coarse surface gravel (>6 cm diam.) and rock outcrop	10-20% coarse surface gravel and rock outcrop	20-50% surface cobble (6-20 cm diam.)and rock outcrop	50-90% surface cobble and rock outcrop, <u>or</u> 20-50% stone and boulders (>20 cm diam.)	>90% surface cobble and rock outcrop, <u>or</u> >50% stone and boulders and rock outcrop
Microrelief	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	Melonholes 30-60 cm deep cover <20% surface area <u>or</u> Melonholes >60 cm deep cover <10% surface area	Melonholes 30-60 cm deep cover 20-50% of surface area <u>or</u> Melonholes >60 cm deep cover 10-20% surface area	Melonholes 60-100 cm deep cover 50 % surface area	Melonholes at least 100 cm deep cover 50% surface area
Wetness	Undulating terrain or elevated plains	Low-lying level plains with melonholes covering <25% surface area, <u>or</u> Rigid soils with sodic subsoil (ESP 6-14) within 60 cm of the surface, <u>or</u> Non-sodic rigid soils with coarse pale grey and yellow mottles within 75 cm of the surface	Low-lying level plains with melonholes covering 25-50% surface area, <u>or</u> Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, <u>or</u> Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Seasonal swamps and low-lying run-on areas	Permanent swamps and lakes
Topography	No gully dissection	Occasional deep gullies impede cultivation slightly	Many deep gullies reduce arable area by < 33% or require major changes to cultivation practices	Many deep gullies make the arable areas too small to cultivate	Abundant deep gullies prevent any practical cultivation
Water erosion	Slopes <0.5% on cracking clays without melonholes, <u>or</u> Slopes <1% on melonhole clays, <u>or</u> Slopes <1% on non-sodic rigid soils, <u>or</u> Slopes <0.5% on sodic rigid soils	Slopes 0.5-1% on cracking clays without melonholes <u>or</u> Slopes 1-3% on melonhole clays, <u>or</u> Slopes 1-2% on non-sodic rigid soils, <u>or</u> Slopes 0.5-1% on sodic rigid soils	Slopes 1-3% on cracking clays without melonholes <u>or</u> Slopes 2-4% on non-sodic rigid soils <u>or</u> Slopes 1-2% on sodic rigid soils	Slopes 3-5% on all cracking clays <u>or</u> Slopes 4-6% on non-sodic rigid soils <u>or</u> Slopes 2-3% on sodic rigid soils	Slopes >5% on all cracking clays <u>or</u> Slopes >6% on non-sodic rigid soils <u>or</u> Slopes >3% on sodic rigid soils
Flooding	No flooding	Rare flooding (only during abnormal 1 in 50 to 100 year events)	Infrequent flooding (inundation occurs <half the times that stream flow increases)	Occasional flooding (inundation occurs ≥half the times that stream flow increases)	Regular flooding (inundation occurs whenever stream flow increases)

TABLE 2.2
SUITABILITY FOR BEEF CATTLE GRAZING

Limitation	Land suitability class (see Table 2.4)				
	1	2	3	4	5
Water availability (See Table 1.3)	PAWC >125 mm	PAWC 100-125 mm	PAWC 75-100mm	PAWC 50-75 mm	PAWC ≤50 mm
Nutrient deficiency	Brigalow, gidgee, blackwood or softwood scrub soils and former scrub soils <u>with</u> Bicarbonate P >10 ppm	Eucalypt vegetation and downs <u>with</u> Bicarbonate P >10 ppm	Other soils with Bicarbonate P 5-10 ppm <u>except</u> Sands and loams at least 75 cm deep or overlying rock at shallow depth	Sands and loams at least 75 cm deep or overlying rock at shallow depth, <u>with</u> Bicarbonate P 5-10 ppm,<u>or</u> Bicarbonate P ≤4 ppm	
Soil physical factors	Cracking clays with very fine self-mulch (peds <2 mm), <u>or</u> Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10 mm), <u>or</u> Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds (peds ≥10 mm) or crust on the surface		
Salinity	Rootzone EC < 0.15 mS/cm <u>or</u> Rootzone Cl <300 ppm	Rootzone EC 0.15-0.3 mS/cm <u>or</u> Rootzone Cl 300-600 ppm	Rootzone EC 0.3-0.9 mS/cm <u>or</u> Rootzone Cl 600-900 ppm	Rootzone EC 0.9-1.2 mS/cm <u>or</u> Rootzone Cl 900-1500 ppm	Rootzone EC >1.2 mS/cm <u>or</u> Rootzone Cl ≥1500 ppm
Rockiness	<20% coarse surface gravel (>6 cm diam.) and rock outcrop	20-50% coarse surface gravel and rock outcrop	50-90% surface cobble and rock outcrop	>90% surface cobble and rock outcrop	Rock outcrop and surface coarse fragments cover total area
Microrelief	Melonholes cover <20% surface area (semi-circular depressions at least 30 cm deep and usually surrounded by mounds)	Shallow melonholes (30-60 cm deep) cover 20-50% surface area	Deep melonholes (>60 cm deep) cover 20-50% of surface area		
pH (1:5)	5.6-6.6	6.6-8.0 5.0-5.6	8.0-9.0 4.5-5.0	9.0-10.0 4.0-4.5	>10.0 < 4.0
ESP (10cm)% Exchangable Sodium Percentage	<5.0	5-10	10-15	15-30	>30
Wetness	Undulating terrain or elevated plains	Low-lying level plains , <u>or</u> Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface, <u>or</u> Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	Shallow seasonal and permanent swamps		Permanent lakes and deep swamps
Topography				Many deep gullies make cultivation for sowing pastures impractical, <u>or</u> Slopes >15% make cultivation along contours impractical	Strongly dissected terrain over ≥75% of the area preventing adequate herd management
Water erosion	Slopes <1% on sodic rigid soils <u>or</u> Slopes <3% on all other soils	Slopes 1-3% on sodic rigid soils <u>or</u> Slopes 3-6% on cracking clays, <u>or</u> Slopes 3-12% on non-sodic rigid soils	Slopes 3-6% on sodic rigid soils <u>or</u> Slopes 6-9% on cracking clays, <u>or</u> Slopes 12-20% on non-sodic rigid soils	Slopes 6-12% on sodic rigid soils <u>or</u> Slopes 9-15% on cracking clays <u>or</u> Slopes 20-45% on non-sodic rigid soils	Slopes >45%
Flooding	No flooding	Periodic flooding (from once in 50 years to whenever stream flow increases)			
Vegetation regrowth (management limitation)	Softwood, brigalow, gidgee or blackwood scrub without melonholes , <u>or</u> Queensland bluegrass grasslands, <u>or</u> Mountain coolabah, bloodwood and ironbark open woodlands	Brigalow, gidgee or blackwood scrub with melonholes, <u>or</u> Box and ironbark woodlands without wattle understorey, <u>or</u> Coolabah woodlands on flooded country		Eucalypt woodlands with wattle understorey <u>or</u> Broad-leaved teatree woodlands	

TABLE 2.3
SURROGATE FIELD PROPERTIES FOR ESTIMATING PLANT AVAILABLE WATER CAPACITY (PAWC)

PAWC ≥150 mm	PAWC 125-150 mm	PAWC 100-125 mm	PAWC 75-100 mm	PAWC 50-75 mm	PAWC ≤50 mm
Cracking clays: ≥90 cm depth to weathered or hard rock and very fine self-mulch (ped size <2 mm) and infrequent cracking at surface when dry (≤1 crack per square metre) and alkaline to neutral pH throughout and Cl<600 ppm within 90 cm of the surface and ESP<15 within 90 cm of the surface	Cracking clays: ≥90 cm depth to weathered or hard rock and fine self-mulch (ped size 2-10 mm) and dense cracking at surface when dry (>1 crack per square metre) and alkaline to neutral pH throughout and Cl<600 ppm within 90 cm of the surface and ESP<15 within 90 cm of the surface	Cracking clays: alkaline to neutral pH throughout and 60-90 cm depth to 1)weathered or hard rock, 2) Cl≥600 ppm or 3) ESP≥15 or acid to neutral pH at depth and 60-90 cm to salt bulge with EC≥0.9 mS/cm or Cl≥900 ppm	Cracking clays: alkaline pH throughout and 40-60 cm depth to weathered or hard rock or acid to neutral pH at depth and 40-60 cm to salt bulge with EC≥0.9 mS/cm or Cl≥900 ppm	Cracking clays: alkaline pH throughout and 20-40 cm depth to weathered or hard rock or acid to neutral pH at depth and 20-40 cm to salt bulge with EC≥0.9 mS/cm or Cl≥900 ppm	Cracking clays: alkaline pH throughout and ≤20 cm depth to weathered or hard rock or acid to neutral pH at depth and ≤20 cm to salt bulge with EC≥0.8 mS/cm or Cl≥800 ppm
	Rigid soils (non-sodic)	Rigid soils (non-sodic)	Rigid soils (non-sodic)	Rigid soils (non-sodic)	Rigid soils (non-sodic)
	Loams, clay loams, non-cracking clays, duplex soils and gradational earths and >125 cm depth to weathered or hard rock or >125 cm to salt bulge with EC≥0.9 mS/cm or Cl ≥900 ppm	Loams, clay loams, non-cracking clays, duplex soils and gradational earths and 75-125 cm depth to weathered or hard rock or 75-125 cm to salt bulge with EC≥0.9 mS/cm or Cl ≥900 ppm	Loams, clay loams, non-cracking clays, duplex soils and gradational earths and 50-75 cm depth to weathered or hard rock or 50-75 cm to salt bulge with EC≥0.9 mS/cm or Cl≥900 ppm	Loams, clay loams, non-cracking clays, duplex soils and gradational earths and 30-50 cm depth to weathered or hard rock or 30-50 cm to salt bulge with EC≥0.9 mS/cm or Cl≥900 ppm	Loams, clay loams, non-cracking clays, duplex soils and gradational earths and ≤30 cm depth to weathered or hard rock
			Sands and sandy loams >90 cm deep	Sands and sandy loams 45-90 cm deep	Shallow sands and sandy loams ≤45 cm deep
			Rigid soils (sodic)	Rigid soils (sodic)	Rigid soils (sodic)
			Duplex soils with subsoil becoming sodic (ESP 6-14) within 60 cm of the surface but not strongly sodic (ESP≥ 15) within 90 cm	Duplex soils with a sodic subsoil (ESP 6-14) becoming strongly sodic (ESP≥15) within 60 cm of surface	Duplex soils with a strongly sodic subsoil (ESP≥25) within 45 cm of surface

TABLE 2.4
MAJOR TYPES OF GRAZING COUNTRY IN EACH LAND SUITABILITY CLASS

Land suitability class	Brief description	Productivity of native pastures	Potential for pasture improvement	Significant limitations
1	Softwood, brigalow, gidgee and blackwood scrub on fertile cracking clays with a very fine self-mulch and few melonholes; not subject to flooding	Low under standing scrub, moderate after clearing	A wide range of sown pastures following clearing	Slight woody weed regrowth
2	Softwood, brigalow, gidgee and blackwood scrub on fertile soils and/or many shallow melonholes; not subject to flooding	Low under standing scrub, moderate after clearing	A wide range of sown pastures following clearing	Minor pasture establishment problems; minor woody weed regrowth; sown pastures don't persist in melonholes
	Uplands with downs and mountain coolabah, bloodwood or ironbark woodlands on cracking clays with a fine self-mulch	High in the virgin state	A limited range of sown pastures on cracking clays; a wide of sown pastures on rigid soils	Minor pasture establishment problems on cracking clays; minor woody weed regrowth in ironbark woodlands
	Uplands with ironbark woodlands on friable red and brown rigid soils	Moderate to high in the virgin state	A limited range of sown pastures	Minor woody weed regrowth
	Flooded country with variable vegetation on cracking clays, loams, clay loams, non-cracking clays, duplex soils and gradational earths	High in the virgin state	A limited range of sown pastures on the areas infrequently flooded; no suitable introduced species for frequently flooded areas	Periodic inundation; woody weed regrowth after clearing some vegetation
3	Brigalow, gidgee and blackwood scrub with 1) infertile soils, 2) poor surface condition, and/or 3) many deep melonholes; not subject to flooding	Low under standing scrub and after clearing	A wide range of sown pastures following clearing	Moderate pasture establishment problems; moderate woody weed regrowth; sown pastures don't persist in melonholes
	Uplands with eucalypt woodlands and no wattle understorey on infertile rigid soils	Low to moderate in the virgin state	Clearing and oversowing with legumes	Phosphorus fertilisers/supplements required; production of improved species severely limited by low fertility in some soils; minor woody weed regrowth
	Uplands with downs and mountain coolibah, bloodwood or ironbark woodlands on cracking clays with a coarse self-mulch	Moderate to high in the virgin state	A limited range of sown pastures	Establishment of sown pastures severely restricted; minor woody weed regrowth in ironbark woodlands
	Shallow swamps	Nil to low in the virgin state	Para grass and a few other grasses	Shallow water required most of the year
4	Hills and mountains with eucalypt woodlands and lancewood/bendee scrub on shallow rigid soils	Low in the virgin state	Nil	Production of improved species severely limited by low fertility
	Uplands with eucalypt woodlands and a wattle understorey on infertile rigid soils	Low in the virgin state	Oversowing with legumes but fertilisers also necessary	Production of improved species severely limited by low fertility; severe woody weed regrowth if mechanically cleared
5	Very steep, strongly dissected hills and mountains	Low in the virgin state	Nil	Extremely low pasture production ; topography prevents effective herd management; high erosion potential precludes clearing
	Rocklands	Nil	Nil	Negligible pasture production
	Lakes and permanent deep swamps	Nil	Nil	No pasture production

Notes:

1. The semi-arid sub-tropics refer to the region bounded by Duaringa, Rolleston, Hughenden and Greenvale. The Mitchell grass downs and vast outwash plains of the Gulf of Carpentaria form the western boundary and the coastal strip to the east is also excluded. The average annual rainfall is approximately 500 to 800 mm of which at least 75% falls during summer but there is also a significant winter component averaging between 50 and 175 mm.
2. Rainfed broadacre crops include sorghum, sunflower, wheat, safflower, cotton, chick peas and annual fodder crops (sorghum, millet and oats). These crops are often grown in sequence, with the actual crops planted being dependant upon rainfall (Shields & Williams 1991).
3. The plant available water capacity (PAWC) of a soil is extremely difficult to measure in the field and there are no models available that can be applied to all soils within the semi-arid sub-tropics to accurately determine these values. The figures used in Table 2.1 have been estimated for a range of soils with a maximum rooting depth of 100cm and compared with long-term crop yields. Surrogate soil properties that can be readily identified in the field and used to allocate soils into a class are presented in Table 2.2.
4. The soil fertility criteria are based on standard QDPI analytical test using a bulk 0-10 cm surface sample. The QDPI soil analytical methods and guidelines for interpreting analytical results are described by Baker and Eldershaw (1993).
5. The effects of soil salinity upon plant growth depend upon the soil type, the plants being grown and the climate. The criteria used in Table 2.1 represent a generalisation of this complex issue and are meant to provide an estimate of salinity effects upon plant growth within the root zone.

   The depth to any salt bulge indicates the maximum depth to which water moves through the soil and is thus used as a surrogate for the rooting depth. Therefore, the depth of a salt bulge is used in estimating PAWC but this represents a physical limit on plant roots (lack of water) and does not account for any chemical effect that soluble salts above this bulge have on plant growth.

   The rootzone salinity accounts for chemical effects on plant growth and is averaged over the rooting depth which is the depth to hard or weathered rock, or the depth to any significant salt bulge (EC≥0.8 mS/cm or Cl≥800 ppm).

   In the absence of any rock or salt bulge the maximum rooting depth is taken as 100 cm for crops and 60 cm for pastures.
6. These tables may be useful when assessing the suitability of soils for topsoiling and as growth media but more detailed guidance is available in the Guideline on Growth Media Management.

References:

Baker, D.E. Eldershaw, V.J. (1993), Interpreting soil analyses - for agricultural land use in Queensland, Queensland Department of Primary Industries Project Report QO93014

Land Resources Branch (1991), Guidelines for agricultural land evaluation in Queensland, Queensland Department of Primary Industries Information Series QI90005

Shields, P.G. Williams, B.M. (1991), Land resource survey and evaluation of the Kilcummin area, Queensland, Queensland Department of Primary Industries Land Resources Bulletin QV91001