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Land Resources Bulletin

Soil Attributes and Agricultural Suitability of the Burnett River Riparian Lands, Gaynedah - Perry River

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Queensland Government
Department of Natural Resources

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Summary

A land resource assessment study was undertaken for the area 5 km either side of the Burnett River downstream of Gayndah to the Perry River. This project will support strategic planning and sustainable resource use for this area by identifying areas prone to or affected by land degradation, land suitable for existing and potential industries, good quality agricultural land and by developing land management guidelines. Land and soil attributes and limitations relevant to land management are also identified and mapped.

The need for this land resource information for the selected area has increased in priority due to the proposal of a new dam on the Burnett River, which would increase irrigation opportunities and development areas for the region.

A fuzzy modelling approach has been used to predict the distribution of soil attributes and land suitability. Conceptual models describing soil attribute distributions in the landscape were captured as fuzzy rule sets. A Digital Elevation Model (DEM) using 2-metre contour interval was used to derive a number of environmental variable layers used as inputs in the fuzzy modelling process. Derived variables include tan and profile curvatures, relative elevation and slope. Satellite images using TM band 4 and gamma ray spectrometry (radiometrics) were other spatial attributes used to predict the various soil attributes. Predicted soil attributes include surface condition, drainage, rockiness, plant available water capacity (PAWC), permeability, soil depth and frost. Salinity and erosion hazards have also been assessed.

Of the total (75 791 ha) land within the study boundary, 46% (35 035 ha) of the total study area is excluded from potential irrigation areas due to steep terrain (slopes exceeding 8%). The total area suitable for individual crops are asparagus is suited to 2063 ha, beans 181 ha, citrus 1564 ha, cotton 2371 ha, furrow irrigated cotton 516 ha, furrow irrigated maize 506 ha, furrow irrigated soybeans 516 ha, furrow irrigation 7600 ha, grapes 182 ha, improved pasture 16 637 ha, macadamias 12 ha, maize 2452 ha, peanuts 174 ha and soybean 2367 ha. Avocado is not suited to this area due to severe climatic limitations.

Land resource assessment of the study area revealed only a relatively small area of land has potential for future irrigation development. These areas consist largely of alluvial landscape, particularly the levee landforms.

1. Introduction

Gayndah is one of the major centres within the Central Burnett. Being Queensland's oldest town, the area was initially settled as sheep country. Citrus orchards were established in the late 1800's, which led to the area being renowned for its oranges. Today, beef cattle grazing is the district's major economy with other agricultural and horticultural crops also important.

Effective land management depends on understanding landscape pressures together with identifying and mapping the land attributes which influence management. Land management issues include land degradation such as salinity erosion, water quality issues associated with inappropriate land use, competition for the limited land and water resources, vegetation management, use of the land according to its capability, environmental management such as riparian areas, and more efficient use of resources.

The riparian areas 5 km either side of the Burnett River are perceived to have a high development potential. However, development and inappropriate land management in this area will potentially impact on all resource managers, users downstream and end-point marine environments.

This land resource information will be used to support catchment management planning, strategic planning and for the sustainable use and management of lands in the Gayndah – Perry River area by:

- Identifying areas prone to or affected by land degradation (salinity/erosion/soil structure/acidification)
- Identifying land suitable for existing and potential agricultural industries
- Identifying good quality agricultural land for designation in planning schemes
- Developing sustainable land management guidelines in cooperation with landholders, Landcare, ICM groups, Government Departments and others.

Medium intensity mapping of the land resources has been done upstream of Gayndah (Tucker and Sorby 1996) and downstream of the Perry River (Wilson 1997). Broad scale land system mapping (1:250 000) covers the whole area (Donnollan and Searle *in prep*; Kent *in prep*). This broad scale mapping lacks information in sufficient detail to address current land use issues. The study area may be seen in Figure 2.

Figure 1. Extensive grazing is a feature of the Gayndah area

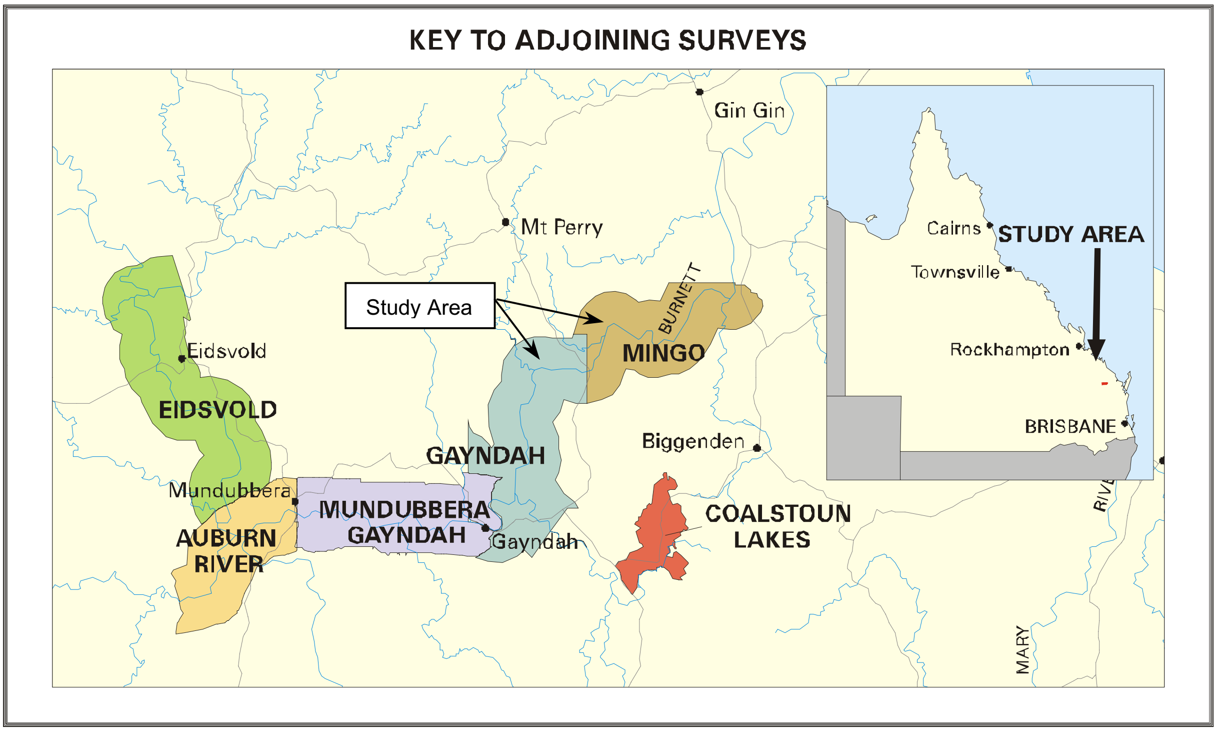

Figure 2. Gayndah – Perry River study area and surrounding land resource surveys

Figure 3. Citrus orchards on the banks of the Burnett River are common in the Gayndah area

2. Study environment

Climate

The climate for the inland Burnett District is subtropical with long, hot summers and mild winters. The mean daily maximum temperature is 32.6°C in December. Temperatures frequently exceed 35°C during the summer months of December and January. July has the lowest mean daily temperature of 5.9°C. Frost does occur in the region, but only in low-lying areas.

The average annual rainfall for the area is 772.9 mm. Approximately 70% of the total rainfall occurs in the summer months of October to March. Droughts are a regular feature in the district. On average, shires are drought declared approximately once every five years (Mahar 1993). Mean daily temperature and rainfall can be seen in Table 1.

Table 1. Mean daily temperature and rainfall recorded at Gayndah Post Office

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Daily Max Temp (deg C)												
32.5	31.8	30.7	28.5	25.1	22.3	21.8	23.6	26.7	29.4	31.5	32.6	28.0
Mean Daily Min Temp (deg C)												
19.9	19.8	18.0	14.3	10.3	7.4	5.9	6.7	10.0	14.0	17.0	19.0	13.5
Mean rainfall (mm)												
117.2	106.9	76.6	38.5	41.3	39.8	39.4	29.3	35.5	64.6	77.1	106.8	772.9

Bureau of Meteorology (2000)

Geology

The Central Burnett region is a complex mixture of metamorphic, igneous and sedimentary rocks. The main geologies found in the study area include: The Gayndah Formation (Rtg) Aranbanga Volcanic Group (Ra), Intrusive Rhyolite (Rir) Abernethy basalt (Raa), Yenda Granodiorite (Pry), Tertiary sediments (Ts), Mount Macella Volcanics (Rtn) and Quaternary Alluvia (Qa).

The Gayndah Formation (Rtg) consists of sandstone, conglomerates, siltstone, mudstone and minor areas of acid volcanics. The unit overlies unconformably the undifferentiated Palaeozoic rocks and lower upper Permian granitic rocks, and is overlain conformably by the Triassic Aranbanga Beds. (Ellis 1968).

The Aranbanga beds (Ra) comprise andesite, rhyolitic, and trachytic flows and pyroclastics, minor tuffaceous sediments and basalt (Ellis 1968). Andesitic flows constitute almost 65% of the unit.

The Ts geology unit occupies significant areas to the east of the Burnett River below Mingo Crossing. This unit comprises quartzose to sublabile sandstones, claystone, conglomerate and minor areas of olivine basalt.

Areas of intrusive rhyolite (Rir) occur on both sides of the Burnett River. Larger areas of this geology unit occur on the eastern side adjacent to the Ts geology.

Abernethy basalt (Raa) is a major component of the Aranbanga group (Ra) in the study area. Larger areas are found to the west of the Burnett River, with minor occurrences elsewhere within the study area. Wetheron basalt (Raw) is the other major basalt unit found in the study area. This basalt is coarser grained than the Raa basalt. Woodmillar Andesite (Rao) is the dominant andesitic unit of the Aranbanga volcanic group.

The Yenda Granodiorite (Pry) geology unit consists mainly of biotite-hornblende granodiorite, and hornblende-biotite granite to granodiorite. The Mingo granite (Pm) geology unit is the dominant granite unit in the eastern section of the study area.

Small but significant areas of Mount Marcella Volcanics (Rtn) are located in the southeastern section of the study area. These areas are dominated by andesite, but also comprise conglomerate, sandstone, siltstone and shales.

The Good Night beds (CPo) are the dominant geology between Mingo crossing and Perry River. This unit consists of slate, phyllite, chert, jasper, arenite, limestone, basic metavolcanics and diamictite.

Recent alluvial (Qa) deposits cover only a relatively small portion of the study along major creeks and the Burnett River.

Landform

The Burnett River with its meandering alluvial landscape forms the central axis of the study area. The river has very high-incised banks, and as such flooding of the adjacent alluvial plains seldom occurs.

The alluvial system primarily consists of levees and level to gently undulating plains. The levees are mostly used to grow crops such as irrigated citrus.

Creeks that form tributaries to the Burnett River are flanked by narrow alluvial landscapes that are not as prominent as the main alluvial system of the Burnett River.

Abernathy basalt to the north of Gayndah gives rise to self-mulching black clay soils on very gently undulating to undulating plains. Soils are deepest in lower landscape positions, with rock outcrops on steep slopes and ridge crests.

Labile sediments and intermediate volcanics of the Gayndah Formation, Wetheron Basalt and other minor formations form undulating plains and rises and low hills. Shallow soils and rock outcrops occur on steeper slopes and hillcrests. Acid volcanic rocks such as rhyolite frequently form prominent steep hills scattered through the area to the north and north east of Gayndah.

Granodiriorites and quartzose sandstone form undulating plains and rises, mainly in the Mingo area. Soils tend to be shallow on crests with rock outcrops.

Water resources

Irrigation of horticultural crops is the dominant use of water in the Central Burnett region, with minor allocations to three towns, including Gayndah and Mundubbera. According to the Burnett River Catchment Overview Study (Sinclair Knight Merz 1998) all of the 28 000 ML of available water in the Central Burnett Region has been allocated. Water quality, in the Central Burnett region, is moderate to poor (450 – 1500 µS/cm) in the Burnett River, based on water quality measurements by DNR. Normal flows in the river are suitable for all purposes. Salinity increases during times of low flow and irrigation may only be suitable for salt tolerant crops.

Floods in the Burnett River can cause much damage to crops and infrastructure. The highest recorded flood level at Gayndah was 19.66 m in February 1942 (Sinclair Knight Merz 1998). Flood events in the Burnett River at Gayndah must be large to break out of the primary channel, records show that floods have infrequently broken the banks of the Burnett. In the previous 136 years of record at Gayndah, the Burnett has broken its banks three times and flowed ‘around the back of the town’ (Maynard 1991). One of the floods to break the banks of the river at Gayndah was in 1864, a quote from The Burnett Argus, found in Maynard (1991), states:

> Many of those living on the banks of the river began to pack up, and make arrangements for decamping to the mountain ... but we are happy to say the flood did not so far obtrude as to induce them to do anything of the sort, although it was much higher than it was during the great flood of '55 (when our townspeople flew up the mountain).
>
> Yet with the greatest of floods not the slightest harm has been done to the town properties. The town being on a great elevation, it would indeed be a terrific flood that could do it harm. When the flood was at its' height parties could walk the streets without even wetting the soles of the shoes.

Many other newspaper articles during times of large floods at Gayndah record similar events occurring.

3. Methodology

Soil attribute survey

A free survey technique was used to collect soil and land attributes for different lithologies within the study area. Aerial photo interpretation of black and white aerial photos at a scale of 1:25 000 was conducted to select a series of transects. These transects were chosen to represent the different geologies, position and patterns within the landscape.

All fieldwork was conducted by vehicle traverse. A total of 363 mapping sites were described and stored in a soil and land information database. This site intensity approximates to one site per 210 hectares (including hills) and one site per 113 hectares (excluding hills).

Australian Map Grid (AMG) coordinates were recorded for each described site to an accuracy of approximately 10 m and added to the site description database. A description of the soil profile and information on vegetation, soil surface characteristics, microrelief (gilgai) and slope were recorded at each site using standard terminology and codes of McDonald *et al.* (1990). Soil profiles were then classified using Isbell (1996).

Samples of representative soil profiles and subsoils of other selected profiles were collected for laboratory analysis.

Spatial attributes

A digital elevation model was created using 2m and 40m contour information. Terrain derivatives were derived from the elevation model. These derived terrain derivatives include plan, profile and tan curvature, relative elevation, topographic wetness index (TWI), flow accumulation, proximity to stream and slope. Six bands of TM satellite imagery were available for the whole area. Radiometric (gamma radiation spectrometry) was available for approximately 60% of the study area.

A more detailed account of the differing lithology could be distinguished by interpreting the radiometric data, rather than by using existing geology maps.

Soil conceptual models

The initial step involved a field reconnaissance to familiarise officers with existing mapping. Three surveys have been undertaken within the surrounding area. These include "Soils of the Riparian lands of the Burnett River between Mundubbera and Gayndah, Queensland" (Tucker and Sorby 1996), "Soils of the Brian Pastures Research Station Gayndah, Queensland" (Reid *et al.* 1986), and "Central Burnett land systems" (Kent *in prep*).

This reconnaissance coupled with the soil attribute survey enabled soil/landscape models to be developed explicitly, thereby, expressing the relationship between geology, soil attributes and landscape position.

By recording AMG coordinates for each described site, spatial attributes could be correlated with soil attributes for all described sites. The soil conceptual models were developed explicitly and when used with the available geographic information, spatial predictions regarding the distribution of soil attributes in the landscape maybe made (Slater and Grundy 1999).

However, this is a difficult process, as explicit modelling requires knowledge of complex landscape processes for the various geological lithologies.

Fuzzy modelling approach

A computer based fuzzy model approach was used to predict the distribution of soil attributes within the study area. The soil/landscape conceptual models were captured as a fuzzy rule set, which is essentially a set of “IF” “THEN” scenarios. The fuzzy modelling approach removes the inconsistencies, which occur in traditional surveys, by having established a set of repeatable rules for the entire study area. The details of the fuzzy rule sets developed for this project may be referenced in “Modelling the soil Attributes and Agricultural Suitability of the Burnett River Riparian lands” (Brough *et al. in prep*).

The fuzzy approach provides a natural way of dealing with the imprecision that occurs when sharply defined boundaries are used to mark changes within the soil landscape. Basically, it determines a degree of membership for the likelihood of predicting a given soil attribute. Most areas had a high degree of membership for the likelihood of predicting a given soil attribute. Transition areas had low membership of any given soil attribute. This realistically shows the natural transgression between soil attributes within a given landscape. Traditionally these areas are ignored with a line being drawn broadly between two differing soil units.

4. Landscape models

Landscape processes influence the type and spatial distribution of soil and land attributes. These attributes determine the conditions and trends of the natural resources under various management practices. For sustainable land management in this area, the following soil attributes need to be predicted: slope, rockiness, rooting depth, actual soil depth, wetness, pedon, surface texture, permeability, frosting and flooding. The 'severity' of these attributes then determines a range of limitations or restrictions to plant growth, machinery use and assess the potential for land degradation.

Soil attributes

Slope

Slope is a primary factor relating to safe machinery operation, planning irrigation layouts and the erosive nature of soil types. Slope also influences other landscape processes such as soil depth, rockiness, wetness and salinity.

Slope was measured in the field at each described site with a clinometer. For modelling processes slope was calculated from the DEM for the entire study area.

Rockiness

Rock fragments and bedrock within the plough layer interferes with the use of machinery, and possibly causes damage. Rocks within the profile also impact on the plant available water capacity (PAWC) by effecting the rooting depth or overall ability to store water.

Field observations concluded that rockiness did not occur on the alluvium landscape. It mainly occurred along ridgelines and hillcrests and steep slopes. These areas could be expressed spatially using relative elevation and tan curvature and lithology. More resistant lithologies (eg basalt, granites) frequently have larger rock fragments on lower slopes compared to less resistant rocks.

Rooting depth

Rooting depth largely influences PAWC and physical support for plants on shallow soils. Rooting depth is the depth to impermeable layers (eg. high salts) or bedrock (see below) that roots extract moisture from.

Rooting depth was recorded at each described site, using the relationship between field pH, field EC and roots in the profile. A pH greater than or equal to 8.5 – 9.0 frequently corresponded to the lower limit where roots were located. This also corresponds to the salt bulge within the soil profile and therefore wetting depth under rainfall or irrigation. Pedons have a typical rooting depth depending on position in the landscape.

Actual soil depth

Actual soil depth is needed to calculate PAWC when soil depth is shallow due to bedrock. It is an attribute that is required for building purposes.

The means of predicting actual soil depth was closely related to the rockiness attribute.

Wetness

Wetness relates to both internal and external drainage. Drainage was assessed at each described site. Indicator attributes of internal drainage include texture, grade and type of structure, colour, mottles, segregations and impermeable layers. Slope and topographic position determine external drainage.

Wetness has been predicted spatially using 'Pedons' (see below), relative elevation, profile curvature and slope.

Pedons

A Pedon is, in many cases, a broad soil group with similar lithology, weathering, clay type, soil chemistry, profile horizonisation, surface condition, landscape and geomorphology. Soil groups have been identified as being either: deep sands (Rudosols, Dermosols) on levees, sandy texture contrast soils (Sodosols) on back slopes of levees, weakly hardsetting texture contrast soils (Sodosols) on acidic rocks (eg granites, siliceous sediments), strongly hardsetting texture contrast soils alluvium or intermediate rocks (eg. andesites) or sedimentary rocks (mudstones and siltstones), pedal clays (Vertosols) on alluvium or intermediate rocks (eg. andesite) and sedimentary rocks or self-mulching clays (Vertosols) on basalts.

Pedons have been predicted spatially using radiometrics, TM satellite imagery and landscape (eg alluvial planes) and geology maps where radiometrics was not available.

Surface texture

Surface condition may be easily predicted from the Pedon output. Each soil group has a definitive range of surface textures. Surface texture influences soil surface physical properties and PAWC.

Permeability

Permeability relates to the soil's ability to transmit water internally and was assessed to a depth of one metre. Permeability influences soil wetness and rooting depth. Together with other attributes it is used to assess irrigation efficiency, deep drainage, salinity hazard and erosion.

Based on field observations of texture, pedality and grade of structure, sodicity, pH and salt bulge, each soil group was assigned a permeability rating according to position within the landscape. Permeability is greatly influenced by the accumulation of sodium on the clay exchange complex in lower landscape positions.

Frosting

Generally the incidence of frosts in the study area is influenced by position in the landscape. Hill tops and upper slopes experience fewer and less severe frosts. The low lying areas such as channel benches and depressions in the terraces along the rivers can receive a large number of severe frosts per year.

Relative elevation and profile curvature and landscape were used to spatially predict the incidence of frost.

Flooding

The flood attributes that affect agriculture are the depth and duration of inundation, velocity, rate of water level rise, time of year and frequency of occurrence (Lawrence *et al*. 1982).

Floods are mainly restricted to the relatively narrow channel benches of the Burnett River and local creeks. Water velocities are higher and it is where sand and silt depositions regularly occurs and bank erosion and scouring is most severe. The lower channel benches are the most severely and regularly affected.

Flooding has not been predicted. Actual flood heights have been used.

Soil attribute conceptual models

Soil attribute conceptual models were developed from field observations during the fieldwork phase of the study. These soil attribute conceptual models formed the basis on which model rules were devised. Lithology and position within the landscape were defining factors of the conceptual models.

Alluvial landscape

Four pedons are found within the alluvial landscape. Levees are located adjacent to the streams, and are generally associated with deep, uniform, sandy to loamy Rudosols and Dermosols. Deep sandy surfaced sodic texture contrast soils occur on the back slopes of these levees. Loamy surfaced sodic texture contrast soils predominantly occur on the alluvial plains. Grey and brown cracking clays occur in drainage lines and back plains. The conceptual model developed for the alluvial landscape is shown in Figure 4.

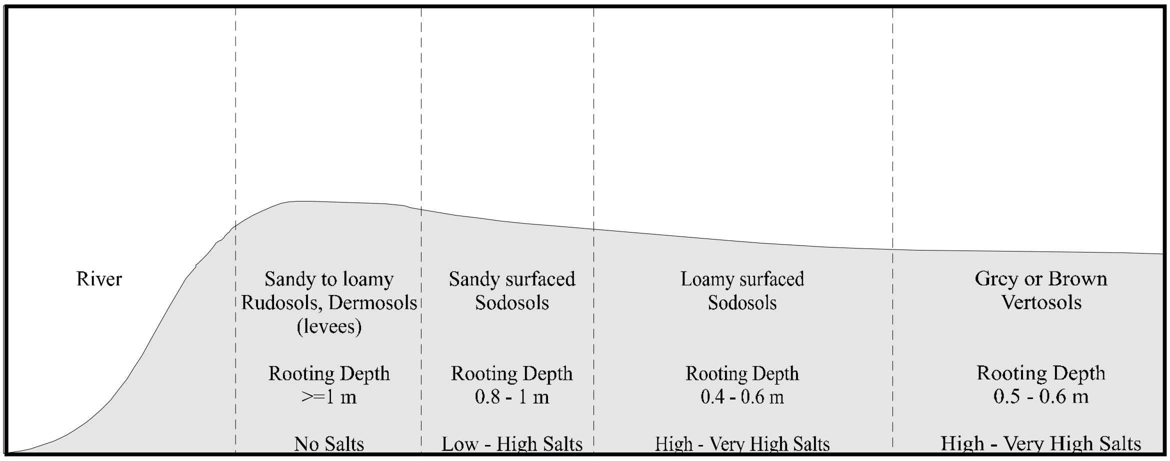

Figure 4. Soil-attribute conceptual model of the alluvial landscape.

The sandy Rudosols (Burnett) and loamy Sodosols (Flagstone) on levees are freely drained and have very low levels of soluble salts, as seen in Figure 6 of the EC profile of the Burnett and Flagstone soils. The pH of the levee soils remains neutral throughout the profile (Figure 5). They have no restriction to rooting depth to one metre. Deep sands have a low cation exchange capacity, which indicates a poor ability to store nutrients. Leaching may occur causing a loss of nutrient inputs, such as nitrogen fertilizer, through the system. Previous soil analysis by Tucker and Sorby (1996) found all of the soils on the Burnett River alluvium have high levels of available phosphorus.

The sodic texture contrast soils on steeper slopes (>4-5 %) are moderately well drained, whilst those on low and medium slopes are imperfectly drained. Most of the texture contrast soils on the alluvium have an alkaline reaction trend, as shown in the Fison and Flagstone soils in Figure 5, which reflects increasing sodicity at depth.

The alluvial landscape was delineated using aerial photo interpretation and by referencing geology maps. As this was the most complex system to predict Pedons and attributes, within the study area, it was separated from non-alluvial material by this method.

No rock is found in the alluvial landscape, and all soils are very deep.

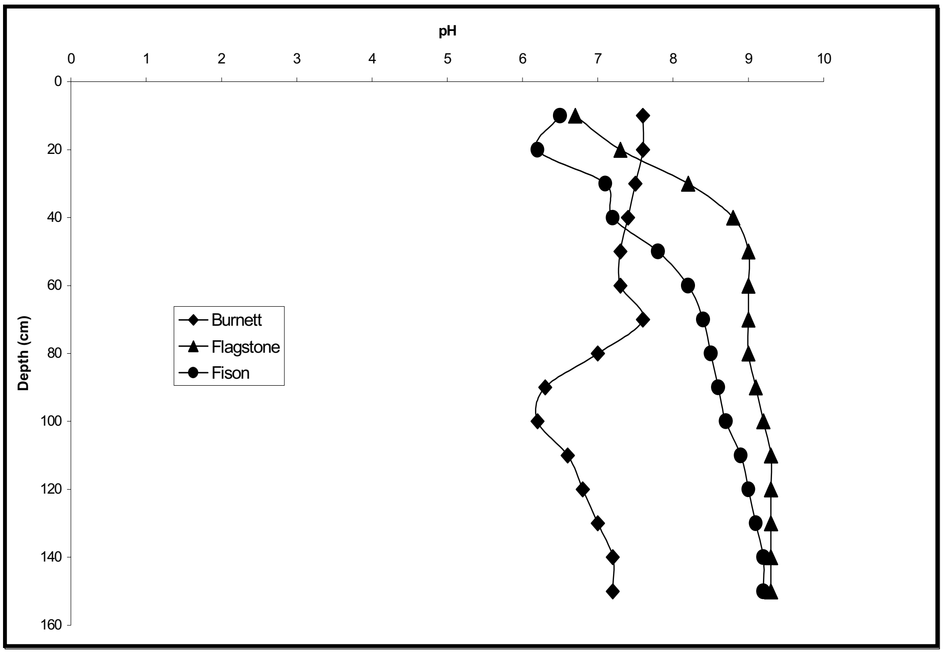

Figure 5. Laboratory pH of alluvial soils: Burnett, Flagstone and Fison

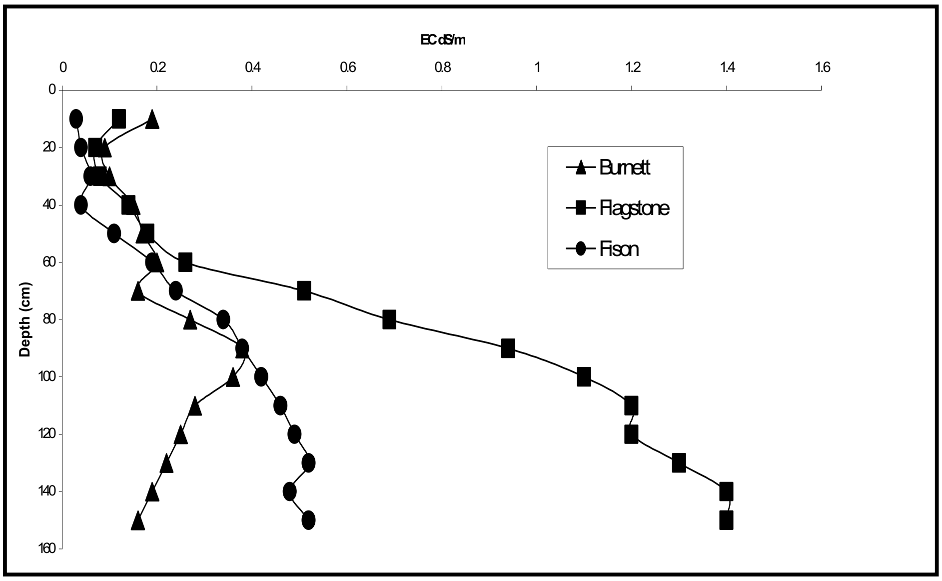

Figure 6. Laboratory EC (1:5 water) of alluvial soils: Burnett, Flagstone and Fison

Self mulching Vertosols on Abernethy Basalt (Raa)

Black self-mulching Vertosols. The Raa basaltic soils are high quality agricultural soils. They are very well structured with a strong self-mulching surface. These soils have little sodicity and salt within the profile, therefore, rooting depth is uninhibited by impermeable barriers other than rock. The Raa clays are moderately well drained and are slowly permeable. Previous soil analysis (Tucker and Sorby 1996) indicates these clays have a high Cation Exchange Capacity, therefore a strong ability to store nutrients within the profile. Soils on the crests of rises within the landscape tend to be shallow, with weathered basalt is encountered before 0.5m. The transition between shallow and deep is very difficult to distinguish on long gentle slopes, as shown in Figure 7.

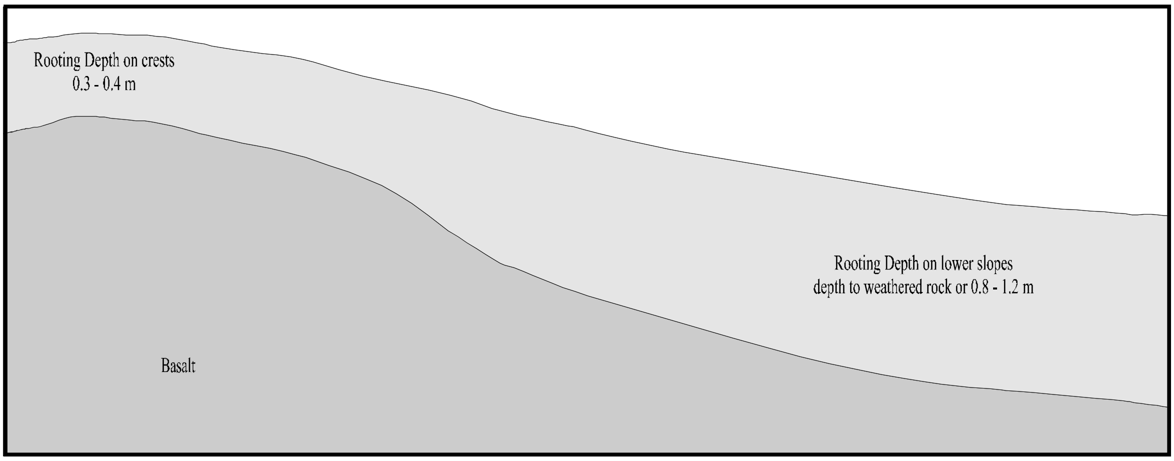

Figure 7. Soil-attribute conceptual model within the Abernethy Basalt (Raa)

Pedal Vertosols on Andesites, other basalts and labile sediments

Black or brown Vertosols/Dermosols. The Vertosols on volcanics, (Gayndah Formation Rtga, Aranbanga Volcanics Ra, Wetheron Basalt Raw, Woodmiller andesites Rao) and labile sediments (Gayndah Formation Rtg) and other basalt units in the study have Vertosol soils with similar attributes. These clays are poorer quality clays compared to the Raa basalts. High salinity and strongly sodic subsoils are a feature of these soils. Soils located on crests and ridges usually have a rooting depth of < 0.5m due to weathered rock. The pedal clay soils have a denser vegetation cover than that of the texture contrast soils on similar lithologies. Slight overlaps in predicting soil attributes occur on the better end of the texture contrast soils and poorer end of pedal clays.

Figure 8 demonstrates that soils that occur on steeper slopes (>2-3%) are moderately well drained and slowly permeable, while soils in lower landscape positions and low slopes tend to be imperfectly drained and very slowly permeable.

The upper slopes of the Raw geology have low salts and a neutral pH due to shallow better drainage of these soils. High EC and high pH reflect poorer drainage and slower permeability attributes of soil found in lower slope positions.

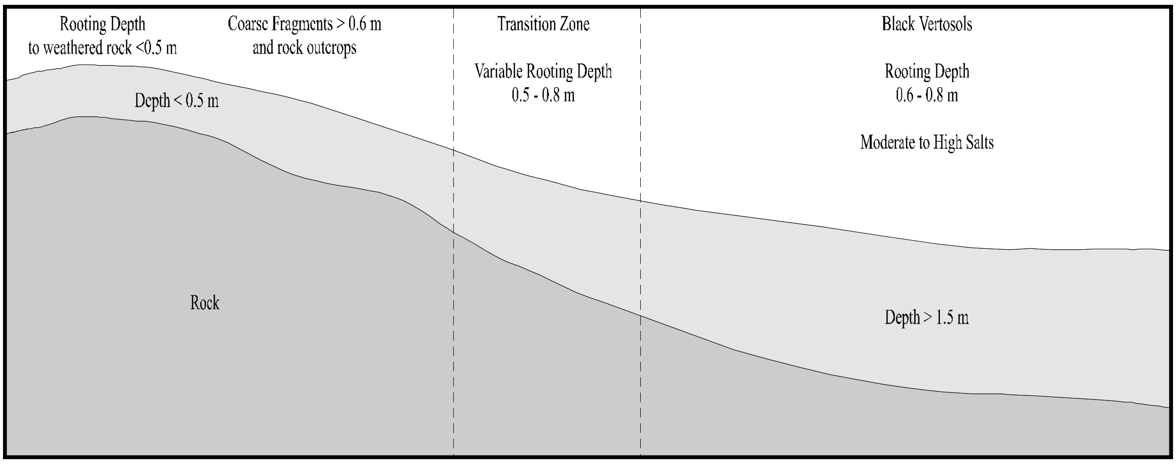

Figure 8. Soil attributes conceptual model of clay soils on Andesites, other basalts (not Raa) and labile sediments

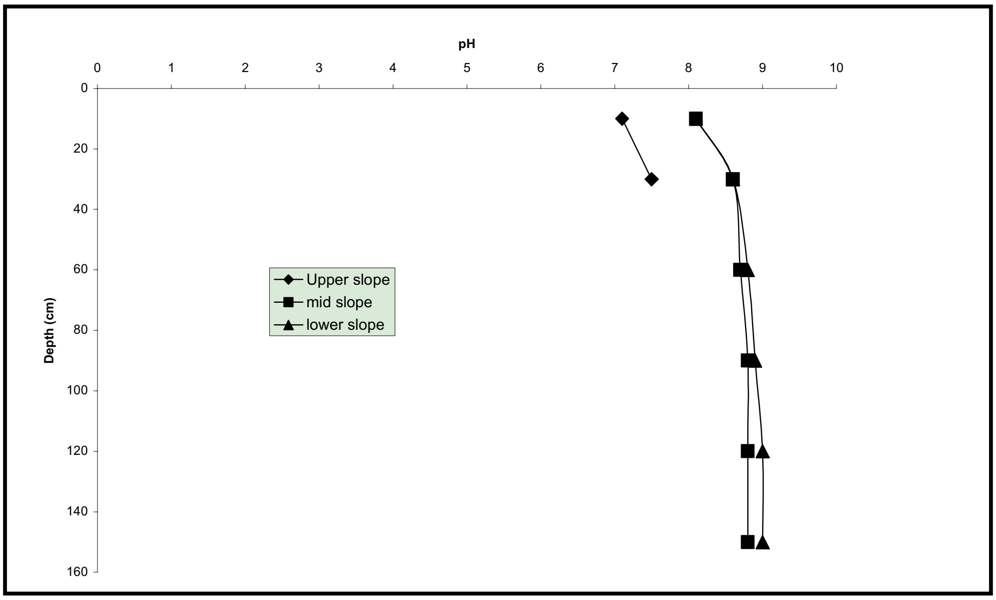

Figure 9. Laboratory pH of upper, mid and lower slopes of the black Vertosols on Wetheron Basalt (Raw)

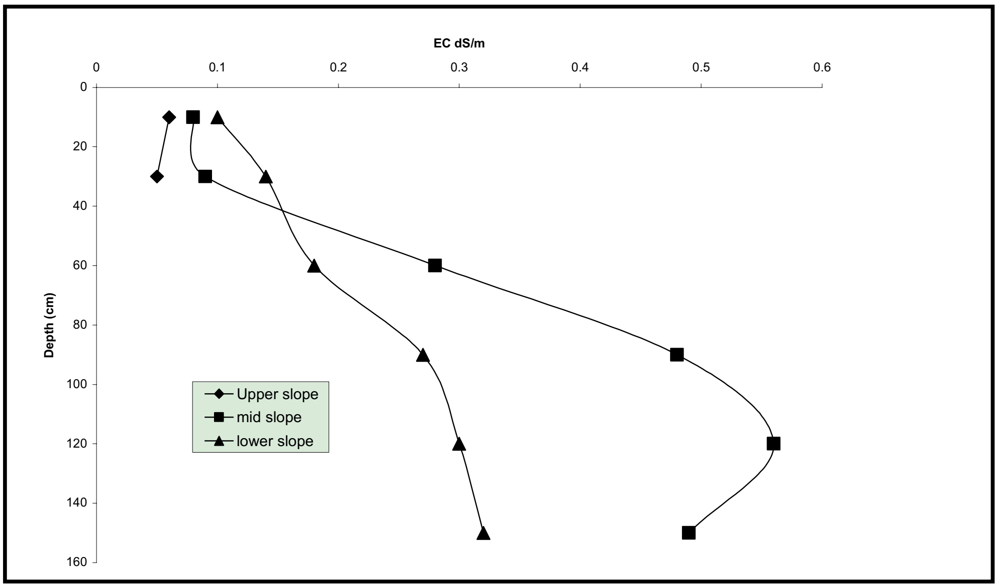

Figure 10. Laboratory EC of upper, mid and lower slopes of the black Vertosols on Wetheron Basalt (Raw)

Strongly hardsetting Sodosols on labile sediments and intermediate volcanics

Sodic texture contrast soils (brown Sodosol) of the Gayndah formation (Rtg) and some andesites (Gayndah Formation Rtg, Wetheron Basalt Raw) have a loamy textured surface that is strongly hardsetting as seen in Figure 11. Average rooting depth is approximately 0.4-0.6m, regardless of soil depth. Weathered rock may be encountered at 0.3-0.5m on hillcrests. Texture contrast soils on steep slopes (>4%) are moderately well drained and slowly permeable, whilst those in lower landscape positions tend to be imperfectly drained and very slowly permeable. These texture contrast soils have a medium cation exchange capacity, thereby having a moderate capacity to hold soil nutrients. Salt tends to accumulate at a depth of 0.4-0.6m within the soil profile. Strongly sodic subsoils are a feature of these soils. The depth at which high salts and high sodicity accumulate corresponds to the depth at which pH reaches 8.5 to 9.0. This correlation has been used as a means to calculate rooting depth of these soils.

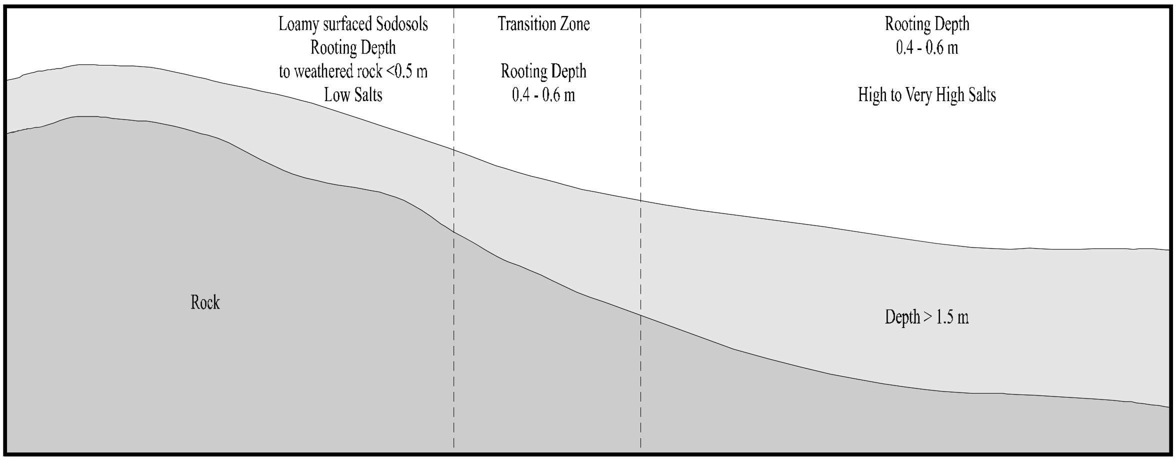

Figure 11. Soil attribute conceptual model of strongly hardsetting Sodosols on labile sediments and andesites

Hillcrests tend to have a rockiness limitation, where greater than 20% of the surface is covered with rock.

Weakly hardsetting Sodosols on Granodiorites

Soil groups formed on these geologies have weakly hardsetting surfaces with textures of sandy loam to sandy clay loam as shown in Figure 12. These soils are usually alkaline at depth, a pH 9 that correlates well with high sodicity and the depth to which plant roots extend within the profile. Rooting depth for these soils on lower slopes is 0.6m. These soils are imperfectly drained and are slowly permeable on low slopes lower in the landscape.

The granodiorite areas were identified using radiometrics and by using geological boundaries established by Ellis *et al.* (1968). Very high potassium gamma-radiation emmisions distinguishes the granodiorites and minor granites from other geologies.

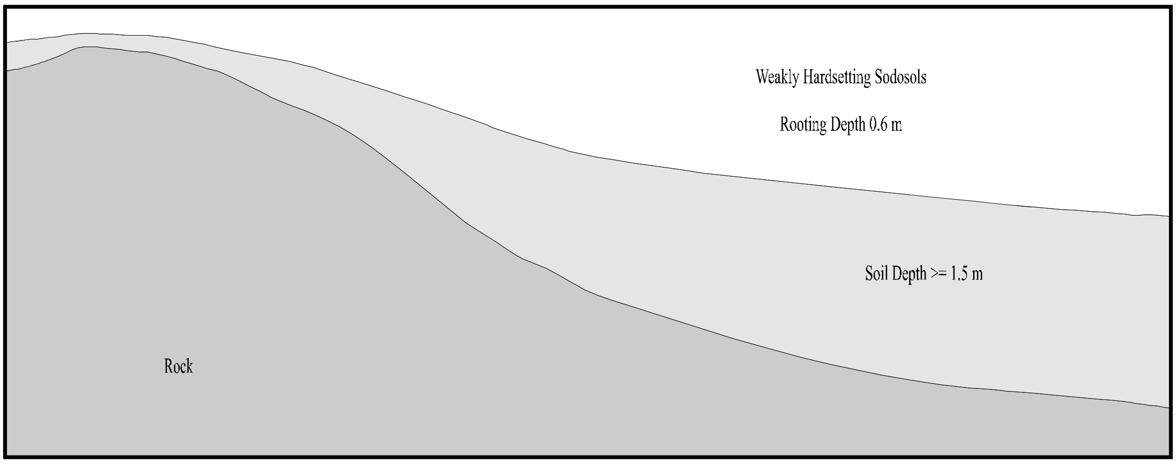

Figure 12. Soil attribute conceptual model of weakly hardsetting Sodosols on Granodiorite

Weakly hardsetting Sodosols on quartzose sandstone

The soil groups formed on the Tertiary quartzose sandstones (Ts) are predominantly weakly hardsetting Sodosols with medium thick (0.3-0.4m) sandy loam surface. Mottling and manganiferious segregations usually occur at depth indicating imperfect drainage. Average rooting depth occurs at 0.3 to 0.4m. This is usually associated with high salts and sodicity in the upper B horizon. This conceptual model is presented diagrammatically in Figure 13.

A majority of the Ts areas have not been cleared of their natural vegetation. Therefore, TM band 4 has a low reliability to distinguish between clay soils and texture contrast soils. This geology also is difficult to distinguish from the Abernethy basalt (Raa) using radiometrics. However, radiometrics was used to distinguish the Ts geology in selected areas where Raa was known not to occur.

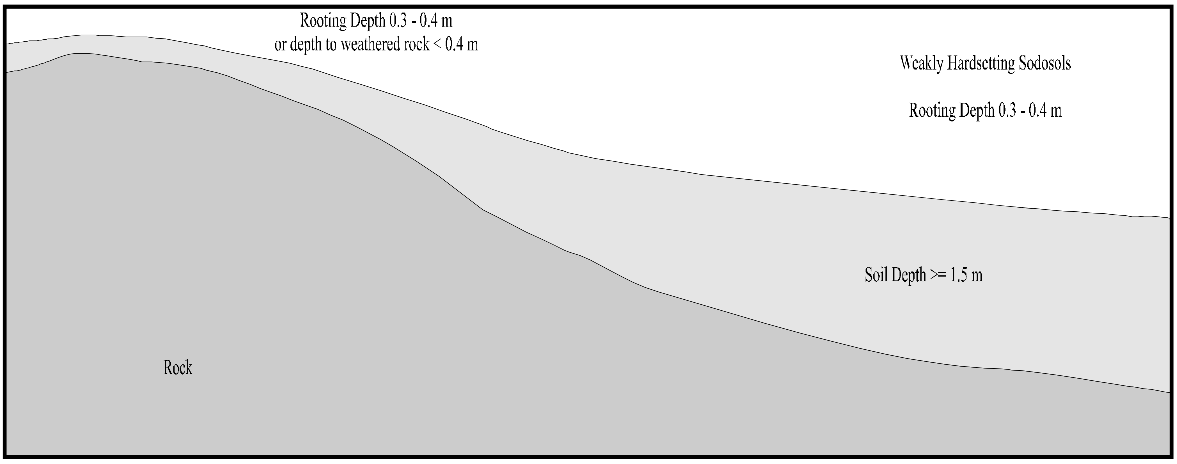

Figure 13. Soil attribute conceptual model of weakly hardsetting Sodosols on Tertiary Sediments (Ts)

Figure 14. Typical soil-landscape for loamy surfaced texture contrast pedon

Figure 15. Typical upper profile for loamy surfaced texture contrast pedon, showing abrupt change between A and B horizons

Figure 16. Typical hardsetting surface for loamy surfaced texture contrast pedon

Figure 17. Typical profile for pedal clay pedon

Figure 18. Typical surface for pedal clay pedon

Figure 19. Typical soil-landscape for sandy surfaced texture contrast pedon, cleared for native pasture

Figure 20. Typical upper profile for sandy surfaced texture contrast pedon, showing clear change between A and B horizons

Figure 21. Typical surface for sandy surfaced texture contrast pedon

Figure 22. Typical profile for deep sand pedon

Figure 23. Typical surface for self-mulching clay pedon

5. Agricultural Land Evaluation

Current land use

The current land uses of the study area consist primarily of beef cattle grazing and trickle irrigated citrus. A large majority of the area remains under native pastures. Some landholders have introduced some improved pasture species, mainly legumes, into their grazing systems.

Very little of the study area is currently farmed using rainfed or irrigated cropping systems. Irrigated forage crops, such as oats or improved pastures, are grown in the area.

Land suitability

Land suitability assessment provides an estimate of the potential of land for a particular land use. In Queensland, land is assessed on the basis of five land suitability classes with suitability decreasing from class 1 to 5 (Land Resources Branch staff 1990). A short definition of the classes is as follows:

Class 1 Suitable land with negligible limitations;
Class 2 Suitable land with minor limitations;
Class 3 Suitable land with moderate limitations;
Class 4 Marginal land which is presently unsuitable due to severe limitations; and
Class 5 Unsuitable land with extreme limitations.

Land resource information gathered during soil surveys, as well as the results of laboratory analysis on selected soil profiles and the attribute information generated from the Fuzzy models, were used in assessing land suitability.

The classification scheme is a summary of each limitation describing the effects of the limitation on plant growth, machinery use and land degradation, and how the soil/land attributes are assessed, and how the limitation classes are determined. The classes are defined in Appendix I.

Irrigation method is assumed to be spray (travelling irrigators or other overhead spray method) unless otherwise stated. Furrow irrigation was deemed to be a separate land use and each raster was also assessed for suitability for surface (furrow) irrigation. Pastures are not listed under the wetness and flooding limitations where species selection enables adaptation to a wide range of conditions.

The agricultural land uses that have been assessed are listed below:

Asparagus	Cotton	Macadamia
Avocado	Furrow Irrigation	Maize
Beans	Grapes	Peanut
Citrus	Improved Pastures	Soybean

Soil and land characteristics that cause land to have less than optimum conditions for a particular crop-irrigation method were recognised as limitations. Local soil and land attributes that provide a measure or an estimate of the effects of each limitation were then selected.

The degree of severity imposed by each limitation on a particular irrigated land use was ranked as a limitation. The most severe limitation allows an overall assessment of suitability.

Limitations to agriculture

Irrigated agricultural within the study area may be affected by the following limitations:

- Climate
- Water availability
- Wetness
- Soil depth
- Rockiness
- Microrelief
- Flooding
- Landscape complexity
- Topography
- Soil physical condition
- Secondary salinisation
- Erosion
- Furrow infiltration

The limitations affect crop production through influences on crop establishment and growth, use of machinery and implementation may result in land degradation. A general description of each limitation follows:

Climate

Except for the incidence of frosts, the climate does not vary significantly within the study area.

Plants vary in their tolerance to frosts. Frosts can suppress the growth of sensitive crops, kill plants or reduce yield through damage to flowers or fruits. Generally, the incidence and severity of frosts in the study is influenced by position in the landscape. Hill slopes and rises experience fewer and less severe frosts and are suitable for sensitive crops such as avocados and mangoes. The lower lying areas such as along the creeks and drainage lines may experience a regular occurrence of frosts. These affected areas limit the suitable crops to deciduous plants such as pecans, low-chill fruits, grapes, and adaptable small crops and field crops.

Local experience and variation in landform were used to determine the suitability subclasses for the various crops. Seasonal adaptation of crops is not considered, for example, frost tolerance of summer crops.

Water availability

Water availability refers to the limitation placed on crop yield by a restriction on soil water supply. For irrigated land, a reduced soil water storage capacity means more frequent irrigation is needed to obtain optimum yields.

Plant available water capacity (PAWC) provides the best estimate of a soil's storage capacity for irrigated land uses. PAWC is the difference in volumetric water content between the upper storage limit (approximately field capacity), and the lower storage limit (approximately wilting point) summed for each layer within the rooting depth of the soil and adjusted by the rooting profile over the rooting depth. Effective rooting depth is the depth to which approximately 90% of plant roots will extract water.

The effective rooting depth is reduced by restrictive layers which are indicated by rock, consistency, pH, salinity peaks (measured by electrical conductivity), sodicity and high levels of segregations such as nodules.

The water availability limitation subclass is based on the frequency of irrigation required for optimal crop growth. Soils with high PAWC require less frequent irrigation after the profile is fully recharged.

A decision regarding when to irrigate and how much to apply may be determined by considering the soil water store, drainage below the root zone, runoff and amount of water used by the crop. By considering these factors crop productivity may be improved, water use efficiency is increased and the likelihood of drainage and salinity problems can be reduced.

As expected, higher PAWC occurs on the deep clays such as the self-mulching black Vertosols on Raa, and lower PAWC on the sandy surfaced Sodosols such as on the Tertiary sediments and granodiorites.

Wetness

Wetness refers to excessive water on the soil surface and in the soil profile as a result of rainfall or local run-on water. The excess water is caused by inadequate surface drainage and poor subsoil drainage and landscape position.

The wetness limitation takes into account the adverse effects of excess water on production through the reduction in crop growth and quality, restrictions in machinery use and the need for reclamation works.

Drainage classes (McDonald *et al.* 1990) are assessed and take into account all aspects of internal and external drainage in the existing state. The attributes used to indicate internal drainage include colour, mottles, segregations and impermeable layers. Red or brown whole colours indicate well drained soils while mottled grey soils with segregations, such as manganiferous nodules, indicate imperfect drainage. Slope and topographic position are used to assess the ease of disposal of excess water. Soil permeability, indicated by texture, pedality, grade of structure, segregation, pH, ESP (exchangeable sodium percentage), affects the supply to and removal of soil water from the root zone.

Generally, soils become wetter on low slopes in lower landscape positions and less permeable due to accumulation on sodium on the clay cation exchange.

Soil depth

All crops require an adequate depth of soil to provide physical support for the aerial portion of the plant. Requirement for physical support will increase with crops that have large canopies such as tree crops. Uprooting of trees is particularly a problem on shallow, wet soils during windy conditions.

Shallow soils generally occur on hillcrests and steep slopes least modified by the weathering resistance of the various rock lithologies.

Rockiness

Rock fragments within the plough layer will interfere with the use of, and possibly cause damage to agricultural machinery and interfere with crop planting depth. The volume of rock fragments within the soil is extremely variable and difficult to estimate for any particular map unit. The limitation increases with the increase in size and/or amount encountered. Tolerance levels will also vary between farmers and between different agricultural enterprises.

In general, crops that require several cultivations annually and have low harvest heights (chickpeas, navybeans, and soybean) have a low tolerance to rock. Root crops (potato, peanuts) are very sensitive. Horticultural tree crops can tolerate considerable amounts.

The size and amount of coarse fragment, as defined by McDonald *et al.* (1990), were used to determine the classes.

Microrelief

Gilgai microrelief will affect the efficiency of furrow irrigation, as depressions will pond water causing uneven crop productivity. Areas with gilgai or other microrelief must be levelled to ensure even slopes for efficient water use under furrow irrigation. Levelling of gilgai soils, which contain sodic and/or saline layers close to the surface, may expose the sodic or saline layers at the soil surface. The vertical interval of the microrelief, which effects the amount of levelling required, is used as a diagnostic attribute to determine subclass limits.

Moderate Gilgai >0.3 m vertical interval is restricted to some minor areas of elevated alluvial grey clays. Due to the minor occurrence, microrelief was not predicted in the Fuzzy models.

Flooding

Adverse effects of flooding are yield reduction or plant death through excessive flow velocity, flood water characteristics such as silt content and water temperature, lack of aeration and physical removal or damage of plants and soil from flowing water. The effects on flooding on individual mapping units cannot be predicted from this study. Landform position in relation to historical flood flows was used to make some distinction between suitable and unsuitable land.

Floods are mainly restricted to the narrow channel benches of the main creeks and rivers.

Crop damage depends on its susceptibility to flooding. Sugar cane is moderately tolerant of inundation and different varieties will vary. Horticultural crops, such as small crops (melons, pumpkins, tomatoes, and capsicums) avocadoes, papaws, pineapples, citrus and mangoes are very sensitive to flooding. Lychees are more tolerant and will withstand flooding for short periods. Other crops, such as maize, sorghum and soybeans are sensitive.

Landscape complexity

To maximise irrigation efficiency, soil attributes within rows should have similar soil water holding capacity, infiltration attributes and management. If these soil properties are markedly different between soil types, productivity over the whole unit will be reduced because of ineffective irrigation scheduling and difficulty in timing for planting, cultural and harvesting operations.

Soil complexity is assessed for a particular crop and irrigation method on the size and isolation of the mapping unit and the compatibility of the soil types in surrounding units. Soil complexity has a greater influence on the suitability of land for cotton or peanuts than it does for citrus because of the requirement for larger areas of these crops.

Criteria relating to production area size are dependent on the type of agricultural enterprise. For example, field crops such as maize and sorghum, will be more severely affected by small areas than high value horticultural crops (Wilson 1997).

Landscape complexity was not assessed because it was not seen to be a problem.

Topography

The topography limitation has a direct affect on the ease of machinery operations and land use efficiency in general. It covers the slope limits for the safe use of machinery.

The slope limit for the safe and efficient use of machinery is 15%. However all land greater than 15% in the study is unsuitable or marginal for agricultural development due to other limitations.

Soil physical condition

Soil physical properties influence seedbed preparation, plant establishment and the harvest of root crops. The soil physical condition is related to properties such as surface condition, moisture range for working, and adhesiveness.

Surface condition of soils will effect seedling emergence and establishment, and root crop development through hardsetting, crusting and coarse structure. Adhesive soils affect the recoverability and condition of root crops such as peanuts. Peanut crops ideally require friable soils to enable harvesting machinery to easily lift and remove crops from the soil. A majority of the massive surfaced clay loam soils or Vertosols that have a clay-textured surface are adhesive to varying degrees. In general, the degree of adhesiveness increases as clay content and/or consistency increase and degree of pedality decreases (Wilson and Sorby 1991).

Soil physical condition relates directly to the 'Pedons' (see Section 4) predicted from the Fuzzy models.

Secondary salinisation

Clearing and irrigation change the hydrology of the landscape to some extent. Less water can be intercepted by trees, and increased percolation of water can cause seepage outbreaks lower down the slope. This excess water can bring salts from the subsoil to the surface on lower landscape positions resulting in secondary Salinisation. This process is exacerbated where very permeable soils occupy upper slope positions and slowly permeable soils occur on lower slopes and valley floors.

Areas where excess water enters the landscape are called recharge areas. Areas where water rises to the surface or close to the surface against an impermeable barrier or change in slope are called discharge areas.

Erosion

Water erosion causes soil degradation and long term productivity decline. Land subject to moderate to severe water erosion will not support sustainable cropping. Crop damage, higher working costs, uneven harvest heights, damage caused by silt deposition and fertility decline also result from soil erosion.

The severity of soil erosion by flowing water is governed by climatic factors such as the amount, distribution and intensity of rainfall, landform factors such as gradient and slope length, soil erodibility and management practices such as maintaining surface cover. All the factors have been taken into account to predict the erosion limitation for various land uses Fuzzy models.

Tree crops such as citrus have higher slope limits than other broadacre crops because of the reduced cultivation and increased surface cover.

Furrow infiltration

The irrigation system and field layout should be tailored to the permeability of each soil. For furrow irrigation, long furrow lengths and application times are inappropriate for soils where a significant deep drainage component is likely to occur. This causes excess infiltration, leaching, seepage, wastage of water, and problems with aeration at the head ditch end of the furrows. Furrow irrigation is suitable only on land with gentle slopes and slowly permeable cracking clays soils and texture contrast soils. Spray, micro/sprinklers or drip irrigation should be used on permeable and sloping soils for even application of water, and to minimise deep percolation and thus avoid off-site seepage and watertable rises.

The furrow infiltration limitation has been predicted from the Fuzzy models and combined with the suitability rating for a particular land use to predict the suitability of furrow irrigating a particular crop.

Discussion

Land resource assessment of the study area revealed only a relatively small area of land has potential for future irrigation development. These areas consist largely of alluvial landscape, particularly the levee landforms. Figure 24 illustrates the suitability assessment areas for the area along the Burnett River downstream of Gayndah to Perry River. Hills are considered to be unsuitable for irrigation development.

Avocados are generally not suited in the study area, however small areas (21 ha in total) are considered marginal. Frosting and drainage are the main attributes that render the land unsuitable for this crop.

Improved pasture is the most suited land use for future developments within the study area. This is due to the wide range of legumes and grasses that are adaptable to varying environmental conditions.

Citrus is suited largely to the deep sands and loamy soils on levees and levee backplains. The areas are moderate to well drained, have no rock, have a very deep rooting depth, moderate to highly permeable, but may experience light to regular frosting.

Asparagus is suited to the deep sands and loams on levees and self-mulching clays.

Cotton is suited to a total of 2371 ha, but only 516 ha are suitable for furrow irrigation.

A total of 174 ha of land is suitable for growing irrigated peanuts. Soil attributes such as deep sands or sandy texture soils, moderate to well drained and have no rock on the surface or within the upper soil profile are required for the crop.

For all crops assessed there was a significant area of land that has a suitability ranking of marginal. This land should not be developed unless limiting attributes undergo remedial treatment to alleviate their impediment to crop growth, machinery use and potential for land degradation.

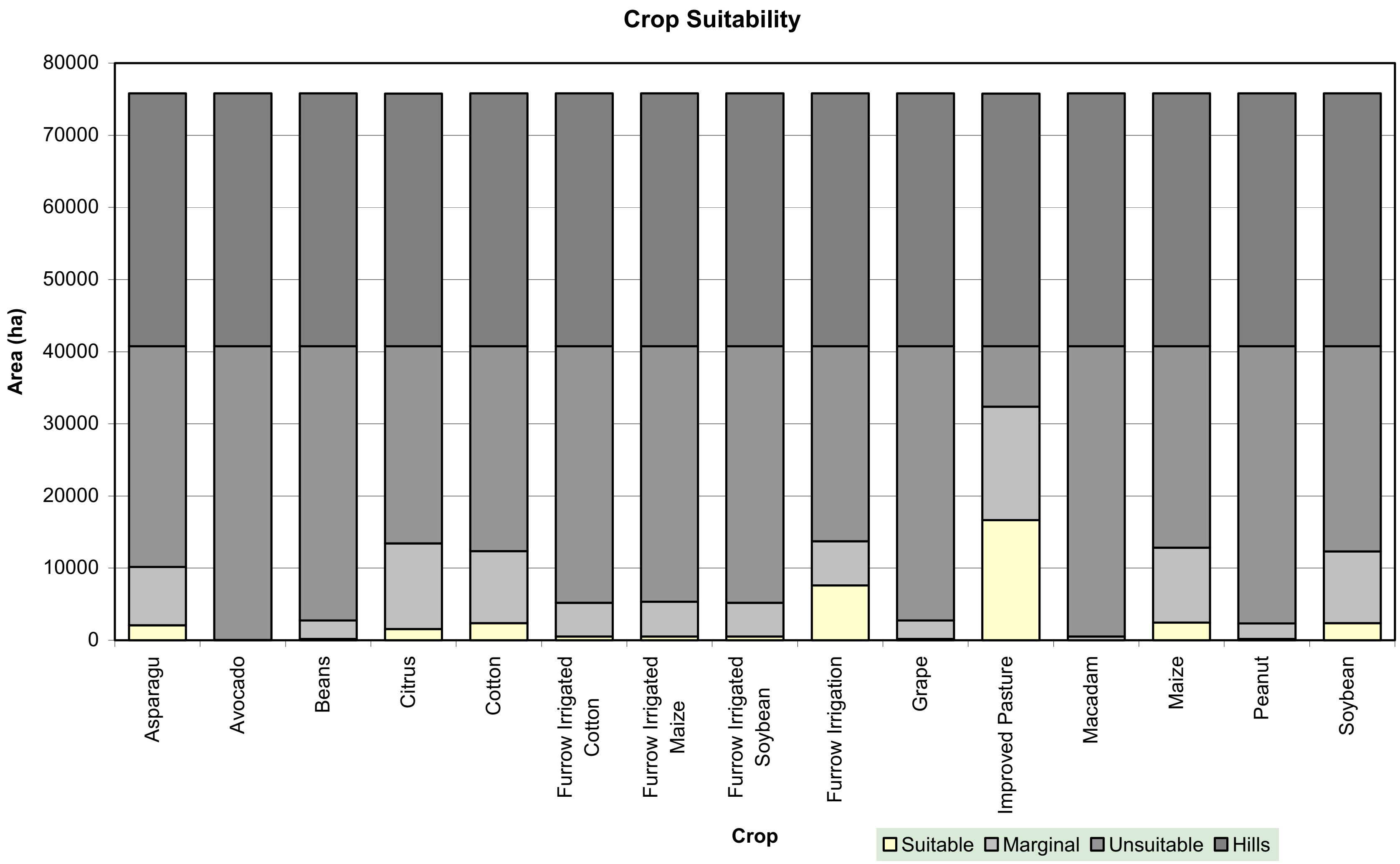

Figure 24. Crop suitability areas of land for each crop assessed.

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Appendix I

Land Suitability Classes

Class definition

Five land suitability classes have been defined for use in Queensland (Land Resources Branch staff 1990), with land suitability decreasing progressively from Class 1 to Class 5. Land is classified on the basis of a specified land use, which allows optimum production with minimal degradation to the land resource in the long term.

Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2	Suitable land with minor limitations which either reduce production or require more than the simple management practices of class 1 land to maintain economic production.
Class 3	Suitable land with moderate limitations which either further lower production or require more than those management practices of class 2 land to maintain economic production.
Class 4	Marginal land which is presently considered unsuitable due to severe limitations. The long term or precise effects of these limitations on the proposed land use are unknown. The use of this land is dependent upon either undertaking additional studies to determine its suitability for sustained production or reducing the effects of the limitation(s) to achieve production.
Class 5	Unsuitable land with extreme limitations that preclude its use.

This study has used three (3) classes for suitability calculations which relate closely to the standard five class system. These three classes are listed below.

Suitable	Class 1, 2, 3 land. Suitable with negligible to moderate limitations.
Marginal	Class 4 land. Marginal land which is presently considered unsuitable due to severe limitations.
Unsuitable	Class 5 land. Unsuitable land with extreme limitations that preclude its use.

Land is considered less suitable as the severity of limitations for a land use increase, reflecting either (a) reduced potential for production, and/or (b) increased inputs to achieve an acceptable level of production and/or (c) increased inputs required to prevent land degradation.

Suitable (the first three classes) is considered that for the specified land use as the benefits from using the land for that land use in the long term should outweigh the inputs required to initiate and maintain production. Decreasing land suitability within a region often reflects the need for increased inputs rather than decreased potential production.

Marginal (Class 4) is considered presently unsuitable and is used for marginal land where it is doubtful that the inputs required to achieve and maintain production outweigh the benefits in the long term. It is also used for land where reducing the effect of a limitation may allow it to be upgraded to a higher suitability class, but additional studies are needed to determine the feasibility of this.

Unsuitable (Class 5) is considered as having limitations that in aggregate are so severe that the benefits would not justify the inputs required to initiate and maintain production in the long term. It would require a major change in economics, technology or management expertise before the land could be considered suitable for that land use. Some unsuitable lands however, such as escarpments, will always remain unsuitable for agriculture.

Land Suitability Classification Scheme for Irrigated Crops

The classification scheme is a summary of each limitation describing the effects of the limitation on plant growth, machinery use and land degradation, and how the soil/land attributes are assessed, and how the limitation classes are determined. The classes are defined in Appendix I. The codes listed in this appendix for each limitation are the soil/land attribute level recorded for each cell.

Irrigation method is assumed to be spray (travelling irrigators or other overhead spray method) unless otherwise stated. Furrow irrigation is a separate land use. Pastures are not listed under the wetness and flooding limitations where species selection enables adaption to a wide range of conditions.

The agricultural land uses listed are:

Asparagus
Avocado
Beans
Citrus
Cotton
Furrow Irrigation
Grapes
Improved Pastures
Macadamia
Maize
Peanut
Soybean

CLIMATE (c)

Effect

Frosts may suppress growth, kill plants and reduce yield.

Assessment

The incidence and severity of frosts are used to distinguish affected areas.

Limitation class determination

Crop tolerance and local experience of the incidence and severity of frosts.

Soil/land attribute level	Limitation classes for various crops		
	Avocado, Macadamia	Citrus, Beans	Asparagus, Cotton, Grapes, Improved Pastures, Maize, Peanut, Soybean
Frost free to light frosts (hill tops)	Suitable	Suitable	Suitable
Regular frosts	Unsuitable	Suitable	Suitable
Severe frosts (channel benches, depressions in lower terraces)	Unsuitable	Marginal	Suitable

WATER AVAILABILITY (m)

Effect

Plant yield will be decreased by periods of water stress particularly during critical growth periods.

Assessment

Plant available water capacity (PAWC) is used as a measure of the amount of water in a soil available to plants over the rooting depth.

PAWC is based on predicted values (Shaw and Yule 1978). Generally, soil texture, structure and clay mineralogy over the effective rooting depth[1] are important attributes affecting PAWC.

Limitation class determination

PAWC classes relate to the frequency of irrigation for spray or furrow irrigation only:

>100 mm = 10 days
75 to 100 mm = 8 to 10 days
50 to 75 mm = 5 to 8 days
<50 mm = <5 days

Irrigation frequency considers crop rooting depth, seasonal evaporation rates (10 mm/day in summer) and the amount of labour and equipment required. For example, shallow rooted crops require more frequent irrigation compared to deep rooted crops, while winter crops require less frequent irrigation compared to summer crops. More frequent irrigation requires a greater amount of labour and/or more equipment. Negligible limitations apply to microsprinkler or drip irrigation systems where small amounts of water are added frequently.

Soil/land attribute level	Limitation class for various crops		
	Microsprinkler/drip irrigation – Avocado, Citrus, Macadamia, Grapes	Asparagus, Beans	Cotton, Peanuts, Maize, Soybean, Pastures
Soil PAWC (to 1.0 m)			
125 mm Very High PAWC	Suitable	Suitable	Suitable
125-100 mm High PAWC	Suitable	Suitable	Suitable
75-100 mm Moderate PAWC	Suitable	Suitable	Suitable
50-75 mm Low PAWC	Suitable	Suitable	Suitable
<50 mm Very Low PAWC	Suitable	Suitable	Marginal

[1] Effective rooting depth is taken to the depth of optimal water extraction by roots. For example, tree crops 1-1.5 m, small crops 0.5 m, field crops and grapes 1.0 m; or to the depth of high salt concentration, rock or impermeable layers.

WETNESS (w)

Effect

Waterlogged soils will reduce plant growth and delay effective machinery operations.

Assessment

Internal and external drainage are assessed. Indicator attributes of internal drainage include texture, grade and type of structure, colour, mottles, segregations and impermeable layers. Drainage class[1] and soil permeability[2] (McDonald *et al.* 1990†) are assessed in relation to plant rooting depth. Slope and topographic position determine external drainage.

Limitation class determination

Consultation, crop tolerance information and the effects of delays in machinery operations.

[1] Drainage class: This accounts for all aspects of internal and external drainage in the existing state.

Drainage class
1. Very poorly drained
2. Poorly drained
3. Imperfectly drained
4. Moderately well drained
5. Well drained
6. Rapidly drained

[2] Permeability
- H Highly permeable (Ks >500 mm/day)
- M Moderately permeable (Ks 50–500 mm/day)
- S Slowly permeable (Ks 5–50 mm/day)
- V Very slowly permeable (Ks <5 mm/day)

Soil/land attribute level	Limitation classes for various crops					
	Depth req. 0 to 1.5 m (Code: W3)		(b) Depth req. 0 to 1 m (Code: W1)		(c) Depth req. 0 to 0.5 m (Code: W2)	
	Avocado	Citrus, Macadamia	Grape	Cotton, Maize, Soybean	Peanuts, Beans	Asparagus
5H	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
5M	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
4H	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
4M	Marginal	Suitable	Suitable	Suitable	Suitable	Suitable
4S	Unsuitable	Marginal	Marginal	Suitable	Marginal	Suitable
4V	Unsuitable	Marginal	Marginal	Suitable	Marginal	Suitable
3H	Marginal	Suitable	Suitable	Suitable	Suitable	Suitable
3M	Unsuitable	Marginal	Marginal	Suitable	Marginal	Suitable
3S	Unsuitable	Unsuitable	Unsuitable	Marginal	Unsuitable	Marginal
3V	Unsuitable	Unsuitable	Unsuitable	Marginal	Unsuitable	Marginal

† McDonald RC, Isbell RF, Speight JG, Walker J and Hopkins MS (1990). Australian Soil and Land Survey Field Handbook. Inkata Press, Melbourne.

SOIL DEPTH (d)

Effect

Shallow soils limit root proliferation and anchorage. Plants may be uprooted during strong winds.

Assessment

Effective soil rooting depth: Depth to decomposing rock, pan, high salts or impermeable layer.

Limitation class determination

Consultation.

Soil/land attribute level	Limitation classes for various crops	
Effective soil depth	Tree crops	All other crops
1 m Code: Very Deep	Suitable	Suitable
0.6 to 1 m Code: Deep	Suitable	Suitable
0.4 to 0.6 m Code: Moderately Deep	Suitable	Suitable
0.3 to 0.4 m Code: Shallow	Marginal	Suitable
< 0.3 m Code: Very Shallow	Unsuitable	Unsuitable

ROCKINESS (r)

Effect

Coarse (rock) fragments[1] and rock 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 root crops and some vegetables.

Assessment

Based on the size, abundance (McDonald *et al.* 1990†) and distribution of coarse fragments in the plough layer, as well as machinery and farmer tolerance of increasing size and content of coarse fragments.

Limitation class determination

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

Soil/land attribute level	Limitation classes for various crops
	All Crops
< 20% coarse fragments (No rock)	Suitable
> 20% Coarse fragments (Rock) and size >0.06m	Unsuitable

[1] Coarse fragments are particles greater than 2 mm and not continuous with underlying bedrock (McDonald *et al.* 1990). Rock is defined as being continuous with bedrock.

† McDonald RC, Isbell RF, Speight JG, Walker J and Hopkins MS (1990). Australian Soil and Land Survey Field Handbook. Inkata Press, Melbourne.

FLOODING (f)

Effect

Yield reduction or plant death caused by anaerobic conditions and/or high water temperature and/or silt deposition during inundation, as well as physical removal or damage by flowing water. Flowing water can cause erosion.

Assessment

Assessing the effects of flooding on an individual UMA is difficult. Flooding frequency has been used to distinguish between suitable and unsuitable land only in extreme frequency situations or for intolerant crops. Where flood frequency is significant but not extreme, a '0' (zero) has been used to indicate the occurrence of flooding, but due to insufficient knowledge[1], it is not used to downgrade this suitability class.

Limitation class determination

Consultation.

Soil/land attribute level	Limitation classes for various crops		
	Soybean, Maize, Asparagus	Avocado, Macadamias, Citrus, Grapes	Beans, Peanuts
No flooding or flooding less than 1 in 10 years. Code: FO, F1	Suitable	Suitable	Suitable
Flooding frequency of approximately 1 in 2 to 1 in 10 years – levees and back swamps and some higher channel benches. Code: F2	Suitable	Marginal	Suitable
Flooding frequency approaches annual occurrence – lower channel benches. Code: F3	Marginal	Unsuitable	Unsuitable

[1] Sugar cane is commonly grown on these lands despite regular flooding. The real effects of flooding do not detract from the value of the land.

SOIL PHYSICAL CONDITION (p)

Effect

- Germination and seedling development problems are associated with adverse conditions of the surface soil such as hardsetting, coarse aggregates, and crusting clays.
- Soil adhesiveness can cause harvest difficulties and affect the quality of subsurface harvest material.

Assessment

- Soils with indicative morphological properties are evaluated in the context of local experience or knowledge of plant characteristics, for example, seed size, tuberous roots.

Limitation class determination

- Plant tolerance limits and requirements in relation to germination and harvesting are matched with soil properties and supported by local experience.

Soil/land attribute level	Limitation classes for various crops	
	Peanut	Avocado, Asparagus, Beans, Citrus, Cotton, Grapes, Macadamias, Maize, Pastures, Soybean
Deep sands	Suitable	Suitable
Sandy texture contrast	Suitable	Suitable
Weakly hardsetting	Suitable	Suitable
Strongly hardsetting	Suitable	Suitable
Pedal clays	Marginal	Suitable
Self-mulching clays	Marginal	Suitable

SECONDARY SALINISATION (s)

Effect

Drainage losses from permeable soils, usually higher in the landscape, may cause secondary salinisation downslope.

Assessment

Soil permeability (McDonald *et al.* 1990) and position in the landscape are used to determine intake areas, and the effect that deep drainage may have on watertables downslope. High watertable may occur above areas where heavy textured slowly permeable soils or other restrictive layers occur. Drainage class, permeability (see wetness) and position in landscape determine the likelihood of salinisation.

Limitation class determination

Drainage class, soil permeability and position in the landscape. Soil hydraulic conductivity, groundwater level and salinity measurements are required for a wide range of soils and landscapes.

Land/soil attribute level	Limitation classes for all crops			
Soil drainage/permeability at 1 m (see wetness limitation)	Landscape position			
	Upper slopes (U)	Lower slope (L)	Drainage depressions+ (D)	Level plains (P) (eg. Alluvial plains)
	All crops	All crops	All crops	All crops
5H	Suitable	Suitable	Unsuitable	Suitable
5M	Suitable	Suitable	Unsuitable	Suitable
4H	Suitable	Suitable	Unsuitable	Suitable
4M	Suitable	Suitable	Unsuitable	Suitable
4S	Suitable	Suitable	Unsuitable	Suitable
4V	Suitable	Suitable	Unsuitable	Suitable
3H	Suitable	Suitable	Unsuitable	Suitable
3M	Suitable	Suitable	Unsuitable	Suitable
3S	Suitable	Marginal	Unsuitable	Suitable
3V	Suitable	Unsuitable	Unsuitable	Suitable

+ Drainage depression – level to gently inclined, long, narrow, shallow open depression with smoothly concave cross-section, rising to inclined side slopes. No incised drainage lines occur. This landscape predominantly occurs adjacent to or on hard rock geology, where the surrounding landscape contributes to groundwater levels.

EROSION (e)

Effect

Land degradation and long term productivity decline will occur on unprotected arable land due to excessive soil erosion.

Assessment

Soil loss will depend on soil erodibility and land slope for a particular crop and surface management system. For each soil type there is a maximum slope above which soil loss cannot be reduced to acceptable levels by erosion control measures or surface management practices.

Limitation class determination

Slope limits are determined in consultation with soil conservation extension and research personnel, and extension and research agronomists. The implications of the classes are:

e1	surveyed row direction only required
e2	conventional parallel structures required or some surface management practices[1]
e3	e2 measures and some surface management practices
e4 or e5	non-arable land

Surface management practices: A range of options aimed at minimum soil disturbance, combined with the retention of harvest residue material as a surface cover.

Soil/land attribute level		Limitation classes for various crops		
Slope %		Avocado, Citrus, Macadamia	Asparagus, Beans, Cotton, Grapes, Maize, Peanuts, Pastures, Soybean	Furrow irrigation
Levee soils: Deep sands				
< 8		Suitable	Suitable	unsuitable
Stable soils: Pedal clays, Self-mulching clays				
0-1	Low	Suitable	Suitable	Suitable
1-2.5	Medium	Suitable	Suitable	Suitable
2.5–5	High	Suitable	Suitable	Marginal
5–8	Very High	Suitable	Marginal	Unsuitable
Unstable soils: Weakly hardsetting, Strongly hardsetting, Sandy texture contrast				
0–1	Low	Suitable	Suitable	Suitable
1–2.5	Medium	Suitable	Suitable	Marginal
2.5–5	High	Suitable	Marginal	Unsuitable
5–8	Very High	Suitable	Unsuitable	Unsuitable

FURROW INFILTRATION (if) (Deep drainage)

Effect

The amount of water applied and the rate of application as furrow irrigation must match the permeability of the soil to minimise deep drainage and to determine more suitable furrow length. Additional management requirements are associated with short furrows and waterlogging in the upper end of the furrows if furrow lengths are too long. The most suitable furrow lengths for flood irrigation needs to be determined.

Deep drainage in recharge areas or undulating landscapes can contribute significantly to watertables in lower landscape positions. The effect of deep drainage on groundwater levels can be managed on very slowly to moderately permeable soils within areas where groundwater is used for irrigation and on level plains with very slowly to slowly permeable soils where there is minimal contribution to groundwater levels from the surrounding landscape.

Assessment

Subsoil permeability (see w limitation) and landscape position. Indicator attributes for soil permeability include texture, grade and type of structure, sodicity, pH, salt bulge.

Limitation class determination

Consultation

Limitation classes relate directly to soil permeability, landscape and whether the site is located within a groundwater area. Hydraulic conductivity (permeability) measurements are required.

Soil/land attribute level	Limitation classes for various landscapes	
	Undulating landscape	Level plains
Subsoil permeability to 1m	All crops	All crops
V- very slowly permeable	Suitable	Suitable
S- slowly permeable	Marginal	Suitable
M – moderately permeable	Unsuitable	Marginal
H – highly permeable	Unsuitable	Unsuitable

Appendix II

Soil Attribute and crop suitability maps

Burnett River Riparian Lands - Gayndah Section –Improved Pasture
(DNR Ref No: 2000-BRRL-A1 5343)

Burnett River Riparian Lands – Gayndah Section – Pedon (Soil Units)
DNR Ref No: 2000-BRRL-A1 5301)

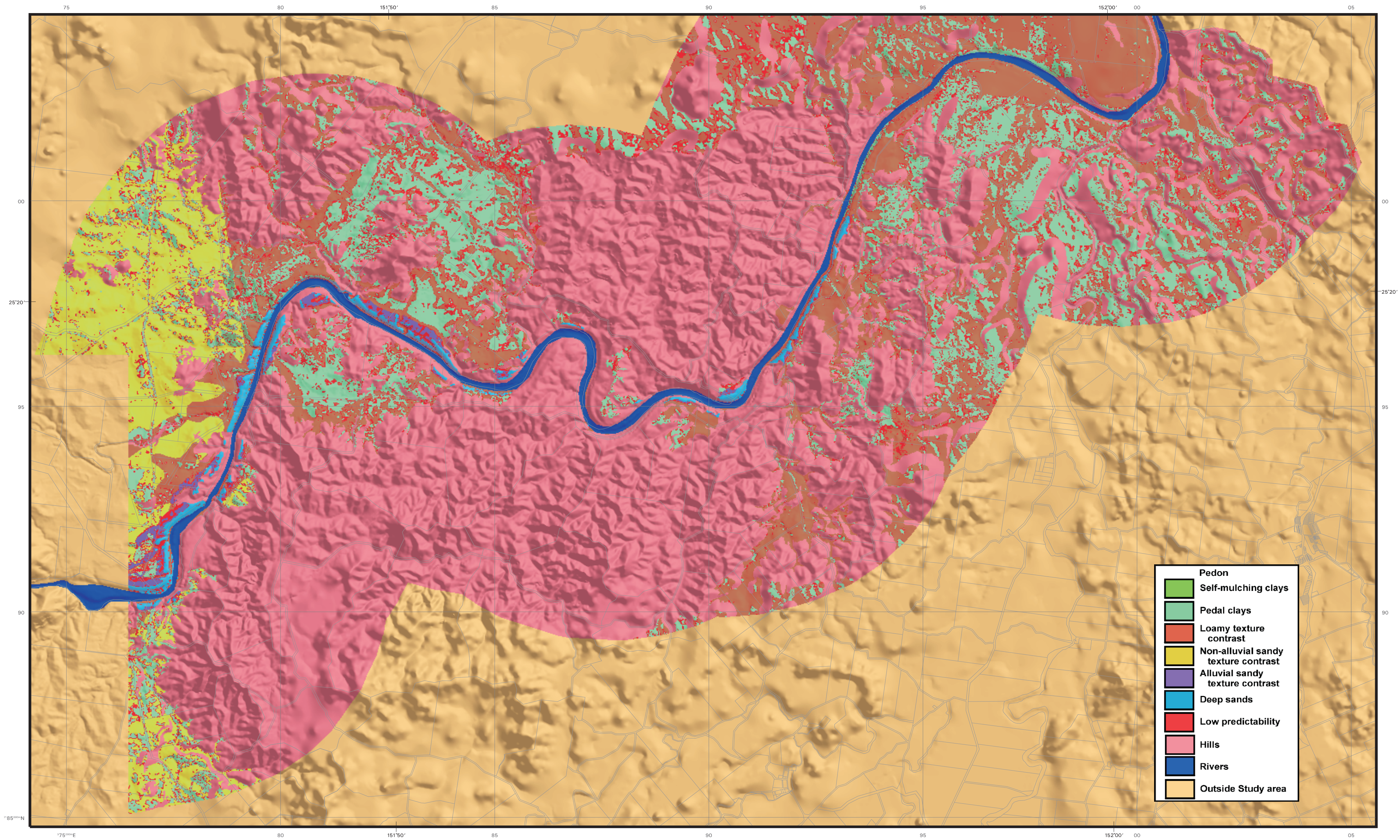
Burnett River Riparian Lands –Mingo Section– Improved Pasture
(DNR Ref No: 2000-BRRL-A1 5342)

Burnett River Riparian Lands –Mingo Section– Pedon (Soil Units)
(DNR Ref No: 2000-BRRL-A1 5302)

NOTE

The maps shown in the back of this report are examples only. Full size maps are available on request or on CD with a number of suitability maps.

CD available from:-
Land Resources Information Officer
Data and information Coordination
Natural Resource Sciences
80 Meiers Road
INDOOROOPILLY QLD 4068
PH 3896 9502



BURNETT RIVER RIPARIAN LANDS MINGO SECTION

Pedon

metres 1000 0 1 2 3 4 5 6 kilometres

GRID VALUES ARE SHOWN IN FULL AT THE SOUTH-WEST CORNER OF THE MAP
GREY NUMBERED GRID LINES ARE 5000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 56, AGD84.
UNIVERSAL TRANSVERSE MERCATOR PROJECTION

INTENSITY STATEMENT

This is medium intensity survey. It is based on aerial photography interpretation and ground observations of the order of one observation to an area of 15 to 40 hectares.

ACCURACY STATEMENT

Due to varying sources of data sets, spatial locations may not coincide when overlaid.

DISCLAIMER

This map is compiled from information supplied to the Department of Natural Resources. Whilst all care is taken in the preparation of this map, neither the Department nor its officers or staff accept any responsibility for any loss or damage which may results from inaccuracy or ommission in the map or from use of the information contained herein.

SURVEY by S.M. McCarroll, D.M. Brough and P.R. Wilson, Department of Natural Resources, Bundaberg.
CARTOGRAPHY by A.L. Paltridge, Department of Natural Resources, Bundaberg.
BASE MAP - Compiled from the Digital Cadastral Data Base, supplied by the Department of Natural Resources, Brisbane.

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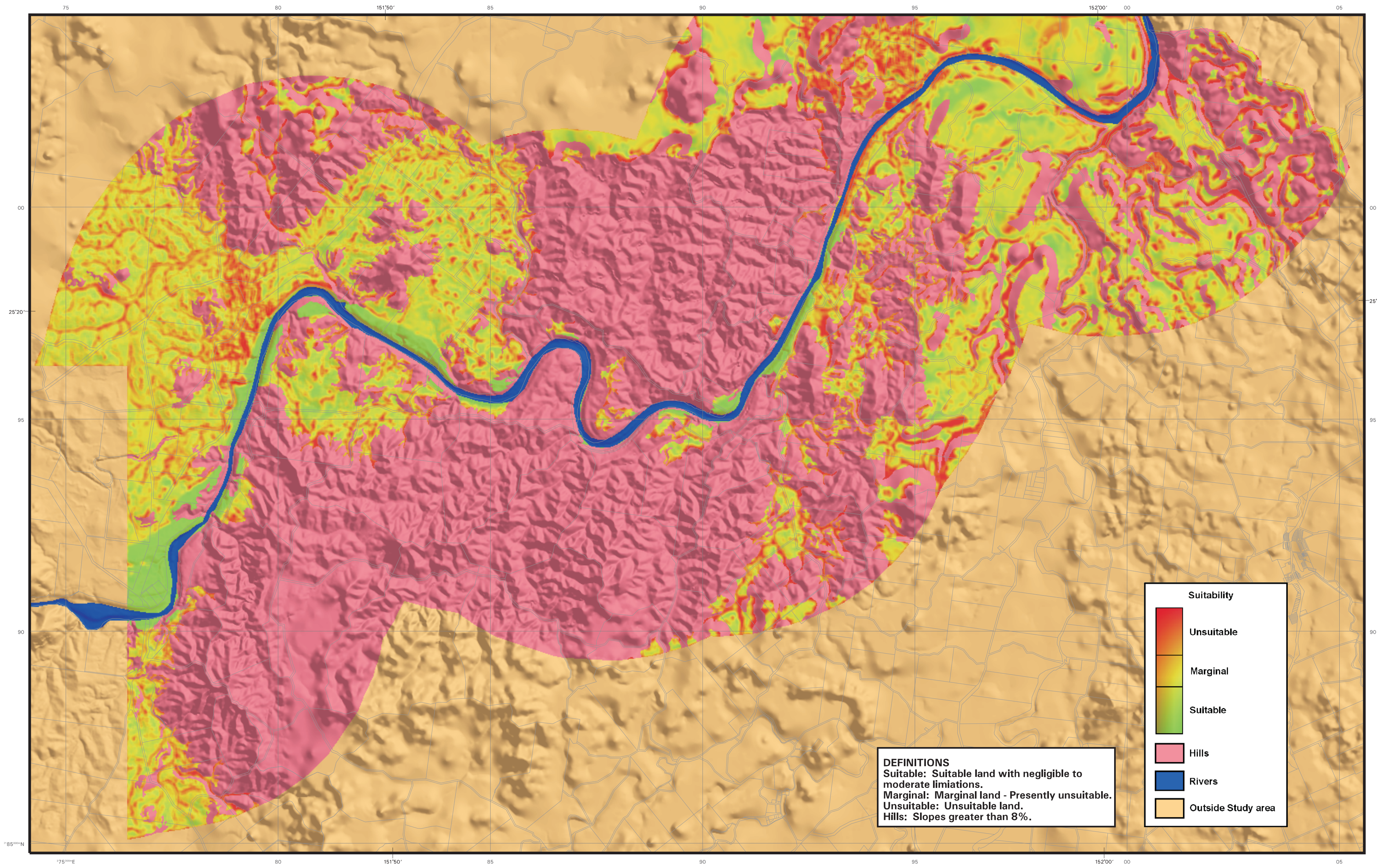
KEY TO ADJOINING SURVEYS

DNR Ref No. 2000-BRRL-B-A1 5302



BURNETT RIVER RIPARIAN LANDS
MINGO SECTION

Improved Pasture

metres 1000 0 1 2 3 4 5 6 kilometres

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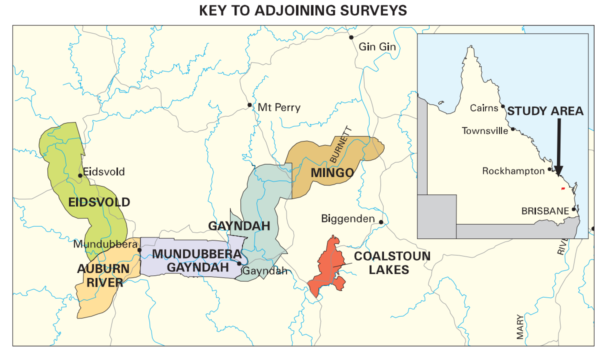

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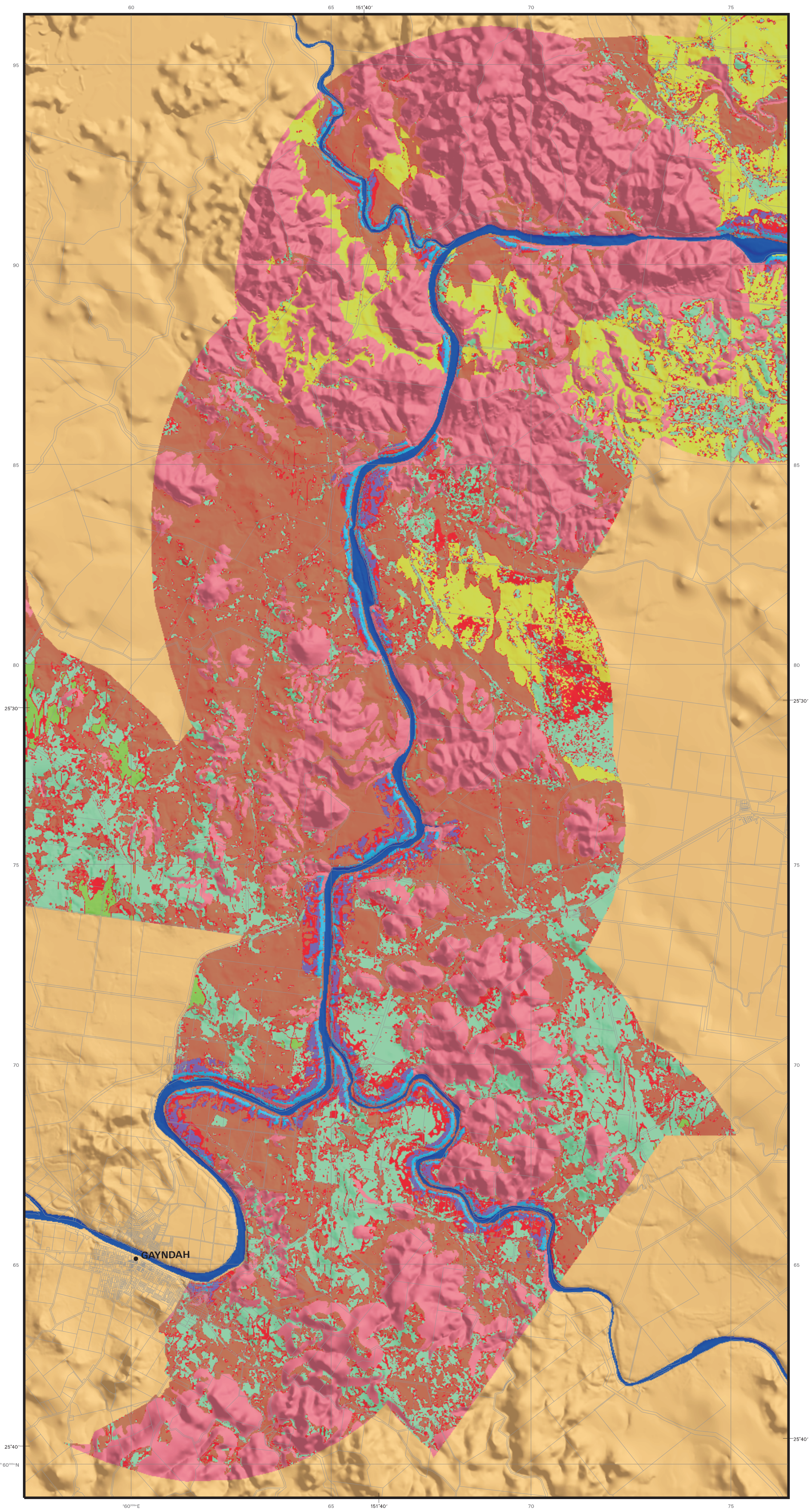

BURNETT RIVER RIPARIAN LANDS
GAYNDAH SECTION

Pedon

metres 1000 0 1 2 3 4 5 6 kilometres

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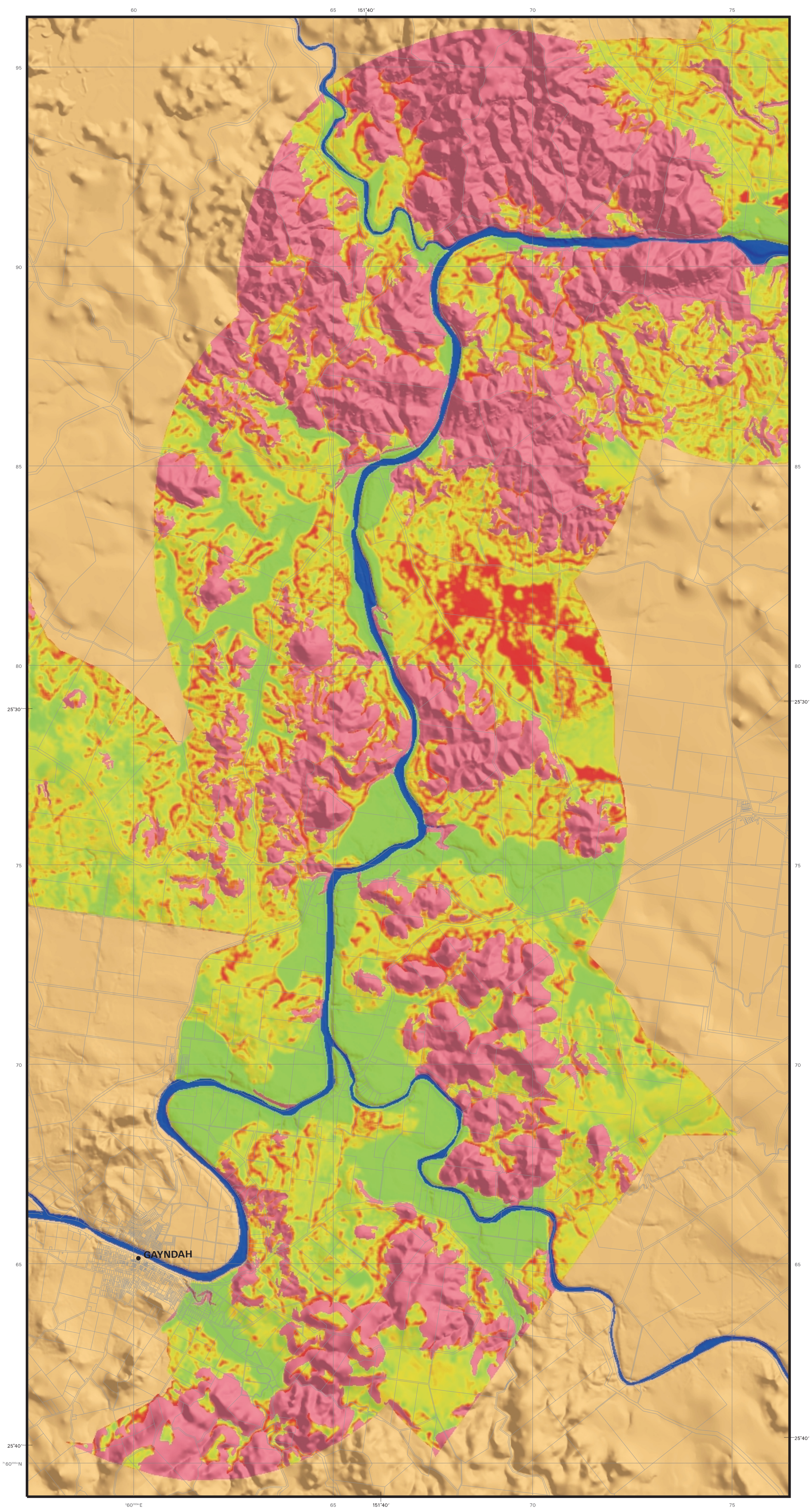
KEY TO ADJOINING SURVEYS

Pedon

- Self-mulching clays
- Pedal clays
- Loamy texture contrast
- Non-alluvial sandy texture contrast
- Alluvial sandy texture contrast
- Deep sands
- Low predictability
- Hills
- Rivers
- Outside Study area

DNR Ref No. 2000-BRRL-B-A1 5301



BURNETT RIVER RIPARIAN LANDS
GAYNDAH SECTION

Improved Pasture

metres 1000 0 1 2 3 4 5 6 kilometres

GRID VALUES ARE SHOWN IN FULL AT THE SOUTH-WEST CORNER OF THE MAP
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EXAMPLE ONLY

KEY TO ADJOINING SURVEYS

Suitability

- Unsuitable
- Marginal
- Suitable
- Hills
- Rivers
- Outside Study area

DEFINITIONS
Suitable: Suitable land with negligible to moderate limiations.
Marginal: Marginal land - Presently unsuitable
Unsuitable: Unsuitable land.
Hills: Slopes greater than 8%.

DNR Ref No. 2000-BRRL-B-A1 5343