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*Lower Balonne Airborne Geophysical Project*

# REGOLITH LANDFORMS IN THE LOWER BALONNE AREA, SOUTHERN QUEENSLAND, AUSTRALIA

*Amy Kernich, Colin Pain,*
*Penny Kilgour and Ben Maly*

**CRC LEME OPEN FILE REPORT 161**

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This report is one of six CRCLEME Open File Reports contributing to the Lower Balonne Airborne Geophysical Project funded by the National Action Plan for Salinity and Water Quality. The project is providing new knowledge and developing methodologies for improved natural resource management in the Murray Darling Basin area of southern Queensland. This integrated project has a multidisciplinary team with skills in regolith geology, geomorphology, bedrock geology, hydrogeology, geophysics and soil science, working to understand the processes and controls on salinnity in a variable regolith terrain.

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## ABBREVIATIONS USED IN THE REPORT

| | |
|---|---|
| ACRES | Australian Centre for Remote Sensing |
| AEM | Airborne Electromagnetics |
| ASTER | Advanced Spaceborne Thermal Emission and Reflection Radiometer |
| AUSLIG | Australian Surveying and Land Information Group (now Division of National Mapping in Geoscience Australia) |
| BRS | Bureau of Resource Sciences |
| CRC LEME | Cooperative Research Centre for Landscape Environments and Mineral Exploration |
| DEM | Digital Elevation Model |
| EM | Electromagnetics |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| K | Potassium |
| Landsat TM | Landsat Thematic Mapper |
| LBAGP | Lower Balonne Airborne Geophysics Project |
| MDBC | Murray Darling Basin Commission |
| NRM | Natural Resource Management |
| PC | Principal Component |
| QDNRM&E | Queensland Department of Natural Resources, Mines and Energy |
| RGB | Red, Green, Blue |
| RLU | Regolith Landform Unit |
| RTMAP | Geoscience Australia's Regolith Landform Database |
| Th | Thorium |
| U | Uranium |

## EXECUTIVE SUMMARY

This report presents results from a study of landforms and surface regolith in the Lower Balonne Airborne Geophysics Project (LBAGP) area. Data sources included Landsat Thematic Mapper (Landsat TM), and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite images, radiometrics and digital elevation models (DEM) from airborne surveys and aerial photographs. These remotely sensed data were supplemented by data derived from field and laboratory work.

The aims of the LBAGP were to provide a better understanding of the nature of regolith materials and groundwater in the project area; a three-dimensional framework of salt stores and regolith characteristics influencing water and salt movement; an overview assessment of areas (land and water) at risk from salinity; and an evaluation of the application of airborne geophysics for salinity investigations. This report contributes to the first part of these aims, and significantly expands knowledge of the surface regolith and soil materials, and the arrangement of the weathered rock, unconsolidated clay and sand which form the subsurface and within which water and salt can move.

The area was subdivided into 8 geomorphic units and 22 regolith landform units on the basis of landforms, surface regolith materials, and geomorphic evolution. All but one of the geomorphic units are sedimentary in nature, and include a major Plio-Pleistocene surface (the Maranoa surface) in the west, Pleistocene anastomosing alluvial surfaces in the centre and east, and the modern Balonne and Moonie River floodplains. One geomorphic unit consists of residual regolith on an erosional landscape formed on the Cretaceous Griman Creek Formation.

It is convenient to begin the geomorphic history of the area with the erosional landscape formed on the Griman Creek Formation during the Tertiary. Towards the end of the Tertiary the Dirranbandi palaeovalley, perhaps fault-bounded, began to fill with sediments. By the beginning of the Pleistocene the palaeovalley was full, and sediments began to spread out across the erosional landscape, to form the Maranoa surface. Deposition of sediments on the Maranoa surface forced rivers to shift to the east, and the Balonne River began depositing sediments in a fan extending from St George to the south, eventually surrounding the Noondoo rises. The Balonne River appears to have shifted gradually westwards during the Quaternary, and now occupies a floodplain adjacent to the Maranoa surface. During the same period the Moonie River filled its valley, and now occupies a floodplain east of the Balonne surfaces.

Landsat TM and radiometric data were the most useful for the work reported here. Airborne electromagnetic (AEM) imagery was compared with the maps produced for this report to see if there was any relationship between conductivity and surface materials. As expected there is some correspondence between the shallow AEM slices and the regolith landform features of the area.

Geology, soil and land system maps of the area were available before the airborne geophysical data were acquired. Of these, the land system map most closely provided the kind of information sought from the geophysics and the regolith landform map. However, this study has been able to add significantly to the information contained in the land system map. The radiometrics provides spatially explicit information on the location of different surface materials in the area, while the regolith landform map and this report provide the interpretation required to provide a basis for interpretation of the 3D information obtained from drill hole data, and from the AEM.

# 1. INTRODUCTION

## 1.1 Objectives

This report is part of ongoing investigations in the Lower Balonne Airborne Geophysics Project (LBAGP), undertaken in collaboration with the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME), the Queensland Department of Natural Resources, Mines and Energy (QDNRM&E) and the Bureau of Resource Sciences (BRS). The study area is in the upper part of the Murray-Darling Basin, and covers an area of approximately 900,000 ha inc.uding alluvial plains and associated upland areas near the Maranoa, Balonne and Moonie Rivers. Water allocation and reported salinity hazard in prime cotton growing country are important natural resource management issues. The main land use is irrigated cotton, with some extensive pastoral farming. Previous work over the Lower Balonne area has either been of a more regional nature or very detailed in specific areas. The LBAGP aims to compile regional detail at a sub catchment scale to be directly applicable for natural resource management (NRM) issues.

The aims of the LBAGP were to provide a better understanding of the nature of regolith materials and groundwater in the project area; a three-dimensional framework of salt stores and regolith characteristics influencing water and salt movement; an overview assessment of areas (land and water) at risk from salinity; and an evaluation of the application of airborne geophysics for salinity investigations. This report contributes to the first part of these aims, and significantly expands knowledge of the surface regolith and soil materials, and the arrangement of the weathered rock, unconsolidated clay and sand which form the subsurface and within which water and salt can move.

The nature of groundwater flow systems and the presence of salinity within the catchment are controlled by the presence and distribution of regolith materials at depth as well as at the surface. Integrating an understanding of present processes and geomorphic boundaries of surface materials with sub-surface information derived from airborne electromagnetics (AEM) and drill-hole data will help to assess groundwater hydrology. The occurrence and importance of salinity in the study area can also be better assessed with a better understanding of the surface and sub-surface character and distribution of regolith materials.

The principal objective is to derive an understanding of the history and development of surface landforms and regolith in the area, both in their own right, and as a means of interpreting regolith at depth. This understanding can then be used in a predictive way.

Specific objectives were:

1) To interpret the different data layers and compile a map of surface morphology and materials.
2) To assess the different data sources, and
3) To gain insights into landscape processes to help interpret sub-surface materials and distribution.

A variety of data sources were used for description and interpretation of regolith and landforms. Another objective, therefore, was:

4) To assess the interpretation of the various data sources used against the outputs of similar work carried out previously in the area.

Outputs from this part of the project are a regolith landform map showing the distribution of landforms and regolith materials, this report, and a number of image layers that will be included in the project Geographic Information System (GIS). It is expected that these data and information will assist with interpretation of the airborne geophysical data and logged drill holes.

## 1.2 Work program

Following initial planning and acquisition of the airborne geophysical data, other data such as Landsat Thematic Mapper (Landsat TM), drill-hole logs and maps of land systems and soils were collected. A number of field visits were then made to collect information on regolith character and distribution. Sites were selected for drilling and sample collection. Following laboratory analyses, and further work on various image data, this report was prepared as a basis for the development of a model of 3D regolith distribution of the area.

# 2. DESCRIPTION OF STUDY AREA

## 2.1 Location

The study area is in south central Queensland close to the NSW state border (Figure 1). The area is part of the present Balonne-Maranoa catchment, which in turn is in the northern Murray Darling Basin. The Balonne River fans out to the south into five sub-catchment river systems on an anastomosing floodplain (Figures 2 and 3). St George is the largest town in the area, and Dirranbandi is the only other major settlement. An irrigation scheme was started at St George in 1957, and recently there has been extensive development of large irrigation schemes both within and outside the study area. The highest part of the area is northeast of St George, at a little over 250m above sea level (asl). The elevation falls to about 160 m asl south of Dirranbandi on the Balonne River floodplain. The Noondoo rises, east of Dirranbandi, rise to 225 m asl.

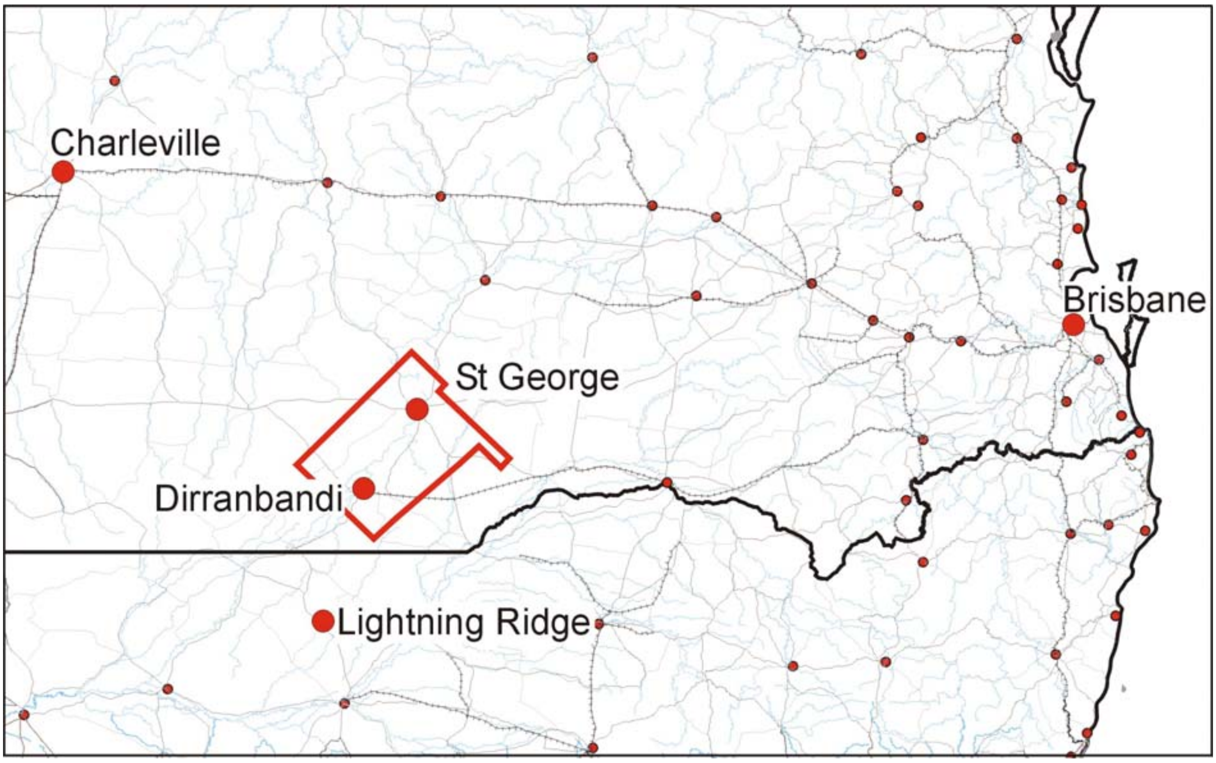


**Figure 1.** Location of the Lower Balonne study area.

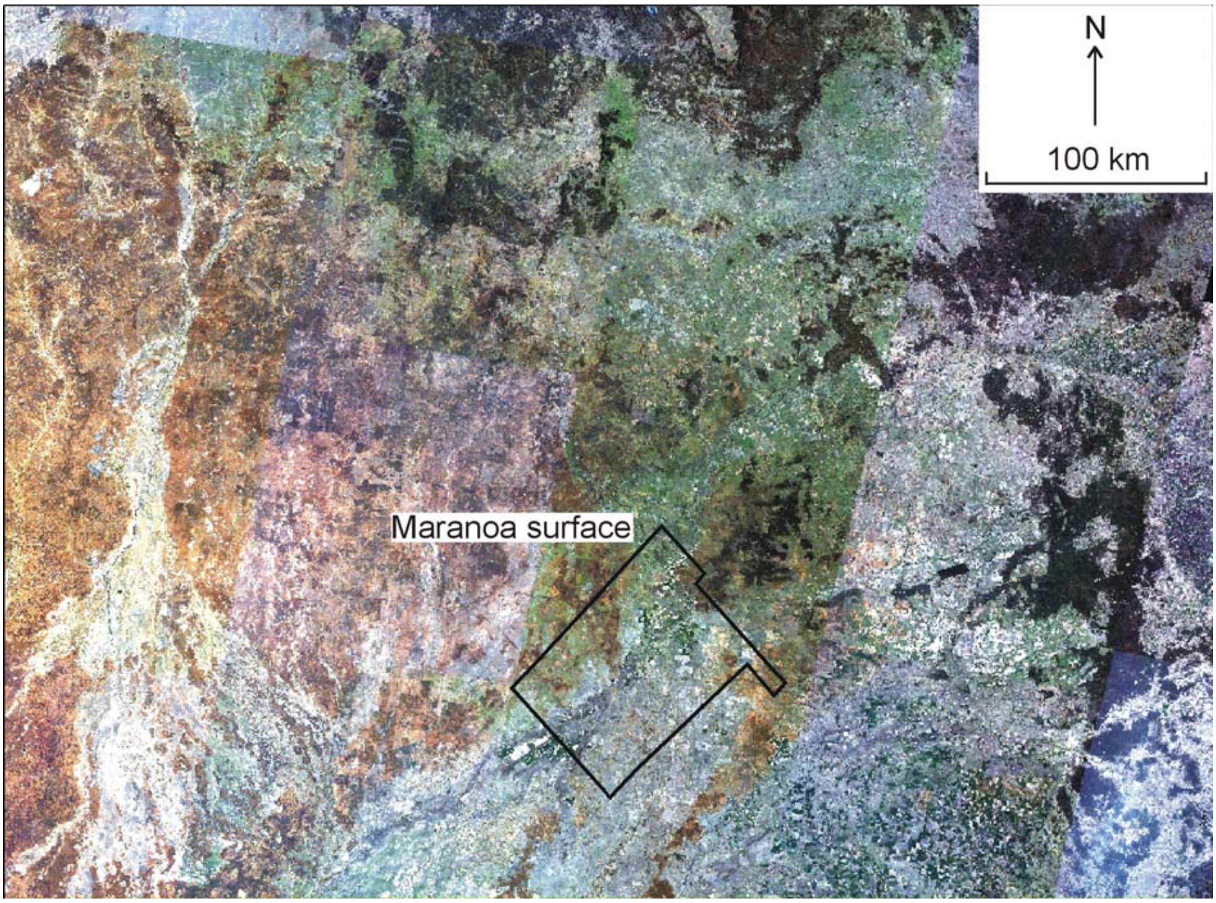


Figure 2. Landsat TM image showing the regional setting of the Lower Balonne study area.

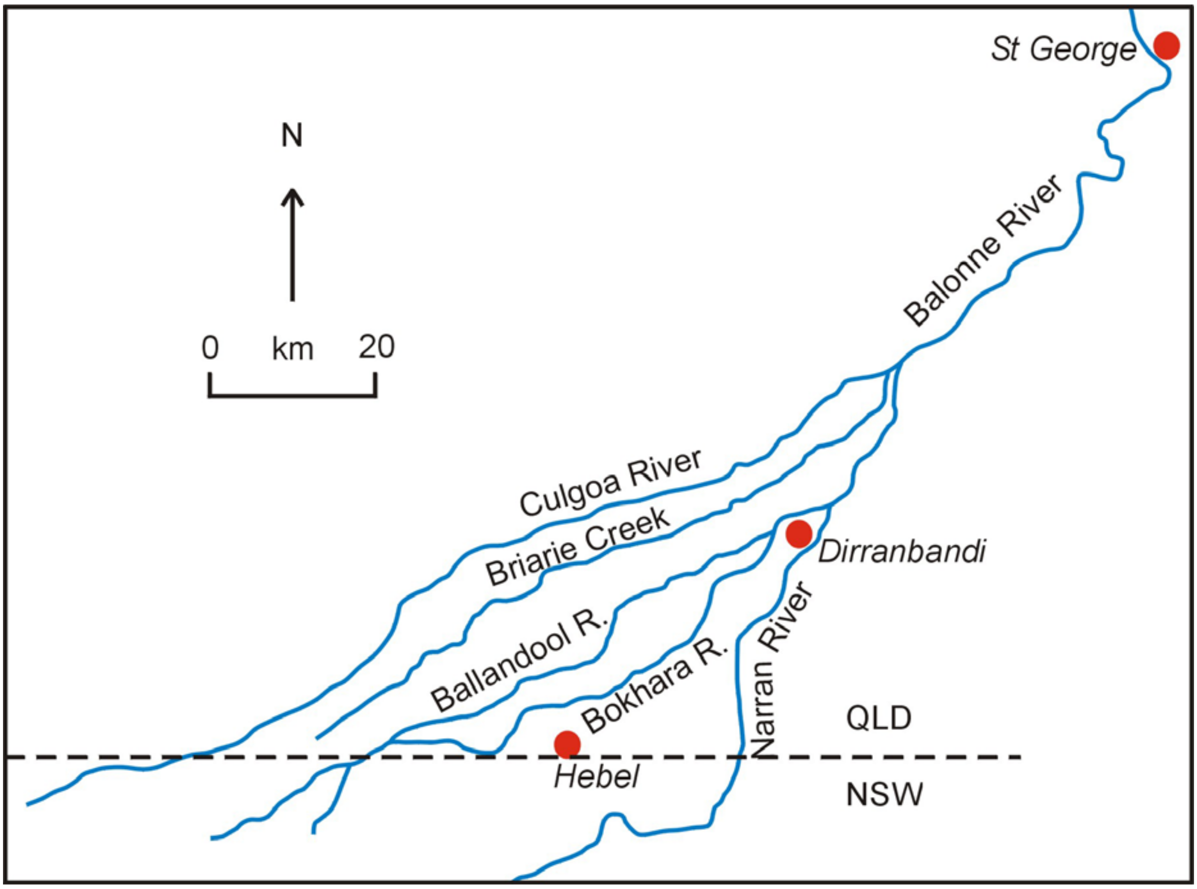


Figure 3. Sub-catchments of the Lower Balonne River

### 2.2 Climate

The climate of the Lower Balonne area is sub-humid to semi-arid warm temperate. Climate data for St George were obtained from the Commonwealth Bureau of Meteorology (2003), and are given in Appendix 1. Mean annual rainfall is 516 mm at St George, with most rain falling in summer (Figure 4). January is the wettest month, while August and September are the driest months. The highest recorded monthly rainfall is in January, with 415 mm, while the lowest recorded monthly rainfall is 0 mm, which can occur in all months, demonstrating a high variability. Mean monthly temperatures range from a minimum of less than 10$^{o}$C in winter to over 30$^{o}$C during summer (Figure 5). Frost occurs during some winters.

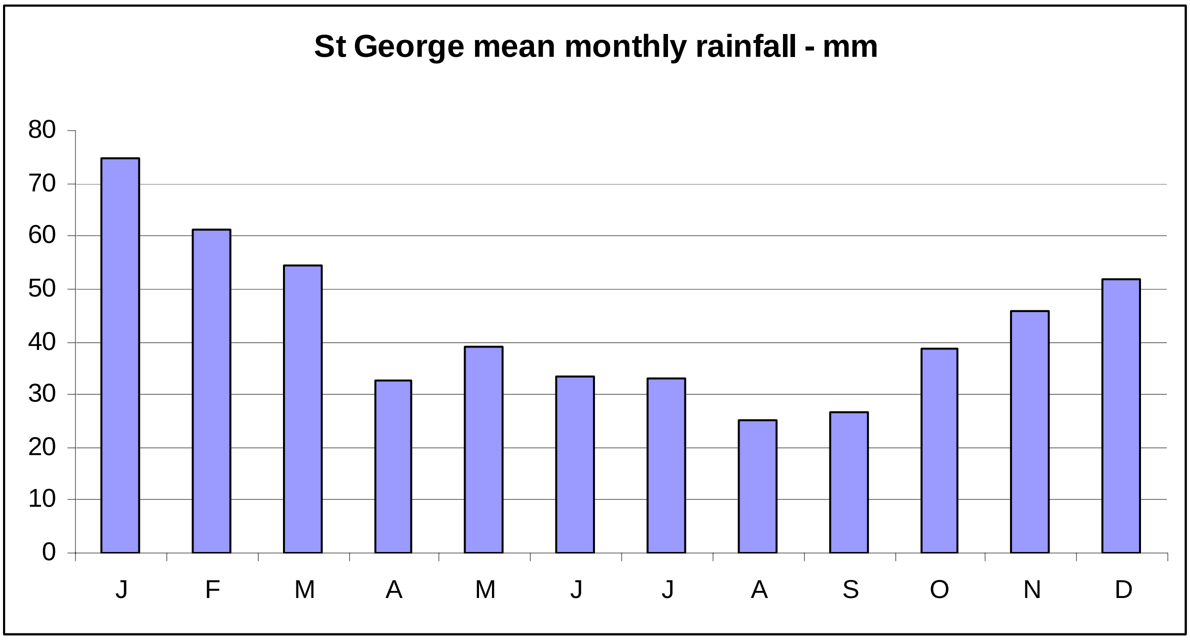


Figure 4. Mean monthly rainfall at St George (data from Bureau of Meteorology – see Appendix 1).

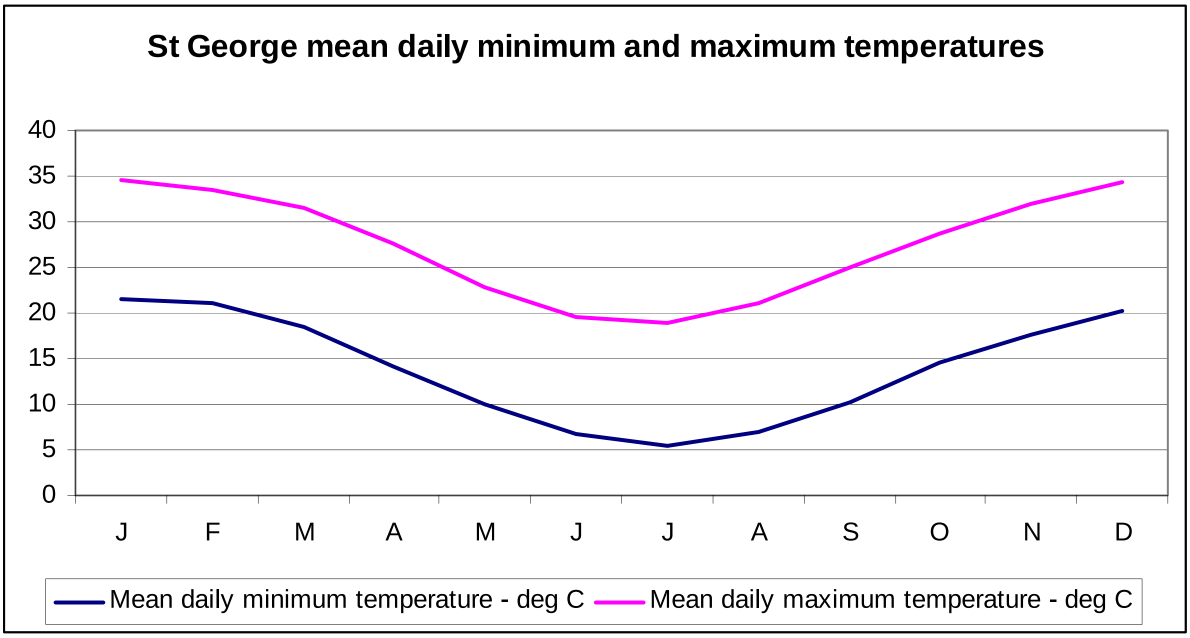


Figure 5. Mean daily minimum and maximum temperatures at St George (data from Bureau of Meteorology – see Appendix 1).

## 2.3 Vegetation

Vegetation consists predominantly of grassland, low open-woodland, open-woodland, woodland and open-forest. Most of the natural vegetation in the study area has been cleared, and human-induced vegetation including pasture, crops and irrigated crops, dominates the landscape.

## 2.4 Geology

The geology of the area is described by four conventional reconnaissance scale (1:250 000) sheets (Graham 1972, Reiser 1971, Senior 1971 and Senior 1972) (Figure 6).

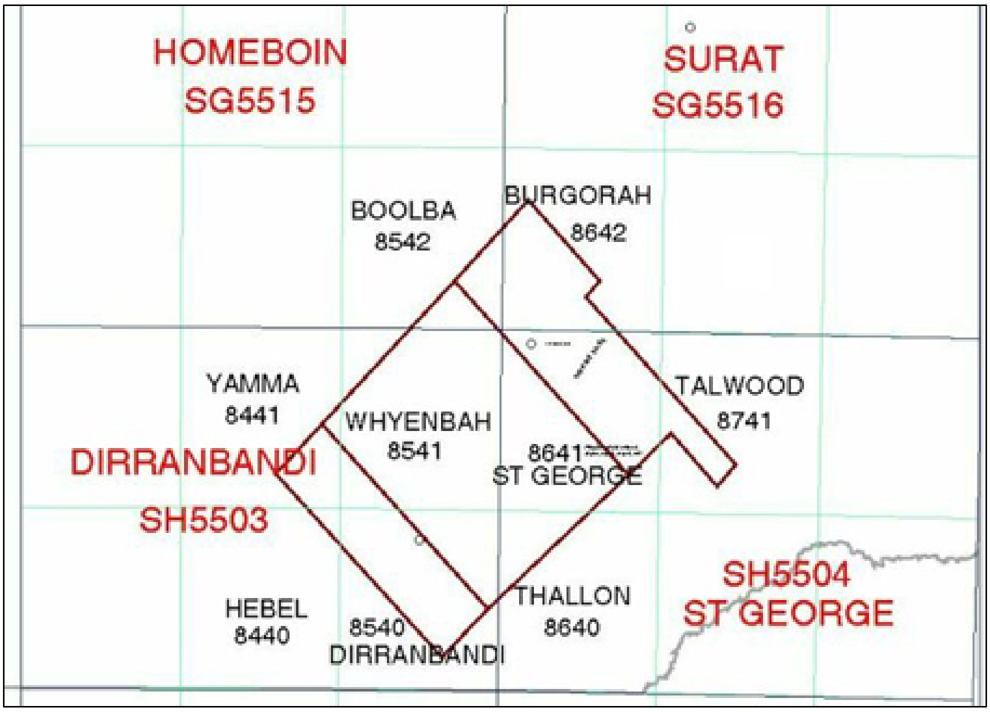


Figure 6. Map sheets covering the Lower Balonne area (1:250 000 - red, 1:100 000 - black).

***Formal stratigraphy***

The Lower Balonne lies on the western margin of the Surat Basin – a source of oil and gas. To the west of the Surat Basin is the Eromanga Basin – also an oil and gas basin. Jurassic sediments occur at depth in the Surat Basin, buried by Cretaceous sediments and/or Cainozoic alluvium. The only formally named exposed rocks in the study area belong to the Cretaceous Griman Creek Formation (Kg) (Table 1). Where it is exposed, the Griman Creek Formation is weathered and commonly silicified. This was noted on the published maps and is depicted in digital data as Kg>w (Figure 7). Typical exposures occur in the Balonne River bed near St George and in the hills to the west of the confluence of the Maranoa and Balonne Rivers. Silcrete from this unit forms part of Beardmore Dam. Significant areas of the reconnaissance mapping were marked as Qs/Kg. These are areas of residual sand over Griman Creek Formation, and the underlying Cretaceous rocks have a complex weathering cover of sand and saprolite (see discussion below).

Much of the Noondoo Rises, in the south of the study area, was labelled as Tertiary fluviatile material (T) by Graham (1972). There are exposures of well-rounded quartzose gravels, some of them silicified, in this area, but they are not as widespread as shown on the geology map.

Table 1. Geological units in the study area (after Graham 1972, Reiser 1971, Senior 1971 and Senior 1972).

| Age | Unit and Map Symbol | Lithology | Thickness (m) | Environment |
|---|---|---|---|---|
| Quaternary | Qa | Unconsolidated sand, silt, gravel, clay and soil | 0-20 | Alluvial |
| | Qs | Red-brown quartz sand, sandy soil, silt, gravel | 0-20 | Older alluvial, colluvial, aeolian, residual |
| Tertiary | T | Quartzose, sandstone and conglomerate, variably silicified and ferruginised: siltstone, minor mudstone | 0-20 | Fluviatile |
| Cretaceous | Griman Creek Formation (Kg) | Labile sandstone, siltstone, minor mudstone, calcareous in part. Upper part weathered (kaolinised, silicified, ferruginised) | 35-600<br><br>0-50 | Fluviatile and deltaic to marine at base |

Note: Various map symbols have been used for the Griman Creek Formation (Klgc, Klg, Ksg, Kg). Kg is the current approved Geological Survey of Queensland symbol and is used in this report.

Quaternary sand (Qs) occurs over a considerable portion of the area (Figure 7). This unit is a mixture of residual and older alluvial sand, soil, and other minor lithologies. A large area on the western side of the study area (Qs/Cz) consists of residual materials on older alluvium (see section 4.2). Quaternary alluvium (Qa) covers about a third of the study area. It consists of a mixture of various lithologies and relative ages. The deposits are part of much larger fan systems that extend into New South Wales. Modern and former alluvial deposits from the Balonne and Moonie Rivers overlie the Cretaceous material to the north east. However, most of the area consists of modern and former floodplain deposits of the Balonne and Maranoa Rivers. Weathering within the Cenozoic sediments is extensive but variable, and produces mixtures of ferruginous and siliceous impermeable zones within the residual material (Senior 1978, 1979).

Geomorphology is discussed in section 4.

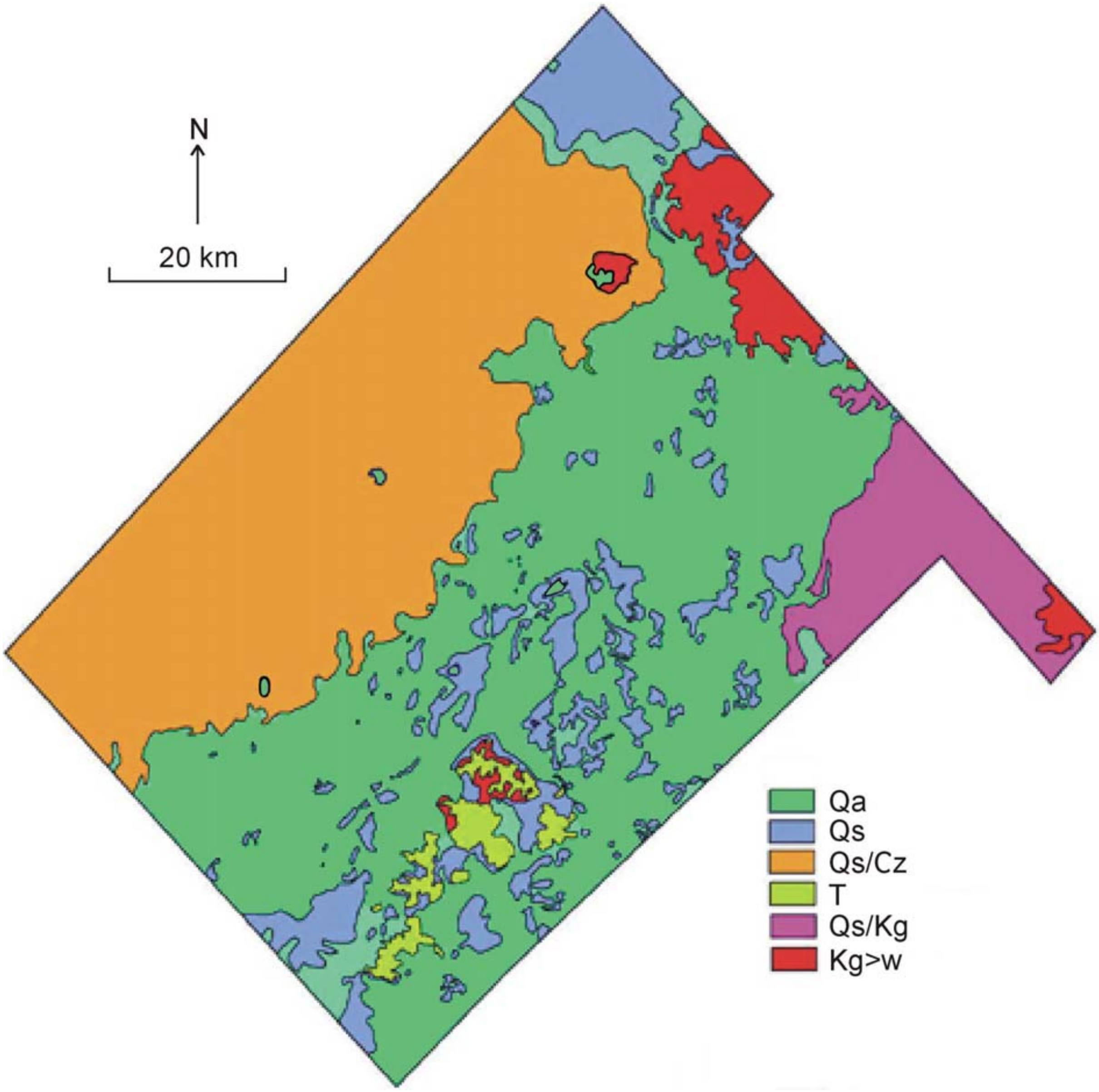


Figure 7. Geology of the Lower Balonne study area.

### *Weathering terminology*

Weathering terminology has been dealt with in different ways in the individual reports on the Lower Balonne AGP, depending on the discipline involved. However, for this report we have integrated the terminology, as set out in Table 2.

The deep weathered profile on the Griman Creek Formation is conductive, and it is therefore important to understand the distribution and characteristics of this weathering surface. The calibration drill-holes (Kellett and Mullen, 2003) intersected four visibly and lithologically distinct zones in the weathered profile of the Griman Creek Formation. These zones are laterally variable, and all are not necessarily present in every hole. However, they were found useful for local correlation.

Table 2. Recommended regolith architectural terminology of the project area

| Lithology | Weathering | Regolith architecture | Litho-stratigraphy | Bio-stratigraphy | Depositional environment |
|---|---|---|---|---|---|
| Semi- and un-consolidated sands, clays, gravels, lignites, etc. | Variably weathered | Cover | See Table 1 (Qa, Qs, T) | Late Neogene | Non marine, mainly fluvial |
| Indurated siltstone and minor sandstone, glauconitic when fresh | Variably leached, ferruginised, and silicified beneath modern land surface and shallow cover | Weathered bedrock (umKg blKg lmKg) | Griman Creek Formation (Kg) | Lower Cretaceous | Marginal marine, strandline and deltaic |
| | Unweathered at depth & beneath Dirranbandi Palaeovalley | Fresh bedrock | | | |

From top to bottom they are informally designated as:

**Upper mottled zone** (umKg): multicoloured (mostly purple and pale grey) with very pronounced mottling patterns, variably silicified and ferruginised saprolite in which depositional structures may still be preserved although the host rock has been extensively chemically altered. Generally umKg is only a few metres thick and in many places is extremely hard in outcrop and shallow subcrop. Where deeply buried, umKg is reasonably soft and tends to be thicker (up to 20 m). In the study area, the water storages Beardmore Dam and Jack Taylor Weir are founded on silicified umKg.

**Bleached zone** (blKg): pale grey to white massive saprolite, variably silicified and fractured at the top, dominantly kaolinitic throughout, with accessory illite at the base (where it may be puggy). Easily recognised by its whitish pigmentation and massive structure, blKg is a prominent marker throughout the Surat and Eromanga Basins. In the study area, blKg is generally 10 m to 30 m thick. In the calibration drilling, blKg attained a thickness of 45 m at hole 5 where it also had an intermediate horizon of maroon and pale pinkish grey saprolite.

**Lower mottled zone** (lmKg): multicoloured, generally soft and puggy saprolite with abundant sesquioxides. Currently the water table in most of the conductive Kg in the study area lies within lmKg. Thickness of lmKg varied between less than 10 m to 40 m in the calibration drill-holes, and was not necessarily proportional to the thickness of the overlying blKg zone.

**Unweathered Griman Creek Formation** (Kg): Sometimes called the marginal marine zone, in the study area this rock unit consists of bluish grey (due to finely disseminated pyrite) and greenish grey glauconitic rocks, dominantly siltstone and very fine sandstone in which sedimentary structures have been preserved. In all ten calibration holes, Kg was noticeably firmer than the overlying lmKg zone, and in some cases contained thin siliceous hard bands. Carbonaceous bands are reasonably common, with rarer pyritic lignite encountered in some holes. All the calibration drill-holes bottomed in Kg.

***Structural controls***

Radke *et al.* (2000), following earlier workers, regarded the orientation of the Balonne River as following a previously existing structural feature in the Mesozoic or older basement, based on the coincidence of the main river orientation with magnetic lineations to the northeast and southwest. We now know that the main structural feature in the area, the Dirranbandi "trough", lies to the northwest of the river. Exon (1976) suggested that the sediments of the Dirranbandi "trough" were deposited in a

Mesozoic down warp. This down warp may have a fault on its south eastern margin, but this has not yet been demonstrated. Some sections show this inferred fault.

The Lower Balonne study area straddles the Darling Lineament, a set of major geological structures that run southwest–northeast along the Darling River (Figure 8). A number of other lineaments are also near the study area. None of these lineaments parallel the Dirranbandi "trough". Figure 8 also shows the location of earthquake epicentres in relation to the Lower Balonne area.

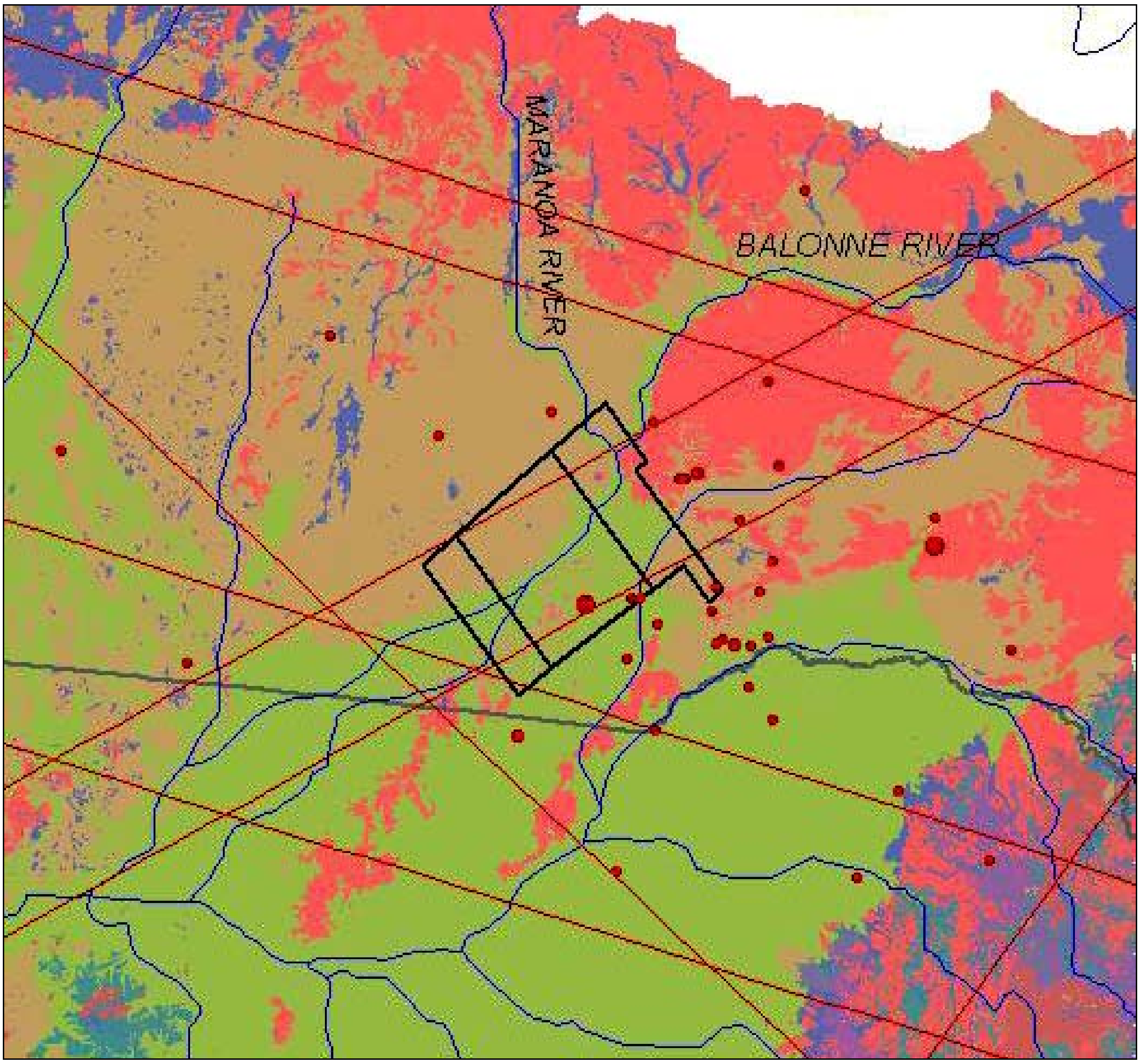


Figure 8. Major geological structures in the Lower Balonne area (red lines), and location of earthquakes (red dots)

### 2.5 Previous land use-related work

Previous regional regolith and NRM work in the lower Balonne area includes a report on Lands of the Balonne-Maranoa area (Galloway *et al.* 1974), and the recent salinity hazard map (QDNRM&E 2002).

QDNRM&E also undertook a detailed soil mapping exercise over 4 key areas in the St George region in 1998. This data was initially going to be interpolated over the catchment but this did not eventuate. A study of sediment provenance and dispersion within the Condamine-Balonne catchment was undertaken by Brennan (2001).

# 3. STUDY METHODS

Because of the short period available for the study, we relied largely on remotely sensed data to carry out the regolith and landform mapping. We used a number of different data sources, each of which had particular characteristics. Some fieldwork, including drilling, was also undertaken.

## 3.1 Data Sources

A comprehensive overview of remotely sensed data and their applications to regolith mapping is covered by the CRCLEME open file report 144: “Geophysical and Remote Sensing Methods for Regolith Exploration” (Papp 2002), which is available for download from the CRCLEME website. Individual chapters in that report are referenced below. Data sources used for this project are listed in Appendix 2.

***Air photos (Craig 2002)***

Air photos at a scale of 1:80 000, flown in June, July and September of 1963 by the Department of Minerals and Energy Division of National Mapping (AUSLIG) were used to help verify the remotely sensed data and to further gain insight into the geomorphology of the surface materials. These photos covered the 1:250 000 scale Dirranbandi and St George map sheet areas.

***Landsat TM (Wilford and Creasey 2002)***

Landsat TM data from the Landsat 5 and 7 satellites are available for the study area. These include TM5 data from periods within 1988, and TM7 data from 1999-2000 (Appendix 2). The TM5 image acquired in October 1988 was selected as the most useful to work with for a number of reasons, but primarily because of the relatively low response from the vegetation cover compared to the February and May images flown in the same year. The TM7 data for the period July 1999 to September 2000 was compiled from several scenes flown over this time. This made interpretation of the data at study area scale difficult because the scenes vary in spectral responses due to the materials, but also seasonal effects, water content, vegetation, human activity including cropping of paddocks and simply the fact that they were all collected at different times.

There was a significant increase in the level of human impact between the 1988 images and the 1999-2000 scenes. Much of the spectral response from the areas surrounding St George, Dirranbandi and south on the current floodplain are dominated by responses from agriculture in the later images (Figure 9). Images from 1988 were a more useful source of information for geomorphological mapping over these areas.

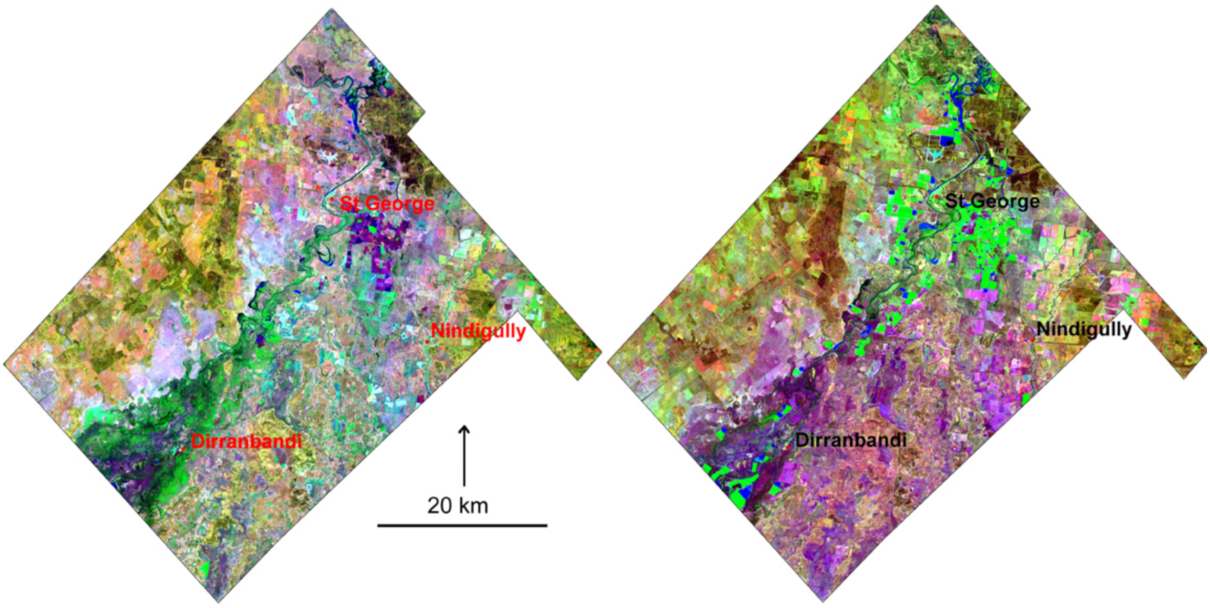


Figure 9. Left – Landsat TM 5 (1988). Right – Landsat TM 7 (2000). Bright green areas in the 2000 scene are dominated by agriculture.

### *ASTER (Rowan and Mars 2003)*

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) has 12 bands of data, the first 3 are in the visible range, and the others in the near, short and thermal infrared. At shorter wavelengths the ground resolution is 15 m, and with increasing wavelength ground resolution increases to 30 m and then 90 m (Appendix 4).

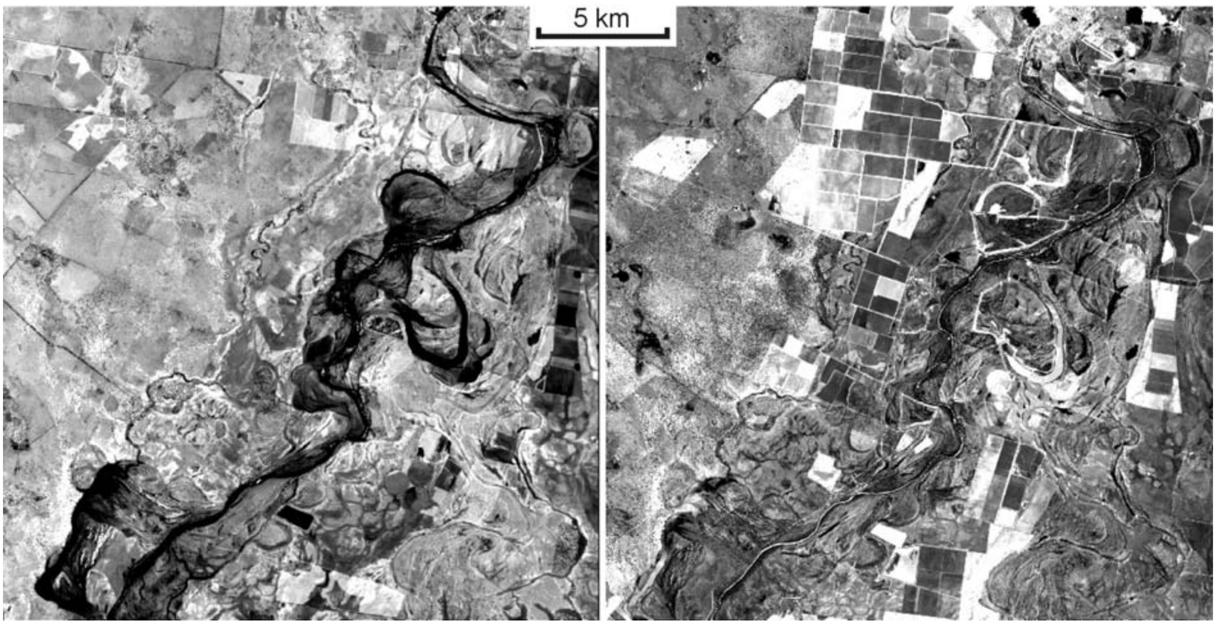


Figure 10. Landsat data from 1988 (left) compared with ASTER data from 2000 (right), showing the increase in agricultural activity.

ASTER data over the study area was acquired between December 2000 and May 2001 and was stitched together into a scene for the study area. A grayscale image of the principal component 1 (PC1) analysis of the first three bands of ASTER data was produced. This image has twice the ground resolution of Landsat and thus shows a finer level of surface material and form detail. The PC1 image helps to highlight the generally similar high spectral responses from the silica rich sandy channel deposits as apposed to variable spectral responses from clay and water rich areas. There is a significant effect from agriculture on the surface spectral response from the ASTER data acquired in 2000 compared to that of the 1988 Landsat TM5 image (Figure 10).

***Radiometrics (Wilford 2002)***

Gamma-ray radiometrics measures relative elemental compositions of uranium (U), thorium (Th) and Potassium (K). Rock types and sediments have unique concentrations of these elements which can be used to identify lithologies, material composition, and sediment provenance and to infer relative ages of sediment packages. In addition, these elements have differing mobility within the weathering environment and this leads to different relative concentrations as a result of the form or extent of weathering that has occurred.

A red, green, blue (RGB) ternary image of K, Th and U concentrations assigned the colours red, green and blue respectively was produced (Figure 11).

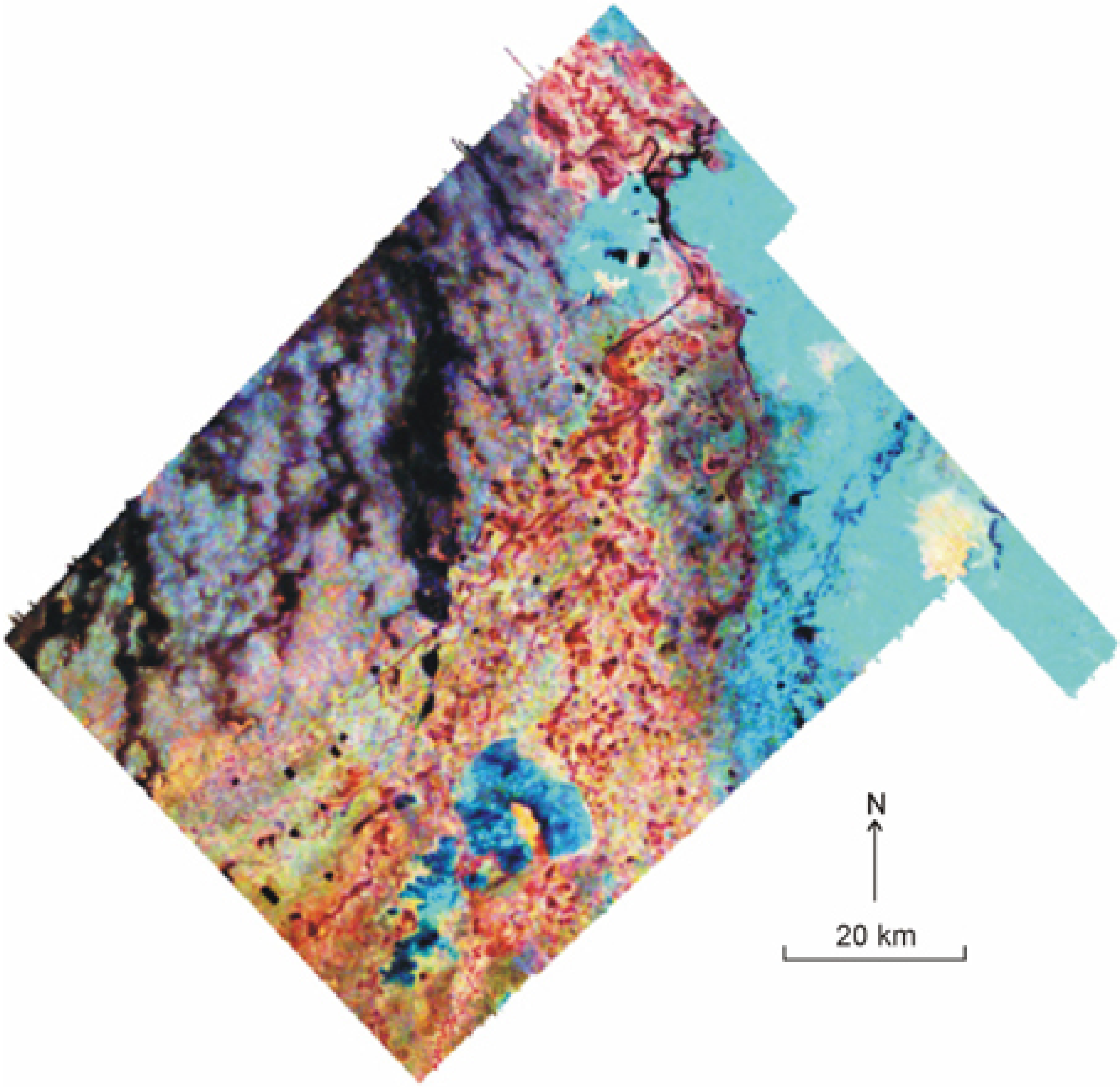


Figure 11. Radiometrics image of the Lower Balonne study area.

***Digital Elevation Model (Hutchinson and Gallant 2000)***

Digital Elevation Models (DEM) can be acquired at the same time as other airborne surveys are flown. Surveys are rarely flown for DEMs alone, and thus their quality depends on the specifications of other surveys such as radiometrics, AEM or magnetics.

In addition to the National 9 second DEM, two new DEMs were acquired, one with the Magnetic susceptibility and radiometric survey, the other with the AEM survey. The DEM from the magnetic survey has a better spatial resolution, because it was flown at 100 m line spacing while the AEM survey had 250 m flight line spacing. The magnetic survey was flown at 60 m above the ground, compared to 120 m for the AEM. This means that the magnetic DEM has a better vertical accuracy compared to the AEM DEM. Tie lines, which help to verify the accuracy of the data, were not flown in the AEM survey to reduce the cost and thus the accuracy of the AEM survey was not verified using tie lines.

The DEM most relied upon for map production was the magnetic survey because it was more detailed. Landscape morphology could be interpreted from the DEM, although there was a marked influence from paddock shape in areas dominated by agriculture, especially irrigation (Figure 12).

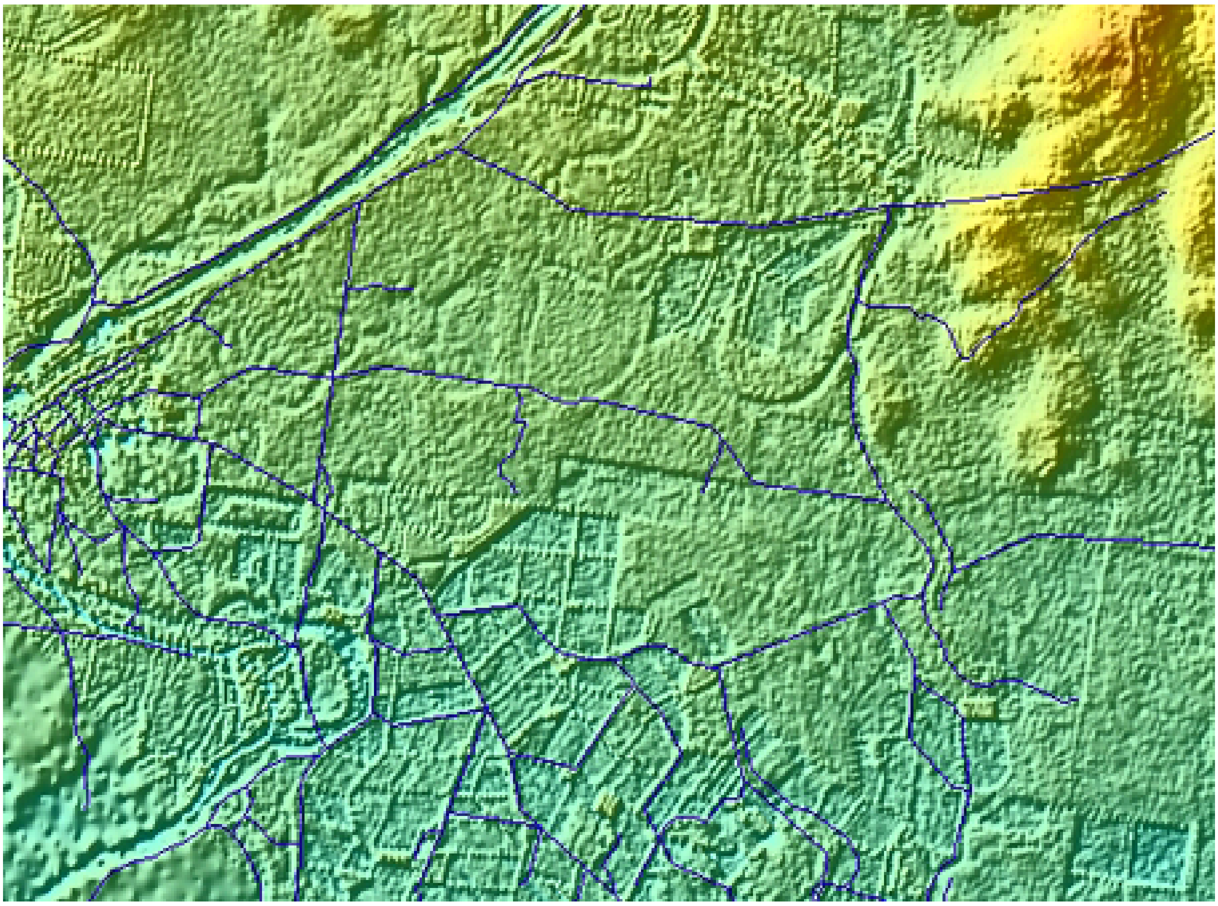

Figure 12. Digital elevation model over the township of St George and surrounding area showing the channel morphology of the modern river and former meanders as well as the extent of paddock effects in this area. The scene is about 25 km across.

***Airborne Electromagnetics (Lane 2002)***

Time domain AEM were acquired over the survey area by Tesla Geophysics in September 2001. Initial processing of the data was carried out by Fugro. The data were then reprocessed by CRCLEME (Lane *et al*., 2003).

Worrall *et al*. (1999) reviewed the development of AEM data as applied to the study of geomorphic process and landscape evolution, while Speed (2002) compares benefits to NRM from the acquisition of AEM data over two catchment areas in Western Australia.

***Ground Electromagnetics (Lane 2002)***

Apparent conductivity profiling using a GEONICS frequency domain electromagnetic instrument (EM31) was undertaken by QDNRM&E in September- October 2001. The data acquired from an EM31 system provides information on the presence of lateral variations in subsurface bulk electrical conductivity. The EM31 instrument was used in vertical dipole mode and has a depth of penetration of around 6 m varying to 4 m in very conductive terrain. The coil spacing was 3.7 m and the operating frequency 9.8 kHz. The GEONICS instrument does not require ground contact and was towed on a wooden trailer over the investigation area with real time Global Positioning System (GPS) data collected at the same time.

***Key soils site data***

Four areas within the Lower Balonne study area were mapped and studied in detail in previous work undertaken by QDNRM&E. These four key areas are in the north of the study area, and the maps show soil properties including structure, permeability, texture, ph and electrical conductivity (EC). Although data from the four key areas were originally going to be extrapolated over the whole study area to produce a new soil map, this did not eventuate. However, the data were used to help verify and extrapolate the information gathered from our own surface sampling sites.

***Fieldwork***

Site data was collected by CRCLEME in two field visits between September 2002 and March 2003. In total there are 127 data locations distributed within all geomorphic units. Surface regolith samples were collected from roadsides within the study area (Figure 13) and attributes were recorded following the Geoscience Australia Regolith database (RTMAP) guidelines (Pain *et al*., in prep.).

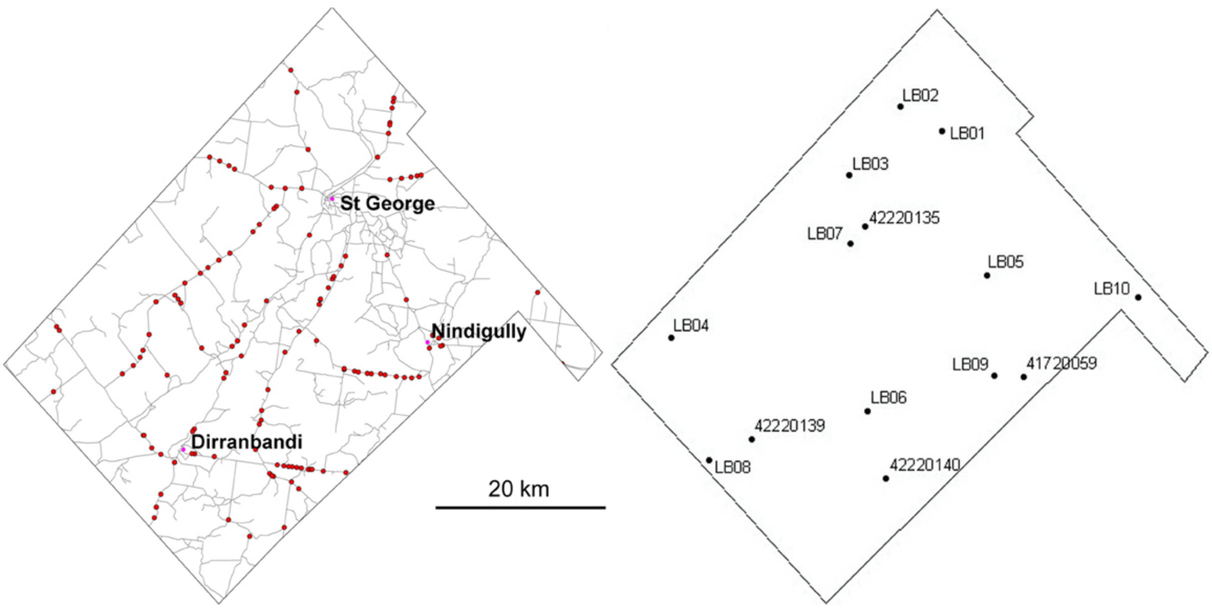


Figure 13. Locations of observation sites (left) and bore holes (right).

## 3.2 Mapping

***Introduction***

An understanding of the current surface regolith, landforms and geomorphic evolution is needed to identify sub-surface aquifer properties and groundwater flow systems within the Lower Balonne region. Surface information is much more accessible, and aids in the interpretation of sub-surface data that is accessible only through drilling, ground electromagnetics (EM) or from remotely sensed forms such as AEM or magnetic susceptibility surveys.

Regolith-landform mapping relies on the ability to group the landscape into discrete units at an appropriate mapping scale. These units are called Regolith-Landform Units (RLU) (Pain *et al*., in prep.). Pain *et al*. make a clear distinction between classification units and mapping units. They note that:

> *Classification units* consist of regolith or landform units that are defined in terms of various regolith or landform characteristics. They are ideal or conceptual units that can be precisely defined.
>
> *Mapping units* are real regolith landform units that can be conveniently mapped, and their definition will therefore depend to some extent on the scale of the map. The more detailed the map scale, the more pure the regolith landform mapping units will be.

Thus RLUs group regolith types that are associated in the landscape, and they contain various classification units that can be precisely defined. All RLUs will contain impurities, depending on the complexity of the landscape. Thus at detailed mapping scales there tend to be less impurities. Both regolith and landforms have been classified by Pain *et al*., and these definitions are used in this report.

Mapping units were compiled at two scales. The regional scale presents the major geomorphic units in the area, while the more detailed scale maps the detail of regolith-landform units. The Lower Balonne regolith-landform map was compiled at a scale of approximately 1:100 000, and thus has a minimum mapping unit of around 150-300 m (McDonald *et al*., 1990). However, it should be noted that the map has been compiled as part of a GIS package, and in a GIS environment data is easily rescaled. An appropriate mapping scale was determined not by the scale of the output but rather the scale of the landscape features present.

***Mapping Methodology***

The Lower Balonne regolith-landform map was compiled from a range of data forms, including aerial photographs, Landsat TM, gamma-ray radiometrics, ASTER, DEMs and ground sampling.

Geomorphic units were delineated primarily from Landsat TM and gamma-ray radiometrics. These large units were delineated mainly on form and materials which were easily recognised in the radiometric RGB image. Smaller regolith landform units were then identified by a mixture of radiometric interpretation, especially for the sand rich channel units and Maranoa surface subdivisions, as well as detailed air photo interpretation. Landsat and ASTER data were used to verify and further delineate the boundaries of the units within the study area as well as enhance the interpretation of surface processes. Process information on unit boundaries was much enhanced from Landsat TM interpretation. Aerial photographs were also used to provide detail of some units. Surface mapping was also validated by field observations, and samples of surface materials taken in the field.

***Data and Mapping Detail***

### Radiometrics

Regolith materials were initially distinguished by their relative radiometric responses (Figure 11). Channel sand deposits, which mainly consist of well sorted quartz rich sand, have relatively high K and lower U and Th responses. Fresh or residual material has a relatively higher U and Th concentration than K when compared to transported material. Age and or provenance can also be assessed from the relative concentrations of all elements; the older deposits are more heavily weathered and thus have an overall lower concentration (and thus darker response) for the elements which are all mobile in the weathering environment (Wilford 2002).

The radiometric data were also classified using an unsupervised routine, to produce a map showing nine classes (Figure 14). These classes helped separate major regolith materials. The classification statistics are listed in Appendix 5.

### Landsat TM

Landsat TM band combinations discussed previously helped to distinguish between clay and sand as well as providing information on regolith form and processes. RGB band combinations of Landsat TM bands 7, 4, 1 and 3, 2, 1 were used to discriminate material within landscape patterns, and to interpret the character of unit boundary. PC2 analysis produced images that were more useful for classification of materials including the clay rich backplains and quartz rich channel sands within alluvial deposits, and possible sodic soils and saline areas on the Maranoa surface.

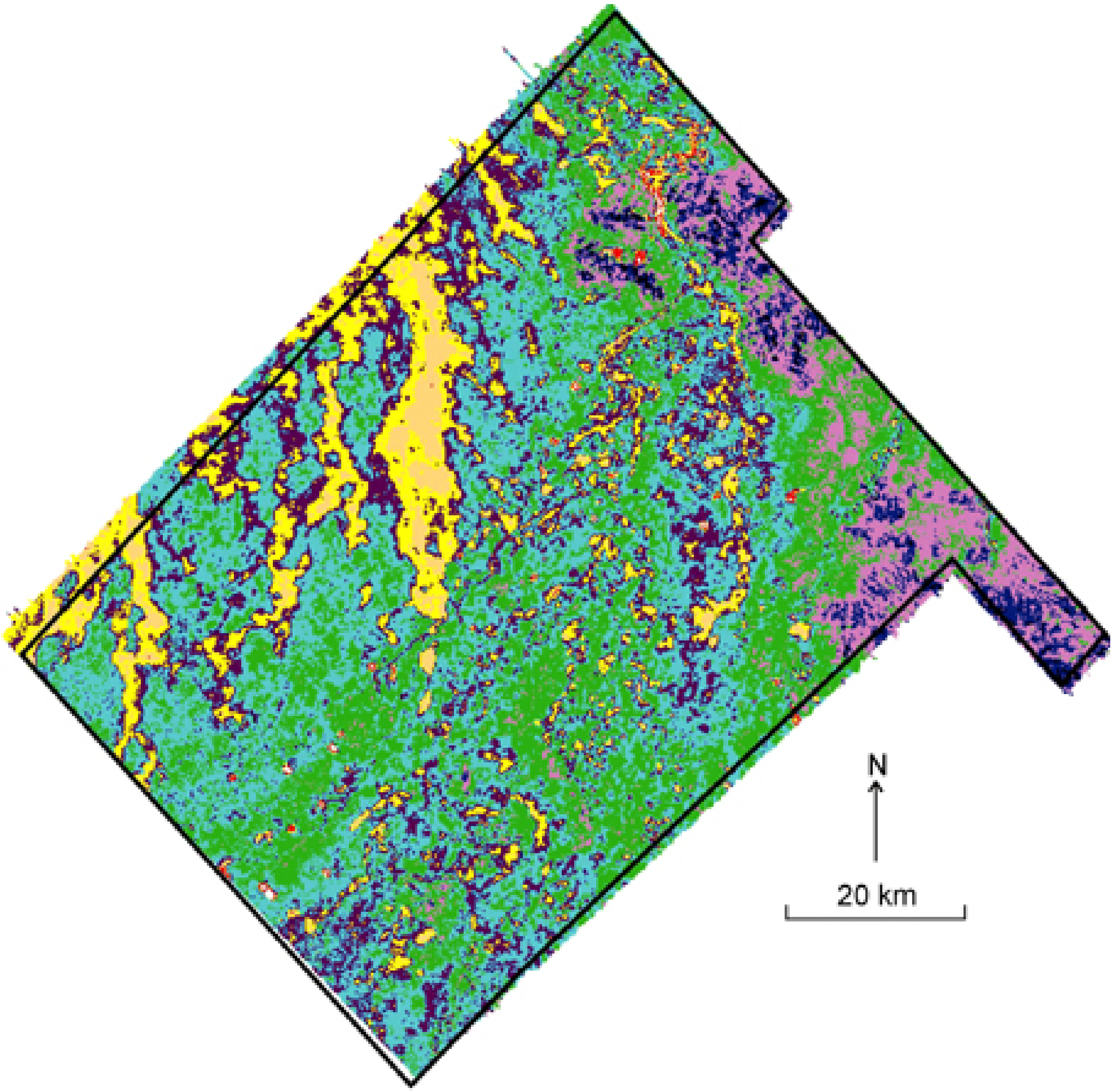


Figure 14. Classification of the radiometrics. The classes on the map are assigned the colours 2=pink, 3=tan, 4=yellow, 5=purple/red, 6=blue, 7=green, 8=purple, 9=dark blue, 10=black, from Appendix 5.

ASTER

ASTER data were primarily used as a backup for Landsat TM interpretation and were not utilised to full capacity as a data source. PC analysis of the three bands within the visible spectral range was useful for distinguishing sand-rich channel forms especially in the south, and highlighting areas with saline or sodic soils. Ground data from field work, and the QDNRM&E key soil site maps, were used to validate remotely sensed interpretation where possible.

## 4. RESULTS

The area is subdivided into 8 geomorphic units on the basis of landform and geomorphic processes (Figures 15, 16) (Table 3). Each geomorphic unit is further subdivided into regolith landform units based on regolith materials and the geomorphic processes responsible for their origin (map in back pocket) (Appendix 6).

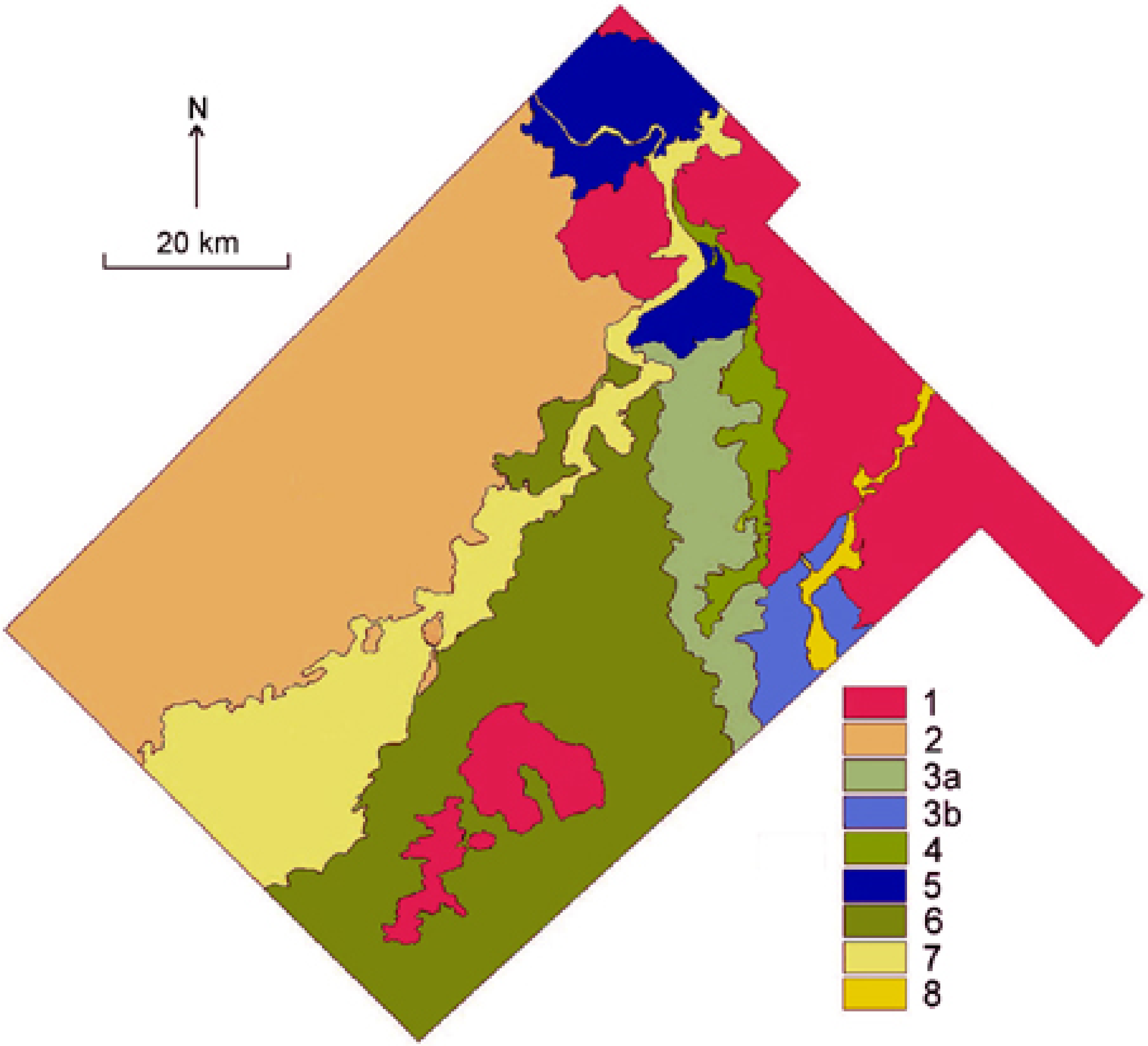


Figure 15. Major geomorphic units in the Lower Balonne study area

Table 3. Geomorphic units numbered in order of relative age

| | |
|---|---|
| 1 | Saprolite and Residual Material on Cretaceous Griman Creek Formation |
| 2 | Maranoa Surface – Early Quaternary fan sediments |
| 3a | Oldest Balonne River Channel deposits |
| 3b | Oldest Moonie River Channel deposits |
| 4 | Older Balonne River Channel deposits |
| 5 | Former Maranoa and Balonne River Floodplain deposits |
| 6 | Younger Balonne River Floodplain and Channel deposits |
| 7 | Modern Balonne River Channel deposits |
| 8 | Modern Moonie River Channel deposits |

Note: Geomorphic units 5 and 6 are likely to be very similar in age.

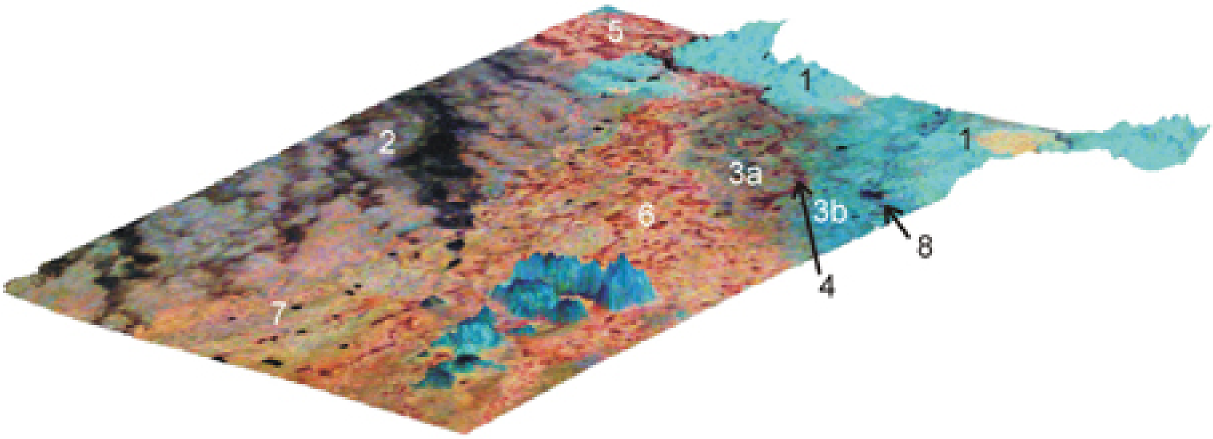


Figure 16. DEM of the study area draped by radiometrics, and showing the geomorphic units.

## 4.1 Geomorphic Unit 1. Saprolite and residual material on Griman Creek Formation

Landforms on the Griman Creek Formation consist of undulating erosional rises and plains. Clay-dominant plains have locally variable gilgai structures, and minor valley floors occur throughout this unit. Regolith is predominantly saprolite and residual sand (Figure 17).

Three regolith landform units are identified in this geomorphic unit:

RSep1 Residual red-brown to yellow quartzose sands with minor clays on erosional plains, derived from the underlying Griman Creek Formation.

SPer1 Residual sands and clays over saprolite formed from the variable weathering of the Cretaceous Griman Creek Formation. In places the saprolite is strongly mottled, and contains silcrete and ferricrete.

Lpp1 Clay pans with saline clay and silty clay sediments.

The present day surface regolith on the Griman Creek Formation is a mix of saprolite, mottled saprolite and residual sand and clay of varying thickness (Figures 17, 18). Some of this regolith has been modified by silicification to produce silcrete, or ferruginisation to produce ferricrete. It has also been kaolinised in places. There is some relationship between thickness and style of regolith, and landscape position (Figure 19). Minor modern alluvium occurs in valley floors.

Figure 17. Saprolite, with a thin residual soil, on Griman Creek Formation.

Figure 18. Residual sand over Griman Creek Formation.

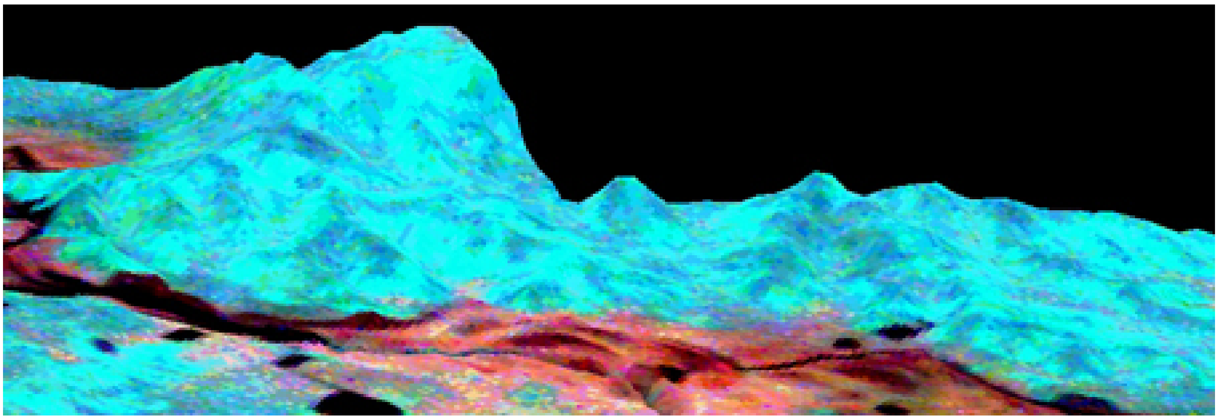

Figure 19. Regolith landform unit SPer1 on erosional hills of the Griman Creek Formation. Dark blue areas have a cover of residual sand, while lighter blue areas have a soil formed on saprolite.

Geomorphic unit 1 passes below younger alluvial units in the study area. The buried weathering profile on the Griman Creek Formation is likely to be similar to that exposed at the present time. This is based on two points.

First, the nature of burial (by aggrading sediments) probably meant that the sub-sediment surface was modified only slightly. Residual sand may have been removed, but any more resistant material such as saprolite, saprock and especially silcrete would have been left behind. The residual sand may have provided a local source for sediments during the earliest stages of burial.

Secondly, the sediments burying the Griman Creek Formation in the study area are all Pliocene to Quaternary in age (Macphail 2003). The weathering profile on the Griman Creek Formation began forming much earlier, and is therefore much older. Moreover, its subsurface expression is unlikely to have been altered much after burial. For these reasons the exposed and weathered surface on the Griman Creek Formation is considered to be a fairly accurate analogue of its buried equivalent.

### 4.2 Geomorphic Unit 2. Maranoa surface – Early Quaternary fan sediments

Within the study area there is a small part of an extensive alluvial fan deposited to the west by the former path of the Maranoa River (Figure 2). The surface consists of undulating rises and plains with very little active stream flow in the depressions (Figure 20).

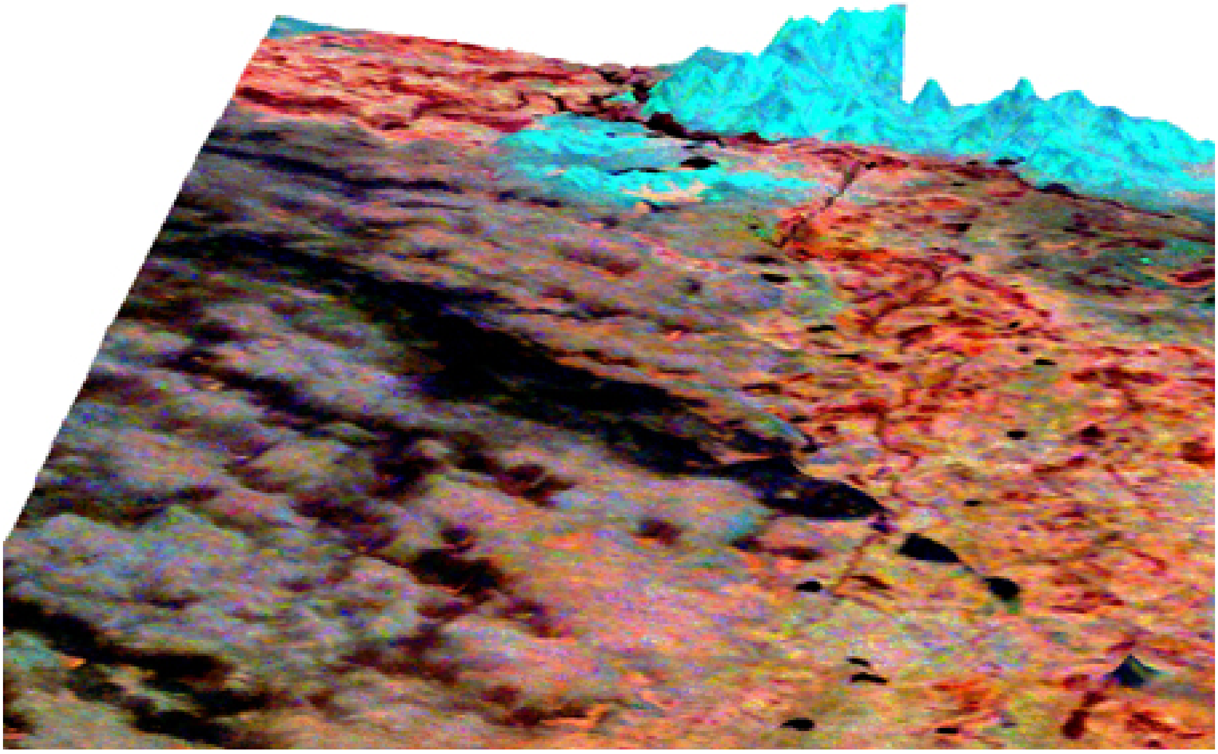

Figure 20. DEM of the Maranoa surface, draped with radiometrics. Dark areas are sand, and lighter areas are clay-rich. The pinkish area in the middle foreground is dominated by sodic soils. The blue in the background is Griman Creek Formation low hills.

Three regolith landform units are identified in this geomorphic unit:

RSap1 Residual sand on low interfluves between drainage lines on the Maranoa surface.

RSap2 Residual clayey sand on slopes below interfluves between drainage lines on the Maranoa surface.

RCap1 Residual predominantly sodic clay on shallow valley floors between drainage lines on the Maranoa surface. Vertisols, gilgai structures and local occurrences of gypsum are present.

Regolith on Geomorphic Unit 2 is derived from alluvial sands and clays. These materials have been considerably modified by weathering and erosion to give red to brown sands on broad ridges and interfluves, and brown to grey clays in depressions. The distribution of these materials is shown on the regolith landform map. Gilgai occurs in some areas of clay, and duplex soils on clay rich subsoils in others. There is also a significant area of sodic soils that can be seen on both the Landsat and the AEM (Figure 21).

Geomorphic Unit 2 is currently being truncated on the east by the modern Balonne River, giving rise to a complex boundary of active channel meanders, splays, and back plains that form part of Geomorphic Unit 7 (Appendix 6) (Figure 22). There are also features that appear to be developing by seepage from the Maranoa surface towards the modern Balonne River (Figure 21, top). In the north the eastern edge of the Maranoa surface is a distinct, although sloping, scarp which becomes less distinctive and lower in the south of the study area, where sediments from the modern Balonne River are being deposited on the surface of the fan.

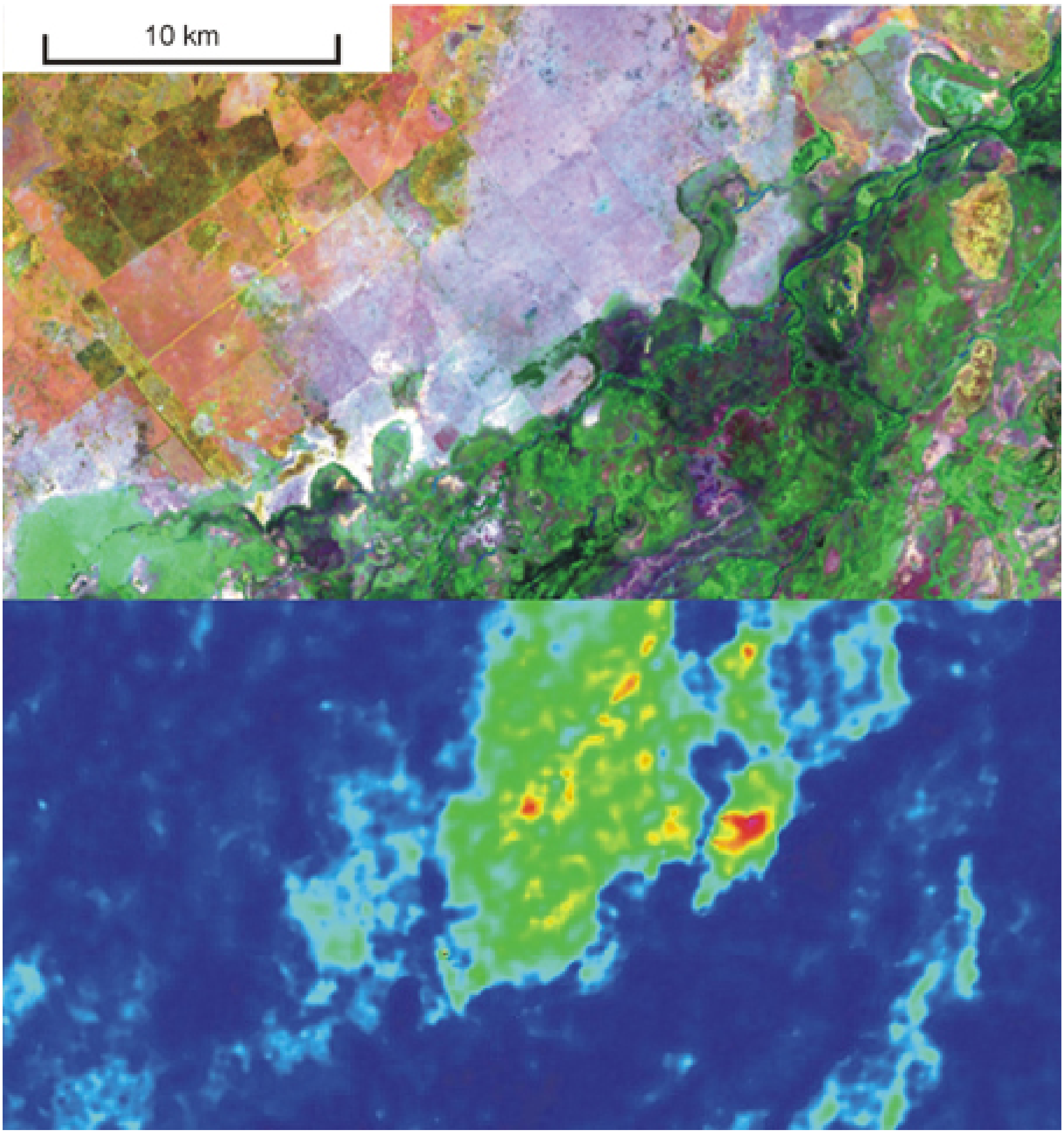


Figure 21. Top – Landsat band 741 image of the Maranoa surface boundary. The light purple area corresponds to sodic soils. Bottom – AEM 0-5m image of the same area. The yellows indicate areas with higher conductivity.

The depth of the Geomorphic Unit is variable, being 20-30 meters in the east, and much deeper (>80 m) in the west. These variations result from the fact that the Maranoa surface materials fill a fault-bounded depression (the Dirranbandi Trough) in the west, and then cover Griman Creek Formation at shallow depths to the east.

Geomorphic Unit 2 is of high concern for salinity risk in the study area and a more detailed study of its sub-surface materials, landscape elements and the eastern boundary is warranted.

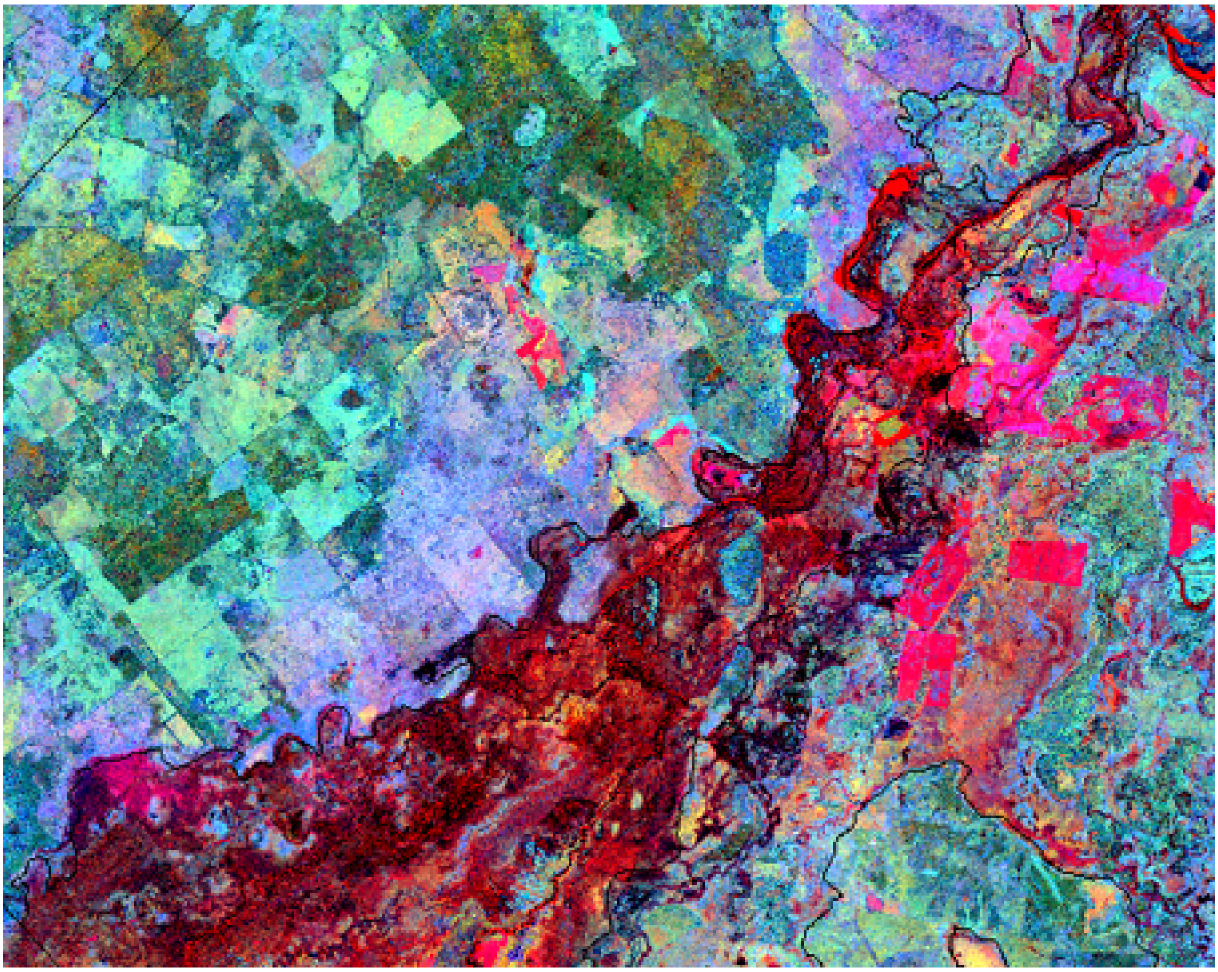

Figure 22. Landsat image of the boundary between the Maranoa surface and the modern floodplain. In the northern part of the boundary the modern Balonne floodplain is inset by several metres to the Maranoa surface. In the south, Balonne floodplain sediments are spilling onto the fan. This scene is about 60 km across.

### 4.3 Geomorphic Unit 3. Oldest Balonne and Moonie Channel deposits

Geomorphic Unit 3 is subdivided into two subunits on the basis of provenance of material. Very little channel morphology is preserved on the surface of the geomorphic unit because it is heavily affected by human activities, and is the main irrigation area in the St George area (Figure 10). Scroll bars in the north and south of the unit exhibit simple symmetry and have a scale of 2-3 km, although these substantial alluvial deposits may be the only surface features large enough to remain visible due to agricultural effects. Three regolith landform units are identified in this geomorphic unit:

AOap2 Clay and sandy clay alluvium on a backplain associated with the former Balonne River. Occasional levees, scroll bars and channel bank deposits.

AOap3 Clay and sandy clay alluvium on a backplain associated with the former Moonie River. Occasional levees, scroll bars and channel bank deposits.

ACap2 Sandy alluvium in levee and scroll bar deposits associated with the former channels of the Balonne River.

The regolith is dominantly alluvial clay, with minor large scale sandy channel deposits, scroll bars and levees. These features are not obvious on the ground because the unit is flat, and has been affected by agriculture. However, the various regolith materials show up well on the radiometric image (Figure 23).

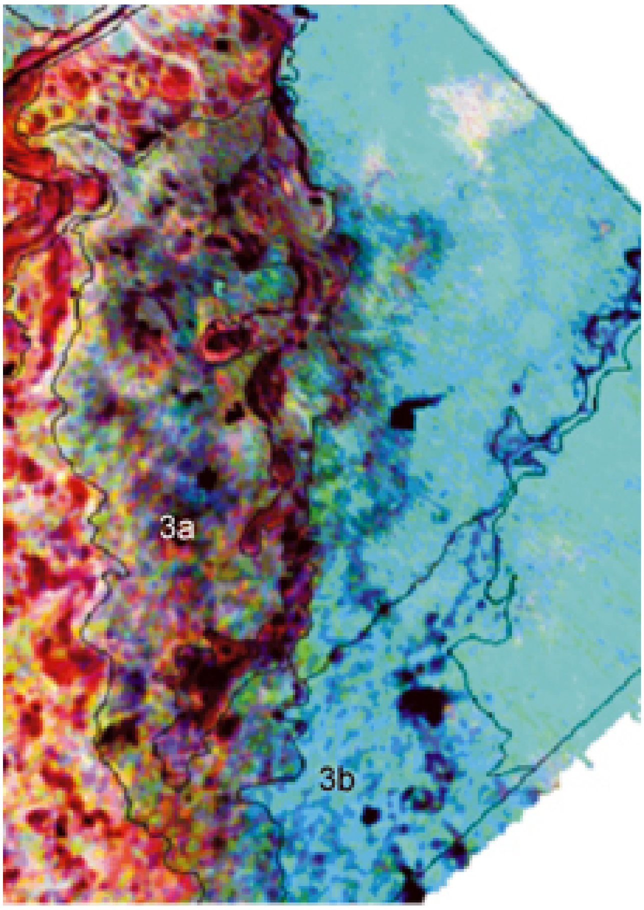


Figure 23. Radiometric image of Geomorphic Unit 3. In the east is the younger Balonne surface; the elongate dark area in the centre is Unit 4. Dark patches in subunit 3a are channel sands. Subunit 3b is in darker blue shades, with black areas of source bordering dunes. Unit 5, at the top, shows former Balonne channels.

Relative age has been determined by both the boundary character with other geomorphic units of the floodplain, and through surface character determined through Landsat and radiometric data. The geomorphic unit has an overall darker radiometric response compared to surrounding depositional units, suggesting that the weathering, particularly of potassium, over time has decreased the radiometric response within the unit. Other factors, especially water content, can influence the level of radiometric response (Wilford 2002), although the darker response within the units is relatively continuous and is therefore more likely to relate to regolith materials than paddock irrigation effects. However, although the boundary between subunits 3a and 3b is obvious on the radiometrics, in the field it is very difficult to distinguish (Figure 24).

Geomorphic Unit 3 is eroded and overlain by channel meanders of Geomorphic Unit 4, to the east. To the north Geomorphic Unit 5 is slightly inset, while to the east it grades into Geomorphic Unit 6.

To the south the subunits are likely to have a complex intermixing of former deposits from the Balonne and Moonie River at depth while to the north and west subunit 3a could be present at depth below all the younger floodplain deposits.

Figure 24. Boundary between geomorphic subunits 3a and 3b.

## 4.4 Geomorphic Unit 4. Older Balonne Channel deposits

This geomorphic unit consists almost entirely of large scale channel landforms ranging from meander channels with accretionary scroll bars to braided channel bars and levees (Figure 25). The shape and scale of the meander scroll bars varies between large meander lobes in the range of 1-4 km wavelength to some small circular scroll bars of around 1 km wavelength. This unit also has abandoned channel lakes and lagoons that run roughly north-south and have wavelengths of between 400-600 meters.

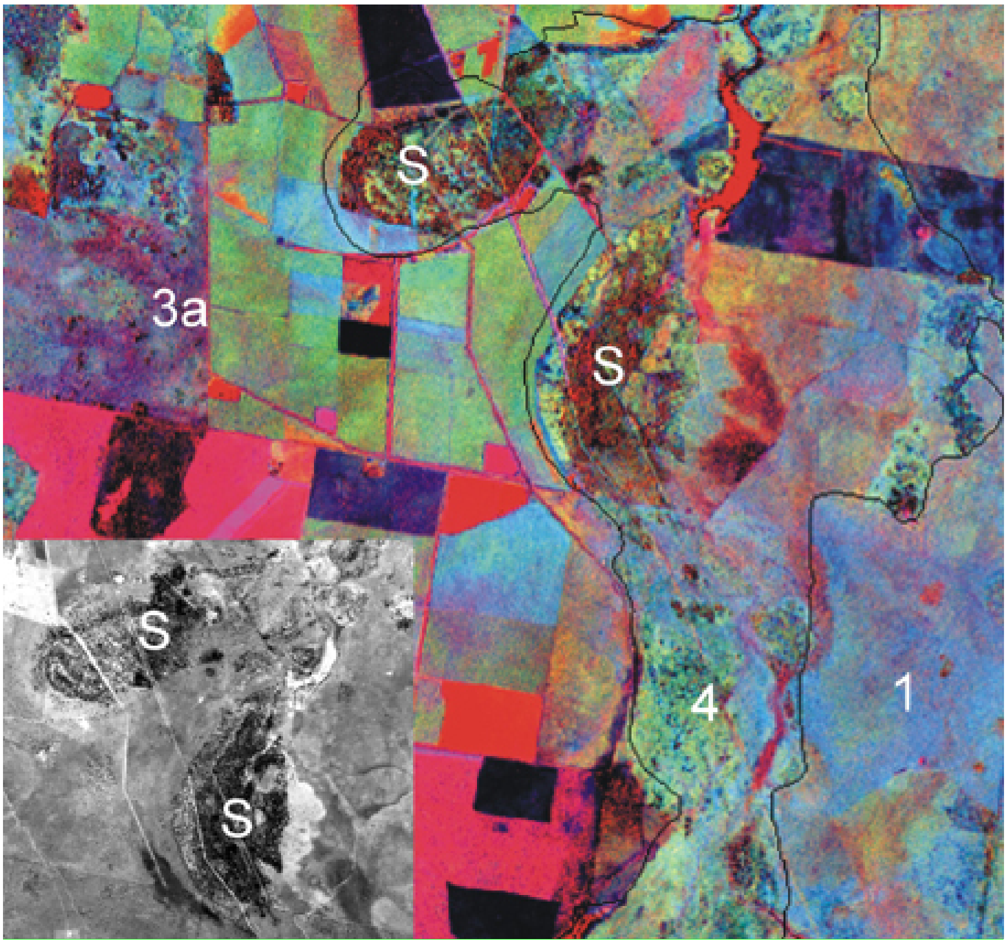


Figure 25. Geomorphic units 3a, 4, and 1. S = Scroll bars in Geomorphic Unit 4. Inset – aerial photograph of scroll bars.

The following regolith landform units are identified in this geomorphic unit:

AOap5 Clay and sandy clay alluvium with some gilgai on a back plain associated with the former Balonne River. Minor occurrences of residual cretaceous sands and clays.

ACap3 Sandy alluvium in levee and scroll bar deposits associated with the former channels of the Balonne River.

Regolith materials are dominated by alluvial sands and sandy clays in sandy levees, scroll bars, channel bars and channel deposits.

This unit both incises into and overlies the oldest Balonne Geomorphic Unit 3a to the west. At its southern extent it appears to have spread out over Geomorphic Unit 3a. The boundary between Geomorphic Unit 4 and the residual material in the Cretaceous Geomorphic Unit 1 to the east is well defined at the northern end as an erosional contact while to the south it is less defined and is more likely to have eroded and overlaid the residual material. At its northern end the unit is cut by Geomorphic Unit 5.

This unit has a narrow lateral extent compared to other alluvial units in the area and its alluvium is possibly quite thin. The lack of complete visible meanders and the subdued morphology of channel deposits within this unit compared to Geomorphic Unit 5 supports the idea this unit predates Geomorphic Unit 5. Subdued radiometric data over this unit compared with Geomorphic Unit 5 also suggests an older age.

### 4.5 Geomorphic Unit 5. Former Maranoa and Balonne floodplain deposits

This unit has three polygons that show slightly different morphologies. The southern-most polygon is an area of large scale, simple symmetric meander channels with scroll bars which are easily visible on Landsat images and aerial photographs. The meanders have wavelengths of 3–4 km and have a visible and constant channel width of roughly 120-190 m (Figure 23, at the northern end).

The two northern polygons are adjacent to the present Balonne and Condamine Rivers, becoming constricted close to St George. Both polygons contain deposits of meander style channels, consisting dominantly of simple symmetrical meander lobes. Meander wavelength varies between 1 and 4 km but channel widths are more variable and their morphology more subdued than in the northern part of this unit. Regolith materials within these polygons consist of alluvial, dominantly channel, sands and clays with some residual sands and clays in the northern polygons (Figure 26).

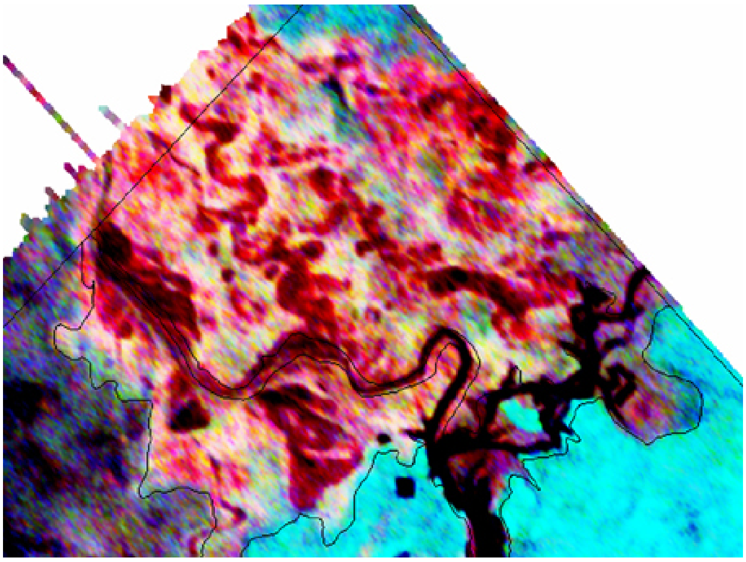

Figure 26. Geomorphic Unit 5, north of St George. Abandoned sandy Maranoa River channels stand out clearly in red colours, and clay-rich back plains in light colours.

The following regolith landform units are identified in this geomorphic unit:

AOap6 Clay and sandy clay alluvium on a back plain associated with the former Balonne River.

ACap4 Sandy alluvium in levees and circular scroll bars associated with former channels of the Balonne River.

The southern most polygon border cuts older Balonne deposits in Geomorphic Unit 3. The modern channel of the Balonne River is eroded into this unit.

AEM images suggest that the alluvium in the most northerly polygon is present to depths of less then 40-60 meters.

Radiometric data over all three polygons within this unit indicates multiple sandy channels, scroll bars and meanders that are not as clearly visible on Landsat images or air photos. This suggests that the unit is dominated by a mix of channel and overbank deposits to an unknown depth (Figure 26).

## 4.6 Geomorphic Unit 6. Younger Balonne floodplain and channel deposits

This geomorphic unit is dominated by scroll bars associated with meandering channels. The northern part of this unit has a surface of predominantly large scale accretionary scroll bars and channels. The complexity of the deposits increases to the south as the size of channel features decreases. Meanders and abandoned channels become more visible, back plains are more prevalent and large portions of abandoned channel systems can be identified. Overall the unit has the form of a large very low angle fan (Figure 27).

A large backplain lies in the middle of this unit and has been shown on the regolith landform map as a separate unit. To the west of this back plain and running roughly north-south within this unit is another set of abandoned channels that display scroll bars of around 1.4 to 2 km in width.

Surface regolith materials are dominated either by sand-rich channel deposits or clay-dominant backplain deposits. To the south the surface deposits reduce in grain size and the sediments are increasingly dominated by backplain, overbank and levee deposits (Figure 27).

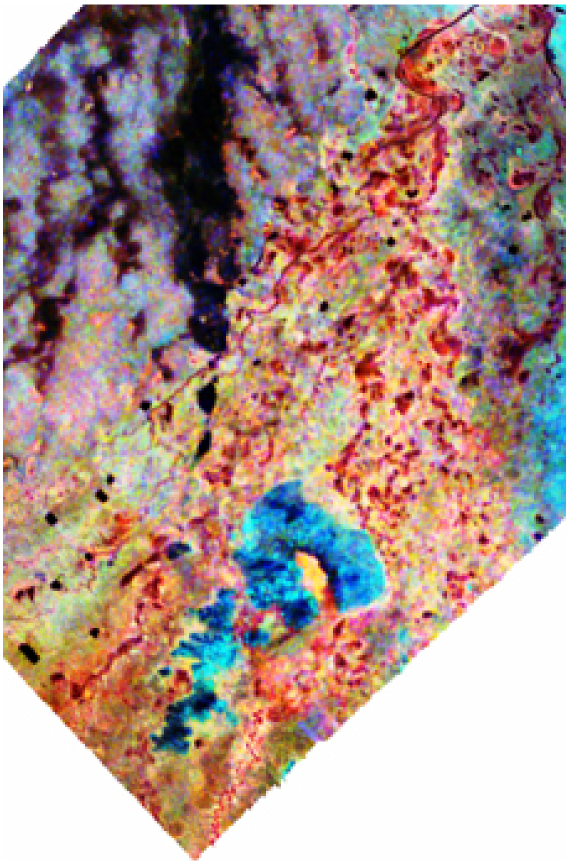

Figure 27. Geomorphic Unit 6, shown in pinks and reds on this radiometric image. The red tones are former channel and levee sands, while the lighter tones are finer backplain deposits.

The following regolith landform units are identified in this geomorphic unit:

AOap1 Clay and sandy clay alluvium on back plains, with vertisols and gilgai structures present as well as some duplex soils (Figure 28).

AOap4 Clay-dominated sediments associated with a large back plain of the former Balonne River with minor sandy channel deposits.

ACap1 Sandy alluvium in levees and scroll bars associated with former channels of the Balonne River (Figure 28).

Tpd1 Fine silt and clay on a depositional plain surrounded by residual Cretaceous material.

ISub1 Well sorted aeolian sand in source bordering dunes adjacent to channels deposits (Figure 29).

In the east this unit is inset to geomorphic Geomorphic Unit 3. On the western side this unit lies adjacent to the modern Balonne floodplain (Geomorphic Unit 7). In the north the modern Balonne floodplain is inset to this unit, while to the south this unit is overlain by the Modern Balonne deposits. Two outcrops of Geomorphic Unit 1 occur within this unit to the south east. In the centre of the major area of Geomorphic Unit 1 there are two units, one of fine silt/clay and one of sorted sands, which have been incorporated into this major geomorphic unit for ease of representation. There are two RLU unit polygons of the modern Balonne floodplain in the south which have also been included in this geomorphic unit for ease of representation.

The materials associated with this unit are likely to be laterally extensive, especially to the west under current floodplain deposits. With depth it is likely that these materials display a complex intermixing of clays and channel sands. Depth of deposits around Geomorphic Unit 1 is locally quite shallow. AEM patterning indicates that conductive bedrock signatures are present at around 30-40 m in the middle and southern parts of the unit. The northern tip/extent may be quite deep, saturated with water or showing palaeo-drainage direction of sediments. AEM data also indicates that the clay rich backplain north of Geomorphic Unit 1 may extend to some depth, or that it may be underlain directly by conductive Griman Creek Formation.

Figure 28. Left – backplain in Geomorphic Unit 6. Right – sandy levee in Geomorphic Unit 6.

Figure 29. Source-bordering dune in Geomorphic Unit 6. Left – the rounded surface form, right – road cutting through the aeolian sand.

## 4.7 Geomorphic Unit 7. Modern Balonne floodplain deposits

The northern part this unit is confined largely to the present channel, which has large scale meanders but very little development of an extensive floodplain. In this area meanders have a maximum wavelength of 6 km (near St George) with a general range of 1 – 4 km. Further south the river diverges into an anastomosing floodplain with several sub-catchment scale river channels (Figure 3). In this area the unit has the form of a narrow very low angle fan (Figure 30). Flooding covered this area in 1996 (Figure 31).

Upstream of St George the river flows through a shallow gorge cut into Geomorphic Unit 1.

In the north surface materials are principally channel clays and sands. To the south, surface regolith materials are mainly clay rich floodplain and overbank deposits with small scale channel sands and overbank deposits. Clays range from grey to dark greys and commonly exhibit vertisol, and occasionally gilgai, structures.

The following regolith landform units are identified in this geomorphic unit:

AOaf1 Sand dominated levees and channel splay deposits of the modern Balonne floodplain, with minor source bordering dunes.

AOaf2 Grey clays of the modern Balonne back plain, commonly with well developed gilgai structures. There are local occurrences of vertisols and nodular carbonate accumulations. Minor sandy levee and channel bank deposits occur throughout.

ACar1 Channel silts and sands and minor levee and channel splay deposits of the modern Balonne and Maranoa River channels.

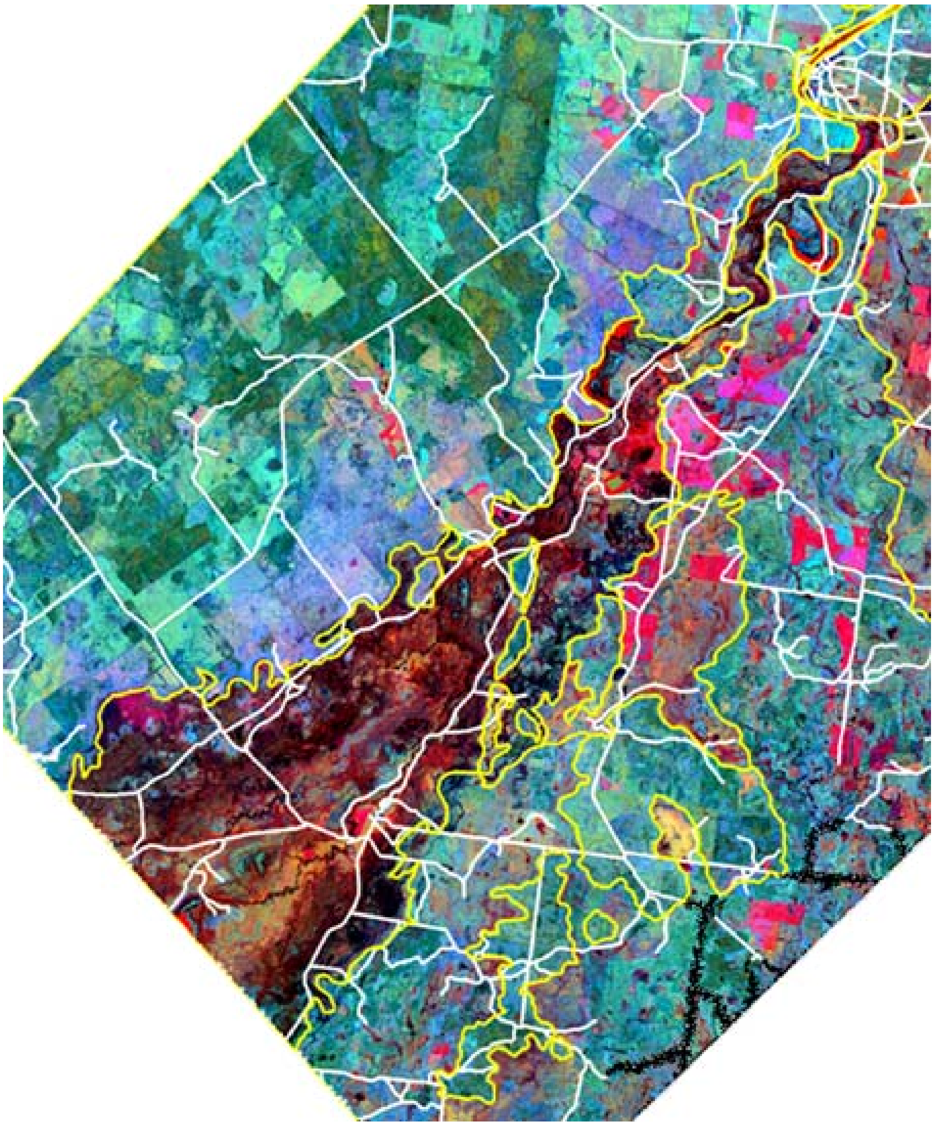

Figure 30. Geomorphic Unit 7 – modern Balonne floodplain, shown in brown tones on a Landsat TM image.

The eastern boundary of this unit is in part a younger continuation of the former Balonne floodplain deposits in geomorphic Geomorphic Unit 6, and in part deposition over the top of these former deposits. To the west of this unit is the older Maranoa surface – this boundary has a complex morphology. To the north the boundary is formed by lateral stream erosion. To the south the boundary is believed to be more actively controlled by water seepage from the Maranoa surface materials (see section 4.2), which causes retreat of the fan margin by sapping.

In the south the unit most probably thickens from a couple of meters in the west, near the active boundary with the Maranoa surface, to tens of meters in the mid west. To the east it most likely thins again to a couple of meters over the Former Balonne deposits before reaching its present boundary.

AEM images show a conductive, probably Griman Creek Formation, influence at a depth of around 20-30 meters in the centre of the unit which is probable, considering the proximity of the bedrock exposure to the east (Geomorphic Unit 1). Both north and south of this bedrock high resistive patterning suggests that the unit may continue to some depth.

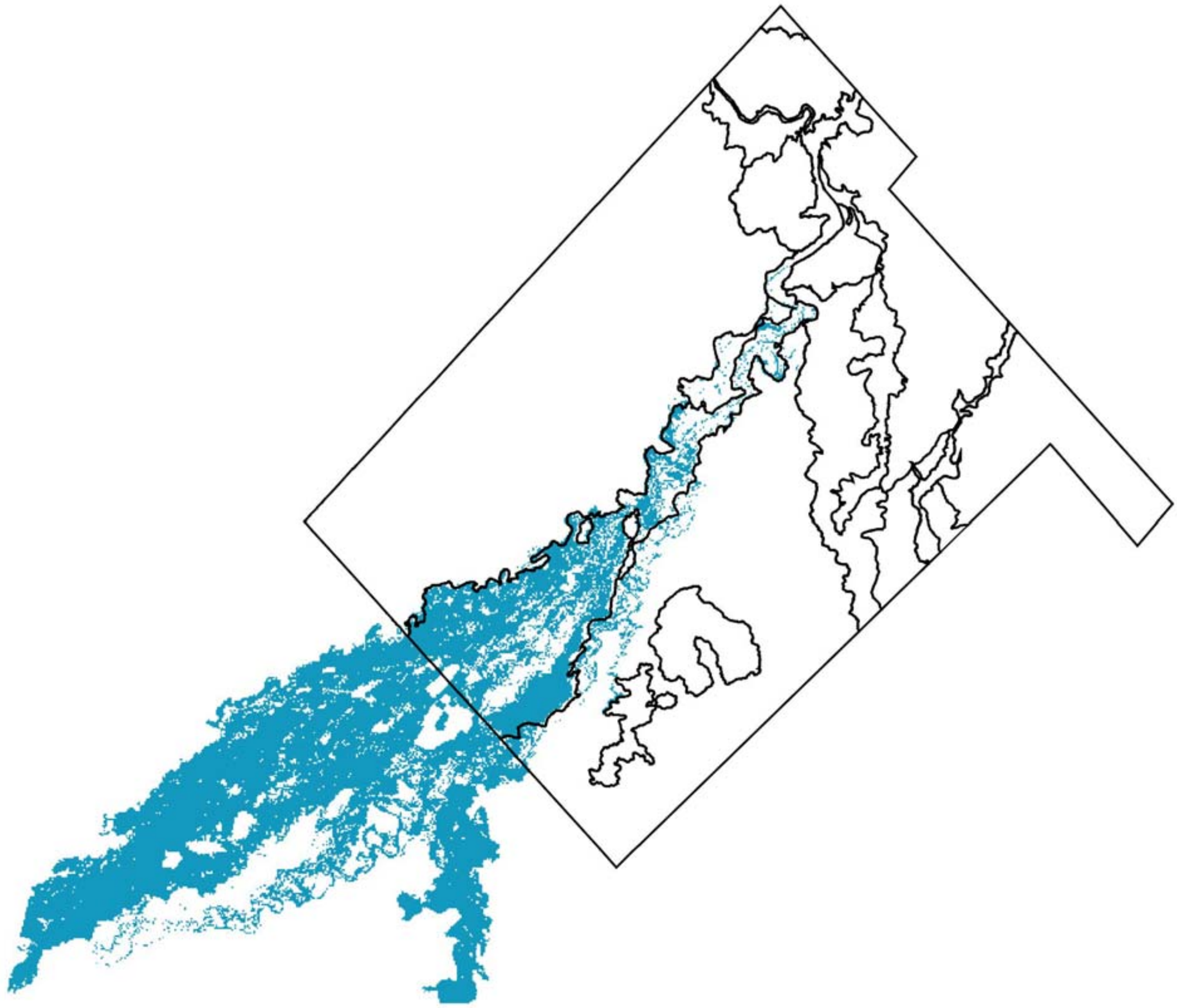

Figure 31. The extent of flood water during the January 1996 flood, showing that the flood covered most of geomorphic unit 7.

### 4.8 Geomorphic Unit 8. Modern Moonie River channel deposits

Channels in this unit have a low sinuosity, with small scale meandering channel deposits, levees, scroll bars and backplain areas. River morphology includes multiple meanders with wavelengths between 300 and 900 m with some larger multiple meanders up to 1.2 km. Also present within this unit are source-bordering dunes that occur mainly on the western side of the channel.

Surface materials range from channel sands in the modern channel, sands in levees and scroll bars, and clay deposits in backplain areas. The radiometrics image suggests that the dominant source of sediment in this unit is the Cretaceous Griman Creek Formation (Figure 23). Aeolian reworking of some channel sands in scroll bars and levee deposits has concentrated well sorted sands along the current channel in the south of this geomorphic unit.

The following regolith landform units are identified in this geomorphic unit.

Aaf1 Stream channels, levees and back plain deposits of the modern Moonie floodplain.

ISub1 Well sorted aeolian sand in source bordering sand dunes adjacent to channels deposits.

The Moonie River incises and overlays the residual weathering materials of the Griman Creek Formation in Geomorphic Unit 1, and older Moonie River alluvium of Geomorphic Unit 3b. The northern part of this unit is constrained by residual bedrock, has a confined lateral extent and is probably relatively thin. To the south the constraining unit is the older Moonie alluvium.

# 5. GEOMORPHIC PROCESSES AND LANDFORM EVOLUTION

Up to this point in the report we have delineated and described the types of landforms and regolith materials present in the Lower Balonne study area. However, in order to make full use of these descriptions we need to understand both the processes involved in their origin and the evolution of the landscape as we see it today.

## 5.1 Geomorphic processes

Three groups of processes are responsible for the evolution and character of the regolith materials in the study area. Here we give brief descriptions of these processes before going on to consider the evolution of the landscape.

***Weathering***

Weathering refers to any process which, through the influence of gravity, the atmosphere, hydrosphere and/or biosphere at ambient temperature and atmospheric pressure, modifies rocks, either physically, or chemically (Eggleton 2001). In the study area the Griman Creek Formation has undergone deep, although not particularly intense, weathering since its exposure at the surface in the late Cretaceous. This weathering has produced zones of bleaching and mottling, although these features are not necessarily continuous. Removal of more mobile materials from the upper part of the weathering profile has led to the development of residual sands up to 2 or 3 m thick in places. In some places mobilisation and reprecipitation of silica and iron has resulted in the formation of silcrete and ferricrete.

Weathering has also affected regolith on Geomorphic Unit 2, the Maranoa surface. This weathering has not been as intense as that on the Griman Creek Formation, nor has it been active for as long. Never-the-less, there are areas of residual sand that indicate removal of the more mobile elements, and silicification of sediments has been observed in some places.

Younger sediments in geomorphic Geomorphic Units 3 – 8 have also been affected by weathering, but only slightly because they are younger (less than 1 million years old).

***Erosion***

Erosion by water, in its broadest sense, takes place both on the surface and beneath. On the surface water flowing down slopes picks up particles and delivers them to streams, which are also a result of water erosion. Surface wash of particles from slopes has removed considerable amounts of sand from the top of the weathering profile on the Griman Creek Formation. This, together with the formation of valleys and the evolution of slopes gives us the surface form and regolith we see today in Geomorphic Unit 1. The same processes have also affected the surface of the Maranoa surface – Geomorphic Unit 2. Here the process is much more recent and thus has not had the same influence on surface form and regolith.

Sub-surface water movement also provides erosive power – more properly called denudation. Soluble materials are entrained in soil and ground water and moved, either to cause induration nearby, or to remove materials entirely. Although we have no measurements of the rates of either surface or sub-surface denudation, their rates are likely to be similar.

Wind is locally an important erosive force in the study area. Source-bordering sand dunes are found in a number of places, adjacent to active or former channels. They indicate that wind has entrained sand from bare channels and floodplains, and transported it, usually for short distances.

Rates of erosion will depend on, among other things, the nature of the surface materials. For example, duplex and sodic soils, and materials rich in fine sand, are more easily eroded by water than clays.

***Deposition***

Water-born sediments are found in all geomorphic units. However, in Geomorphic Unit 1 they are relatively unimportant, being confined to narrow valley floors, and small playa areas. Geomorphic Units 2 to 8, on the other hand, are dominated by water-born sediments. These sediments consist of channel and levee sands, and backplain deposits dominated by clay. They are a result of typical fluvial processes with a spatial pattern typical of fluvial systems. Channel sands form linear features and adjacent sandy levees are deposited close to the channels by overbank deposition. Backplains are further from the channels and result from deposition of fine materials carried over levees during floods. Some of the alluvial deposits, such as those in Geomorphic Unit 4, and in the northern parts of Geomorphic Units 6 and 7 are confined to incised channels; this is also the case with the southern part of Geomorphic Unit 6. Others, especially the major parts of Geomorphic Units 6 and 7, are formed by distributary channels that spread across an alluvial plain to form very low angle fans (Figures 27 and 30).

Wind deposition has been an important local process, forming the source-bordering dunes mentioned in sections 4.8 and 5.1.2. These dunes range from a few tens to a few hundreds of metres in size, are dominated by sand, and have a low rounded top surface (Figure 29).

***Comments on grain size***

Grain size distributions of samples collected from the area illustrate some of the points made above (Figure 32). Residual materials tend to be more mixed than many alluvial sediments (Figure 32 A, B, C, and D). Residual sand can be reasonably well sorted (Figure 32 C), and are a kind of lag deposit where fine material is removed by either surface or sub-surface water, leaving the coarser material behind. The size of the coarse material is controlled by the size range of particles in the underlying bedrock. Sample C, a better sorted sand than sample B, probably reflects its alluvial origin and shorter weathering history. Interestingly the grain size analyses did not show any samples dominated by silt-size particles, suggesting that wind-blown dust (parna) is not an important component of regolith in the study area.

Figure 32 E and F are from alluvial backplain areas. Sample E is from a typical backplain where clay is deposited from suspension during floods. Sample F is also from a backplain, but closer to a channel and levee, and thus contains more sand.

Sample G is from a levee adjacent to a former channel on Geomorphic Unit 6, and is very well sorted sand, as would be expected from a deposit derived largely from a sandy channel. Sample H comes from a source bordering dune adjacent to a former channel in Geomorphic Unit 6; its similarity to sample G shows clearly that it is derived from alluvial sand that has been transported only a short distance by wind.

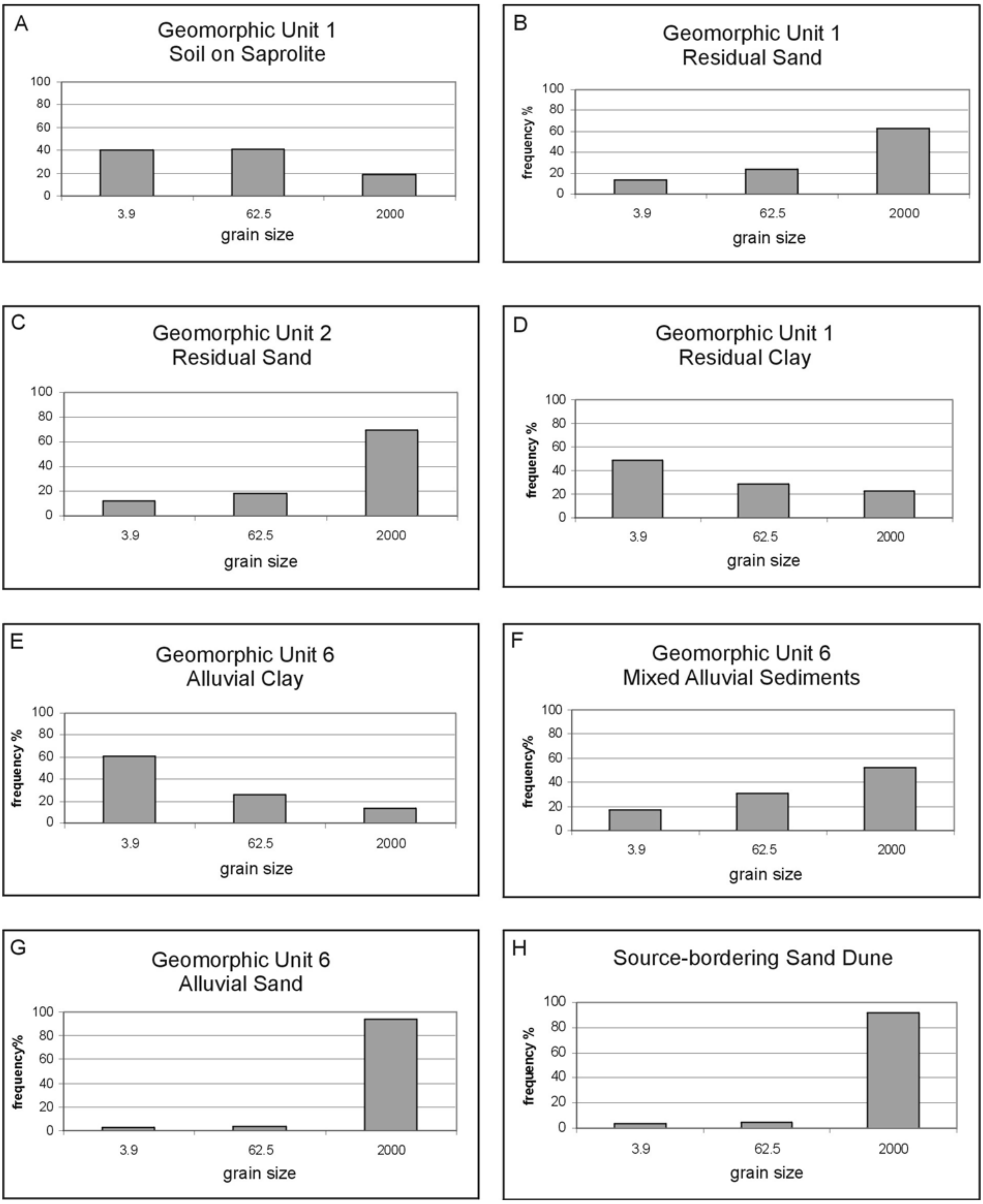

Figure 32. Grain size distributions for selected depositional materials.

## 5.2 Geomorphic history

In this section we describe briefly the events that shaped the landscape that now exists in the Lower Balonne area (Figure 33). Ages used here are set out in Table 4.

Table 4. Geological timescale and events for the Lower Balonne area

| Era | Period | Epoch | Basal age | Lower Balonne (Figure 32 stages) |
|---|---|---|---|---|
| Cainozoic | Neogene | Holocene | 11,000 - present | F |
| | | Pleistocene | 1.8 Ma | C, D, E |
| | | Pliocene | 5.3 Ma | B |
| | | Miocene | 23 Ma | ?B |
| | Paleogene | Oligocene | 33.9 Ma | ?A |
| | | Eocene | 55.8 Ma | |
| | | Paleocene | 65.5 Ma | Exposure of Kg |
| Mesozoic | Cretaceous | Upper | 99.6 Ma | Deposition of Kg |
| | | Lower | 145.5 Ma | |

Ma = million years

Note: Although *Tertiary* and *Quaternary* are commonly used in reference to the age of rocks or events, they are no longer part of the international geological timescale. However, where they are used, *Quaternary* refers to the Pleistocene and Holocene epochs (1.8 Ma to present) and *Tertiary* refers to the Paleocene to Pliocene epochs (65.5 – 1.8 Ma).

The origin of the materials within the Griman Creek Formation (Kg) (Unit 1) is well understood and is documented by Senior (1978, 1979). Originally deposited as marginal-marine and freshwater sediments in the Cretaceous, since exposure Kg has been slightly deformed and extensively weathered to form kaolinite, silcrete and ferricrete in various amounts (Senior 1978). Weathering and erosion of Kg since its exposure at the surface in the late Cretaceous has resulted in the present form of Unit 1.

There are very few clues to the early erosional history of the Kg surface, before the situation illustrated in Figure 33A. The highest parts of the study area are now northeast of St George, at a little over 250m above sea level (asl), and the Noondoo Rises, east of Dirranbandi, at up to 225 m asl. However, it would be expected that considerable erosion took place between the end of the Cretaceous when the area became land, and the Pliocene – Pleistocene, when much of the area was buried by younger sediments. Alluvial gravels on the Noondoo Rises are the only hint as to how this erosion impacted on the Kg landscape. The alluvial nature of these gravels indicates that the top of the Noondoo Rises was once a valley floor that has now become a hill, a process called relief inversion (Pain and Ollier 1995). However, we do not even know which way the "Noondoo palaeo-river" was flowing. The Noondoo Rises are more than 50 m higher than the surrounding area, and up to 100m above the buried Kg surface. This means that at least 100 m may have been eroded from the top of Kg between time of the "Noondoo palaeo-river" and the burial of the Kg surface by younger sediments.

Towards the end of the Tertiary, a valley (the Dirranbandi palaeo-valley – Clarke and Riesz 2004) formed on the western side of the study area, flowing from north to south (Figure 33A). It has been suggested that this valley may have formed by faulting along its eastern side, but there is not sufficient evidence of this – it may be a tectonic depression rather than a fault valley, and it was certainly deepened by erosion because its sediments lie directly on unweathered Kg. The bottom of the palaeo-valley is now as much as 200m below the present surface. Sediments within the valley fill have pollen ages of Early (?) Pliocene (MacPhail 2004), but it is likely that the valley is much older. Sediments nearer the base have not been dated, and might be as old as Miocene.

Thus, at some time in the Tertiary, sediments from the Maranoa and Condamine Rivers began to fill the Dirranbandi palaeo-valley from the north (Figure 33B). During this same period the Moonie River was bringing alluvium from further east, and transporting it in the Moonie palaeo-valley. Sediments gradually filled the valley, and then spilled over to the east, to be deposited onto the weathered and eroded Griman Creek Formation (Figure 33C). This last stage of deposition formed the Maranoa surface (Unit 2). At present there is little active channel flow on the Maranoa surface (Galloway *et al.* 1974) and it now has a slightly weathered and eroded form. The Maranoa surface is probably Late Quaternary in age, based on the Pliocene age of the sediments (MacPhail 2004).

During the deposition of the Maranoa surface, the Balonne River was diverted to its present course in a shallow gorge between two low hills in Unit 1 upstream from St George (Figure 33D). This shallow gorge has the appearance of antecedence, that is, the river originally flowed on a higher surface, and was subsequently lowered to cut the shallow gorge through which it now flows. This may have been a result of gradual uplift of Geomorphic Unit 1 in the area. After it changed course, the Balonne River flowed to the east of its present course, in the area now occupied by Geomorphic Unit 3a, which was deposited at this time. The large scale meanders present in the area suggest that the Balonne River may have been larger than it is at present. At the same time the Moonie River was bringing material from further east and, presumably because it was blocked by sediments from the Balonne River, began to share the same floodplain (Figure 33D). This Geomorphic Units 3a and 3b were formed at the same time, although the radiometrics suggest that at the surface there is very little mixing of sediments from the two sources.

Following the deposition of Unit 3, the Balonne River flowed for a time further east to form the small area of Unit 4. Wider channels and meanders and sand dominated deposits suggest a higher flow regime during the deposition of this unit compared with present-day deposition. The Balonne River then began its move to the west (Figure 33E) and formed Unit 5 after cutting the northern part of unit 4. Unit 6 appears to be have been formed by transgressive movement from east to west. It is marked by a great complexity and number of individual channel packages, some distributary and some anastomosing. The Modern Balonne River system, Unit 7, is a western continuation of Unit 6 (Figure 33F). In the north, the modern Balonne River is deep and well established and has been confined to the same channel since the beginning of formation of Unit 6. To the south the modern channel opens out onto an anastomosing plain with branching and reconnecting small scale channels. The floodplain and low terraces of the modern Moonie River are contained in Unit 8. Source bordering dunes have also formed along the western and eastern sides of the modern Balonne River and are prominent in large dunes in the south along the present Moonie River.

Following the deposition of Geomorphic Unit 4, the Balonne River cut slightly into the northern part of Geomorphic Unit 4 deposits to form the area of Geomorphic Unit 5 east of St George. At the same time, the part of Geomorphic Unit 5 upstream of Beardmore Dam was deposited from sediments supplied from the Maranoa and Condamine Rivers.

Geomorphic Unit 6 appears to have originated when the Balonne River flowed adjacent to Geomorphic Unit 3. Geomorphic Unit 6 appears to be have been formed by transgressive movement from east to west (Figure 33 D, E). It is marked by a great complexity and number of individual channel packages. Gentle tilting to the north-west may have influenced the movement of the Balonne River across this unit.

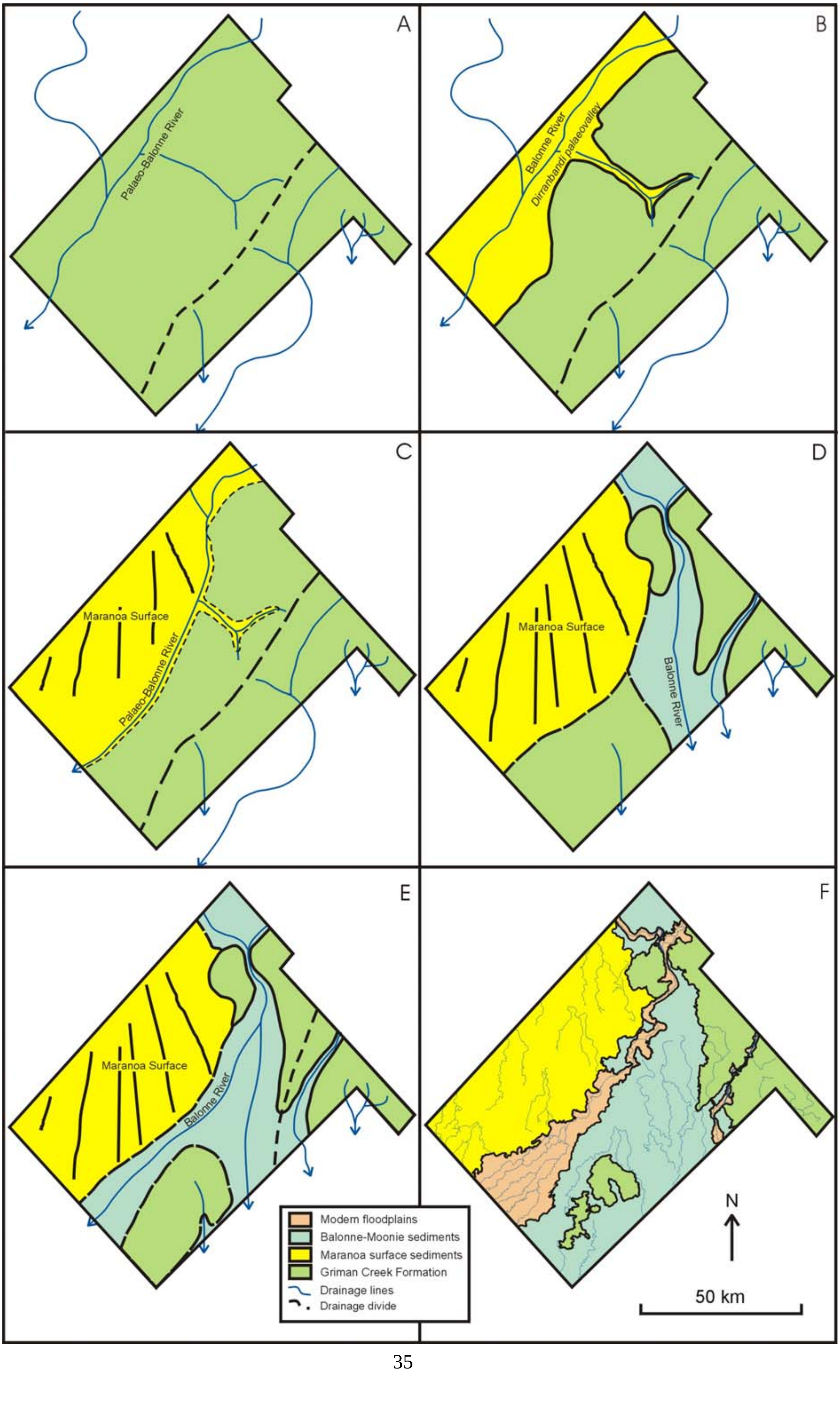
A
Palaeo-Balonne River
B
Balonne River
Dirranbandi palaeovalley
C
Maranoa Surface
Palaeo-Balonne River
D
Maranoa Surface
Balonne River
E
Maranoa Surface
Balonne River
F
Modern floodplains
Balonne-Moonie sediments
Maranoa surface sediments
Griman Creek Formation
Drainage lines
Drainage divide
N
50 km

Figure 33 (previous page). Diagrammatic representation of six stages in the development of the landforms of the study area, starting from erosion of the Griman Creek Formation during the Tertiary (A) through to the modern landscape (F).

The Modern Balonne River system, Geomorphic Unit 7, is a western continuation of Geomorphic Unit 6, at least in its southern part. In the north, the modern Balonne River is deep and well established and has been confined to the same area since the beginning of formation of Geomorphic Unit 6. To the south the modern channel opens out onto an anastomosing plain with branching and reconnecting small scale channels of the Balonne sub-catchment (Figures 3, 30).

Geomorphic Unit 8 is the floodplain and low terraces of the modern Moonie River.

During formation of the younger parts of Geomorphic Unit 6, and the modern Balonne and Moonie Rivers, there has been development of source-bordering dunes. Relatively large dunes are present along the present Moonie River channel (Figure 34). There are also sand dunes along the western and eastern sides of the modern Balonne River.

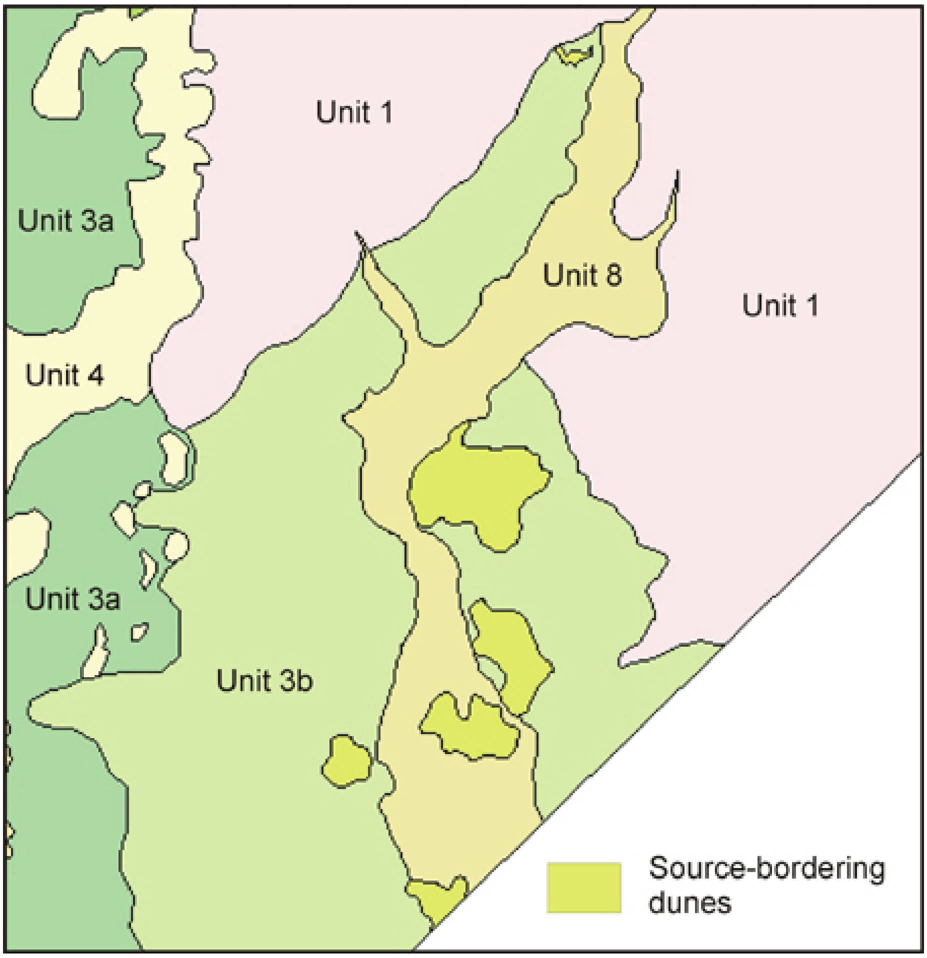


Figure 34. Source-bordering dunes associated with the modern Moonie River.

## 6. DISCUSSION OF DATA TYPES AND FORMATS

The purpose of this section is to assess the value of different data sources for compiling the regolith landform map, and for describing the characteristics of landforms and surface regolith in the area.

### 6.1 Landsat TM

Simple Landsat TM band combinations of 3 2 1 (visible spectrum) and 7 4 1 (for determining iron content, vegetation type, and clay) are quite effective for highlighting geomorphic and regolith landform units and separating out materials such as silica rich sands, clays and iron oxides. In the band combination 7 4 1 the iron oxide rich sands and sandy clays in the Maranoa surface stand out from the clay-rich areas, which could also have been showing a response from salt or gypsum.

Because there is a lot of mixing of signals from various materials in individual bands, PC analysis was used to further clarify the identification and extent of some materials, especially within Geomorphic Unit 6 where silica-rich channel sand deposits had a generally high spectral response within all bands and showed up bright compared to the generally more variable responses from water and clay which showed up darker. The areas of sodic soils on the Maranoa surface also have a bright light purple response which can be attributed to the salt content (Figure 21).

Landsat TM data was useful in terms of identifying geomorphic units, regolith landform units and material compositions and was one of the most valuable datasets over the area for this mapping exercise.

### 6.2 ASTER

ASTER data has a higher ground resolution than Landsat TM for the first three bands. However, for this study, much geomorphic information was obscured by increases in human activity in the 12 years between the acquisition of Landsat TM and ASTER. Moreover, the ASTER data were during a period of denser vegetation cover. For these reasons very little use was made of ASTER data in this study.

### 6.3 Gamma-ray Radiometrics

Initial unsupervised classification helped to define the extent of some of the geomorphic units. This was carried out from a RGB 3 band radiometric image of Th, K and U. This image was especially useful for interpretation of regolith landform units on a materials classification and was combined with aerial photographs and Landsat TM data for further clarification of form and boundaries. Radiometric images were useful for determining the location and extent of Griman Creek Formation because of its relatively high concentrations of U compared with alluvial deposits in the study area. Mixed provenance of material sourced from the Moonie River and Balonne River was identifiable in Geomorphic Unit 8 from the radiometric response. Large channel sand deposits from the Balonne River deposits were easily identifiable along with the large scale clay rich back-plains on the older Balonne floodplain (Geomorphic Unit 6) and interfluves of the Maranoa surface (Geomorphic Unit 2).

Unsupervised classification of radiometric data was undertaken to further separate materials. This helped to delineate Maranoa surface sub-divisions.

### 6.4 Digital Elevation Models

Neither of the available DEMs were good sources of information. The low relief in the area meant that the vertical resolution was not good enough for interpretation of small landform features. This made DEM interpretation of landforms for individual regolith landform units nearly impossible although, the data were good for an overall study area scale interpretation of elevation levels.

### 6.5 Air Photos

Air photos were relied upon extensively to clarify the interpretation from radiometric and Landsat data of regolith landform units, their internal variability and their boundary character. In the absence of a reliable DEM for the study area the air photos provided insight into elevation from stereoscope interpretation. Air photos were thus a primary source of data.

## 6.6 Comparisons with AEM data

Characteristics of AEM data are set out in other reports in this series. Here we discuss those elements of the surface AEM slice that contribute to an understanding of surface regolith materials.

The red speckled zones (Figure 35) were created by outlining the conductive areas within a conductivity depth interval (CDI) slice from the reprocessed AEM data at approximately 5-10 meters depth. The 0-5 meter CDI slice shows similar patterns but was not used for comparisons because the nature of data acquisition and processing techniques in the top 5 meters of AEM data is still somewhat unreliable compared with data at depth. These data show that regolith landform units mapped for this study are reflected in the upper two AEM slices.

There are also indications of strong AEM correlations with ground EM31 acquired over specific locations within the study area. Correlation coefficients have yet to be processed for the AEM and ground EM31 but a graph of a sample of the EM31 compared to the reprocessed AEM data over the same area shows a strong correlation between the two (Figure 36).

Confidence in the AEM patterns in the top 10 m is strengthened by the correlations between AEM patterns and surface mapping units.

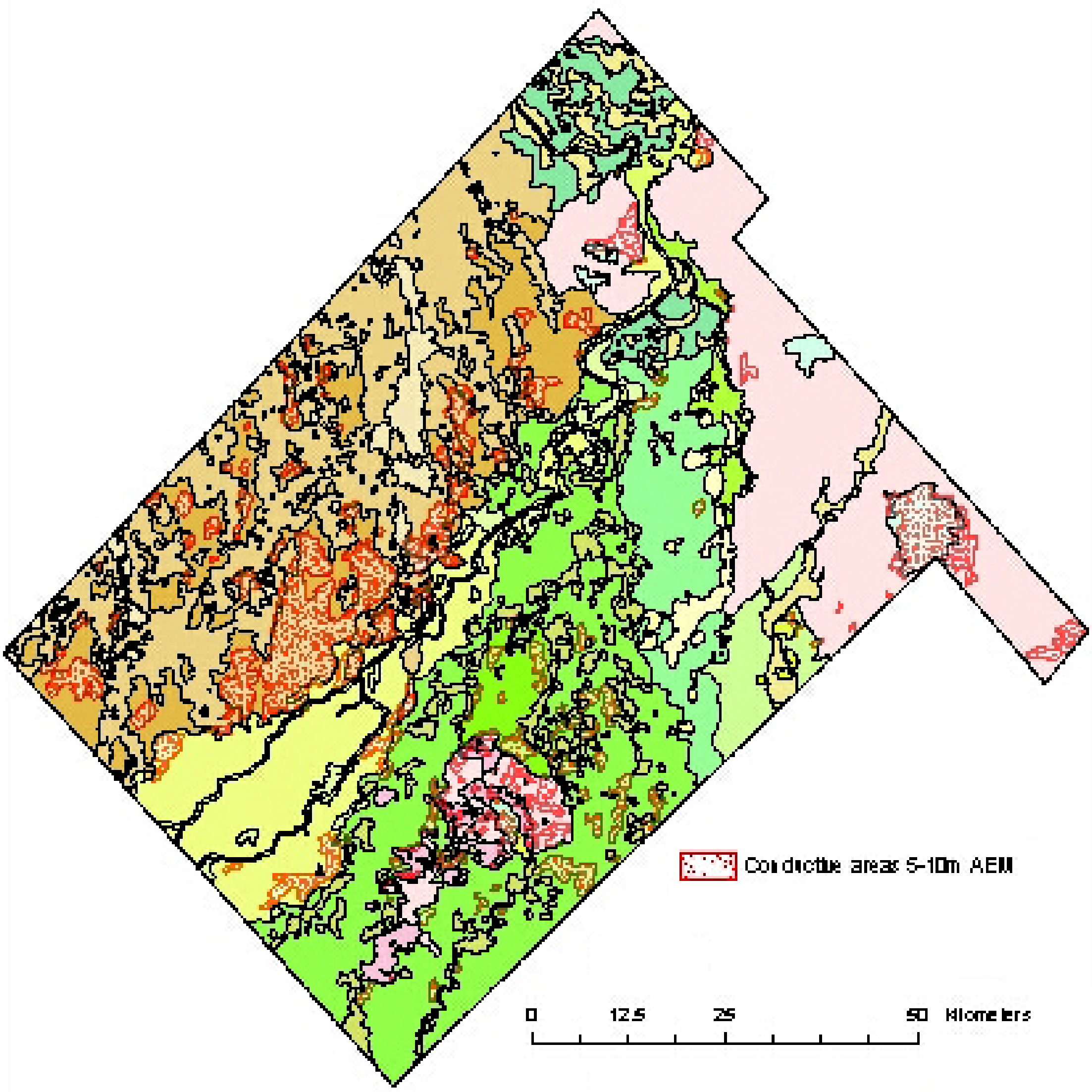


Figure 35. Geomorphic units with red stipple overlay showing areas with high conductivity in the 5-10 m slice.

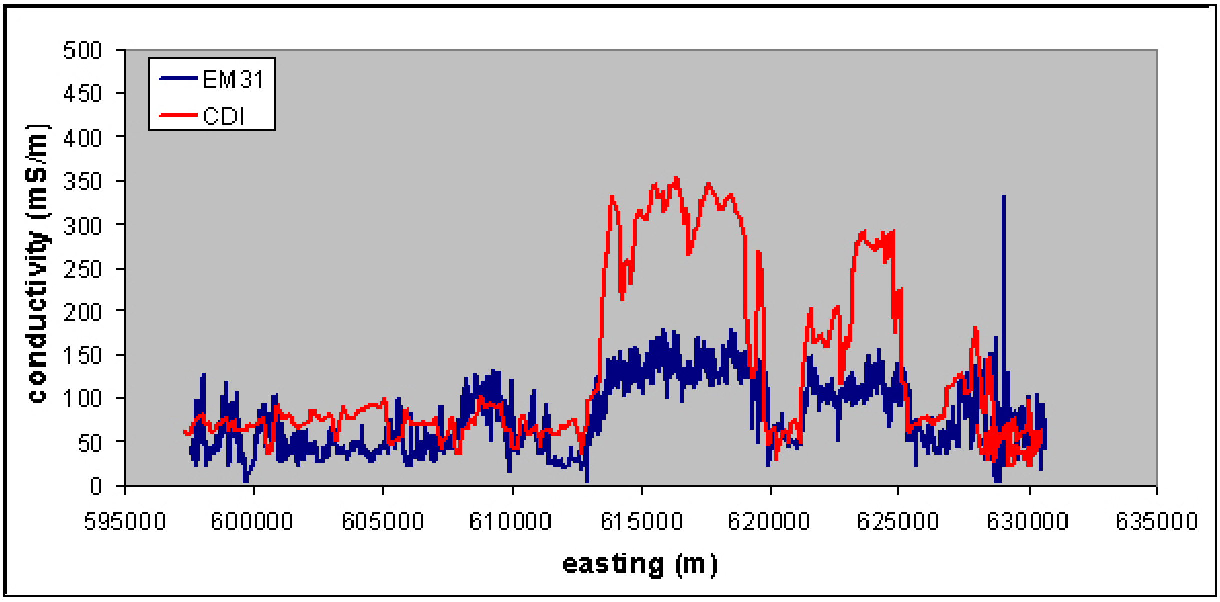


Figure 36. Comparison of EM31 (blue) and AEM data for part of the study area.

The general correlation between mapped surface units and AEM slices continues down to about 20 m. In the upper 10 m there is a very clear correlation (Figure 37), but this correlation is reduced markedly at the 20 m level (Figure 38).

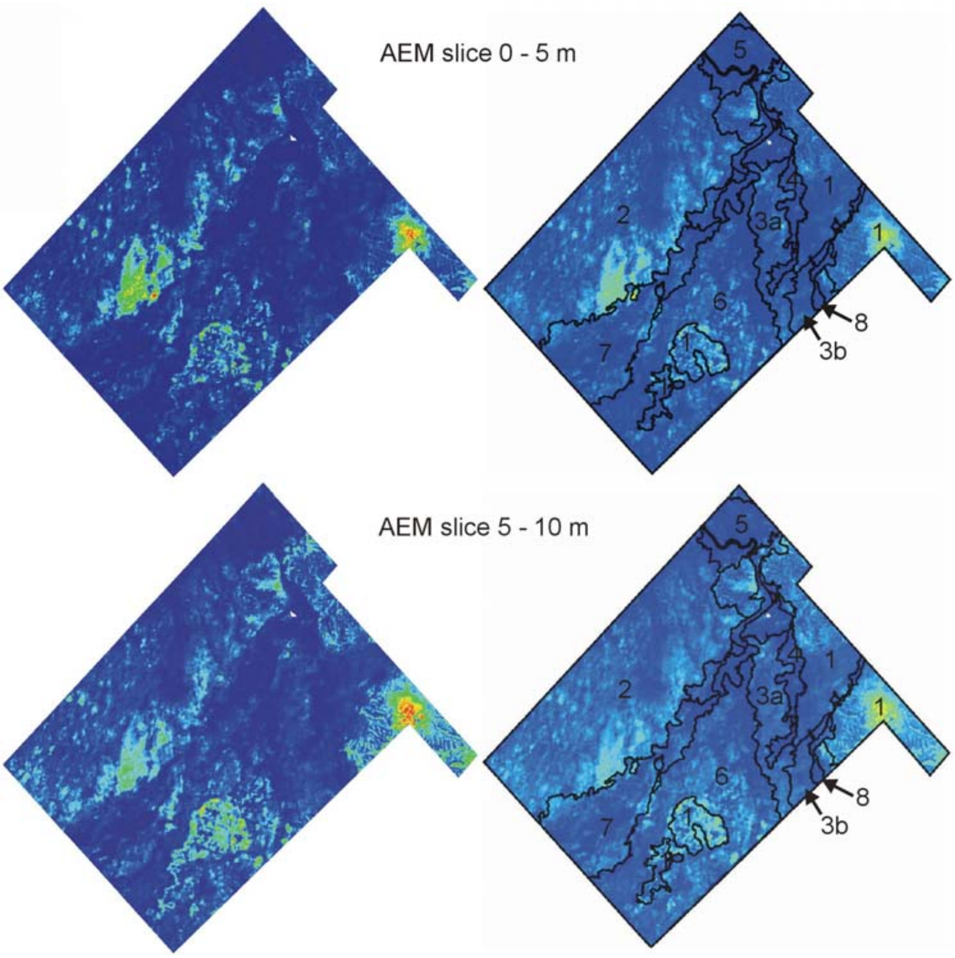


Figure 37. AEM slices 0-5 m and 5-10 m (geomorphic regions shown in outline on the right). Note the general correlation between geomorphic regions and AEM patterns, particularly along the eastern boundary of the Maranoa surface (geomorphic region 2).

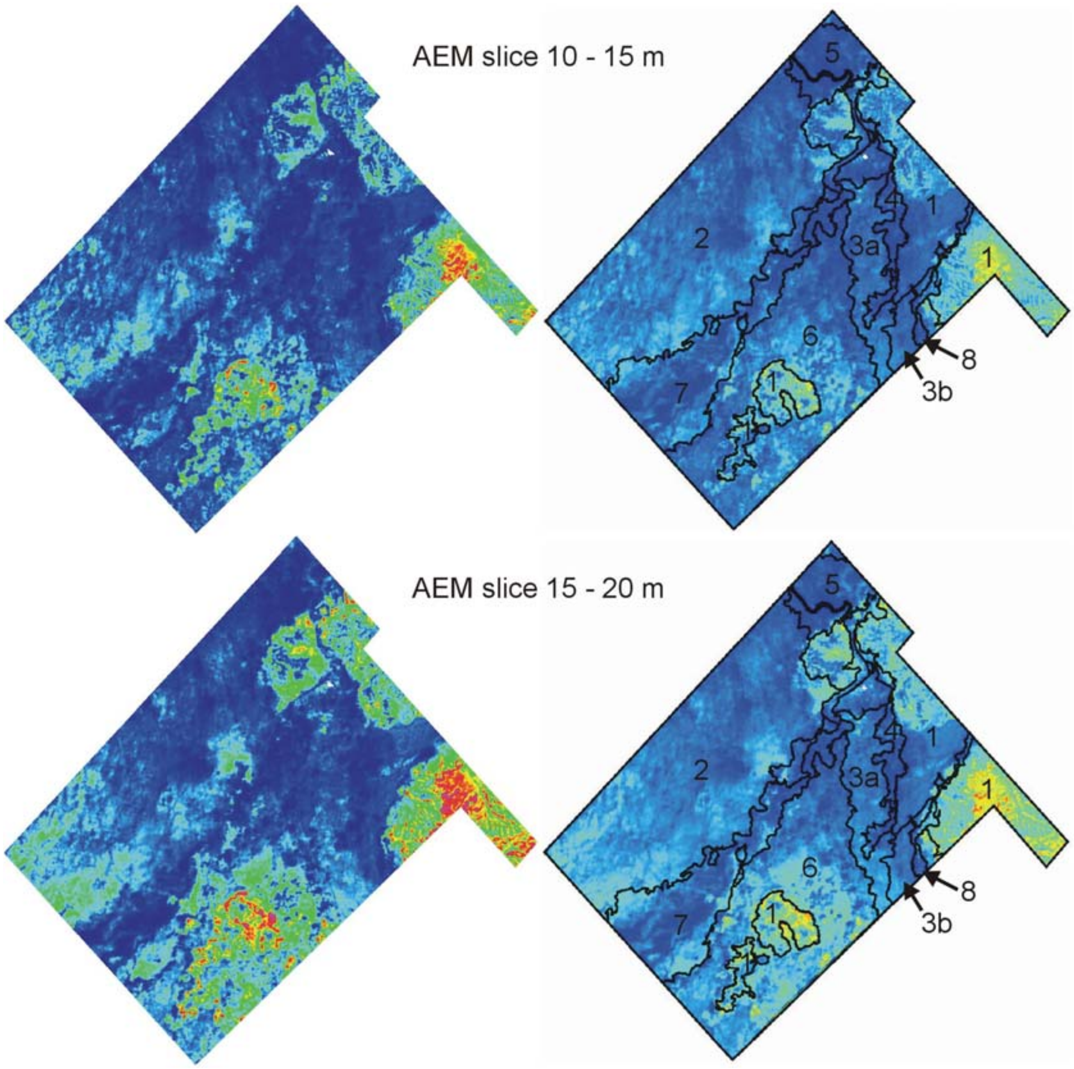


Figure 38. AEM slices10-15 m and 15-20 m (geomorphic regions shown in outline on the right). Note the general correlation between geomorphic regions and AEM patterns in the 10-15 m slice, particularly along the eastern boundary of the Maranoa surface (geomorphic region 2). Note also the breakdown in this correlation in the 15-20 m slice.

The general correlation down to 20 m between surface features and those visible in the AEM slices suggests that the AEM can be used with some confidence to predict the general patterns of 3D regolith distribution in the upper 10-15 m.

## 7. IMPROVEMENT OVER EXISTING WORK

Previous work in the area is outlined in the introduction of this report. The evaluation presented here compares the detail and value to NRM of the new regolith landform map with the previous geology and land system maps that provided the only information for the region until the present study.

The salinity hazard map was produced at regional scale from regional data by QDNRM&E, Murray Darling Basin Commission (MDBC) and Conservation Farmers Incorporated. This map was not intended nor detailed enough to be used at a catchment management scale. It indicated that the St George study area was possibly at high risk of salinisation, and was therefore a suitable area for detailed study.

The LBAGP is aimed at characterising sub-surface hydrology and salinity risks, and the surface regolith landform mapping component helps this characterisation.

## 7.1 Soil Maps

The key soil study areas mapped by QDNRM&E in 1998 focused on soil properties, which are inherently concerned with the top 5 meters of the soil profile. The nature of the survey meant that the soil materials are closely detailed but regolith properties, landscape development and processes are poorly covered in the descriptions. The survey data is also at specific locations within the catchment with no broad links to catchment evolution or processes that would help to interpolate the data to a catchment scale. Some of the soil attributes identified in the key soil survey areas were utilised in the identification of geomorphic units, but regolith properties were the focus rather than detailed soil properties in subsequent field work. In this way, the mapping units were characterised by regolith material descriptions and are more applicable to sub-surface correlations than the existing land-system and detailed soil sites maps.

## 7.2 Geology Map

The geological units shown in Figure 7 are briefly discussed in Section 2.4. The geology map and the accompanying notes are useful background information, especially the discussion of the characteristics of the Griman Creek Formation. However, the maps are not as useful as the regolith landform map for the following reasons:

1. The geological map units have mixed materials and origin, which makes their value for extrapolation lower.

2. The geological units are generalised, as would be expected at their scale of compilation. This is shown particularly in the north and west of the study area, where the Maranoa surface is shown as one unit on the geology map.

## 7.3 Land Systems Map

Galloway *et al*. (1974) carried out a land system survey over the more extensive Balonne-Maranoa area., and that part of their map covering the Lower Balonne study area is included here as Figure 39. Their survey was carried out over a three year period and the main purpose of their study was to map the area in terms of its land use capacity in relation to vegetation cover, climate and landforms. It is thus more similar in concept to a regolith landform map than any of the other surveys carried out previously to the one reported here, and is the baseline against which we can compare the regolith landform map. Unfortunately, although the map shows land systems, the accompanying text describes land units, subdivisions of land systems that are not mapped.

The primary basis of classification of mapping units was vegetation cover with supporting evidence from geology, landforms and soils. Groupings were carried out according to 10 types of materials and 23 classes of vegetation and the resulting map could be used as a surrogate for dominant vegetation types. This infers that the land systems map produced over the region in 1974 had a primary emphasis on vegetation rather than regolith materials.

The following are brief descriptions of the land systems present in the study area, taken from the original map legend:

21 – Rolling terrain, low hills, and shallow stony massive soils. In the study area it occupies a small area on the northeast.

14 and 15 – These land system occupy polygons in the northern part of the study area. They consist of moderately weathered sedimentary rocks on lowlands with massive earth soils. They are differentiated on the basis of vegetation.

16 and 17 – These land systems are also on moderately weathered sediments. They consist of undulating lowlands with massive earths and duplex soils. Sixteen is in the northern part of the study area, and 17 coincides with the Noondoo rises in the south.

20 and 21 – Poorly resistant weathered sediments form the basis of these two land systems. They consist of lowlands with duplex soils and cracking clays with some gilgai.

22 and 23 – These land systems are plains on Late Cainozoic sands, silts and mixed fine sediments, on the Maranoa surface. Uniform soils occur in 22 and massive earths in 23.

26 – This land system consists of plains on Late Cainozoic clays, with cracking clay soils and frequent gilgai.

28 and 30 – These land systems are formed on alluvial sands, silts, and mixed fine sediments. Higher alluvial plains and levees with duplex soils comprise 28, while 30 consists of alluvial plains also with alluvial soils.

31 and 33 – These land systems are formed on alluvial clay. They occur on lower alluvial plains and back swamps, with cracking clay soils.

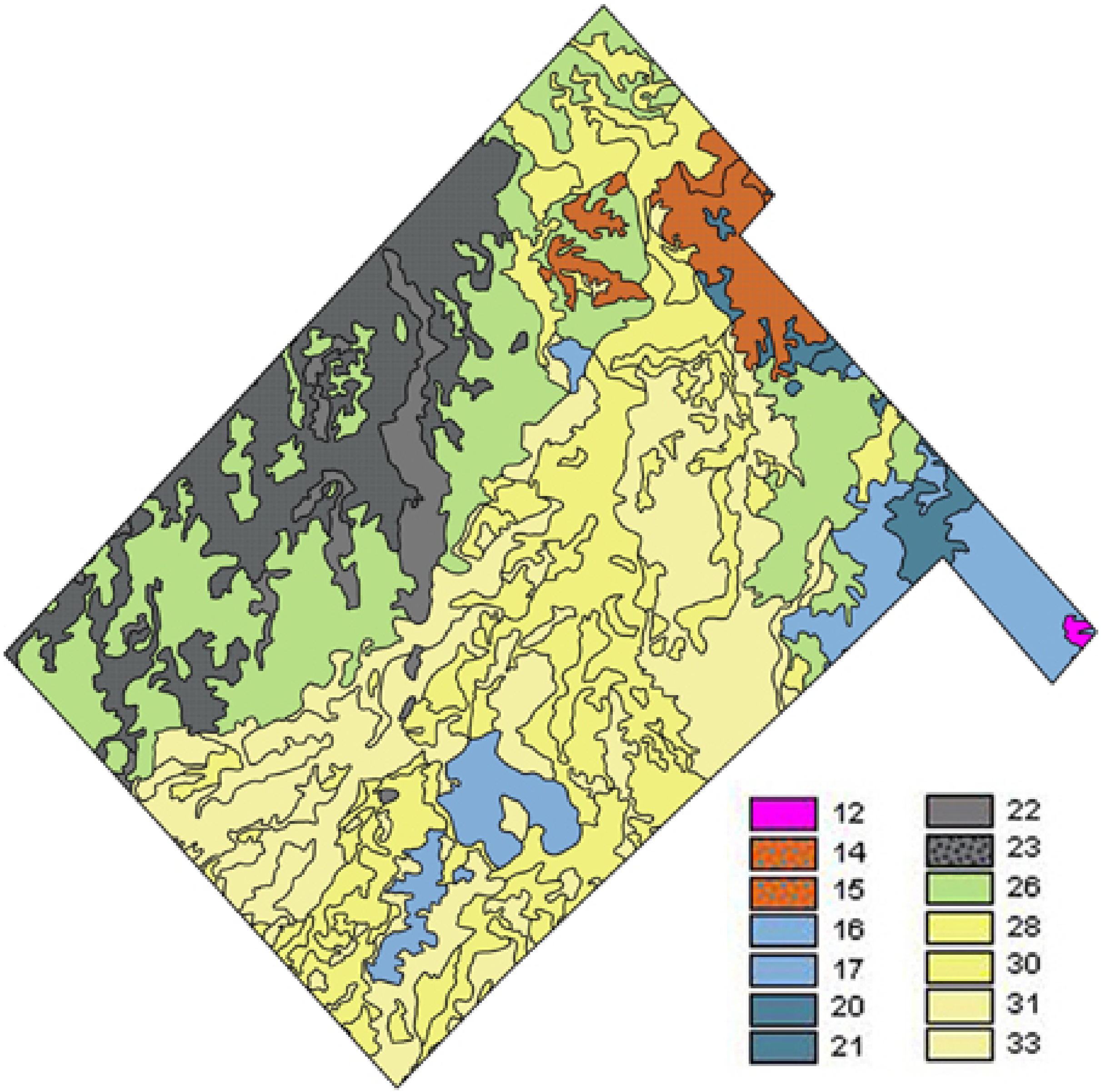


Figure 39. Land system map of the Lower Balonne study area, from Galloway *et al*. (1974).

### 7.4 General Comments

Table 5 gives a comparison between the geomorphic units and regolith landform units mapped for this study and their equivalents from the geology and land system maps from previous surveys. There are no clear one-to-one relationships. The geological units are too general for the type of information sought for this survey. The same holds for the land systems. In part this is because of the map scale, in that the geology and land systems maps are at 1:250 000 and 1:500 000 respectively, while the regolith landform map presented here is at 1:100 000. The land units described by Galloway *et al*. (1974) may be equivalent to regolith landform units, but this cannot be checked because there is no map of land units.

The scale of the regolith landform map is more suitable for addressing catchment management issues than either the geology map or the land systems map. The regolith landform map is based upon regolith properties and highlights regolith material and geomorphic processes. It is therefore directly applicable to sub-surface correlations for groundwater and salinity management issues which rely heavily on material properties and sub-surface morphology.

Table 5. Geomorphic units and regolith landform units from this study and their geology and land system equivalents.

| Geomorphic Units | Geology | Land Systems | Regolith Landform Units |
|---|---|---|---|
| 1 | Klg>w, Qs/Klg, T | 12, 14, 15, 16, 17 | RSep1, SPer1, Lpp1 |
| 2 | Qs/Cz | 22, 23, 26 | RSap1, RSap2, RCap1 |
| 3 | Qa, Qs | 26, 30, 31 | AOap2, AOap3, ACap2 |
| 4 | Qa, Qs | 28, 30 | AOap5, ACap3 |
| 5 | Qa | 26, 28, 30 | AOap6, ACap4 |
| 6 | Qa, Qs | 28, 30, 31, | AOap1, AOap4, ACap1, Tpd1, ISub1 |
| 7 | Qa, minor Qs | 28, 30, 31, 33 | AOaf1, AOaf2, ACar1 |
| 8 | Qa | 30, 31 | Aaf1, ISub1 |

As noted in the methods section, the regolith landform map makes full use of the airborne geophysics obtained for the present study. However, had the geophysics data not been available, a combination of the geology and land system maps, with field checking and use of the Landsat TM and ASTER images, would have allowed the compilation of a product that would have given similar, if not as accurate, information. Certainly the regolith landform map units would have been very similar. Without the radiometrics, however, the spatial accuracy of the map would not be as good.

## 8. REGOLITH LANDFORM INFORMATION AND SALINITY HAZARD ASSESSMENT

The regolith landform map highlights some important points for land use planning in the study area. Four of these are discussed briefly below.

### 8.1 Complexity of the weathering profile on the Griman Creek Formation

The nature of the weathering profile on the Griman Creek Formation has been described in Section 4.1. The main points are that it is complex in three dimensions, and therefore there is the distinct likelihood that there is considerable vertical as well as lateral water movement within this material. It also seems likely that this complexity will be present within the top part of the buried land surface on this rock unit, and that the exposed surface and its associated regolith provide a useful analogue for its buried equivalent. This means that the hydrological properties of the upper part of the Griman Creek Formation are likely to be more complex than if the weathering profile were a simple and consistent “layer cake” zonation. These points should be taken into account when modelling water movement through this unit.

### 8.2 Distribution of sodic soils, and evidence of seepage on the Maranoa surface

Section 4.2 notes the presence of sodic soils on the distal part of the Maranoa surface, and the geomorphic evidence for seepage in the same area. Surface sampling information, although sparse, suggests that this region is clay rich, with gypsum present in varying amounts. Sodic soils suggest the possible presence of salt near the surface. Salts stored within this area could be mobilised through increased near surface drainage. The seepage features noted above do not indicate movement of groundwater, which is at some depth in the area (B. Pearce pers. com.). Rather they suggest intermittent lateral movement of water close to the surface during wet periods when the soil is saturated. The modern Balonne River has an active erosional boundary with this area, which provides a pathway for any salt released to be further dispersed in the modern Balonne floodplain. Sources for this sodic or saline material are unknown but could originate from the underlying Griman Creek Formation or from saline ground waters.

There are other areas displaying surface AEM conductivity further to the north along the Maranoa surface boundary that also warrant further study.

### 8.3 Location and character of former channels in Geomorphic Units 3-6

The older Balonne, Maranoa and Moonie alluvial surfaces all show evidence of former channels and levees dominated by sandy sediments, in contrast to areas of back plains where clays are much more dominant. Of the various images used in this study, the radiometrics in particular allows the recognition of these former alluvial environments. Geomorphic Units 3-6 all show evidence of sandy channels and levees, and these are particularly obvious in units 5 and 6 (Figures 26, 27). These channels can in many cases be reconstructed, as for example, in Figure 40.

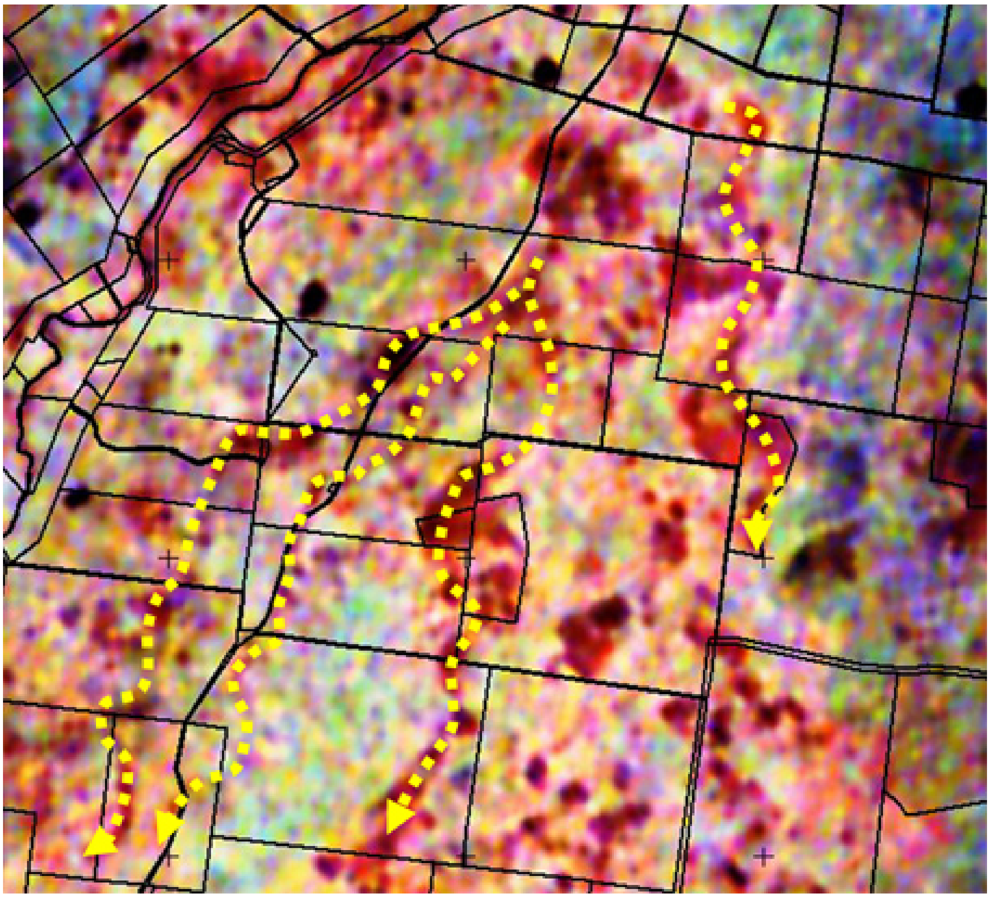

Figure 40. Radiometric image of part of Geomorphic Unit 6 showing reconstruction of channels in yellow. Other channels that can be reconstructed are also present.

The fact that these former channels are continuous and linear at the surface has important implications for the distribution of various alluvial lithologies at depth. The surface pattern on Geomorphic Units 3-6 is similar, although altered to varying degrees depending on age of the surface. Given the reasonable assumption that these units all evolved by the same processes that produced the surface pattern, the buried pattern of lithologies must be similar. Only the spatial locations of former channels will change. This means that there will be preferred sandy pathways for movement of water at depth. There is also the distinct possibility that there is at least some connection between the surface sandy deposits and those at depth, thus allowing vertical movement of water as well. These factors must clearly be taken into account when modelling ground water flow in and under these units.

## 9. CONCLUSIONS

The surface distribution of regolith materials on most geomorphic units is a fair indication of the complexity of regolith materials at depth. We can describe the pattern of distribution of sands, for example, even if we can not predict their actual location. The only unit where this generalisation falls down is Geomorphic Unit 2, where surface weathering and erosion has caused the surface distribution of materials on the Maranoa surface to be quite different from subsurface material distribution. However, overall knowledge of the surface distribution of regolith materials, and the processes that are responsible for that distribution, can be used as part of the input into models of the 3D regolith architecture, and of the evolution of the Lower Balonne landscape.

This study of the regolith and landforms of the Lower Balonne area highlights a few areas that have a higher salinity hazard than most of the study area. These areas are mainly along the eastern boundary of the Maranoa surface. This boundary is the major area of concern for salinity hazard because of its sodic soils, the active seepage that appears to be going on in the area, and its proximity to the Balonne River.

The regolith landform map produced here was compiled mainly from Landsat, ASTER and radiometric imagery. The latter in particular allowed more accurate location of regolith materials than the former two. However, the surface map could have been compiled from existing information, without the airborne geophysical data. The important point here is that all the Landsat, ASTER and radiometric images, and the resulting map, are about the surface, and perhaps to a depth of 2-3 m. Yet, as other reports in this series will show, the surface information is only part of the story, and is in many respects misleading in that it gives no clue to the shape of the important boundary between the Griman Creek Formation and the overlying sediments that form most of the study area.

The regolith landform map is certainly of adequate scale to allow planning at a sub-catchment and perhaps farm scale. Importantly, when used in conjunction with the radiometric images, it shows situations where multiple land holdings must be involved in any planning exercise, because it shows the surface connectivity of the different regolith materials.


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## APPENDIX 1. Climate averages for St George Post Office

Commenced: 1881; Last record: 1997; Latitude (deg S): -28.0361; Longitude (deg E): 148.5814

| Element | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean daily maximum temperature - deg C | 34.5 | 33.4 | 31.5 | 27.6 | 22.9 | 19.6 | 19 | 21 | 25 | 28.7 | 31.9 | 34.3 | 27.5 |
| Mean no. of days where Max Temp >= 40.0 deg C | 1.8 | 0.7 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 1.7 | 4.8 |
| Mean no. of days where Max Temp >= 35.0 deg C | 14.6 | 10.4 | 4.4 | 0.5 | 0 | 0 | 0 | 0 | 0.3 | 2 | 7.3 | 13.9 | 53.3 |
| Mean no. of days where Max Temp >= 30.0 deg C | 27.3 | 24.8 | 22.6 | 8.2 | 0.2 | 0 | 0 | 0.3 | 4 | 11.9 | 20.6 | 26.6 | 146.5 |
| Highest daily Max Temp - deg C | 45 | 43 | 40.5 | 37.2 | 32.6 | 27.8 | 28.8 | 34.4 | 36.2 | 40.7 | 43.3 | 44 | 45 |
| Mean daily minimum temperature - deg C | 21.5 | 21.1 | 18.5 | 14.1 | 10 | 6.7 | 5.4 | 6.9 | 10.2 | 14.6 | 17.6 | 20.2 | 13.9 |
| Mean no. of days where Min Temp <= 2.0 deg C | 0 | 0 | 0 | 0 | 0.2 | 2.3 | 6.1 | 2.4 | 0.2 | 0 | 0 | 0 | 11.2 |
| Mean no. of days where Min Temp <= 0.0 deg C | 0 | 0 | 0 | 0 | 0 | 0.3 | 1.1 | 0.2 | 0 | 0 | 0 | 0 | 1.6 |
| Lowest daily Min Temp - deg C | 12.8 | 12.2 | 7.8 | 3.3 | 0.5 | -2.2 | -1.7 | -1 | 1.5 | 4.9 | 8.3 | 11.1 | -2.2 |
| Mean 9am air temp - deg C | 27.2 | 26.2 | 24.2 | 20.4 | 15.7 | 11.8 | 11.1 | 13.5 | 17.9 | 21.9 | 25.2 | 27.1 | 20.2 |
| Mean 9am wet bulb temp - deg C | 20.3 | 20.2 | 18.5 | 15.6 | 12.5 | 9.5 | 8.4 | 9.8 | 12.5 | 15.3 | 17.4 | 19.2 | 14.9 |
| Mean 9am dew point - deg C | 15.8 | 16.3 | 14.3 | 11.5 | 9.8 | 7.1 | 5.2 | 5.7 | 6.9 | 9.5 | 11.1 | 13.7 | 10.6 |
| Mean 9am relative humidity - % | 51 | 57 | 56 | 58 | 67 | 73 | 69 | 60 | 51 | 47 | 44 | 46 | 57 |
| Mean 9am wind speed - km/h | 11.2 | 11 | 11 | 9.7 | 8.1 | 7.4 | 8.1 | 9.8 | 11.5 | 13.6 | 11.9 | 11.2 | 10.4 |
| Mean 3pm air temp - deg C | 32.9 | 32.4 | 30.4 | 26.9 | 22.2 | 18.9 | 18.2 | 20.1 | 24.1 | 27.6 | 30.5 | 32.7 | 26.4 |
| Mean 3pm wet bulb temp - deg C | 21.4 | 21.5 | 19.8 | 17.5 | 15.2 | 12.7 | 11.6 | 12.5 | 14.4 | 16.7 | 18.5 | 20.3 | 16.8 |
| Mean 3pm dew point - deg C | 13.4 | 14.4 | 12.2 | 9.8 | 8.8 | 6.4 | 4.2 | 3.7 | 4.5 | 6.7 | 8.5 | 11 | 8.7 |
| Mean 3pm relative humidity - % | 35 | 37 | 36 | 37 | 45 | 46 | 42 | 36 | 31 | 30 | 29 | 30 | 36 |
| Mean 3pm wind speed - km/h | 10 | 10.1 | 10 | 8.9 | 9 | 9.2 | 10.5 | 10.9 | 11.1 | 11.2 | 11.3 | 10.2 | 10.2 |
| Mean monthly rainfall - mm | 74.7 | 61.3 | 54.4 | 32.7 | 39 | 33.3 | 33.1 | 25.3 | 26.7 | 38.8 | 45.8 | 51.8 | 516.8 |
| Median (5th decile) monthly rainfall - mm | 56.2 | 45 | 35.3 | 16.3 | 23.5 | 25.3 | 26.6 | 16.8 | 21 | 29.5 | 33.3 | 43.5 | 496.6 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9th decile of monthly rainfall - mm | 151.9 | 146 | 144.7 | 81.9 | 87.7 | 73.3 | 79.3 | 57 | 64 | 85.2 | 105.3 | 106.7 | 761.2 |
| 1st decile of monthly rainfall - mm | 10.6 | 5 | 2.4 | 0 | 0.5 | 3.6 | 0.8 | 0.4 | 1.3 | 2.9 | 4.8 | 9.5 | 303.6 |
| Mean no. of raindays | 6.3 | 5.1 | 4.7 | 3.2 | 4 | 4.2 | 4.4 | 3.7 | 3.8 | 5 | 5 | 5.5 | 54.7 |
| Highest monthly rainfall - mm | 415.7 | 292.7 | 360.2 | 203.8 | 310 | 151.7 | 261.2 | 136.9 | 128.2 | 156.8 | 181.8 | 172.7 | 116.4 |
| Lowest monthly rainfall - mm | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 116.4 |
| Highest recorded daily rainfall - mm | 138.2 | 116.3 | 218.7 | 88.9 | 192.4 | 57.2 | 68.1 | 48.8 | 55.4 | 81.5 | 74.2 | 107.2 | 218.7 |
| Mean no. of clear days | 13 | 10.8 | 14.8 | 14.7 | 12.8 | 14.9 | 16.9 | 17 | 17.7 | 14.6 | 13.5 | 12.8 | 173.5 |
| Mean no. of cloudy days | 7.7 | 6.3 | 6.1 | 5.3 | 7.8 | 6.3 | 5.6 | 5.3 | 4.5 | 5.6 | 5.7 | 6.4 | 72.7 |

Source: http://www.bom.gov.au/climate/averages/tables/cw_043034.shtml (10 July 2003)

## APPENDIX 2. Data sources

| TYPE | WHEN AQUIRED | WHO BY | DATA FORMATS | SCALE | COMMENTS |
|---|---|---|---|---|---|
| Landsat TM5 and TM7 | 1988, 1999, 2000 | ACRES and Geoscience Australia | RGB and pseudocolour images of the band combinations 7,4,1. 3,2,1. Principle component pseudocolour and RGB colour images of PC1 and PC2 | 30 m pixels | |
| AEM survey | June - August of 2001 | Tesla Airborne Geoscience Pty Ltd | RGB colour composite image of CDI slices at 0-5 and 5-10, 10-15, 15-20, 20-30, 30-40, 40-60, meters depth. | 250 and 400 m line spacing | |
| Ground Electromagnetic survey - Ground EM31 | September-October 2002 | QDNRM&E | RGB colour composite image | depth of reading 4-6 meters | |
| Gamma-ray Radiometrics | April - May of 2001 | Tesla Airborne Geoscience Pty Ltd, for BRS? | RGB colour composite images of the 3 bands K, Th U, red, and green, blue. A 9 band RGB colour composite image derived from an unsupervised classification of band values. | 25 m pixels | |
| Digital Elevation Model (DEM) | April - May of 2001 | Tesla Airborne Geoscience Pty Ltd, for BRS? | Flown at same time as magnetic susceptibility survey | 100 m line spacing | |
| Digital Elevation Model (DEM) | June - August of 2001 | Tesla Airborne Geoscience Pty Ltd | Flown at same time as AEM survey | 250 m line spacing | |
| ASTER | 2000 | Geoscience Australia | Principal components pseudocolour images PC1 and PC2. | bands 1-3 15 m<br>4-9 30m 10-90 m | |

| | | | | |
|---|---|---|---|---|
| Aerial photographs | June, July and September 1963 | Department of Minerals and Energy Division of National Mapping, (AUSLIG) | Black and white photographs | ~ 1:80 000 |
| Detailed soil mapping areas - 4 Key areas soil survey | 1998 | QDNRM&E | Soil attributes and soil chemistry, arcGIS coverage maps and point data. | 1:100 000 |
| Surface regolith sampling | September 2002 and March 2003 | CRC LEME | ArcGIS coverage points with attributes recorded in RT-MAP format. | |
| Palanology | May 2003 | CRC LEME | Geological age determination from bore hole samples. | at intervals in selected drill cores where suitable material occurred |

## APPENDIX 3. Landsat TM bands spectral range and responses

| Band | Wavelength (um) | Description | General spectral responses and characteristics | Regolith spectral responses |
|---|---|---|---|---|
| 1 | 0.45 - 0.52 | Visible Blue | Ferric and ferrous iron absorption. | Ferruginous duricrusts, ferruginous saprolite low. Heamatitic iron very low. Kaolinite high. |
| 2 | 0.52 - 0.60 | Visible Green | Ferric iron absorption and ferrous iron reflection. Chlorophyll reflection peak. | Ferruginous duricrusts, ferruginous saprolite low. Kaolinite high. |
| 3 | 0.63 - 0.69 | Visible Red | Short-wavelength shoulder of ferric iron reflection. Ferrous iron absorption. Chlorophyll absorption. | Moderate reflection for goethiitic and heamatitic iron. Kaolinite high. |
| 4 | 0.76 – 0.90 | Near Infrared | Short-wavelength shoulder of ferric iron and ferrous iron absorption. Vegetation reflectance peak. | Moderate reflection for goethiitic and heamatitic iron. Kaolinite high. |
| 5 | 1.55 - 1.75 | Middle Infrared | Highest reflection for most rock types. High reflection peak for hydrothermally altered rocks. Vegetation absorption. | Highly reflective for heamatitic Ferruginous duricrusts and ferruginous saprolite and clays. |
| 7 | 2.08 - 2.35 | Middle Infrared | Absorption band for clays, micas, carbonates, sulphates. Vegetation water absorption. Dry grass high. | Absorption associated with hydroxyl bearing minerals and carbonates (Bleached or pallid zone, secondary carbonate-calcrete and travertine). Highly reflective for heamatitic Fe duricrusts and ferruginous saprolite. |
| 6 | 10.4 - 12.5 | Thermal Infrared | Soil moisture and thermal mapping. | |

Compiled from Wilford and Creasy (2002) and NASA web page http://www.math.montana.edu/~nmp/materials/ess/rs/index3a.html 24/09/2002, or http://observe.arc.nasa.gov/nasa/education/reference/main.html.

**APPENDIX 4. Performance parameters for the ASTER radiometer**

| Subsystem | Band number | Spectral range (Am) | Spatial resolution |
|---|---|---|---|
| VNIR | 1 | 0.52– 0.60 | 15 m |
| | 2 | 0.63– 0.69 | |
| | 3N | 0.78– 0.86 | |
| | 3B | 0.78– 0.86 | |
| | 4 | 1.600– 1.700 | |
| | 5 | 2.145– 2.185 | |
| SWIR | 6 | 2.185– 2.225 | 30 m |
| | 7 | 2.235– 2.285 | |
| | 8 | 2.295– 2.365 | |
| | 9 | 2.360– 2.430 | |
| | 10 | 8.125– 8.475 | |
| | 11 | 8.475– 8.825 | |
| TIR | 12 | 8.925– 9.275 | 90 m |
| | 13 | 10.25– 10.95 | |
| | 14 | 10.95– 11.65 | |

(Simplified from Fujisada, 1995)

VNIR – very near infrared
SWIR – short wave infrared
TIR – thermal infrared

**APPENDIX 5. Statistics from the unsupervised classification of the gamma-ray radiometric data**

| | Red (K) | Green (Th) | Blue (U) |
|---|---|---|---|
| **All Data** | | | |
| Number of Non Null Cells | 33320640 | 33320640 | 33320640 |
| Minimum Value | 0 | 0 | 0 |
| Maximum Value | 2.467575311661 | 18.05472373962 | 4.326658248901 |
| Mean Value | 0.4217466569461 | 3.495118319215 | 0.9884374605061 |
| Median Value | 0 | 0 | 0 |
| **Region 1** | | | |
| Number of Non Null Cells | 18593802 | 18593802 | 18593802 |
| Minimum Value | 0 | 0 | 0 |
| Maximum Value | 0.3088753223419 | 1.001798033714 | 1.365455746651 |
| Mean Value | 8.650502289613E-005 | 0.0001378200970694 | 0.0004907542863 |
| Median Value | 0 | 0 | 0 |
| **Region 2** | | | |
| Number of Non Null Cells | 40111 | 40111 | 40111 |
| Minimum Value | 0.0007964377873577 | 0.1896302998066 | 0.1927670091391 |
| Maximum Value | 0.8348278403282 | 2.824641227722 | 2.128511428833 |
| Mean Value | 0.3179830288451 | 1.611806576843 | 1.180670134616 |
| Median Value | 0.2972685396671 | 1.630651950836 | 1.175762176514 |
| **Region 3** | | | |
| Number of Non Null Cells | 535282 | 535282 | 535282 |
| Minimum Value | 0.1319003850222 | 2.647725582123 | 0.5864783525467 |
| Maximum Value | 1.252193927765 | 4.771164417267 | 2.644848823547 |
| Mean Value | 0.4933261529138 | 4.088849873379 | 1.528705952004 |
| Median Value | 0.4513590931892 | 4.157357692719 | 1.519177436829 |
| **Region 4** | | | |
| Number of Non Null Cells | 1384707 | 1384707 | 1384707 |
| Minimum Value | 0.1543835699558 | 4.424842834473 | 0.7342313528061 |
| Maximum Value | 1.517854571342 | 6.153454303741 | 2.815577030182 |
| Mean Value | 0.7148990429599 | 5.34533820701 | 1.746233951551 |
| Median Value | 0.6816633939743 | 5.363424777985 | 1.734252929688 |
| **Region 5** | | | |
| Number of Non Null Cells | 2578700 | 2578700 | 2578700 |
| Minimum Value | 0.2029005289078 | 5.774541378021 | 0.7988592982292 |
| Maximum Value | 1.708486199379 | 7.521964550018 | 3.47158408165 |
| Mean Value | 0.9327733154667 | 6.737785116704 | 2.007175664589 |
| Median Value | 0.9086438417435 | 6.791596412659 | 1.999497413635 |
| **Region 6** | | | |
| Number of Non Null Cells | 5106867 | 5106867 | 5106867 |
| Minimum Value | 0.2064033895731 | 7.087719917297 | 0.5954290032387 |
| Maximum Value | 2.212981700897 | 8.705096244812 | 3.571578025818 |
| Mean Value | 1.059499282532 | 7.939201139842 | 2.214142413992 |
| Median Value | 1.068605065346 | 7.953269004822 | 2.199759244919 |
| **Region 7** | | | |
| Number of Non Null Cells | 3448880 | 3448880 | 3448880 |

| | | | |
|---|---|---|---|
| Minimum Value | 0.2714576721191 | 8.282114982605 | 1.005574584007 |
| Maximum Value | 2.467575311661 | 10.40947818756 | 3.922783374786 |
| Mean Value | 1.078073161086 | 9.021603926833 | 2.408940154699 |
| Median Value | 1.137894749641 | 8.955225944519 | 2.38441157341 |

| **Region 8** | | | |
|---|---|---|---|
| Number of Non Null Cells | 1162143 | 1162143 | 1162143 |
| Minimum Value | 0.294710367918 | 9.356380462646 | 1.335701704025 |
| Maximum Value | 2.376747369766 | 11.54106998444 | 4.20353603363 |
| Mean Value | 0.8129809807946 | 10.40927133901 | 2.887201390628 |
| Median Value | 0.7094911932945 | 10.37191963196 | 2.892846107483 |

| **Region 9** | | | |
|---|---|---|---|
| Number of Non Null Cells | 404797 | 404797 | 404797 |
| Minimum Value | 0.3023731708527 | 11.0605134964 | 1.365399599075 |
| Maximum Value | 2.043790102005 | 12.98164367676 | 4.326658248901 |
| Mean Value | 0.6621476404823 | 11.80924332289 | 3.151146919076 |
| Median Value | 0.6356912851334 | 11.71339797974 | 3.158349275589 |

| **Region 10** | | | |
|---|---|---|---|
| Number of Non Null Cells | 65351 | 65351 | 65351 |
| Minimum Value | 0.2777906954288 | 12.79180335999 | 2.299376010895 |
| Maximum Value | 1.639424324036 | 18.05472373962 | 4.322014331818 |
| Mean Value | 0.5733066766328 | 13.63318538473 | 3.370703448242 |
| Median Value | 0.5650103092194 | 13.4085521698 | 3.366001605988 |

## APPENDIX 6. Map Units and Descriptions

| MAIN GROUP | SUB GROUP | | REGOLITH | LANDFORM | MAP SYMB | DESCRIPTION |
|---|---|---|---|---|---|---|
| TRANSPORTED REGOLITH | Geomorphic Unit 8 | Alluvial sedIments | Alluvial Sediments | Flood Plain | Aaf1 | Stream channels, levees and back plain deposits of the modern Moonie floodplain. |
| | Geomorphic Unit 7 | Alluvial Sediments | Channel Deposits | Stream Channel | ACar1 | Channel silts and sands and minor levee and channel splay deposits of the modern Balonne and Maranoa River channels. |
| | Geomorphic Unit 7 | Alluvial Sediments | Overbank Deposits | Flood Plain | AOaf1 | Sand dominated levees and channel splay deposits of the modern Balonne floodplain with minor source bordering dunes. |
| | Geomorphic Unit 7 | Alluvial Sediments | Overbank Deposits | Flood Plain | AOaf2 | Grey clays of the modern Balonne back plain commonly with well developed gilgai structures. Local occurrences of vertisols and nodular carbonate accumulations. Minor sandy levee and channel bank deposits. |
| | Geomorphic Unit 6 | Alluvial Sediments | Channel Deposits | Alluvial Plain | ACap1 | Sandy alluvium in levees and scroll bars associated with former channels of the Balonne River. |
| | Geomorphic Unit 6 | Alluvial Sediments | Overbank Deposits | Alluvial Plain | AOap4 | Clay dominant sediments associated with a back plain of the former Balonne River with minor sandy channel deposits. |
| | Geomorphic Unit 6 | Alluvial Sediments | Overbank Deposits | Alluvial Plain | AOap1 | Clay and sandy clay alluvium on a back plain associated with the former Balonne River. Vertisols and gilgai structures present as well as some duplex soils. |
| | Geomorphic Unit 6 | Terrestrial Sediments | Terrestrial Sediments | Depositional Plain | Tpd1 | Fine silt and clay on a depositional plain surrounded by residual Cretaceous material. |

| MAIN GROUP | SUB GROUP | | REGOLITH | LANDFORM | MAP SYMB | DESCRIPTION |
|---|---|---|---|---|---|---|
| | Geomorphic Unit 5 | Alluvial Sediments | Overbank Deposits | Alluvial Plain | AOap6 | Clay and sandy clay alluvium on a back plain associated with the former Balonne River. |
| | Geomorphic Unit 5 | Alluvial Sediments | Channel Deposits | Alluvial Plain | ACap4 | Sandy alluvium in levees and circular scroll bars associated with former channels of the Balonne River. |
| | Geomorphic Unit 4 | Alluvial Sediments | Overbank Deposits | Alluvial Plain | AOap5 | Clay and sandy clay alluvium with some gilgai on a back plain associated with the former Balonne River. Minor occurrences of residual cretaceous sands and clays. |
| | Geomorphic Unit 4 | Alluvial Sediments | Channel Deposits | Alluvial Plain | ACap3 | Sandy alluvium in levee and scroll bar deposits associated with the former channels of the Balonne River. |
| | Geomorphic Unit 3 | Alluvial Sediments | Overbank Deposits | Alluvial Plain | AOap2 | Clay and sandy clay alluvium with some gilgai structures on a back plain associated with the former Balonne River. |
| | Geomorphic Unit 3 | Alluvial Sediments | Channel Deposits | Alluvial Plain | ACap2 | Sandy alluvium in levees and scroll bars associated with former channels of the Balonne River. |
| | Geomorphic Unit 3 | Alluvial Sediments | Overbank Deposits | Alluvial Plain | AOap3 | Clay and sandy clay alluvium on a back plain associated with the former Balonne and Moonie Rivers. Occasional levees, scroll bars and channel bank deposits. |
| | Geomorphic Unit 1 | Lacustrine Sediments | Lacustrine Sediments | Playa Plain | Lpp1 | Clay pans with saline clay and silty clay sediments. |
| | Geomorphic Units 6, 8 | Aeolian Sediments | Aeolian Sand | Source Bordering Dune | ISub1 | Well sorted aeolian sand in source bordering dunes adjacent to channels deposits. |

| MAIN GROUP | SUB GROUP | | REGOLITH | LANDFORM | MAP SYMB | DESCRIPTION |
|---|---|---|---|---|---|---|
| IN-SITU REGOLITH | Geomorphic Unit 2 | Residual Material | Residual Sand | Alluvial Plain | RSap1 | Residual sand on low interfluves between drainage lines on the Maranoa surface. |
| | | Residual Material | Residual Sand | Alluvial Plain | RSap2 | Residual clayey sand on slopes below interfluves between drainage lines on the Maranoa surface. |
| | | Residual Material | Residual Clay | Alluvial Plain | RCap1 | Residual predominantly sodic clay on shallow valley floors between drainage lines on the Maranoa surface. Vertisols, gilgai structures and local occurrences of gypsum present. |
| | Geomorphic Unit 1 | Residual Material | Residual Sand | Erosional Plain | RSep1 | Moderately weathered residual red/brown to yellow sands with minor clays on erosional plains, derived from the underlying Griman Creek Formation. |
| | | Saprolith | Saprolite | Rises | Sper1 | Residual sands and clays over saprolite formed from the variable weathering of the Cretaceous Griman Creek Formation. In places strongly mottled with silcrete and ferricrete. |